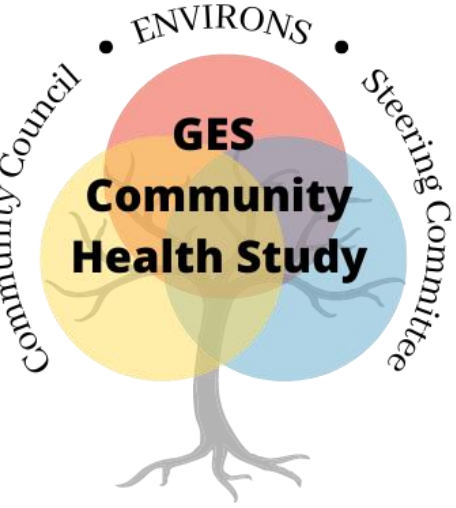

Community Health Study

In response to Deliverable 2.11

March 31, 2025

Updated April 28, 2025

ENVIRONS

COMMUNITY RELEVANT SUMMARY

Written by the Globeville, Elyria, Swansea Community Health Study Community Council:

Community Experience with the Study

- Participants have gained valuable knowledge and grown together.
- The study has changed how they engage with the community, allowing them to be involved in every step of the process rather than just providing input.
- Unlike past experiences where they were excluded from decision-making, they now feel heard by researchers, the steering committee, and other stakeholders.
- The study has fostered a true sense of teamwork between community members, researchers, and organizations, making participants feel valued.
- While challenges exist, they see both the positive and difficult aspects of the process as opportunities for learning and growth.
- Some participants initially felt judged for their emotional connection to the community but now feel acknowledged and understood.
- They expressed admiration for their own and each other's resilience, emphasizing the importance of rebuilding and moving forward.
- Trust in the study process has grown; while some initially doubted the researchers' intentions, they now recognize that many genuinely care about the community.
- Single mothers in the group expressed deep appreciation for one another's dedication, recognizing the difficulty of balancing work, parenting—especially with children with disabilities—and community engagement.

Applying Study Findings for Future Community Work

- Findings should be presented in a simple, accessible format without technical or scientific jargon.
- Visual materials would be the most effective way to communicate the results.
- It is essential to distribute printed copies of deliverables directly to community members rather than relying solely on online access.
- Providing physical handouts ensures that information reaches those who may not have internet access or the time to seek it out.

Returning Data to the Community

- Data must be made accessible and actionable for the people most affected.
- The study's results should not only inform academic research but also empower the community to advocate for change.

Satisfaction with the Study

- Some participants felt the study did not provide a satisfactory solution to the community's problems.
- Future research projects should prioritize offering tangible benefits and solutions for affected communities.

Environmental Justice (EJ) and the Role of the Community Council

- Participants strongly identify with EJ principles, particularly in addressing systemic inequities.
- Meaningful community engagement goes beyond surveys or formal meetings—it requires researchers to truly listen, understand local history, and remain committed to the community's well-being.
- Researchers must keep their promises, ensuring that findings are shared transparently and used to benefit the people involved.
- Participants reported experiencing discrimination from researchers who assumed they lacked education or knowledge.
- They emphasized that their lived experiences make them experts in their own communities.
- Systemic issues—such as government neglect—must be addressed in environmental justice work.
- This study has reinforced their commitment to advocating for their neighborhoods and ensuring that research projects genuinely serve their communities.

Key Themes

- While the study provides important data, it is frustrating and exhausting to have to repeatedly conduct new studies to prove what residents already know.
- This is the first study to return data directly to the community, allowing them to use it for advocacy and reinforcing what they have been saying all along.
- Many residents are leaving the area due to environmental health concerns, underscoring the urgency of addressing these issues.

Community Reflections on Data Accuracy and Impact

- Participants believe that actual conditions are worse than the data indicates.
- The accuracy of the study depends on available data, which needs to be updated regularly.
- The burden of continually proving environmental injustices is exhausting for the community.
- Many residents have already moved away due to pollution-related health concerns.
- While the findings confirm what residents have long suspected, having concrete data allows them to demand action.
- Historically, their community has been studied repeatedly without receiving meaningful or accessible data in return—this study represents a positive shift.
- Residents question whether relocating would improve their health, highlighting the deep impact of environmental issues on their lives.

This summary captures the community's perspectives, emphasizing the importance of transparency, accessibility, and meaningful engagement in research.

Your GES Health Study Community Council

LETTER FROM THE STEERING COMMITTEE

April 30, 2025

In 2017, the Elyria-Swansea Neighborhood Association, Chaffee Park Neighborhood Association, Colorado Latino Forum, and the Colorado Sierra Club ("Petitioners") challenged the Colorado Department of Transportation's ("CDOT") expansion of Interstate 70 ("I-70") over concerns for increased traffic, noise, and air pollution to areas where pollution is already concentrated (Sierra Club et al. v. Chao et al. D. Colo. No. 1:17-cv-01661-WJM-MEH). A settlement was reached in 2018 ("Settlement Agreement") regarding the I-70 expansion project.

Among other things, under the Settlement Agreement:

1) CDOT contributed $550,000 for a data-driven health assessment ("assessment").
2) A committee ("Steering Committee") was established. The Steering Committee consisted of four representatives: one from the City and County of Denver (CCD), one from the Colorado Department of Public Health and Environment (CDPHE), one representing the Petitioners, and one elected Independent Member.
3) The Steering Committee outlined a process to select or procure an independent, qualified contractor with demonstrated expertise to conduct the assessment (the "Expert"). They selected the Expert and managed the development of the assessment. Residents of and stakeholders in the GES neighborhoods received regular updates and opportunities to meaningfully engage the Steering Committee.
4) When conducting the assessment, the Expert was not to consider the specific effects of the I-70 Project separately. The Expert was to consider the effects of pollution, noise, and vehicle and rail traffic as part of the overall range of possible significant causes of current and future adverse health outcomes.
5) The assessment was not to include policy measures or make policy recommendations.

In 2018, a memorandum of understanding ("the Memorandum") was signed by the parties to the legal proceeding and two additional agencies: the CCD and CDPHE. Petitioners and these two agencies indicated that there would be benefits to analyzing the contributors to adverse public health outcomes in the Globeville, Elyria, and Swansea neighborhoods. CDPHE agreed to manage the contracting and fiscal requirements associated with completing this assessment. The Memorandum directed that the assessment shall not be attributed to CDOT or the Federal Highway Administration (FHWA). Similarly, the assessment does not reflect the opinions of CDOT, CDPHE, CCD, or the FHWA.

This letter details the Steering Committee's formation and activities from its perspective.

Formation of the Steering Committee and Community Council

The initial three-member Steering Committee formed in September 2019. The CDPHE provided additional support to post, recruit, and evaluate potential candidates to serve as the independent member of the Steering Committee. The fourth member was selected by unanimous approval of the three-member Steering Committee in early 2020. The four-member Steering Committee began holding monthly meetings in April 2020 with the community until the Expert was hired.

During these initial meetings led by the Steering Committee, the community called upon the Steering Committee to ensure the assessment would incorporate expertise from the community's lived experiences. Residents requested assurance that study outcomes would benefit the community and ensure settlement dollars were invested back into GES. This input led to structuring a Community Council responsible for working alongside the Expert throughout the assessment and being financially compensated for their efforts.

The CDPHE and the CCD provided additional support before the Expert was selected in order to support the community. The CDPHE provided administrative support including printing/mailing hard copies of documents, facilitating virtual and in person meetings, staff to record meeting minutes, drafting of memos, troubleshooting support, legal and fiscal support, translation and interpretation services, and accessible tracker development for the public to see the progression of this assessment in real time. The CCD also provided additional support during this time including preparation and assembly of culturally-relevant food boxes with information about the health assessment, providing meeting spaces at no cost, and supporting translation and interpretation services.

Use of Settlement Agreement Funds Prior to the Expert

On April 22, 2021, the CDPHE and CDOT approved advance release of settlement funds ($6,000) to compensate Community Council members to lay the groundwork that would later inform the assessment. The Community Council was initially composed of six residents representative of the three GES neighborhoods. The Community Council activities included hosting two leadership workshops (December 2020), the development of and execution of walking tours with residents and senior leadership of government agencies (October 2021 – April 2022), Las Posadas food box donation events sponsored by the City and County of Denver (December 2021), and a *Conocimiento* event for community engagement (April 2021).

Setbacks

There were several extenuating circumstances that impacted the timely progress of the assessment. In March 2020, the COVID-19 pandemic was declared a national emergency, disrupting all aspects of society around the world. The immediate impact on the GES assessment was to switch regular community meetings to the zoom online platform. Initially, community engagement remained robust but, over time, fewer and fewer attended. This was due to several reasons: limited access to the Internet, competing

activities between other GES meetings, and time constraints brought on by the pandemic lockdown.

The Steering Committee, in coordination with the CDPHE, first requested proposals in 2020. The Steering Committee evaluated the proposals; however, it did not result in a successful contract. The Steering Committee prepared a second request for proposals and repeated this process in the fall of 2021. This second effort resulted in a successful contract.

Selection of the Expert

In March 2022, the Steering Committee with support from the Community Council selected Colorado State University's ENVIRONS team as the Expert to complete the assessment focusing on the Globeville, Elyria, and Swansea (GES) neighborhoods.

The aim of this assessment was to provide an independent evaluation of the potential causes of the disparate health outcomes in the GES neighborhoods, including but not limited to those outcomes identified in the City and County of Denver's 2014 health impact assessment entitled "How Neighborhood Planning Affects Health in Globeville and Elyria Swansea". This included the consideration of pollution (air, soil, water, noise), socioeconomic factors, mobility, and availability of healthy food and how these factors may have contributed to disparate health outcomes. The spirit of this assessment was to accurately describe the living environment, empower the GES community with a platform to amplify their voices, and present a portrait of the health status of GES residents relative to those environmental factors and disparate health outcomes.

Final Thoughts

The GES community is a dynamic, vigorous community at the forefront of environmental justice issues. Engagement is highly sought after by both internal and external groups where multiple issues vie for attention and support. The initial Community Council disbanded prior to ENVIRONS coming onto the project. The delay in the implementation of the assessment, the constraints imposed by the Settlement Agreement, and the extenuating circumstances of the pandemic all contributed to a longer timeline to get started, resulting in community frustration with the process.

With ENVIRONS on board in March 2022, the Steering Committee's responsibilities shifted to oversight of the assessment through review of deliverables, review of invoices, community engagement, and communication. ENVIRONS and the Steering Committee agreed on a communication schedule overseen by the ENVIRONS team that included regular community meetings, technical meetings between the Steering Committee and ENVIRONS, and routine office hours with the community. All deliverables are available in English and Spanish at www.geshealthstudy.org and were made available for community review and input.

Long before the Settlement Agreement, individuals, grassroots organizations, and neighborhood coalitions were already hard at work defending their interests in the face of the CDOT's I-70 expansion plans. Other sources of environmental health threats facing the GES neighborhoods are from not only the I-70 highway exhaust but include emissions of hydrogen cyanide from the Suncor refinery, excavation of a Superfund site to facilitate I-70 expansion, an odoriferous pet food factory, and multiple marijuana warehouses.

The alliances developed during the assessment study laid the groundwork to address other community environmental justice issues. The lessons learned from this undertaking highlighted the importance of coequal partnership with organizations and leaders in the environmental justice communities being affected by government decision making. The process of completing this assessment illuminated the fragmented, siloed approach to community health issues and the need for increased coordination between the public sector and those they serve. With this learning, the Community Council is situated to continue this important work having gained critical skills and alliances, but they need adequate support and funding to facilitate durable community engagement and robust action plans.

The Steering Committee has been privileged to participate with and learn from the GES Community Council, the GES community, and the ENVIRONS team.

Thank you,

The Steering Committee

This begins the section written by ENVIRONS.

Members of the GES Community Council frequently remind us that the true benefit to the community comes when studies actively engage residents in the research process and share their data and findings with local residents. We acknowledge that many documents and datasets listed here are highly technical and may not seem useful or accessible to community members.

We hope the Community Relevant Summaries, located at the beginning of each GES Community Health Study Deliverable, are more approachable for community members. We recognize that one limitation of our Study is the heavy reliance on technical documents and the production of data that may not always be inclusive and equitable for community engagement. Nevertheless, the data belong to the community, and we hope that these findings contribute to achieving the environmental health goals, actions, and aspirations of GES residents.

ACKNOWLEDGEMENTS

The success of the Globeville, Elyria, Swansea Community Health Study can be credited to the exceptional involvement and leadership of the dedicated Community Council. Comprising a diverse group of women from the community, this council has devoted the last three years to deepening their understanding of environmental health issues that affect their neighborhoods. Through workshops, community meetings, and personal engagement, they have shared invaluable insights, poignant stories, and their lived experiences with local health challenges. We extend our deepest gratitude for their unwavering commitment to this study and the impact they have made in advocating for the health and well-being of their community.

GES Community Health Study Community Council
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Sandra Ruiz Parrilla, Globeville Resident
Nancy Santos, Swansea Resident
Ana Varela, Elyria Resident

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Melinda Laituri, PhD, Independent Member
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Other Acknowledgements
We would like to acknowledge former members of the Community Council, ENVIRONS, and Steering Committee.

- Community Council members Rebecca Trujillo, Globeville Resident, and Maria de Santiago, Swansea Resident.
- Former ENVIRONS members include Marshall Thomas, Judy Heiderscheit, Doreen Martinez, Lindsay Kastner, and Sarah Penilla Montoya.
- Former SC members include Andrea Kingcade, CDPHE, Tristan Sanders, DDPHE, and Meaghan Guyader, Petitioners Representative.

Facilities and Gathering Spaces

- Colorado State University SPUR campus
- National Western Center
- Project Angel Heart
- Johnson Recreation Center
- Valdez-Perry Library

Translation and Interpretation Services

- Community Language Cooperative
- The WordPoint

Funding: The Globeville, Elyria, Swansea Community Health Study is funded by the Central 70 Settlement (Sierra Club et al. v. Chao, et al. (D. Colo. No. 17-1679)) (PI: Magzamen, Contract: CT 2022*3418) managed by Colorado Department of Public Health and Environment.

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LIST OF ACRONYMS, DEFINITIONS, AND DESCRIPTIONS

Table 1. List of acronyms, definitions, and descriptions.

Term	Definition
CC	Community Council is a group of resident collaborators part of the research team that act as community representatives, experts, and liaisons.
CCoD	City and County of Denver.
CDOT	Colorado Department of Transportation.
CDPHE	Colorado Department of Public Health and Environment. CDPHE is the principal department of Colorado state government responsible for public health and environmental regulations.
CEBA	Community Environmental Burden Assessment; Deliverables 2.4-2.6.
CO	Carbon monoxide; a type of air pollutant.
ENVIRONS	Estudio de Nuestros Vecinos para Investigar los RiesgOs y Nuestra Salud (ENVIRONS) research team is based out of Colorado State University in Fort Collins, CO and is responsible for conducting the GES Community Health Study.
EPA (US EPA)	United States Environmental Protection Agency; the primary agency of the United States government tasked with environmental protection.
GES	Globeville, Elyria, Swansea neighborhoods.
Health	Health is a state of physical, mental, and social well-being and not merely the absence of disease.
HIA	Health Impact Assessment; Deliverable 2.2 *The ABCs of GES: The State of Health and Environment* of the GES Community Health Study.
I-70	Interstate 70.
Neighborhood	The City and County of Denver recognizes 78 official neighborhoods, including Denver International Airport (DIA). These are often made up of a collection of census tracts. For example, GES includes three census tracts.
NO_2	Nitrogen Dioxide; a type of air pollutant.
O_3	Ozone; a type of air pollutant.
PM	Particulate matter; a type of air pollutant.
RCA	Root Cause Analysis; Deliverable 2.8.
SC	The Steering Committee are stewards of the settlement agreement to ensure it is carried out appropriately, including through the approval of work plans, invoices, and deliverables.
SO_2	Sulfur dioxide; a type of air pollutant.

INTRODUCTION

Globeville, Elyria, and Swansea (GES) are among the oldest neighborhoods in Denver, Colorado. These communities span approximately four-square miles in northeast Denver and are separated from other areas of the city by highways, rail lines, large industrial sites, and the South Platte River.[1] GES has a vibrant and proud cultural community. Initially settled in the late 1800s by European immigrants who worked in the rail and smelting industries, GES underwent demographic changes by the 1950s, with Hispanic/Latino and African American populations establishing their roots in the area.[2,3] Today, GES is home to some of Denver's largest Hispanic/Latino communities. Throughout its history, residents have had to advocate against industrial encroachment and investors while raising awareness of the environmental hazards they face.

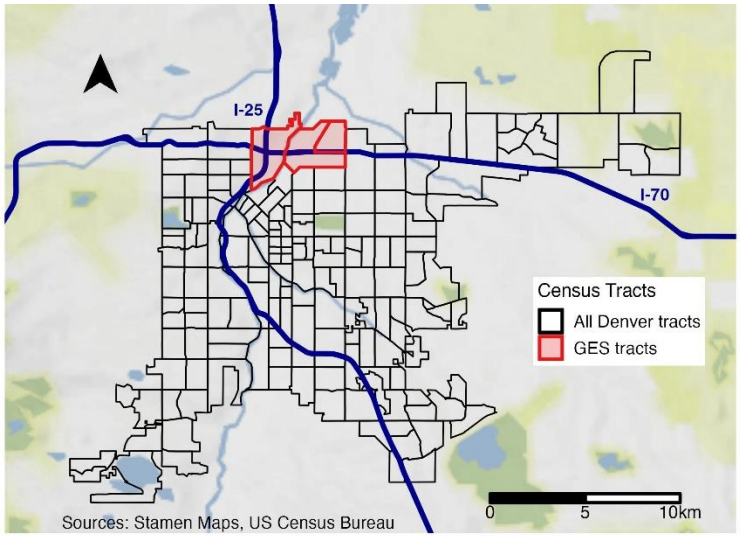

Figure 1. Globeville and Elyria Swansea census tracts in relation to City and County of Denver area.

A coalition was established in response to the Colorado Department of Transportation (CDOT) Central Interstate-70 (I-70) expansion project. This coalition included the Elyria-Swansea Neighborhood Association, the Colorado Latino Forum, and the Chaffee Park Neighborhood Association, with invaluable support from the Colorado Sierra Club. Together, they took proactive legal action against the expansion, resulting in a lawsuit and settlement. The Sierra Club v. Chao settlement agreement allocated funding for the Globeville, Elyria, and Swansea Community Health Study.[4,5]

The Globeville, Elyria, Swansea (GES) Community Health Study originated as a top-down response to a community-driven settlement agreement to address longstanding environmental health concerns in the area. Before forming the GES Community Health Study Community Council (CC), ENVIRONS submitted a proposal detailing their research methodology and objectives. It was subsequently selected for funding by the Steering Committee (SC), with oversight from the Colorado Department of Public Health and Environment (CDPHE).

During the first year (Phase I) of the Study, ENVIRONS worked with the SC and members of the GES community to form the Community Council. However, initial work and team-building led to some tension, as ENVIRONS's initial proposal, the resources available for the study, and the community's expectations for the study's scope and impact differed. ENVIRONS dedicated the first year of the study contract to fostering a collaborative atmosphere and building trust with the Community Council and the Steering Committee. This involved conducting multiple norming sessions to align all partners' goals and developing a set of Operational Principles (Deliverable 1.1) that would guide the project.[6] Next, Deliverable 1.4 provided a thorough historical overview of the GES area, which served as a foundational document, allowing community members to recount their lived experiences and express their environmental concerns. Sharing personal narratives enhanced mutual trust between ENVIRONS and the community.[1]

Over the past three years, ENVIRONS has worked closely alongside the GES Community Council and the GES Steering Committee, collaborating on a series of deliverables designed to systematically explore the relationships between environmental exposures and health outcomes impacting the GES community. This report represents the culmination of Phase II of the Study, which expanded on the foundation of Phase I by integrating qualitative insights and quantitative data across study deliverables to provide an understanding of the environmental health landscape in the GES area (Table 2).

Table 2. GES Community Health Study Deliverables.

Deliverable	Description
Phase I	Planning and Foundations deliverables included
Deliverable 1.1: ENVIRONS Questionaries	After participating in a tour of the GES neighborhoods, each ENVIRONS team member completed a questionnaire prepared by the Community Council. In addition to individual responses, a summary for the team was created.
Deliverable 1.2: Shared Operational Principles	The Community Council, ENVIRONS, and Steering Committee identified roles and defined shared values, motivations, expectations, and limitations for the study.
Deliverable 1.3: Community Engagement Plan	The Community Engagement plan was developed with the Community Council and Steering Committee. It defines how ENVIRONS will communicate with the Community Council and the Steering Committee, and outlines strategies for communicating with residents, soliciting community input, and maintaining transparency.
Deliverable 1.4: Narrative	ENVIRONS identified sources of data, literature, and on-going projects that will be used in Phase II. As part of this, ENVIRONS reviewed the materials provided in the "crowd sourced literature review" folder curated by the Steering Committee prior to ENVIRONS coming onto the study.

Deliverable 1.5: Mapping and Website	The website is available in English and Spanish, and maps are available on the Maps page.
Deliverable 1.6: Course Correction Plan	ENVIRONS worked with the Community Council and Steering Committee to create a course correction plan. This plan ensures that the study is headed in the right direction for Phase II.
Phase II	Analysis
Deliverable 2.1: Data Rubric and Literature Evaluation	ENVIRONS created a rubric to evaluate the quality of literature and data, then applied this rubric to the sources of information identified in the crowd-sourced literature folder or in the Preliminary Data Identification and Narrative.
Deliverable 2.2: The ABCs of GES: The State of Health and Environment	This report characterizes areas of community concern, provides updated data to topics identified in the 2014 Health Impact Assessment report, and evaluates the implementation of recommendations from the 2014 report.
Deliverable 2.3: Exposure Outcome Matrix	The Exposure Outcome matrix demonstrates the connections between environmental exposures in GES, health outcomes, and health disparities based on existing research. This matrix visualizes how environmental exposures (e.g., pollutants) are connected to adverse health outcomes.
Deliverable 2.4: Community Environmental Burden Assessment (CEBA): Planning, Scoping, and Problem Formulation	This document outlines the plan for how ENVIRONS will conduct the Community Environmental Burden Assessment (CEBA), which makes up Deliverables 2.4, 2.5, and 2.6 for the study.
Deliverable 2.5: Community Environmental Burden Assessment (CEBA): The Exposure Response Assessment Phase	This document outlines the methods and preliminary results of the CEBA including modeled air pollution exposures across Denver and literature review of exposure-response relationships.
Deliverable 2.6: Community Environmental Burden Assessment (CEBA): Burden of Disease and Future Scenarios	As the final installment of the CEBA, this deliverable highlights the extent to which health outcomes are attributable to air pollution in GES.
Deliverable 2.8: Root Cause Analysis	This document investigates a root cause analysis of the environmental causes of concerns and health outcomes in GES. Informed by community members and previous deliverables (2.2-2.7).

Deliverable 2.9: Static Maps	This document contains the static maps created in Deliverables 2.2-2.8.
Deliverable 2.10: Dynamic Maps	This document details the process for creating the study's web-based, interactive mapping tool that investigates environmental health concerns.

All Study deliverables are accessible online at GESHealthStudy.org. The Study website will remain accessible for seven years following the end of this Study, as outlined in the Settlement's contract requirements. In addition to hosting Study deliverables, this website also contains meeting minutes from the Study's Community Council meetings and public community meetings, as well as maps, presentations, and other educational materials for community members to learn more about environmental health conditions in GES. Website materials will be transferred as PDF files to CDOT and archived on CDOT's webpage for view-only access to the public.

DELIVERABLE 2.1 DATA RUBRIC & LITERATURE EVALUATION

The GES Community Health Study leveraged publicly available data to understand the relationships between environmental exposures and health outcomes that impact the GES community. To ensure our research was rigorous and relevant to the GES community, ENVIRONS developed two evaluation rubrics to systematically assess the quality of materials used in our research. One rubric focused on the evaluation of literature, while the other targeted datasets. These rubrics were applied to evaluate the materials included in the appendices of Phase I Deliverable 1.4 Narrative, as well as various items curated in the Crowd-sourced Literature Folder, which included potential data sources identified by community members. For the literature rubric, we established criteria that emphasized several critical factors. These included the type of document (e.g., journal articles, reports, or policy papers), the objectivity versus subjectivity of the information presented, and the timeliness of the publications. For instance, we noted that some documents had been published as early as the early 2000s, which raised concerns about their relevance in the context of current research and practices. The dataset rubric was grounded in a complementary set of criteria tailored to evaluate the datasets' integrity and relevance. Key elements included the accuracy of the data, its timeliness, and its relevance to the goals of the GES Community Health Study.

Overall, ENVIRONS evaluated 95 items as part of Deliverable 2.1. Among these items were 42 articles and reports, which included a mixture of both peer-reviewed and gray literature (non-peer-reviewed sources), reflecting a wide range of perspectives and findings. We reviewed 49 datasets, as well as 4 ongoing studies. Importantly, Deliverable 2.1 was limited to data and literature listed in Deliverable 1.4 Narrative and the Crowd-Sourced Literature folder. The purpose of Deliverable 2.1 was to organize and assess literature provided to ENVIRONS, prior to Phase II of the Study.

Key Takeaway: While completing the data and literature evaluations for Deliverable 2.1, we found that there are less data about the GES community published in peer reviewed research journals than expected, despite the GES community's widespread feeling of being overstudied in the neighborhood. Publicly available data mainly comes from government sources and are often not provided in a manner that is usable to the general public by requiring specialized knowledge of geospatial data and software. This suggests a communications gap between researchers, policymakers, and the community members they study or serve.

DELIVERABLE 2.2 THE ABCS OF GES: THE STATE OF HEALTH AND ENVIRONMENT

Deliverable 2.2, titled "The ABCs of GES: State of Health and Environment," is a comprehensive health impact assessment that analyzes the current health and environmental conditions in Globeville and Elyria Swansea (GES). To develop Deliverable 2.2, we built upon the 2014 health impact assessment "How Neighborhood Planning Affects Health in Globeville and Elyria Swansea," published by the Denver Department of Public Health and Environment.[7] Our primary goal was to utilize publicly available data to compare health metrics in GES with those across the broader Denver area, enabling us to evaluate the

strength and reliability of the evidence. Additionally, we assessed the recommendations from the 2014 report in relation to our findings, incorporating valuable insights gained from community feedback.

Overall, our findings were mixed when comparing the state of health and environment between GES and the Denver average. For social determinants of health, we found that GES has a lower rate of educational attainment, higher cost of housing burdens, and mixed trends around substance use. We also found that GES has higher rates of adverse health outcomes compared to the Denver average, including risk factors during pregnancy, congenital abnormalities, all-cause mortality, chronic respiratory diseases, diabetes, and obesity. However, there is some evidence to suggest other health outcomes are comparable to the rest of Denver, such as cardiovascular disease and mental health outcomes. For environmental quality, we found that GES has worse exposure to noise pollution and odors, mainly due to where the community is located and the large industrial presence. Air quality generally follows regional trends and falls below health-based thresholds except for occasional short-term events when air quality may exceed these thresholds. Considering the built environment, it has been well documented that GES is significantly impacted by decreased access to goods and services, and our findings support this conclusion. Specifically, there is a lack of healthy food access and tree cover, and greenspaces remain underused due to safety concerns. GES has a higher rate of traffic accidents and crime than Denver. Conversely, there is evidence to suggest that soil quality and water quality are comparable to the rest of Denver. Most of the properties in GES that fall within the two Superfund sites have been sampled and remediated as necessary. Denver Water is currently working on updating the water infrastructure to provide safer water to the city and is prioritizing GES. The final part of our report provides an overview of the status of the 2014 recommendations, highlighting areas where more work is required to accurately evaluate the state of health and environment in GES.

Key Takeaway: Understanding social determinants of health is important for assessing the current health context of GES. Additionally, many recommendations from the 2014 Health Impact Assessment (HIA) have been left unaddressed.[7] This suggests a disconnect between researchers, local government, organizations, and community members, as well as highlights pathways for future community-driven intervention.

DELIVERABLE 2.3 EXPOSURE OUTCOME MATRIX

Deliverable 2.3, the Exposure Outcome Matrix, visualizes the connections between environmental exposures (such as pollutants) and adverse health outcomes. Community members can use this matrix to understand how specific environmental factors are linked to the illnesses they are concerned about or vice versa. While viewing the Exposure Outcome Matrix, we encourage users to explore how the built environment, air pollution, walkability, and other environmental factors affect health. This matrix includes all environmental exposures identified in our previous report, *The ABCs of GES: The State of Health and Environment*, which have a strong evidence base linking them to health outcomes. It also incorporates all health outcomes associated with these exposures. Please note that some exposures have been grouped to enhance the Matrix's readability.

Key Takeaway: This matrix offers many key takeaways, including illustrating the various pathways that connect the environment to community members' health outcomes.

DELIVERABLES 2.4 - 2.6 COMMUNITY ENVIRONMENTAL BURDEN ASSESSMENT (CEBA)

The Community Environmental Burden Assessment (CEBA) for the Globeville, Elyria Swansea (GES) Community Health Study was divided across three study deliverables, Deliverables 2.4, 2.5, and 2.6. The CEBA aimed to quantify the health impacts of increased air pollution exposures estimated in two communities in Denver, Colorado: Globeville and Elyria-Swansea (GES).

Deliverable 2.4, *Community Environmental Burden Assessment (CEBA): Planning, Scoping, and Problem Formulation*, marked a critical initial phase in the CEBA process. This stage was essential for establishing a structured framework that closely aligns with the specific environmental health needs identified within the community. Deliverable 2.4 emphasized the importance of employing rigorous scientific methodologies to ensure the assessment's validity and reliability.

Key Takeaway: By outlining strategic planning and scoping procedures, Deliverable 2.4 fostered a collaborative approach that engaged both community members and field experts.

Deliverable 2.5, *Community Environmental Burden Assessment (CEBA): The Exposure Response Assessment Phase*, centered on the critical evaluation of exposure-response relationships. Deliverable 2.5 built upon the groundwork established in Deliverable 2.4. Deliverable 2.5 presented the methodology designed to assess exposure levels associated with the six criteria air pollutants monitored throughout the City and County of Denver (CCoD) by the US Environmental Protection Agency (EPA). Deliverable 2.5 detailed the data collection processes, and integrated findings from an extensive review of existing scientific literature, encompassing multiple studies and reports, to identify and define relevant health impact measures of association linked to these air pollutants.

Key Takeaway: While our long-term aim was to cover a broad spectrum of environmental exposures, we were unable to include every potential factor in this analysis due to statistical limitations. Nevertheless, we believe that the air pollution exposures and health outcomes we included capture an important portion of the health burden GES residents face.

Deliverable 2.6, *Community Environmental Burden Assessment (CEBA): Burden of Disease and Future Scenarios*, served as the concluding piece in the CEBA. We conducted a quantitative burden assessment using a Monte Carlo approach to estimate the health impacts attributable to air pollution in GES. Air pollution data from 2017-2021 for fine and coarse particulate matter ($PM_{2.5}$, PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO) were obtained from EPA monitoring stations within the metropolitan area, and long-term concentrations in each neighborhood were estimated using inverse distance weighting. Health outcomes were selected based on community interest, and health data were obtained from the Global Burden of Disease. This deliverable provided an in-depth analysis of the disease burden attributable to differences in exposure levels. It offers an examination of how these

differences contribute to health disparities, with a particular focus on the GES neighborhoods. By utilizing statistical models and data visualization techniques, Deliverable 2.6 highlighted the relationships between environmental exposures and health outcomes.

Key Takeaway: Our findings suggest that exposure to higher air pollutant concentrations in GES neighborhoods results in greater health burdens compared to other neighborhoods in Denver. Addressing air pollution could significantly improve the health and well-being of community members.

DELIVERABLE 2.7 UPDATED DATA & LITERATURE EVALUATION

Deliverable 2.7 included a comprehensive list of literature and data sources we used to describe, model, and report environmental health in the GES community throughout our Study. This deliverable aimed to support community members by providing access to the data and literature that informed the GES Community Health Study. Each source was paired with a descriptive summary that outlines the available data, the rationale for its inclusion in the Study, and any limitations we identified. It is important for residents to access this information, share their insights, and draw their own conclusions.

For Deliverable 2.7, we assessed 597 sources identified in Deliverable 2.1 (Data and Literature Evaluation) and subsequent deliverables to determine whether they specifically relate to GES community health and environment. Among these, 49 data sources and 42 literature sources were previously evaluated and discussed in Deliverable 2.1 and, therefore, excluded from Deliverable 2.7. Additionally, 427 sources were omitted from this report because they do not specifically address GES, resulting in 76 sources evaluated in Deliverable 2.7. While developing Deliverable 2.7, we summarized various sources, including environmental data, health outcome information, and details on social determinants of health. We also identified important gaps in the data and literature that may hinder scientists, policymakers, and community members from drawing conclusions about GES community health.

Key Takeaway: The data and literature included in Deliverable 2.7 have a pronounced impact on GES residents, but community members emphasize that existing data and literature often fail to match their lived experiences. Further, community members stress the critical need for transparency and accessibility; They have pointed out that accessing and interpreting information from studies and government reports can be prohibitively challenging.

DELIVERABLE 2.8 ROOT CAUSE ANALYSIS

Deliverable 2.8, titled "Root Cause Analysis," utilized a systems-thinking approach to examine the environmental factors affecting health in GES (the community). This problem-solving tool breaks down complex issues into smaller parts, making identifying intervention and action pathways easier. The GES Health Study's root cause analysis (RCA) process was community driven. Community Council members selected the RCA model utilized and identified the four health topics to be addressed. The health topics

identified were asthma, odor, food access, and citizenship status. The bulk of Deliverable 2.8 provides insights and key themes from the Community RCA Activity conducted at the study's Community Meeting in February 2025. During the Community RCA Activity, the following key themes regarding root causes were identified:

1. The impact of historical issues continues to affect the community.
2. There is a tendency to prioritize profit over health and well-being.
3. Current processes and procedures are often inadequate to address the concerns of GES residents.

These themes significantly impact health and well-being, particularly mental and emotional health, community cohesion, and intergenerational effects.

Key Takeaway: Health outcomes are not inevitable, but rather have underlying and systemic root causes that are entangled in ongoing histories, relationships, and processes. Addressing root causes is vital for achieving health equity in GES.

DELIVERABLE 2.9 STATIC MAPS

Deliverable 2.9 Static Maps served as a permanent record for all of the maps created for GES Community Health Study Deliverables 2.2 through 2.8. All of the maps available in Deliverable 2.9 are also available in these original deliverables. The goal of Deliverable 2.9 was to archive the work of the GES Community Health Study to date.

Key Takeaway: The Community Council identified maps as an accessible way for community members to engage with Study findings. Maps help present data clearly and visually, making it easier to highlight existing environmental health conditions.

DELIVERABLE 2.10 DYNAMIC MAPS

The GES Community Health Study Interactive Maps app is an important aspect of our work. The goal of the app is to allow residents to create their own visualizations of available data to further their self-advocacy goals. Working collaboratively, the ENVIRONS team and the GES Community Council developed an online, interactive mapping platform that is responsive to the needs of neighbors living in the Globeville, Elyria, and Swansea neighborhoods of North Denver. Our interactive mapping tool aims to advance the goals of the GES Community Health Study by engaging with community members to determine what data are most beneficial and providing a method for community members to develop their own data visualizations so that they can augment evidence of their lived experiences with quantitative data that are routinely used and accepted by decision makers.

The app includes data visualization tools to help users understand better the distribution of environmental exposures and health outcomes across Denver. The purpose of the app is to visualize spatial trends in the

environmental factors that impact health in Denver neighborhoods so that community residents can learn more about the conditions that exist where they live. The data available in the app should not be used to make determinations about specific causes of health or disease for any resident living in Denver.

The GES Interactive Maps application is available in English and in Spanish:

www.maps.geshealthstudy.org (English)

www.maps-es.geshealthstudy.org (Spanish)

Key Takeaways: The interactive nature of Deliverable 2.10 allows community members and partners to generate maps based on the environmental health issues they care most about and enables them to present these maps to relevant organizations or policymakers.

CONCLUSIONS AND NEXT STEPS

The Globeville, Elyria, and Swansea (GES) communities are rich in history and cultural pride, but they face significant environmental injustices. Environmental injustice occurs when historically marginalized communities disproportionately endure pollution, toxins, and adverse social determinants of health. Our findings across various assessments indicate the following consistent issues:

ENVIRONMENT.

- GES experiences higher pollution rates, with evidence showing that air quality is poorer compared to the least affected neighborhoods in Denver.
- Residents encounter challenges accessing goods and services and limited connectivity and mobility to other parts of Denver.
- Residents have voiced that streets and alleyways are frequently littered with garbage, citing that local authorities do not adequately clean their neighborhoods.
- Community safety, including traffic, crime, and a lack of streetlights, continues to be a concern voiced by the community.
- Odor is higher in GES than in other parts of Denver, and residents mention that odor is a nuisance that contributes to a perceived lower quality of life in GES compared to other Denver neighborhoods.
- There continues to be mistrust of soil clean-up efforts, with fears of contaminated soils. There is also confusion around what past actions government officials have taken to address soil concerns, with some government agencies declaring the soil safe and others offering free soil testing, which in turn creates mistrust.
- Water quality was not brought up as often, but when discussed with community members, there were concerns that the drinking water was unsafe and contaminated. This concern is tied directly back to the unclear drinking water information regarding the Denver Water lead service line replacement program.

HEALTH.

- Compared to other Denver neighborhoods, GES residents face a higher risk of adverse health outcomes.
- We found that between 2017 and 2021, the overall mortality rate in GES was 24% higher than the Denver average.
- There is evidence that the rate of adult asthma hospitalizations in GES is significantly greater than the Denver average. Further, we estimated that the difference in air pollution in GES compared to the least exposed neighborhoods in Denver contributes to higher rates of childhood asthma.
- Compared to the Denver average, GES has a higher percentage of adults who are obese, overweight or have type two diabetes.
- GES has a higher percentage of uninsured people and a greater percentage of people not up to date on preventative healthcare.

RECOMMENDATIONS FOR FUTURE RESEARCH IN GES AND OTHER ENVIRONMENTAL JUSTICE NEIGHBORHOODS.

The top-down origins of our study, coupled with limitations of the secondary data utilized, restricted our ability to analyze the environmental exposures and health outcomes that are often expressed as most important to the GES community by community members and partners. Throughout our research, a recurring theme emerged from discussions with community members: many residents articulated feelings of being over-researched and expressed frustration over the lack of feedback and clear communication regarding the outcomes of the various studies they had previously participated in. This sentiment highlights a broader issue of trust and engagement between researchers and the community, and contributes to community burnout.

Despite these concerns, by the end of our study, some neighbors communicated a desire for new, more comprehensive, and community-engaged data collection initiatives. They expressed that in any future research, it is critical for the community to be involved in the entire research process, emphasizing the need for transparency and collaboration from the outset. Further, community members often voiced disappointment in the lack of neighborhood specific data. Collecting primary data at appropriate spatial scales, such as the neighborhood level, would have facilitated direct comparisons across Denver neighborhoods and yielded a more nuanced understanding of the connections between environmental exposures and health outcomes. However, primary data collection is not without its own challenges; it is often both costly and time-consuming, requiring significant investment in resources and community engagement. To address the extensive objectives of our study within the settlement constraints we faced, we ultimately chose to rely on secondary data rather than narrowing our focus to undertake primary data collection at the neighborhood level. This decision allowed us to collate broader secondary data but at the expense of capturing the localized nuances critical for community-specific interventions.

Future environmental health research within GES should focus on deepening the understanding of environmental exposures' historical and systemic contexts. To achieve this, we recommend establishing a

community-led Institutional Review Board (IRB) for overseeing the ethical review of research studies involving residents and constituents. This board would ensure that all research conducted within the community adheres to ethical guidelines, prioritizing the safety and well-being of participants while fostering trust between researchers and the community.

Additionally, based on conversations with GES residents, researchers should prioritize the report-back process, which is crucial for closing the feedback loop. This would ensure that participants receive clear and meaningful information about the data they provide to, or results from, local research studies. The primary goals of report-back are threefold: (1) to increase trust in scientific research by fostering transparency, (2) to improve health literacy among participants by making study findings accessible and understandable, and (3) to empower individuals and communities by involving them actively in the conversation about their health and environment.[8] Recent trends within the field of environmental health research indicate a growing support for report-back initiatives, particularly concerning exposure data. This strategy aims to enhance participant engagement by providing timely and relevant information that acknowledges their contribution to the research.[9] Studies have shown that participants who receive their individual study data often report feeling more respected and informed about issues affecting their health and well-being.[10] Implementing robust report-back practices not only benefits research outcomes but also strengthens the relationship between researchers and the communities they study, ultimately promoting a more collaborative approach to public health research and intervention efforts. In our study, we have experienced the positive impacts of the report-back process firsthand from CC members, who express gratitude and enthusiasm about being privy to all study findings. GES residents have expressed desires for future research projects to corroborate data by including important details from community insight to achieve these report-back goals.

In conclusion, our study was limited from the outset because it came from a top-down settlement. That said, the Community Council, Steering Committee, GES neighbors, and partners all supported a community-engaged process that resulted in valuable lessons-learned and a meaningful report-back process. We recommend that future research initiatives build on these takeaways by continuing to strengthen an equitable environmental health research and policy landscape in GES.

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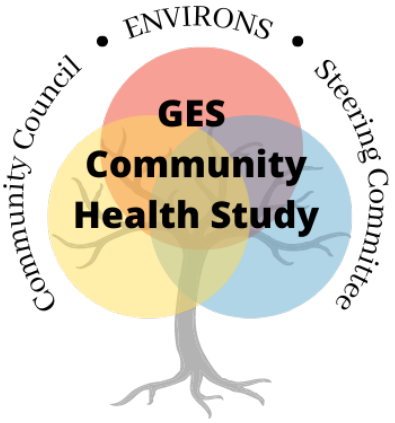

Data and Literature Evaluation

GES Community Health Study

In response to deliverable 2.1

August 31, 2023

ENVIRONS

Colorado State University

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List of Acronyms, Definitions, and Descriptions

Acronym	Name/Description
APCD	Air Pollution Control Division (Colorado Department of Public Health and Environment); the division responsible for monitoring air quality and issuing air permits in Colorado.
ATSDR	Agency for Toxic Substance and Disease Registry; ATSDR is a federal public health agency within the US Department of Health and Human Services. The agency focuses on minimizing human health risks associated with exposure to hazardous substances.
BTEX	Benzene, toluene, ethylbenzene, xylenes; a group of hazardous air pollutants related to traffic.
CAG	Community Advisory Group
CCoD	City and County of Denver
CDC	Centers for Disease Control; the Centers for Disease Control and Prevention is the national public health agency of the United States.
CDOT	Colorado Department of Transportation; the principal department of the Colorado state government responsible for maintaining interstates and highways in Colorado.
CDPHE	Colorado Department of Public Health and Environment; CDPHE is the principal department of Colorado state government responsible for public health and environmental regulations.
CHP	Community Health Program
Crowd-sourced Literature Folder	The Crowd-sourced Literature Folder was created by the GES Community Health Study Steering Committee as a way for GES residents and other concerned individuals to add documents they had or found to what would be used in the health study. The Crowd-sourced Literature Folder was created before ENVIRONS started on the study. It can be accessed as part of the *GES Master Folder* on Google Drive and is available here [https://drive.google.com/drive/folders/1GJIv4VKg8jUDicU2VKqU1JtT9IvxMUJf?usp=drive_link].
DDPHE	Denver Department of Public Health and Environment; the city department responsible for public health and environmental regulations, serves a similar function as CDPHE, but at a local level.
DRCOG	Denver Regional Council of Governments; serves as the metropolitan planning organization for the region
EPA	United States Environmental Protection Agency; the primary agency of the United States government tasked with environmental protection.
FHWA	Federal Highway Administration; the division of the United States Department of Transportation that specializes in highway transportation.
GES	Globeville, Elyria, and Swansea neighborhoods
HAP	Hazardous air pollutants; a group of air pollutants that do not fall under the NAAQS but are known to cause serious health effects and are regulated under the Clean Air Act
HIA	Health Impact Assessment; a process that usually produces a report describing how a proposal will impact health
NAAQS	National Ambient Air Quality Standards; The Clean Air Act requires EPA to set NAAQS for carbon monoxide (CO), lead (Pb), ground-level ozone (O_3), nitrogen dioxide (NO_2), particulate matter (PM), and sulfur dioxide (SO_2).
NGO	Non-governmental organization

PM	Particulate matter; PM contains microscopic solids or liquid droplets that can be inhaled and cause serious health problems. Some particles less than 10 micrometers in diameter can get deep into your lungs and some may even get into your bloodstream.
RTD	Regional Transportation District; the public transit system that operates buses and trains in the Denver metro area.
VB/I-70	Vasquez Boulevard and Interstate 70 Superfund site; this superfund site was created to remediate soil contamination primarily from historic smelting activities. The site includes two commercial/industrial areas as well as residential properties in all or part of the following neighborhoods: Cole, Clayton, Swansea/Elyria, southwest Globeville and northern Curtis Park.
VOCs	Volatile organic compounds; VOCs are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects.

Community Relevant Summary

Note: This section was written by the Community Council as a preface to the report. It is presented in Spanish as originally written. An English translation is available below.

Spanish

Este resumen fue escrito por el Consejo Comunitario del Estudio de Salud de la Comunidad GES compuesto por residentes de Globeville, Elyria y Swansea.

Desde hace más de 130 años, estos vecindarios han sido azotados directa y desproporcionadamente. Abusados, ignorados, abandonados por el sistema y por la ciudad por mucho más de un siglo. El ignorar a nuestros vecinos, y a la justicia medioambiental que merecemos como cualquier otro ciudadano o persona es un acto de violencia terrorista a nuestros vecinos y familias. Desde el principio de la ciudad de Denver hasta hoy, nuestras comunidades, compuestas por gente indígenas de la tierra o inmigrantes de europa o latino america, nos han discriminado por nuestra etnia y por nuestros bajos ingresos. Nuestro derecho al aire libre continúa siendo violado. Nuestra salud mental, mutilada. Han aplastado a nuestros derechos humanos, y tememos que seguirán. Sin embargo, todos los días, cumplimos nuestros deberes cívicos y pagamos los impuestos como cualquier persona, ciudadano o comunidad- nos van a escuchar con esta evaluación o esperaremos otros 130 años?

Lo primero a tener en cuenta es que estamos haciendo referencia a muchos datos, pero muchos de ellos son antiguos, algunos de los años 90. Si bien ha pasado tiempo desde que se recopilaron estos datos, no se han realizado mejoras en nuestra salud y bienestar.

Es importante señalar que muchos de nuestros vecinos que fueron estudiados fueron desplazados de la zona. El seguimiento es difícil o imposible. ¿Cuáles han sido los efectos a largo plazo de tantos de nuestros vecinos?

Históricamente hemos sido estudiados en exceso sin encontrar respuesta, según. A esta comunidad se le han prometido estudios para mostrar mejoras. Sin embargo, muchas personas y o grupos solo comenzaron sus estudios dentro de este vecindario para completar una tesis, una clase o un análisis de un proyecto de construcción o desarrollo local. Los investigadores y las organizaciones obtienen millones de dólares para realizar investigaciones y proyectos, pero los residentes no obtienen nada y, a menudo, ni siquiera ven los datos. Como miembros de la comunidad nos hubiese gustado ver los resultados. Cuando terminan sus proyectos, se van del vecindario- nos falta la segunda mitad en casi todo. En adición a esto, aunque haya habido muchos estudios e informes dentro del vecindario, y también listados en nuestro reporte, muchos de ellos no reconocemos porque no hicieron suficiente alcance comunitario para avisar ni difundir acerca de los resultados de los estudios.

Los datos muestran que nuestros vecindarios tienen niveles más altos de contaminación. Esto se menciona históricamente ya que la ciudad de Globeville se construyó alrededor de fundiciones que derretía metales tóxicos que se filtraron en el suelo. Las ordenanzas locales de la época permitían una contaminación tan pesada que las cortinas de seda de los hogares locales se desintegraron y la lana de oveja de la zona estaba manchada e inútil.[1] En nuestros materiales más antiguos y nuestros materiales más recientes esta falta de acción sigue.

Nuestra experiencia:

Debido a que los únicos datos y/o análisis personales de las experiencias actuales de los vecinos incluidos en nuestra investigación vienen de un estudio de 2017, entonces aquí explicamos nuestra perspectiva de hoy, otra vez. Sorpresa- no ha cambiado nada.[2]

Vivimos con basura dentro de infraestructuras no invertidas por la ciudad y si hay algunas, vienen de desarrollos privados diferentes avanzados por otros intereses fuera de la comunidad. Por esto desde los datos viejos todavía no tenemos comida saludable, agua limpia (sin plomo), aire limpio y sin olor ni tampoco infraestructura actualizada como banquetes ni iluminación de calles. Lo que sí todavía tenemos es el olor a Purina, los tóxicos de Suncor, olor de marihuana de los nuevos dispensarios, olores de la carne podrida de los mataderos, planta de procesamiento y agricultura entre otros.

También, con todos estos problemas que afectan la salud mental y física, la ciudad piensa poner a las personas sin hogar dentro de los vecindarios más desaventajados, más olvidados, cuando aquí casi no hay aire aceptable para los vecinos que ya están aquí. Ya tenemos pocos recursos. No tenemos suficiente para compartir- aunque quisiéramos.

Un estudio más, aparentemente no hará la diferencia. Si ya desde los años 90 (y antes) demuestran situaciones deplorables y eso no ha mejorado (basado en las experiencias vividas de los vecinos). Hemos sido estudiados una y otra y otra vez y casi nunca hemos recibido los resultados, además de no tener ninguna reacción o respuesta de la ciudad o el estado. Publicar datos por sitio web, el mínimo esfuerzo para compartir datos, tampoco es suficiente. Por falta de recursos, muchos de nuestros vecinos no tienen acceso al internet debido a circunstancias de edad, barreras de lenguaje, y tiempo libre para invertir en leer los estudios. Los estudios utilizan mucho lenguaje técnico que hace que sea difícil de entender y los residentes se agotan de tratar de leerlo todo. Además, muchos informes son muy largos y a los residentes no se les paga por leerlos como lo hace el gobierno. Entonces recomendamos ver este estudio como cumulativo. Ya la comunidad no debe ser más “instrumentos de experimento” y que es hora de acción.

Si el lector no tiene conocimiento de dónde empezar para tomar acciones personales o políticas que tendrán efectos importantes en las vidas de los vecinos, entonces nos referimos a las sugerencias del estudio de Green Latinos.[3]

Solicitaremos que si a la comunidad se le hacen nuevos estudios tienen que ser completos, y legibles por el público. En nuestra misma evaluación necesitábamos poner más que una página de acrónimos para explicar términos. Ni hablar de los tóxicos y los impactos de esos. En español no nos acostumbramos a usar acrónimos entonces estos estudios son inaccesibles para una gran parte de nuestra población.

Todos los días, cumplimos nuestros deberes cívicos y pagamos los impuestos como cualquier persona, ciudadano o comunidad- nos van a escuchar con esta evaluación o esperaremos otros 130 años?

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English

This summary was written by the GES Community Health Study Community Council, made up of residents of Globeville, Elyria and Swansea.

For more than 130 years, these neighborhoods have been hit directly and disproportionately. Abused, ignored, abandoned by the system and by the city for well over a century. Ignoring our neighbors and the environmental justice that we deserve like any other citizen or person is an act of terrorist violence against our neighbors and families. From the beginning of the city of Denver until today, our communities, made up of indigenous people of the land or immigrants from Europe or Latin America, have been discriminated against because of our ethnicity and our low income. Our right to the outdoors continues to be violated. Our mental health, mutilated. They have crushed our human rights, and we fear they will continue. However, every day, we fulfill our civic duties and pay taxes like any other person, citizen or community - will they listen to us with this assessment or will we wait another 130 years?

The first thing to note is that we're referencing a lot of data, but a lot of it is old, some from the 1990s. While it's been a while since this data was collected, no improvements have been made to our health and wellness.

It is important to note that many of our neighbors who were studied were displaced from the area. Tracking is difficult or impossible. What have been the long-term effects on so many of our neighbors?

Historically we have been studied excessively without finding an answer. This community has been promised studies to show improvements. However, many individuals and/or groups only began their studies within this neighborhood to complete a thesis, class, or analysis of a local construction or development project. Researchers and organizations get millions of dollars to conduct research and projects, but residents get nothing and often don't even see the data. As members of the community, we would have liked to see the results. When they finish their projects, they leave the neighborhood- we lack the second half in almost everything. In addition to this, although there have been many studies and reports within the neighborhood, and also listed in our report, many of them we do not recognize because they did not do enough community outreach to notify and disseminate about the results of the studies.

Data shows that our neighborhoods have higher levels of pollution. This is referenced historically as the town of Globeville was built around smelters that melted down toxic metals that seeped into the ground. Local ordinances at the time allowed for contamination, so heavy, that the silk curtains in local homes disintegrated and the local sheep's wool was stained and useless.[1] In our older materials and our newer materials this lack of action continues.

Our experience:

Since the only data and/or personal analysis of the current experiences of neighbors included in our research comes from a 2017 study, here we explain our perspective today, again. Surprise- nothing has changed.[2]

We live with garbage within infrastructures with no investment by the city and if there is any investment, it comes from different private developments, advanced by other interests outside the community. For this reason, since the old data we still do not have access to healthy food, clean water (lead free), clean, odor-free air and no updated infrastructure like sidewalks or street lighting. What we do still have is the smell of Purina, the toxins from Suncor, the smell of marijuana from the new dispensaries, the smells of rotting meat from slaughterhouses, processing plants, and agriculture, among others.

Also, with all these problems affecting mental and physical health, the city plans to put the homeless within the most disadvantaged, most neglected neighborhoods, when there is almost no acceptable air here for the neighbors who are already here. We already have few resources. We don't have enough to share - even if we wanted to.

One more study apparently won't make a difference. Since the 90s (and before) they show deplorable situations that have not improved (based on the lived experiences of the neighbors). We have been surveyed over and over and over and we have almost never received the results, plus no reaction or response from the city or state. Publishing data on a website, the minimal effort to share data, is not enough either. Due to lack of resources, many of our neighbors do not have access to the internet due to circumstances of age, language barriers, and free time to invest in reading the studies. The studies use a lot of technical language that makes them difficult to understand and residents get exhausted from trying to read everything. Also, many reports are very long and residents are not paid to read them like the government is. So, we recommend viewing this study as cumulative. The community should no longer be "instrument of experiment" and that it is time for action.

If the reader does not know where to start to take personal or political actions that will have important effects on the lives of the neighbors, we refer to the suggestions of the study of Green Latinos.[3]

We will request that if new studies are done to the community, they must be complete, and readable by the public. In our own review we needed to put in more than a page of acronyms to explain terms. Not to mention the toxins and their impacts. In Spanish we are not used to using acronyms so these studies are inaccessible to a large part of our population.

Every day, we fulfill our civic duties and pay taxes like any other person, citizen or community - will they listen to us with this assessment or will we wait another 130 years?

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Introduction

Note: This section begins the report written by the ENVIRONS research team.

Every community member has their own story to tell about Globeville, Elyria, and Swansea (GES); likewise, each document, research paper, and news article written about these neighborhoods contributes its own story of GES. At times, these stories align, and at others they diverge, creating confusion and misunderstanding. As technical advisors to the GES community, one task ENVIRONS is charged with is to help sort through the information to draw out a comprehensive story that intertwines the lived experiences of residents with what the data, technical reports, and research demonstrate. In this deliverable, *Data and Literature Evaluation*, we began that process by reviewing information sources, including written materials and datasets, that were either included in the Crowd-sourced Literature Folder managed by the GES Community Health Study Steering Committee (SC) or in the appendices of the Phase 1 Deliverable 1.4 *Narrative*. For each information source reviewed, this report describes our decision to include or exclude the source from future deliverables, the reasoning behind our decision, and a brief summary of the information source. Our intention is that residents can use this document as a reference in understanding source information from the Crowd-sourced Literature Folder and Phase I Deliverable 1.4 *Narrative*, and whether it is high quality, relevant material.

In Phase I of the GES Community Health Study, we used online databases to obtain past research findings, and manually reviewed Colorado Department of Public Health and Environment (CDPHE), City and County of Denver (CCoD), and Denver Regional Council of Governments (DRCOG) open data sites. We found that there are few published research studies about health or the environment in GES, despite community feelings of being over-studied. Data, for the most part, are only available from government agencies and applicable datasets are still scarce. In parallel to our efforts to find information, residents had the opportunity to contribute to the Crowd-sourced Literature Folder, which we reviewed as potential sources of information to use in the GES Community Health Study. The Crowd-sourced Literature Folder contains government reports, news articles, and court documents, which are reflective of how information written about GES shows up in the lives of residents.

Before using any information, both what we found through literature searches and what residents shared, we have to determine the quality of that information. This is a similar process to what individuals do every day sorting through streams of news on TV, newspapers, and social media to find the most reliable source of information. Like individuals searching for the most accurate source of news, we as researchers search for the most reliable source of information regarding the health and environmental conditions of GES. In research, it is important to evaluate the quality of data and past study findings to make informed decisions about research methods, study conclusions, and the use of findings. Unfortunately, this process is not consistent across the scientific community. This deliverable aims to create a uniform process for evaluating literature and data for the GES Community Health Study.

Community members have voiced multiple concerns that we are attentive to in this report. First, a desire for transparency, as it applies to all activities and information about GES. Information about GES is often difficult to access and interpret, particularly from government sources that are sometimes multi-hundred-page reports. When used as reference material, Deliverable 2.1 will help residents look up and understand different information sources that may not otherwise be easily accessible. This report also serves to provide transparency about our process, the data we have collected, and our decisions regarding its

usability. Second, there is considerable apprehension related to perceived conflicts of interest among the producers of information. Conflicts of interest arise when the producer has something to gain or lose depending on what the data show. An example of this is when a car salesperson tells you how great a particular car is; the salesperson is motivated to overstate how good the car is in hopes that you buy it, and they stand to gain from this transaction. This is concerning in research because we rely on data being accurate to draw scientifically valid conclusions. If data or information has been manipulated or collected in a way to prove a point, then the conclusions drawn from that data may be incorrect. We have attempted to identify potential sources of conflicts of interest and when possible, exclude sources that have clear conflicts of interest. Finally, issues with transparency and conflict of interest both contribute to pervasive mistrust and skepticism of information about GES, particularly from government sources. This is an enduring challenge for our research team as government sources make up the majority of the data available for us to use, and for the most part, were determined to be reliable sources. We aim to work with the community to break down and explain government reports and processes, which we recognize can be long and confusing.

In research, many of these same concerns are addressed through a process called peer review. In the peer review process, a researcher shares a detailed description of their study and results with other scientists who critically evaluate the data to ensure it is objective and answers the original question asked by the scientists. This process is conducted before results from the study are published, so by the time a study is published, it has already been reviewed by other experts to ensure that it is high quality. ENVIRONS relies on peer reviewed studies as trustworthy sources of data and information because of this rigorous process. However, we found that there are relatively few peer-reviewed studies about health and environmental conditions in GES. Instead, for the GES Community Health Study, we must partially rely on other types of information, including government reports, court documents, reports from non-governmental organizations, websites, and news articles. Government reports often undergo a similar process to peer review before being published, and are written by subject matter experts, making them a reliable source of information. The remaining source types must be more carefully examined to assess the quality of information and data. News articles, in particular, are often written with a particular angle or goal in mind. For news articles based on another scientific report or data source, we excluded the news article in preference of the original information source.

Another characteristic of scientific information that is important to consider is the age of the literature and when the data were collected. As data ages, the people or places the data represent may change in ways that result in a lack of data accuracy. This happens at different speeds for different topics, so we considered each information source individually to evaluate if data presented were still relevant and accurate. In some cases, there have been major changes in the GES neighborhoods that clearly make older data inaccurate and prevent the data from being used to understand current conditions. These older data have value from a historical perspective. One example of this is air pollution monitoring from I-70 before the I-70 East expansion project construction. Since the construction, air pollution near the interstate may be significantly different than it was before. On the other hand, some data are inherently delayed due to the way they are collected and processed. Examples of this include census data and health data from state records. In any case, we are limited to the best available data that have been published. Limitations due to the age of the information have been noted where appropriate.

While completing the evaluations for Deliverable 2.1, we noticed a few trends similar to what was noted in the Phase I Deliverable 1.4 *Narrative*. Primarily, there are less data about the GES community published

in peer reviewed research journals compared to what we expected to find given the widespread feeling of being overstudied in the neighborhood. Further, publicly available data are limited to government sources and are not often provided in a manner that is usable to the general public by requiring specialized knowledge of geospatial data and software.

ENVIRONS recognizes this report is not comprehensive of all possible data and information available about the GES neighborhoods and its residents. The current version is limited to what was in the Crowd-sourced Literature Folder and/or identified in the Phase I Deliverable 1.4 *Narrative*. As the GES Community Health Study progresses, this report will be updated with data and literature sources that are found and used; as such, Deliverable 2.1 should be viewed as the first edition. As new literature and data sources are identified, each one will be evaluated for inclusion or exclusion, while the source they are replacing will be moved to the "exclude" category. We believe it is unlikely that sources will move from exclude to include, though the most likely cause of this would be a change in the scope of the study. A major planned update to these evaluations will occur following completion of Deliverable 2.2 Health Impact Assessment and Deliverable 2.4 Cumulative Risk Assessment in January 2025, followed by a minor update at the conclusion of the study in February 2025.

Summary of Activities

ENVIRONS created two rubrics, one for data and the other for literature, which we used to evaluate materials in the appendices of Phase I Deliverable 1.4 *Narrative,* as well as materials in the Crowd-sourced Literature Folder. Criteria used in formulating the literature rubric included questions relating to document type, whether the information provided was objective or subjective, as well as the timeliness of the document (e.g., some documents were published in the early 2000s). Criteria used to create the dataset rubric included questions related to accuracy, timeliness, and if it was relevant to the GES Community Health Study. Full definitions of these terms are located in Table 8.

ENVIRONS evaluated a total of 95 items as part of Deliverable 2.1. Of these, 42 were articles and reports in the peer-reviewed and gray (*i.e.*, non-peer-reviewed) literature , 49 were datasets, and 4 were ongoing studies. For the literature evaluations, document types varied, consisting of peer-reviewed journal articles, technical reports from government agencies, court documents, news media, and public reports. Additional document types consisted of public presentations, public comments to a governmental technical report, and product reviews. Table 1 highlights the final determination for the literature documents evaluated based on their type.

Table 1. Final determination for literature sources by type.

Literature Type	**Included**	**Excluded**	**Total**
Peer-reviewed Journal Articles	6	4	10
Technical Reports	15	3	18
Public Reports	3	0	3
News Media	1	2	3
Other	2	6	8
Total	**27**	**15**	**42**

Datasets were primarily accessed through CDPHE Open Data and Denver Open Data Catalog. Other sources included the Environmental Protection Agency (EPA), Regional Transportation District (RTD), Denver Regional Council of Governments (DRCOG), and Colorado Department of Transportation (CDOT). In cases where the authoring organization is not the publishing organization, we have noted the original authors according to the credits available for the dataset. Table 2 highlights the final determination for the evaluated datasets based on their source.

Table 2. Final determination for data sources by type.

Dataset Source	**Included**	**Excluded**	**Total**
CDPHE Open Data	18	6	24
Denver Open Data Catalog	9	9	18
Other	3	4	7
Total	**30**	**19**	**49**

There are four ongoing studies and projects that have been summarized in Table 7. We are aware of additional studies and projects that are not included in this report. This report is limited to sources, including ongoing studies and projects that were previously listed in Phase 1 Deliverable 1.4 *Narrative* or the Crowd-sourced Literature Folder.

Literature

Included Literature

The following table outlines literature documents determined to be included in the GES Community Health Study. The table highlights a summary of the document, reasoning for inclusion, as well as limitations. Source information is denoted by Crowd-sourced Literature Folder §, Phase 1 Deliverable 1.4 *Narrative* †, and Peer reviewed *.

Table 3. Included Literature Documents.

Title (Publication; Date)	Summary	Inclusion Reasoning	Limitations
2019 Status of Denver's Children. † CCoD; published 2019; authors affiliated with CCoD Department of Children's Affairs.	This report includes information and data on Denver's children. This document discusses many factors that can influence a child's success, including social determinants of health, access to goods and services, birth outcomes, and youth health outcomes. These data indicators are shown at the neighborhood level. For most indicators, GES was reported to have a greater disadvantage than other parts of Denver. This document also talks about programs and policies that are helping the children in Denver.	This is a relatively recent report that comprehensively assesses factors affecting children in Denver, including topics that are relevant to the GES Community Health Study such as health and social determinants of health. While some data is available elsewhere, many of the data and maps presented are not openly accessible elsewhere at this time.	Data used in this report are four years old and from before the pandemic, so many factors affecting children may have changed. Most data are presented as static maps and will be difficult to reuse in the current form.

2021 Air Quality Data Report. † Report Repository. CDPHE; published November 3, 2022; authors affiliated with CDPHE Air Pollution Control Division.	This technical report is the 2021 Annual Air Monitoring Report from CDPHE. The report provides an overview of the air monitoring network, criteria pollutants, and spatial variability for the state. There were no violations of National Ambient Air Quality Standards (NAAQS) levels for particulate matter 10 and 2.5 (PM_{10}, $PM_{2.5)}$, nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) for the Denver Metropolitan and North Front Range monitoring area. However, this region violated the NAAQS for ozone (O_3). CDPHE's Air Monitoring report repository provides annual air quality data reports for 2000-2021, network plans for 2007-2023, as well as 5-year network assessments.	This technical report was determined to be included in the GES Community Health Study because air quality is a large concern voiced by community members. The closest monitoring site (I-25 Globeville) is located at Acoma St and West 49th Ave. The annual report is to serve as an example of the many published reports within the CDPHE database.	Meteorological measurements are limited to 19 locations across the state of Colorado. The I-25 Globeville monitor is limited to NO_2, $PM_{2.5}$, and meteorological measurements.

Analysis of Diagnosed vs. Expected Cancer Cases in Residents of the Vasquez Boulevard/ I-70 Superfund Site Study Area. † Citizen's Summary: Analysis of Diagnosed vs. Expected Cancer Cases in Residents of the Vasquez Boulevard/I-70 Superfund Site Study Area. § † CDPHE; published November 2003; authors affiliated with CDPHE.	These two documents are linked together because one is the technical report on the study and the other is the citizen summary of the study. The study was conducted by CDPHE to examine cancers diagnosed and reported to the state Cancer Registry between 1982 to 1998 for the geographical area around the Vasquez Boulevard/Interstate 70 Superfund Site (VB/I-70). The study found that while the census tracts within this area had higher rates of multiple cancers, there was no relationship found between arsenic exposure and these cancers. The study does acknowledge that the higher rates of various cancers are likely due to socioeconomic and environmental factors, including, but not limited to, air quality, race, work environment, and access to medical care.	Both documents were determined to be included in the GES Community Health Study as background information on cancer rates within the VB/I-70 area. The topic relevancy and presented results support inclusion due to the expressed concerns of residents, geographical study area, and the study design and methods. The study's findings address the study question and acknowledge limitations adequately.	These two documents are not peer-reviewed and are dated as they were published in 2003 and the data used are from 1982-1998. While the findings suggest that there is a trend of a higher-than-expected rate of cancer in the VB/I-70 community when compared to cancer in the rest of the Denver metropolitan area, this must be taken with caution as the results were mixed in terms of statistical significance. Additionally, soil data were not available for many of the properties where cancer was diagnosed. Although arsenic soil levels can be useful as an indication of potential exposure within the home, no information was available on residence history of individuals diagnosed with cancer. Therefore, no individual dose levels could be estimated.

Assessment of mobile source air toxics in an Environmental Justice Denver community adjacent to a freeway. § † * Journal of the Air and Waste Management Association; published February 4, 2021; authors affiliated with Sonoma Technology Inc., CDPHE, and Air Resource Specialists Inc.	This study conducted air pollution testing near Swansea Elementary at different distances away from I-70 to see if there was more pollution closer to the interstate. They found that there was 30-80% more black carbon downwind of the interstate. However, when averaged for the whole day, including when the wind changed directions, being close to the interstate was associated with about 15% more black carbon. The study also sampled volatile organic compounds (VOCs), which includes benzene, but did not have enough samples to make conclusions about the concentration close to the interstate. Overall, this study shows that some pollutants are more concentrated close to the interstate, but this may have changed with the I-70 construction.	This document was determined to be included in the GES Community Health Study because pollution from the highway is a stated concern of residents and this is a peer-reviewed study done in GES on that topic.	There have been significant changes to I-70 since original data collection took place, which may have changed how pollution from the interstate impacts the air quality right next to it. Additionally, the authors were not able to determine if there was a higher concentration of VOCs near the interstate due to not having enough samples.
Cancer In North Denver 1998-2000. † CDPHE; published September 2002; authors affiliated with CDPHE-Comprehensive Cancer Control Program.	This technical document was part of a series of reports on cancer rates across Colorado using region-specific data between 1998-2000. The study found that North Denver had higher rates of cancer-related risk behaviors, like smoking and not using sunscreen, and lower rates of screenings and preventative care, like mammograms and colonoscopies when compared to other regions of the state.	Though the data used is 15+ years old, the document provides historical information about cancer rates and how they are related to cancer-related behaviors. The document also provides a comparison between Hispanic populations and non-Hispanic white populations which further examines trends in disproportionate exposure to environmental harms that the GES community may be experiencing.	This technical report is not peer-reviewed and is dated as it was published in 2002 and used data from 1998-2000. 80216 zip code is included in the results; however, the report does not account for individual zip code results. Study methods used different scales between the incidence and mortality rates for all cancers and those for the individual cancers, making the comparisons between the two more difficult.

Community Health Program Design Work Plan. § † EPA; published March 2003; authors affiliated with the contracted consulting firms (MFG, Inc. and Tetra Tech EM Inc.), and EPA.	This technical report published by EPA highlights the conceptual design work plan of the Community Health Program (CHP) associated with soil removal activities at Operable Unit 1 (OU1) of VB/I-70. The CHP was implemented to increase the level of health services available to the community within the site boundary during the soil removal and replacement component of the clean-up action. The CHP consisted of a biomonitoring program, community outreach, documentation of the remediation efforts, and referrals to local health service agencies for lead-based paint abatement.	This technical report was determined to be included in the GES Community Health Study due to topic relevancy, expressed concerns of GES residents, geographical area, and government agency partnerships. The CHP emphasized that children's exposure to lead and arsenic is mainly through pica behavior. The report describes the CHP's objectives and approach, provides the general planning documents and standardized procedures needed to implement the program, and identifies participating agencies and their planned roles in implementing the program.	The primary regulation used for addressing child exposure to lead from lead-based paint is limited to homes constructed prior to 1978. This criterion limited the number of homes eligible for the assessment. The pilot study conducted as part of the preliminary findings was limited in the number of samples collected (15 properties). The CHP services were initially provided by EPA; however, the intentions of this work plan were to also develop and establish a program that would eventually be managed and administered through cooperative efforts of local health and housing agencies.

Draft – Elyria/Swansea Neighborhood Plan. § Elyria & Swansea Neighborhood Plan 2015. § CCoD; published November 2003 and February 2015; authors affiliated with CCoD.	The 2003 Draft Neighborhood Plan discusses many aspects of the Elyria and Swansea neighborhoods. It was to serve as an update to the 1983 Neighborhood Plan. The 2015 Neighborhood Plan was adopted by Denver City Council in February 2015. This plan covers environmental and health factors faced by Elyria and Swansea community residents. It also outlines concerns and celebrations of the community residents.	Both the 2003 Draft and 2015 Neighborhood plans were determined to be included in the GES Community Health Study due to the nature of the reports. The 2015 neighborhood plan was written in conjunction with the 2014 Health Impact Assessment (HIA), which serves as a leading document for the GES Community Health Study. The neighborhood plan also highlights recommendations and implementation strategies for improving the overall health of Elyria and Swansea. It provides recommendations on zoning, development, and partnering with community and stakeholders.	The 2003 Plan draft was never released as a finalized version. The data used is from the early 2000s. The 2015 Neighborhood Plan serves as the most recent plan for Elyria and Swansea, which is now 8 years old.
Exhibit 33 Second Declaration of Dr. Gregory Rowangould. § US District Court for the District of Colorado; filed March 9, 2018; author affiliated with University of New Mexico and Sustainable Systems Research LLC.	This court document used a model to predict the concentration of $PM_{2.5}$, a type of air pollution, near I-70 in 2040 following construction. The results predicted that $PM_{2.5}$ would exceed National Ambient Air Quality Standards (NAAQS) around the I-70/I-25 intersection. The modeling was performed by an expert, but the results were not peer reviewed. However, it followed the same methods and used the same data as the models used by CDOT to predict PM_{10} and carbon monoxide. CDOT did not model $PM_{2.5}$, which is why this model was conducted separately.	While not peer reviewed, the modeling in this document was conducted using the same parameters and data as CDOT's models for PM_{10} and follow EPA guidance. The model results are for 2040 and can be used to assess reasonably foreseeable future scenarios.	Like all models, this analysis makes assumptions using best estimates for baseline conditions and predicted future conditions. The model used in this research used the same assumptions that CDOT used in their modeling following CDPHE and EPA recommendations and are appropriate in this situation.

Globeville Elyria-Swansea: The Peoples' Survey - A Story of Displacement. § GES Coalition; published 2017; authors affiliated with community organizations, GES Coalition Organizing for Health and Housing Justice.	This public community report presents findings of a 2016 surveying effort hosted by a group of GES residents, youth leaders, community organizers, service providers, and nonprofit organizations to address and understand the displacement and gentrification occurring in the community. GES resident views were collected using door-to-door surveying between May and August of 2016. In total 500 surveys were collected.	This report was determined to be included in the GES Community Health Study due to topic relevancy, and direct community input. This report provides the GES Community Health Study with a perspective from the community. Overall, this document highlights the displacement vulnerabilities GES residents face (e.g., lack of leases and renters' rights). This document also presents possible solutions and remedies to mitigate displacement through supporting GES families to stay in the neighborhoods, retaining low-income and senior homeowners, and maintaining affordable rental units.	One limitation is that the report is limited in scope. It does not include many environmental health issues; however, it does discuss the built environment, which is a large concern for GES residents.
Globeville Neighborhood Plan. § CCoD; published December 2014; authors affiliated with CCoD.	This is the current neighborhood plan for Globeville and outlines the city's vision and plan for Globeville, including strategies to improve environmental quality, connectivity and mobility, and access to goods and services.	The neighborhood plan supports analysis of the 2014 HIA recommendations as part of the updated HIA (Deliverable 2.2).	This document is a plan and does not necessarily reflect actions taken and outcomes.
How Neighborhood Planning Affects Health in GES. § † CCoD; published September 2014; authors affiliated with DDPHE.	This document is the 2014 Health Impact Assessment (HIA), written by DDPHE as a summary of key findings about the health hazards posed by the environment to GES residents. This report includes history, demographics, health, environmental quality (e.g., air, water, soil, noise, odor), connectivity and mobility, access to goods and safety, and mental wellbeing. It also provides recommendations for the community in terms of planning for future efforts, neighborhood plans, and research.	The 2014 HIA is foundational to the work that ENVIRONS will do in this study and has been a critical starting point for creating the next iteration of the GES HIA. It is a government document and is based on high quality data.	The data presented about health and environment in the HIA are about 10 years old and may not represent current conditions. However, the information is useful for understanding environmental quality in GES from a historical perspective.

I-70 East Final EIS: Chapter 7 Section 4(f) Evaluations. † Report Repository. FHWA and CDOT; published January 2016; authors are affiliated with FHWA and CDOT.	Chapter 7 of the I-70 East Final Environmental Impact Statement (EIS) discusses properties and the use of other properties by the I-70 project alternatives. It presents a discussion of alternatives which minimize harm. This document uses the Supplemental Draft EIS from August 2014 as a starting point and incorporate design changes to avoid South Platte River Greenway Trail and Burlington ditch areas. While the EIS found that the Partial Covered Lowered Alternative is the alternative which would cause the least harm, the Federal Highway Administration (FHWA) determined that there are no feasible and prudent avoidance alternatives.	This section of the EIS was determined to be included in the GES Community Health Study for background information regarding activities associated with the I-70 expansion project. The full report repository contains a list of documents relating to the I-70 East expansion activities.	This document was written for city planners and FHWA and is difficult to understand because of the technical language used. This section of the EIS was published in January 2016 before the I-70 Expansion project began. While the document could be used for historical purposes, some of the information is dated. For example, one alternative presented in this document discusses moving the rail lines, which is not a feasible option.
The Impact of Industrial Odors on the Subjective Well-Being of Communities in Colorado. † International Journal of Environmental Research and Public Health; published May 28, 2018; authors affiliated with University of Colorado.	This study assessed the impact of industrial odors on the subjective well-being (SWB) of North Denver residents compared to Greeley, Fort Collins, Fort Lupton, and Pueblo. Data was collected through an online survey for 2016 and 2017. Results showed that participants who reported that the air is very fresh, or the odor is highly acceptable had higher levels of SWB. A comparison between the five communities showed that well-being levels in North Denver and Greeley were not significantly different than those in Fort Collins or Fort Lupton. The comparison, however, showed that Pueblo had the lowest levels of well-being among all communities.	This study was determined to be included in the GES Community Health Study because the topic is an expressed concerns of GES residents and study area includes GES.	Limitations include small sample size, particularly with the longitudinal analysis (55 entries with only 5 covering the full year).

Industrial Odor Sources and Air Pollutant Concentrations in Globeville, a Denver, Colorado Neighborhood. † * Journal of the Air & Waste Management Association; published August 14, 2015; authors affiliated with University of Colorado and Groundwork Denver.	This study conducted air sampling to investigate the chemicals causing odors and the potential source of the odors. No single chemical was found to be above the limit that people can smell, but the main chemical is likely naphthalene as part of a mixture. The source was identified to be the wood preservation facility (now closed) and/or a roofing and asphalt company. The concentration of naphthalene during periods of high odor was found to be above the amount where long term exposure can cause health problems. The amount of naphthalene and benzene during periods of high odor were above the amount where exposure over a lifetime would increase the risk of cancer by one in a million.	This is a peer-reviewed study of odors and VOCs in GES, which are stated concerns of residents.	The number of air samples for odor events was small, only six, and were only collected at one location in GES. This means that the data may not be representative of all odor events or all locations in GES. Additionally, the study is eight years old, and some facilities have closed and the process at others might have changed so the cause and chemicals in odors now may be different than during the study. During odor events, naphthalene and benzene were detected at concentrations that long term exposure may result in health problems, however this assumes constant exposure at that level, which is likely not what happens in GES because the odors are not always present. This means the health risk is likely less than these data show.

Industrial Odor Source Identification Based on Wind Direction and Social Participation. § † * International Journal of Environmental Research and Public Health; published April 8, 2019; authors affiliated with University of Colorado.	This study examined the spatial distribution of odors and wind data for the Denver Metropolitan and Front Range regions. Dead animal and sewage odors were associated with a North Denver meat and grease recycling facility, and the Metro Wastewater treatment plant, respectively. Another odor that was often described as a refinery odor was less likely to be associated with the Denver oil refinery and more likely to be associated with one of the four facilities in northwest Globeville that use asphalt and creosote materials. The majority of North Denver odor complaints were pet food, refinery, roofing tar, dead animals/rendering, and sewage. The study does acknowledge that all odor-emitting facilities (except Purina) which impact North Denver residents are located in Adams County, outside of City and County of Denver limits.	This study was determined to be included in the GES Community Health Study as the study directly investigates North Denver, specifically Globeville, Elyria, and Swansea. The topic relevancy (odors) and presented results support inclusion due to the expressed concerns of residents and geographical study area.	The study does make hypotheses on which facilities could be associated with each specific odor complaint. For example, for roofing tar odor complaints, there are four possible sources. However, the study and data used cannot be attributed to one facility specifically. Wind data from I-25 Globeville station, which is more representative of the study area, only became available online starting in November 2016. Therefore, between March 2016 through October 2016, wind data from the CAMP station was used. The CAMP station is located in downtown Denver at the intersection of 21st Street and North Broadway and may be less representative of the wind conditions in GES. This means that the sources may not be accurately identified. The CAMP station accounted for 73% of the reports used in this study.

Public Health Assessment - Vasquez Boulevard/I-70 Superfund Site. § † ATSDR; published August 12, 2003; authors affiliated with ATSDR.	The Agency for Toxic Substances and Disease Registry (ATSDR) conducted a 2003 public health assessment surrounding the Vasquez Boulevard/I-70 Superfund (VB/I-70) areas relating to arsenic and lead contaminants in the soil. ATSDR determined that soil arsenic levels at many (but not all) of the properties in the VB/I-70 study area were safe for children and adults with typical soil intake levels. ATSDR, however, was concerned about soil arsenic levels in approximately 650 of the 2,986 properties that were sampled. Some properties within the site had high levels of lead in soil that were a health hazard to some preschool children living at those properties.	This report was determined to be included in the GES Community Health Study because contaminated soil from superfund sites is an expressed concern of GES residents. The report also discusses possible pathways for children and adult exposure to potentially contaminated soils, which is beneficial information for GES residents.	While no children were diagnosed with arsenic poisoning in the VB/I-70 area that can be related to arsenic in soil, it is possible that cases could have been missed because the most likely symptoms (nausea, vomiting, etc.) are common symptoms in children that can result from a variety of causes. There is uncertainty in estimating the maximum arsenic level in a property based on 2003 sampling procedures, the varying amounts of dirt soil-pica children eat, and the varying patterns of this behavior. Blood lead testing conducted by CDPHE in the summer of 2000 found roughly 10% of the 86 preschool children tested had blood lead levels above 10 ug/dL. However, it was not possible to determine how much lead contamination in soil contributed to these blood lead levels.

Screening-Level Ecological Risk Assessment for the VB/I-70 OU2. § † EPA; published August 2009; authors affiliated with EPA.	This is a screening ecological risk assessment (animals and plants) for VB/I-70 Operable Unit 2 (OU2) site which is underneath the Denver Coliseum, Pepsi Co. bottling facility, and Globeville Landing Park, as well as in the South Platte. Historically the site was used for smelting (1883-1903) and municipal waste incineration (1933-1945). Remedial investigation efforts included soil borings and monitor well borings (duration over 2004-2005), and in 2008, a feasibility study/risk assessment/remedial investigation collected surface and subsurface soil samples. The report used data from these previous OU2 projects, including from surface soil, soil up to 10 feet deep, water samples, and river sediment samples. Deep soil under the Pepsi Co. bottling and commercial buildings along Brighton Blvd. was found to have lead, zinc, and arsenic at concentrations that could be harmful to plants. The water and sediment in the South Platte downriver of the site was about the same as upriver and did not have arsenic, lead, cadmium, or zinc at concentrations dangerous to aquatic life.	This report is from a trusted source and provides raw data from soil sampling in OU2 as well as the methodology and results that led to the conclusions presented in the report. The presence and risk from heavy metals in soil are stated concerns of residents. For surface water and sediment, metals were also detected but were consistent up and down stream of sampling sites. Only lead in sediment tended to be higher up stream versus downstream.	The data used are old and some portions of OU2 have undergone remediation or construction which could have changed the levels of heavy metals in the soil. If used directly, soil sample data would have to be copied from printed data tables. The sample locations are marked on a map but do not include exact longitude and latitude, which would result in a small amount of error if these data are reused.

Soil-Pica, Soil-Ingestion and Health Outcome Investigation: Site-Specific Health Activities. § † ATSDR, published May 2005, authors affiliated with CDPHE.	This study examined the association between soil characteristics, playing in soil, eating soil, housing characteristics, and the concentration of lead and arsenic in children living within the VB/I-70 area. This was a large study that included almost 1,000 children between 6 months and 6 years old. The study found that lead concentrations were higher than the national average and were related to housing conditions such as peeling paint more than the amount of lead in the soil around the house. The amount of arsenic in children tested was not higher than what is normal and was not related to the amount of arsenic in soil. This means that the study did not find evidence that soil exposure was causing high amounts of lead or arsenic in children.	This is a comprehensive study of lead and arsenic in children in GES, and their relation to soil and household exposures. Lead exposure, especially from soil, is a stated concern of residents. While this study is over 15 years old, it is one of the few comprehensive assessments of lead and arsenic exposure in children in GES.	This study is over 15 years old and conditions may have changed since the study was conducted.
A Spatiotemporal Prediction Model for Black Carbon in the Denver Metropolitan Area, 2009–2020. † * Environmental Science and Technology; published February 17, 2021; authors affiliated with University of Illinois at Urbana-Champaign, Colorado State University, ZevRoss Spatial Analysis, Colorado School of Public Health, and University of Colorado at Anschutz Medical Campus.	In this study, conducted by several of the ENVIRONS team members, researchers were able to predict the amount of black carbon (BC), a type of air pollution, at a high level of detail in the Denver area on a weekly basis. Results showed that these predictions matched up well with actual sampled measurements, meaning the prediction can be used to determine exposure to black carbon at a high level of detail in Denver. Black carbon was predicted to be greatest in the winter and close to major roadways and interstates.	This is a recent peer-reviewed study about a type of air pollution in Denver, and data from the model described in the paper can be used as part of the environmental exposures in GES.	The major limitations of this model are common to all air pollutant models. It cannot account for every factor that might influence BC concentrations (e.g., human activity, weather patterns, changes in the types of vehicles that travel along specific roads). Importantly, the model does not account for changes in land use since 2020 (e.g., the expansion of I-70) that will impact BC estimates in unknown ways. Additionally, because the model predicts weekly concentrations, it cannot account for short term changes in concentration that might occur on a daily or even hourly basis

Spatial Surveillance of Childhood Lead Exposure in a Targeted Screening State: An Application of Generalized Additive Models in Denver, Colorado. † * Journal of Public Health Management and Practice.; published September/October 2017; authors affiliated with CDPHE.	In this study, researchers used 2010-2014 blood lead level testing data reported to the Colorado State Health Department to assess risk factors for elevated blood lead levels in the Denver metropolitan area. The study considered demographics, socioeconomic status, housing characteristics, and proximity to lead related superfunds, toxic release inventory facilities, and major roads. Two distinct clusters were identified, neither of which included GES. Overall, results showed that lead exposure risk was associated with socioeconomic status, demographics, and housing characteristics, but not proximity to lead related superfunds, toxic release inventory facilities, and major roads. This suggests that lead exposure in Denver is attributable to housing, not soil or other sources. Housing older than 1946 is at the greatest risk.	This report was determined to be included in the GES Community Health Study because lead poisoning is a relevant topic, and the study area includes GES. Lead has been mentioned by community members multiple times as a primary concern. Researchers found that low socioeconomic status, Hispanic ethnicity, Asian race, and older housing were positively associated with an increased elevated blood lead level risk. All of these factors can be directly applied to the GES population.	Based on the nature of this study design, results should be considered exploratory rather than explanatory. Additionally, based on the time of this study, researchers used a blood lead level reference value of 5 ug/dL. In 2021, the CDC lowered the reference value 3.5 ug/dL.
Suncor Air Quality Health Risk Evaluation. § † CDPHE; published 2017; authors affiliated with CDPHE Environmental Toxicology Department.	CDPHE's Toxicology Program reviewed air quality data collected around Suncor Refinery between 2012-2016. Measured levels of VOCs were below health guideline levels for all 5 years. Cancer risk estimates for the two carcinogenic substances (benzene and ethylbenzene) were less than one in ten thousand, which is within the acceptable risk range of $1x10^{-6}$ to $1x10^{-4}$. The measured levels of the criteria air pollutants, sulfur dioxide (SO_2) and nitrogen dioxide (NO_2), were below EPA NAAQS at all locations near Suncor.	Both air quality and cancer are concerns of the community. This technical document was determined to be included in the GES Community Health Study due to topic relevancy and expressed concerns of GES residents.	It is not possible to isolate the specific emissions from Suncor Refinery using these data. All of the air monitoring stations are located one mile or more away from the Suncor facility. An important limitation of this analysis is that the pollutant levels closer to the Suncor plant may be higher (or lower) than those measured at these monitoring stations.

Swansea Ambient Air Monitoring Station (SAMS) Phase II-III 1st Quarter CY2023 Air Quality Data Report. † Report Repository. CCoD; published April 23, 2023; authors affiliated with Montrose Air Quality Services, LLC., the company contracted by CCoD.	This technical report presents air monitoring results for the data collected during the beginning of Phase III, approximately covering the months of January, February, and March 2023. The Swansea Elementary monitoring site collects data for Volatile Organic Compounds (VOCs), Black Carbon (BC), Carbon Monoxide (CO), Particulate Matter less than 10 Microns (PM_{10}), Particulate Matter less than 2.5 Microns ($PM_{2.5}$), Meteorological Measurements, and Nitrogen Oxides (NOx). Results of these monitoring efforts indicated concentrations of NO_2, CO, BC, and VOCs were below NAAQS for the reported period.	This report includes data from an air monitor located in the GES neighborhood and is relevant in terms of time period of data and publication. This technical report was determined to be included in the GES Community Health Study due to topic relevancy, expressed concerns of GES residents, and geographical area of the monitoring site. The Report Repository provides site reports between 2017 through 2023.	The sampling equipment had limitations due to a variety of reasons. The site experienced a power outage resulting in no data collected between February 7 at 5:00 PM to February 8 at 10:00 AM. Due to this power outage, the CO and analyzer malfunctioned, resulting in no CO data being collected between February 7 and February 21. The meteorological equipment did not operate properly throughout the sampling period due to repairs, therefore, there was no temperature, relative humidity or pressure data for the sampling period. Due to malfunction and repair needed for another analyzer, there was no PM2.5, PM10, temperature, pressure, or relative humidity data collected during the sampling period.

Urban Air Toxics Concentrations in Denver. † CDPHE; published October 2006; authors affiliated with CDPHE Air Pollution Control Division and the Disease Control and Environmental Epidemiology Division.	Weekly sampling for air pollutants was conducted at three locations in Denver from 2002-2003. One location was at Swansea Elementary. Sampling was done for a large number of toxic air pollutants including VOCs (including benzene), aldehydes, and metals. A risk analysis showed that no chemical individually reached the level of risk for cancer or non-cancer health effects. However, the cancer risk at all sites when considering all the chemicals at the same time was 100 to 200 excess cancers per one million people (the Swansea site was at 100 excess cases per one million), which falls on the border of what is considered an acceptable level of risk. The risk assessment also found that there was a risk of respiratory effects at the Swansea and central Denver site, and a risk of neurologic effects at the Swansea, central Denver, and Commerce City sites.	Air toxics are an expressed community concern. This was a thorough sampling and assessment of a wide variety of hazardous air pollutants, including in Swansea.	The data used in this report are 20 years old and may not be representative of current conditions due to changes in vehicle emissions and I-70 construction. These data will be useful from a historical perspective.
Welcome to Globeville. § 5280 News; published November 2014; author affiliated with 5280 News.	This news article documents the trials and tribulations of Globeville across time. This report gives the community perspective and lived experience.	This article was determined to be included in the GES Community Health Study to serve as background information.	This news article serves as historical and background information only.

Who Bears the Cost? North Denver Environmental Justice Report and Data Audit. † GreenLatinos; published May 2022; authors affiliated with GreenLatinos and Colorado School of Public Health.	Green Latinos and partners conducted a search of literature and data around goods, services, and infrastructure for North Denver. The report outlines methods, key findings, and data gaps for land use and EPA violations, power generation and transportation energy production, goods production, roads and rails, and waste management. The authors found that there are 183 facilities with at least one EPA violation in the last three years, though this number likely under-represents the actual number of violations due to reliance on business self-reporting and limited inspection capacity.	This document provides a valuable look at the environmental justice problems in North Denver and the GES area, all of which fall under the concerns that have been mentioned by CC members and the community at large. This document was determined to be included in the GES Community Health Study due to topic relevancy, expressed concerns of GES residents, and geographical area.	This document provides a valuable review of available information for the GES Community Health Study; however, it is unclear when the project started and when data were collected.

Excluded Literature

The following table outlines the documents determined to be excluded from the GES Community Health Study. The table provides a summary of the literature document and the reason behind the exclusion determination. Source information is denoted by Crowd-sourced Literature Folder §, Phase 1 Deliverable 1.4 *Narrative* †, and Peer reviewed *.

Table 4. Excluded Literature Documents.

Title (Publication; Date)	**Summary**	**Exclusion Reasoning**
Breaking Down coronavirus infections in Denver by Neighborhood. § The Denverite; published April 9, 2020, author affiliated with The Denverite.	The article visually compares maps of income and COVID-19 cases as of April 8, 2020, to make the conclusion that lower income neighborhoods have more cases. The article has interviews advocating for increased reporting of cases by race and ethnicity.	This news article briefly describes COVID-19 cases in Denver at one time point early in the pandemic. It visually compares maps of income and COVID-19 cases to make the conclusion that lower income neighborhoods have more cases. However, there is no evidence presented in this article to support that conclusion. The maps do not show a clear trend, and there is no statistical analysis. Further, this is from early in the pandemic and only provides a snapshot in time. While this is an important topic to investigate, other sources with more robust analysis will be used instead.
Conditions Leading to Elevated PM2.5 at Near-Road Monitoring Sites: Case Studies in Denver and Indianapolis. † * International Journal of Environmental Research and Public Health; published May 10, 2019; authors affiliated with Sonoma Technology and Washington Department of Technology.	This study was specifically looking at factors that influence high $PM_{2.5}$ concentrations at an air monitoring station next to I-25 and 6th Ave. This station was found to usually have the highest concentration of $PM_{2.5}$ in Denver, and that this is likely due to the curve of I-25 and nearby buildings.	This study was specifically looking at factors that influence high $PM_{2.5}$ concentrations at an air monitoring station next to I-25 and 6th Ave. This monitor is not near GES and the environment/structures around the monitor are unique, so the findings are not generalizable to GES.
The Denver Air Toxics Assessments. § CCoD; published 2007; authors affiliated with DDPHE.	This document is a presentation on Denver Air monitoring for the early 2000's.	While the images cover the GES area, a formal technical report or peer reviewed journal article should be used instead.

DRAFT - Exposure Investigation Protocol VB/I-70 Site. § ATSDR; published March 2000; authors affiliated with ATSDR.	This is a draft of the methods for testing urine and hair for arsenic at the VB/I-70 superfund site among residents with the highest measured soil arsenic. This report does not report the findings from the investigation.	This is a draft procedure for arsenic biomonitoring at the VB/I-70 site and does not report findings from the investigation. The results from this investigation would be useful to assess health impacts from arsenic exposure, but this document does not contain that data and is of minimal use in the GES Community Health Study.
EPA Letter to Resident. § † EPA; published October 1, 2003; authors affiliated with EPA.	The letter is addressed to a resident and states that EPA sampled the resident's yard for arsenic and lead and determined that it does not require a cleanup. This is an example of the letters sent to residents during the superfund soil cleanup.	This letter is specific to one property and does not provide information regarding environmental exposures or health outcomes in GES.
Estimating urban air pollution contribution to South Platte River nitrogen loads with National Atmospheric Deposition Program data and SPARROW model. † * Journal of Environmental Management; published January 2022; authors affiliated with US Geological Survey and DDPHE.	This study modeled how much nitrogen is deposited from the air into the South Platte in the Denver area.	This study does not provide information regarding environmental quality or health specifically in GES. Air and water quality is better assessed from other sources of direct measurements.
Expert Report as Public Comment on Notice of Intent to Delete VB/I-70 OU1 from NPL. § EPA R8 Public Comment; published March 4, 2019; author affiliated with Geo-Hydro Inc.	This document was summited as a public comment on notice of intent to remove the VB/I-70 OU1 from the National Priorities List (NPL) and presents an analysis of the history of OU1 to argue against the removal of the site from the NPL.	The document is clearly against removal of OU1 from the NPL and presents data through this perspective and was therefore determined to not meet the criteria to be objective. By not including this document, we are not necessarily determining agreement or disagreement with the arguments presented, rather, ENVIRONS will assess conditions at the VB/I-70 site through primary documents and data from EPA and CDPHE.

Geospatial Monitoring of Body Mass Index: Use of Electronic Health Record Data Across Health Care Systems. * Public Health Reports; published February 13, 2020; authors affiliated with University of Colorado, CDPHE, Kaiser Permanente, DDPHE, Children's Hospital, University of Colorado School of Medicine	The Colorado BMI Monitoring System was developed to assess geographic (i.e., census tract) patterns of obesity prevalence rates among children and adults in the Denver metropolitan region. Results indicated that the highest obesity prevalence rates were concentrated around the central part of the metropolitan region.	This study was determined to be excluded from the GES Community Health Study because the results cannot be directly applied to GES. The study was limited to 5 health care organizations Children's Hospital Colorado, Denver Health, Kaiser Permanente Colorado, Metro Community Provider Network, and Salúd Family Health Centers. Additionally, data records from these locations were only used if a measured height and weight between January 2013 and December 2015.
Health Disparities: Exploring Health Equity in Colorado's 10 Winnable Battles. § CDPHE; published 2013; authors affiliated with CDPHE.	CDPHE has identified 10 winnable battles and believes that they can achieve gains in those areas. This report presents selected measures for each "winnable battle" to establish a baseline on the broader Colorado population. These battles include clean air and water, infectious disease prevention, injury prevention, mental health, obesity, oral health, safe food, tobacco, and unintended pregnancies.	This document has been determined to be excluded from the GES Community Health Study because the results and recommendations are for state-level public health programs and are not specific to GES.
Healthy Air for North Denver. § † EPA; published December 23, 2008; authors affiliated with Groundwork Denver.	This document is the final report for a grant received by Groundwork Denver from EPA to conduct education, outreach, and community engagement in North Denver relating to reducing environmental harms. It does not describe environmental conditions or health outcomes.	The CARE Grant received by Groundwork Denver supported education and outreach efforts across a variety of environmental-related topics, this report describes those efforts. Neither the grant nor this document describe environmental exposures or health outcomes in GES.
Indoor Air Quality Assessment - Garden Place Academy. § PURETi Group, LLC.; published November 2017; authors affiliated with PURETi Group, LLC.	PURETi tested one of their products in Garden Place Academy to demonstrate that it can reduce indoor VOC air pollution. As part of this, PURETi conducted limited sampling of VOCs before and after application of their product. Air samples contained VOCs that were likely from vehicle emissions and the report notes the level of benzene detected was 3x higher than the maximum concentration allowed by the US Green Building Council (USGBC) LEED v4 standard. This is a non-enforceable standard, and the USGBC is not a government agency.	This report is from PURETi, a private business, trying to demonstrate that their product reduces VOCs to convince Denver Public Schools to purchase their product. The air sampling conducted as part of this product test cannot be considered free of bias because the company is trying to sell their product. Further, the air sampling did not follow rigorous methods, was based off of one sample, and does not make conclusions supported by the data presented.

Maps of toxic hazards show a wash of chemicals over the Denver metro's north and west edges. § The Denverite; published April 9, 2021; author affiliated with The Denverite.	In this news article, the author illustrates maps of metro Denver that show modeled risk from toxic chemicals based on 2019 EPA data from the toxic release inventory (TRI). The article then describes a few industrial sources in Denver that are large contributors to air toxins according to the TRI data.	This article has been determined to be excluded from the GES Community Health Study because the source/referenced data (RSEI based on TRI) should be used as the primary source rather than the news article coverage. Further, the industrial sources described were not selected following systematic methods, and more rigorous descriptions are available in the Green Latinos report: *Who Bears the Cost: North Denver Environmental Justice Report and Data Audit.*
Quantifying the Effects of Residential Infill Redevelopment on Urban Stormwater Quality in Denver, Colorado. † * Water (journal); published April 3, 2021; authors affiliated with Colorado School of Mines, ReNUWIt, UNESCO, University of Maryland, and NASA.	This study looked at stormwater quality in the Berkley neighborhood of Denver to see if stormwater quality was related to land use and changes in the neighborhood. The study did not find that land use impacted stormwater quality.	The study area does not cover GES and is in the Berkley neighborhood. If results from this study were applied to GES, it would not be an accurate depiction of urban stormwater quality in GES.
Sampling and Analysis Plan for VB/I-70 NPL Site - Phase 3 biomonitoring of Lead and Arsenic Exposure. § EPA; published February 14, 2000; authors affiliated with ISSI Consulting Group, Inc.	This is the plan for testing the amount of lead and arsenic in people (biomonitoring) who had elevated amounts of lead or arsenic in their soil in the VB/I-70 area.	The results of the phase 3 biomonitoring effort are not included in this document. Results should be included in the GES Community Health Study instead of this document.
Vasquez Boulevard/I-70 Superfund Site Operating Unit 1 Review and Assessment. § No direct publication (Citizen presentation); published July 17, 2018; author affiliations unknown.	This presentation on Vasquez Boulevard/I-70 Superfund Site Operable Unit 1 (OU1) was made by a citizen and presented to the Vasquez Boulevard/I-70 Community Advisory Group in 2018. This presentation provides some common talking points from public comment based on EPA and CDPHE past actions of sampling and closure actions around the superfund site.	While the topic (superfund sites around GES) is relevant to the GES Community Health Study, reports and primary sources of information should be used instead.

Datasets

Included Datasets

The following table outlines datasets determined to be included in the GES Community Health Study. The table highlights a summary of the document, reasoning for inclusion, as well as limitations. Source information is denoted by Crowd-sourced Literature Folder §, Phase 1 Deliverable 1.4 *Narrative* †, and Peer reviewed *.

Table 5. Included Datasets.

Title (Source; Date)	Summary	Inclusion Reasoning	Limitations
CDPHE Open Data			
Childhood Lead Risk by Census Tract. † CDPHE; Published and updated August 2018.	This dataset uses census data to calculate a relative score of childhood lead risk using 2011-2015 data. The score is calculated from three things: 1) number of housing units built in different time periods, 2) overall poverty rate, and 3) population of children under age 6.	Lead is a stated concern of residents. While this data does not describe the actual prevalence of elevated blood lead levels, the risk of lead poisoning is a valuable contribution to the discussion of built environment and SDOH.	The relative score does not describe how many children actually have elevated levels of blood lead. This data is also approaching 10 years old, and neighborhood characteristics, particularly the age of housing, may have changed with redevelopment.
Colorado Life Expectancy by Census Tract Published by NAPHSIS-USALEEP (2010-2015). † US CDC National Center for Health Statistics, CDPHE, Robert Wood Johnson Foundation; published September 2018, updated June 2019.	This dataset shows the estimated average age someone can expect to live to in each census tract in Colorado. These data are from 2010-2015.	Life expectancy is a common measure used to compare health and will be useful in assessing the state of health in GES compared to Denver.	Data are old and may not be reflective of current conditions. Additionally, there are large confidence intervals so the apparent differences between census tracks may not truly represent actual differences in life expectancy.

Community Level Estimates (Census Tracts), 2014-2017. † - Alcohol Consumption - Asthma Prevalence in Adults - Delayed Medical Care in Adults due to Cost - Depression in Adults - Diabetes in Adults - Heart Disease in Adults - Mental Health in Adults - No Regular Medical Checkup in Adults - Obesity in Adults - Overweight and Obese Adults CDPHE; Published May 2016, updated February 2019.	CDPHE Community Level Estimates (Census Tracts) are a collection of datasets that report predicted (modeled) prevalence of health conditions and access among adults (age 18+) for each census tract in Colorado using 2014-2017 Colorado Behavioral Risk Factors Surveillance System data. The predicted prevalence is based on the relationship between age, race, gender, poverty, education, location and health conditions or risk behavior indicators, and applied to the population for each census tract in Colorado based on the 2014-2017 American Community Survey. The estimates are based on statistical models and are not direct survey estimates.	We determined to include these datasets based on the importance of these health outcomes and access, the completeness of the data, and the reliability of the data producer. The methods used to generate the estimates are widely used for small geographic areas such as census tracks.	These data are estimates, not measurements, and therefore have an associated margin of error. If more accurate data is obtainable, that will be used in conjunction or instead of this dataset.

Composite Selected Health Outcomes (Census Tracts). † - Asthma Hospitalization Rate - Diabetes Hospitalization Rate - Drug Poisoning or Overdose Mortality Rate † - Heart Disease Mortality Rate - Influenza Hospitalization Rate - Low Birth Weight Crude Rate - Live Births to Females Age 15-17 Crude Rate - Motor Vehicle Accident Mortality Rate † - Suicide Mortality Rate † CDPHE; Published March 2017, updated March 2022.	CDPHE Selected Health Outcomes are a collection of datasets that describe the rate of certain health outcomes by census tract in Colorado. The rates are calculated as an average from 2015-2019 and are direct measures as opposed to the estimates from the community level estimates.	These data represent health outcomes that are important to GES residents. These are high quality data and are relatively recent.	Not all census tracts have values for all outcomes. This is due to low numbers of reported events that have been hidden to protect the privacy of individuals. The data are also from 2015-2019, which is prior to the I-70 construction, so there may have been changes that are not reflected in this data.
Health Facilities. † CDPHE Health Facilities and Emergency Medical Services Division; Published March 2022, updated March 2023.	This dataset contains address information on health facilities across CO.	The location of healthcare facilities can be used to assess access to goods and services, specifically access to healthcare.	Limited details are provided for each facility.
Denver Open Catalog			

311 Service Reports. † CCoD; Published annually (2007-2022), updated October 2022.	This dataset is a log of all the 311 service complaints, including reports of odor. Where relevant, complaints include location information that can be used to map what neighborhood it occurred in.	311 and odor complaints are of interest to the community.	The 311 data are not always complete and certain complaints may be missing important information that makes it unusable. This data will be used unless a better source is identified for odor complaints.
Crime. † Denver Police Department Data Analysis Unit; Past 5 years and the current year to date. Annual Data Snapshots published annually (2010-2021).	This is a dataset of all crimes that have been reported in Denver for the past five years. It contains the location of crimes when possible.	Crime and safety are a reported concern of residents and is a topic in the HIA.	Data for some incidents may be incomplete and lack location information; data codes are also challenging to interpret. Recent crime data may change as investigations continue. It only contains information on crimes that are reported to Denver Police.
Food Access by Neighborhood (2021). † DDPHE; Published May 2021.	This dataset measures food access by the percentage of residents that are more than a 10-minute walk to a full-service grocery store. A full-service grocery store is defined based on the size of the store and availability of healthy food options such as produce.	This dataset was determined to be included in the GES Community Health Study based on the applicability to measuring access to goods and services, how recent the data is, and ease of data use.	Neighborhood percentage estimates do not account for residential vs. other types of parcels within the walkshed. There may be cases where a non-residential unit was included in a neighborhood percentage.
Food Retail Locations (2021). † DDPHE; Published May 2021.	This dataset includes the location of grocery stores, small food markets, and convenience stores within Denver in 2021. It also shows whether each store participates in SNAP and WIC programs. Factors of food retail include Convenience Stores, Small Food Markets, and Full-Service Grocery Stores.	This dataset was determined to be included in the GES Community Health Study based on the applicability to measuring access to goods and services, how recent the data is, and ease of data use.	This layer was updated in the first quarter of 2021. However, it is possible that since the start of COVID-19 lockdowns and restrictions some of these locations have since closed temporarily or permanently.
Parks. † Denver Parks and Recreation; Published July 2023.	This dataset represents parks, golf courses, and recreation areas managed by the Department of Parks and Recreation in the City and County of Denver.	Parks are an important indicator when measuring green space and the built environment. This dataset will be used when assessing green space in the GES neighborhoods.	Data is based on parcel ownership and does not include other areas maintained by the department such as medians and parkways.

Street Light Poles. † CB&I under contract with CCoD; Published November 2019.	This dataset contains locations of light poles, quantity, and type of lights. Other variables include descriptions like physical appearance of light poles, circuit boxes, ID numbers, etc.	Street lights are important to consider in community safety and have been a concern mentioned by the community. This seems to be the most recent rendering of the data.	New lights may have been built since the dataset was last updated. This dataset does not provide the current working status of each light pole.
Traffic Accidents. † Denver Police Department Data Analysis Unit; Past five years and the current year to date.	This dataset includes motor vehicle crashes reported to the Denver Police Department, that occurred within CCoD limits. The data are dynamic, which allows for additions, deletions and/or modifications at any time, resulting in more accurate information in the database.	Safety, and in particular, road safety, is a concern of residents. This dataset provides up to date information on traffic accidents.	Due to continuous data entry, the number of records in subsequent extractions are subject to change.
Tree Inventory. † Denver Parks and Recreation; Updated March 2023.	This dataset contains information on trees managed by CCoD Department of Parks and Recreation. Data is based on GPS locations of trees located in parks, medians, parkways, and along streets. These data are updated quarterly.	This data is an up-to-date record of all trees in Denver, which may be incorporated into green space analysis.	This dataset does not include trees on private property, some of which may include the more recent tree planting projects around GES.
Water Quality Data. † DDPHE; Annual data available (2011-2022), updated June 2023.	These data sets include the results for water quality sampling of the lakes and rivers in Denver from 2011 through 2022.	All data is collected by the Department of Environmental Health in accordance with the Water Quality Program's Quality Assurance Project Plan.	The 2022 data has an error when downloading, making it unavailable.
Other Sources			
CDPHE Air Quality Data. † CDPHE Air Pollution Control Division; Current.	This is the central website for air quality monitoring at CDPHE. It contains lots of different types of data and reports that can be used to assess air quality across the state. It is the trusted source of air quality data for Colorado. It also now has information on sources of air pollution.	Data from this website is a valuable contribution to the GES Community Health Study as it is an authoritative source of air quality monitoring in GES. However, some data will be sourced from a separate analysis of air monitoring data from multiple sources conducted by the Magzamen lab group at CSU.	Data are not easily accessible and there are only a few monitors in or around GES. CDPHE air monitoring data is reported to the EPA, who then conducts quality assurance and quality control (QA/QC) procedures. CDPHE air quality data will be used secondarily to the EPA data that has undergone QA/QC.

EPA Air Quality Data. † EPA; 1980 to six months ago.	EPA's Air Data service provides trusted air quality monitoring information for the entire United States, including Colorado. There are many different datasets available for recent and historical data.	Air quality data from EPA is authoritative and trusted. However, actual data may be taken from another analysis done by the Magzamen lab group at CSU that has already processed and analyzed the air quality data.	Data are largely the same as CDPHE Air Quality Data. The advantage of EPA air data is that it has gone through QA/QC measures. The data is easy to download and use, however data are slightly delayed in timeframe.
EPA EJ Screen. † EPA; Data currency varies.	The EJ Screen tool uses a wide variety of environmental, health, and demographic measures to compare the health, risks, and vulnerability of communities across the country. It uses data that are available from other nationwide programs.	This dataset is a valuable source of a large number of environmental measurements. In some cases, the original source may be found and used instead.	Only data that are available nationwide are included. The webpage goes through many updates, some of which can result in error codes.
RTD GIS Current Runboard. † RTD; Updated June 2023.	RTD's data for ArcGIS online resources. RTD's publicly available GIS data including bus and rail routes and stops, facilities, and FlexRide areas.	This is the current route of RTD bus and rail lines, which will be useful for assessing connectivity and mobility between the neighborhoods.	Each data layer has to be downloaded separately.

Excluded Datasets

The following table outlines the datasets determined to be excluded from the GES Community Health Study. The table provides a description of the dataset and the reason behind the exclusion determination. Source information is denoted by Crowd-sourced Literature §, Phase 1 Deliverable 1.4 *Narrative* †, and Peer reviewed *.

Table 6. Excluded Datasets.

Title (Source; Date)	**Summary**	**Exclusion Reasoning**
CDPHE Open Data		
Colorado Census Tract Retail Alcohol Outlet Density (2020). † CDPHE; Published January 2022, last updated January 2023.	This dataset shows the density of where alcohol is sold by census tracts as of January 2022 in the state of Colorado. It was created using lists of alcohol licenses and their associated addresses. Density is shown in three different ways in this dataset, including just counting the number of locations, diving the number of locations by the population, and dividing the locations by the size of the census tract.	The ENVIRONS team will be conducting a similar assessment of alcohol outlet density using current data and different measures of density.
Colorado Retail Alcohol Outlet Points (2020). † CDPHE; Published January 2022, last updated January 2023.	This dataset contains the location of places that sell alcohol in the state of Colorado as of January 2022.	The ENVIRONS team will be conducting an analysis of access to alcohol, tobacco, and marijuana that will use current data.
Colorado Substance Use Disorder (SUD) Health Professional Shortage Areas. † CDPHE; Published May 2019, last updated August 2019.	This dataset shows areas that were determined to not have enough substance use disorder professionals according to state regulations.	Access to healthcare is vital to assessing the overall health of the community, however, access to substance use disorder professionals has not been a concern mentioned by the community and is outside of the current scope of the study. Other datasets provide a more complete picture of where service providers are located.

Disproportionately Impacted Communities (DRAFT Version September 2021). † CDPHE; Published September 2021, last updated January 27, 2023; archived.	This dataset was used as a draft to identify communities that are disproportionately impacted. Disproportionately impacted communities are defined as census block groups where greater than 40% of households are 1) low income, 2) housing cost-burdened, or 3) include people of color. This dataset has been replaced with a layer on the Colorado EnviroScreen.	This dataset has been archived and replaced with a layer on the Colorado EnviroScreen. The Colorado EnviroScreen layer should be used in place of this one.
Health Insurance Coverage for Adults. † CDPHE, Community Level Estimates; Published February 2019.	These data represent the predicted (modeled) prevalence of adults who have Health Insurance Coverage of any kind for each census tract in Colorado. The model was developed using BFSS 2014-2017 data.	More recent data on health insurance coverage are available from the ACS that does not involve as much modeling as this dataset.
Physical Health in Adults. † CDPHE, Community Level Estimates.	These data represent the predicted (modeled) prevalence of Frequent Physical Distress among adults (Age 18+) for each census tract in Colorado. Frequent Physical Distress is defined as experiencing more than 14 physically unhealthy days within the past 30 days in which physical health was "not good." Health conditions for measuring physical health include physical illness and injury.	Since publication of the Phase 1 Deliverable *Narrative*, this dataset has been archived and is no longer available to access. It will be excluded from the remainder of the GES Community Health Study.
Denver Open Catalog		
Active Business Licenses. † CCoD Office of Marijuana Policy; Current	This is a list of all the active business licenses in Denver.	Active business information is not relevant to the GES Community Health Study because it does not represent an environmental exposure included in the scope of this study. Business and economic activity is more relevant to the social determinants of health, which are not the main focus here. Marijuana, alcohol, and tobacco will be included but will be sourced for the Colorado Department of Revenue, which maintains active license lists including addresses.

Bike Racks. † CCoD Public Works; Published and updated December 17, 2019.	This dataset contains the location of all bike racks maintained by the City and County of Denver.	The location of bike racks is not within the scope of the study. While it may pertain to bike use, it is not a commonly used indicator of mobility or connectivity.
Denver Bike Ramps. † Denver Department of Transportation and Infrastructure; Published and updated February 2020.	This data contains the location of all bike ramps in the City and County of Denver.	While location data regarding bike ramp information is useful to a built environment perspective, other mobility data would be better suited for this use.
Equity Index 2020 - Neighborhood. † CCoD GIS; Updated October 2020.	This dataset represents socioeconomic characteristics, healthcare access, built environment features, and health barriers in Denver neighborhoods compared to other neighborhoods. This shows which neighborhoods face more barriers to health and which face less.	This dataset only contains indices representing categories of measures, rather than the actual measure itself. Further, there are more comprehensive indices available, such as the CO EnviroScreen tool.
Existing Bicycle Facilities. † CCoD; Current, updated June 2022.	This data contains the existing bicycle facilities in the City and County of Denver.	Bike facility locations are outside the scope of the study. Other measures will be used for connectivity and mobility.
Groundwater Seeps. † DDPHE; Updated July 2023.	Groundwater seeps are where significant amounts of groundwater are converted into surface water. This coverage contains the locations of some groundwater seeps that discharge groundwater into the South Platte River.	This dataset does not provide information on if contamination occurs at these locations.
Historical Fill Areas. † Pinyon Environmental Engineering Resources, Inc. with post processing by The TSR Group, Inc; Published November 2000.	This dataset provides historical information regarding fill areas, types of waste and potential contamination from 1997.	Locations of historical fill areas are approximations and should not be used for detailed planning or engineering purposes. These data can only be used for historical purposes.

Pedestrian Routes. † URS Corporation; Published May 2006.	These pedestrian routes show the routes that pedestrians were observed to follow in the early 2000's. They were identified by CCoD staff via field investigation using three datasets created for the Pedestrian Master Plan: Green Streets, Enhanced Bus Corridors and Pedestrian Routes which fell into neither of those categories. The original published date is May 2006 with an update to the metadata in 2013.	These pedestrian routes are outdated. It is unclear when the more recent update was conducted to this specific dataset. Other data available should be used to assess GES connectivity.
Recommended Bicycle Facilities. † CCoD; Updated February 2022.	This dataset is a list of recommended bike facility locations.	While important to consider in city planning, they do not represent current connectivity or mobility built environmental conditions. Other datasets should be used instead.
Denver Regional Council of Governments		
Railroad Crossing Incidents (2015-2019). † DRCOG; Published January 2020.	This dataset highlights highway-rail crossings with incidents including fatalities and serious injuries to highway users and railroad employees and reported incidents including trespassing or near misses for 2015-2019. It is important to note that railroad crossings have been mentioned as a concern by CC members, specifically in Swansea around York St and E 47th Ave.	There are very few data points overall, making it difficult to draw conclusions. Additionally, it is unclear what the data are reporting other than point locations. Parsing out what the variables are is also difficult as there are no variable definitions or descriptions.
Traffic Counts (2010-2022). † CDOT; Published December 2022, updated May 2023.	Total traffic volume data for 2010-2022, as available was given to DRCOG. These data were then used to calculate regional traffic counts for the years 2010-2022.	The data is not consistent over time which would make it difficult to draw conclusions. Other datasets will be used to assess air pollution impacts from traffic and safety concerns from traffic.
Truck Recurring Safety Hotspots (2013-2015). † DRCOG; Published January 2020.	This analysis identifies locations with greater than 20 commercial vehicle crash locations over a three-year period between 2013 and 2015. These locations indicate problem areas that are likely to have higher truck and general traffic volumes.	There are very few data points overall, making it difficult to draw conclusions. Other indicators of roadway safety, such as car accidents, will be used instead.
Other Sources		

Traffic Data Explorer. † CDOT; published 2021.	This interface provides data on CDOT highway traffic counts.	Other datasets will be used to assess air pollution impacts from traffic that also provide pertinent information like variable descriptions and methods of data collection.

Ongoing Studies

There are a number of going studies in and around GES. If and when data and results become available, ENVIRONS will evaluate each to determine final inclusion in or exclusion from the GES Community Health Study. Source information is denoted by Crowd-sourced Literature §, Phase 1 Deliverable 1.4 *Narrative* †, and Peer reviewed *.

Table 7. Ongoing Studies.

Title	Summary
Air Quality Investigation and Research for Equity. † Sponsored by Cultivando and conducted by Boulder A.I.R.	This was an air monitoring project sponsored by Cultivando and conducted by Boulder A.I.R. The project collected air samples at a fixed site and mobile site in Commerce City from 2022-2023. Pollutants monitored included sulfur dioxide (SO2), hydrogen sulfide (H2S), carbon monoxide (CO), methane (CH4), volatile organic compounds (VOCs), hydrogen cyanide (HCN), ozone (O3), nitrogen oxides (NOx), particulate matter (fine and coarse aerosol), and radioactivity. Data from this study were shared with another group at CDPHE and CSU that will analyze the data as part of a larger project looking at air quality in North Denver and will share results with the GES Community Health Study. The program stopped operating in July 2023 when funding ended, and the program is currently looking for new funding opportunities.
Environmental Justice in Commerce City – North Denver. † EPA.	Website detailing recent EPA activities in Commerce City-North Denver.
Monitoring the Air in Our Community: Engaging Citizens in Research. † Researchers affiliated with Research Triangle Institute, National Jewish Medical and Research Center, Groundwork Denver.	This was a study conducted from 2018-2019 that collected air samples using stationary monitors and monitors worn by participants. Researchers also studied the best way to communicate air quality information. The goal of the study was to test how communities can use low-cost sensors to understand air quality. Results have not yet been published.
Social Justice & Environmental Quality – Denver. † Researchers associated with University of Colorado Boulder and University of Colorado Denver.	The Social Justice and Environmental Quality – Denver (SJEQ-D) study has been investigating the disruptions and air pollution caused by the I-70 construction. This has involved multiple groups of participants using personal air monitors and completing surveys regarding disruptions, pollution, health, and wellbeing. This study is concluding in 2023, and results will be available thereafter.

Methods

Rubric Creation

ENVIRONS created two rubrics, one for data and the other for literature, which we used to evaluate materials in the appendices of Phase 1 Deliverable 1.4 *Narrative,* as well as materials in the Crowd-sourced Literature Folder. Criteria used in formulating the literature rubric included questions relating to document type, whether the information provided was objective or subjective, as well as the timeliness of the document (e.g., some documents were published in the early 2000s). Criteria used to create the dataset rubric included questions related to accuracy, timeliness, and if it was relevant to the GES Community Health Study. These criteria are outlined in Table 8 and linked to corresponding rubric questions. Flowcharts were created to clarify question order and decision points for exclusion (Figure 1 and Figure 2).

We determined that a scored rubric was not appropriate in this context for multiple reasons. Primarily, the wide variation in data source types, formats, and topic resulted in excess N/A entries that prevented accurate scoring and comparisons across sources. Additionally, there are some questions that are more critical than others, so a source could score highly but be eliminated for one critical item. However, the critical items can vary across types, formats, and topics, making development of a weighting system challenging. Finally, the motivation for this deliverable is to address the community's desire to have the quality and results from sources interpreted and made clear. Following this rational, we determined that the most appropriate way to complete this deliverable and meet the needs of the community is to use a rubric that allows the reviewer to critically evaluate the source while leaving room for professional judgement. Each reviewer uses their evaluations to make a professional judgement on the usability of each source. A summary and reasoning are then written based on results from the entirety of the rubric responses from both reviewers.

Evaluation Methods

Each data source from the Crowd-sourced Literature Google folder or included in the appendices of Phase I Deliverable 1.4 *Narrative* was independently evaluated by two reviewers using the respective rubric for literature (written sources) or datasets. When both reviewers agreed on inclusion or exclusion, a summary, reasoning, and limitations were written by one of the reviewers using results from both evaluations. For excluded sources, limitations were not defined, and summaries were kept brief to focus on reasonings. When reviewers disagreed on inclusion or exclusion using the forms, they met to discuss the source. In case of an inability to reach consensus, a third reviewer evaluated the source, reviews, and made a final determination. There were no instances requiring a third reviewer and there was generally a high level of consensus between reviewers. Summaries, reasoning, and limitations were written with community members as the audience and were edited for clarity, conciseness, and removal of technical language.

Process Flow Diagram

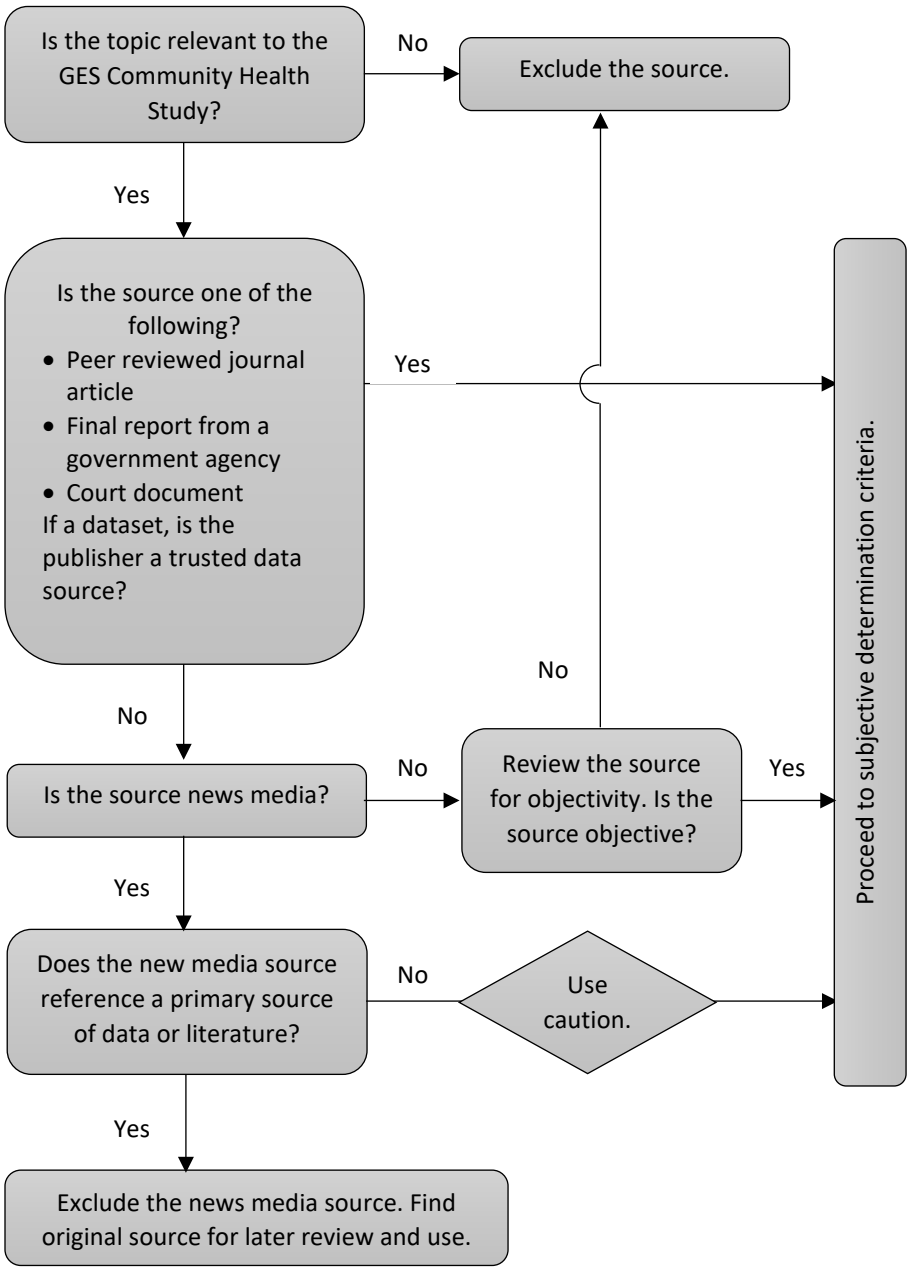


Figure 1. Primary determination criteria.

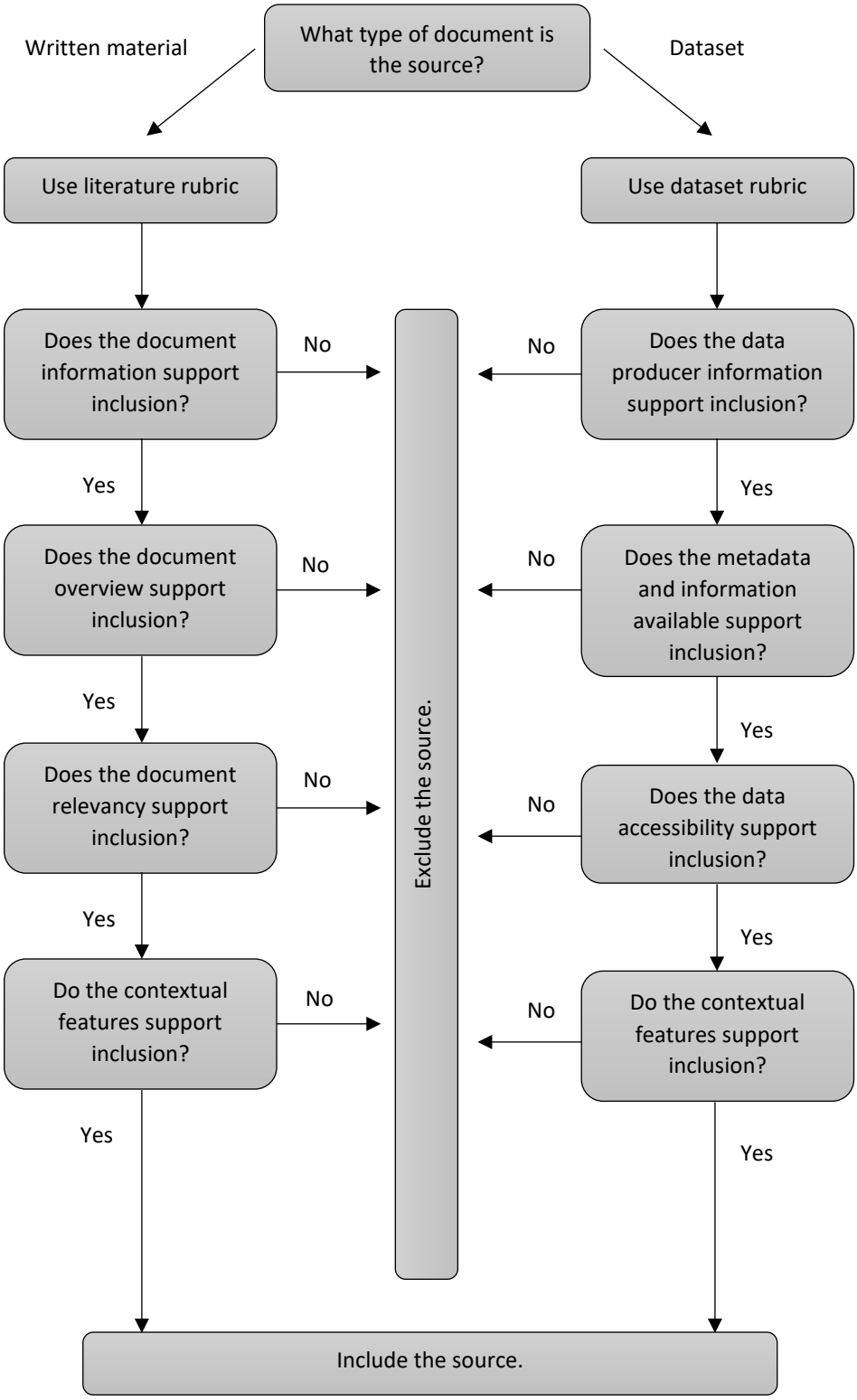
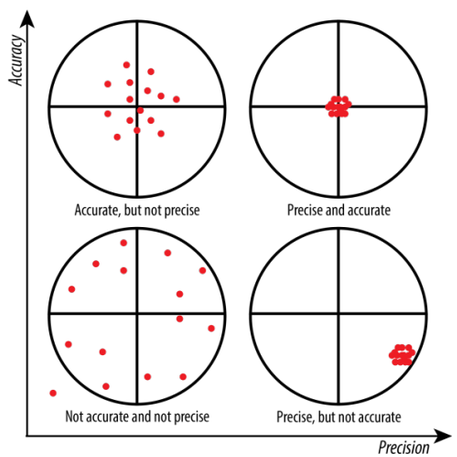


Figure 2. *Subjective determination criteria.*

Data Evaluation Criteria

Table 8. Data Evaluation Criteria

Term	Definition	Linked Literature Rubric Questions	Linked Dataset Rubric Questions	Example
Internal Validity				
Accuracy Often used synonymously for validity, lack of systematic error, completeness, and reliability	• Data are accurate when the data measure what they are intended to measure. • Accuracy measures whether data were recorded correctly and reflects realistic values. • Data are correct, objective, reliable, certified and validated.	38, 40, 41	18, 21, 22, 39, 40, 45, 46	When you feel sick and take your temperature using a thermometer, the reading would be accurate if it is your true body temperature. If you took your temperature multiple times and got the same measurement, then it would be precise. However, if you have a low-quality thermometer or use it wrong, the reading may be off from your true temperature (not accurate) and could vary a lot between tests (not precise). **Figure 3** is a common representation of the relationship between accuracy and precision.
Precision Often linked with accuracy, validity, and consistency	• Precision refers to a lack of random error or variation in a study's estimates. • Precision is consistency in study results. • Data should have a sufficient level of detail to permit decision making (e.g., the margin of error is less than anticipated change).	38, 40, 41	18, 21, 22, 39, 40, 45, 46	 ***Figure 3**. Visual representation of accuracy and precision.* Image credit: https://wp.stolaf.edu/it/gis-precision-accuracy/

Reliability Also refers to accuracy, integrity, consistency, completeness	• Data collected are based on protocols and standards that do not change. Data are reliable because of how they are measured and collected. • Data should reflect stable and consistent data collection processes and analysis methods over time.	8, 16, 18, 19, 21 – 25, 37, 40, 41	4, 10, 18, 21, 22, 25, 27, 28, 39, 45, 46	For example, a doctor or nurse collecting blood pressure measurements of a patient follow a gold standard set by the American Heart Association. While there have been updates to the gold standard as new technology is developed, the standards are reliable across all health clinics.
Objectivity	• Data are unbiased and impartial.	5, 6, 8 – 11, 13 – 19, 21, 23 – 25	4, 7, 10 – 13, 16, 17, 21, 22	An example of this is when a car salesperson tells you how great a particular car is; the salesperson is motivated to overstate how good the car is in hopes that you buy it, and they stand to gain from this transaction.
Completeness Often used to mean accuracy and linked with amount of data, and representativeness	• Data are appropriately inclusive, there is minimal missingness of data entries. • All necessary data that could have been reported have been. • Data are sufficient in breadth, depth and scope.	NA	23 – 25, 37, 38, 45, 46	Data meeting the intrinsic feature of completeness would have the appropriate amount of data entries, with no data fields missing. This, however, is very subjective. For example, when a new patient is filling out a health form, they may leave a few data fields empty, or a battery may die in an air monitor and one afternoon does not have any readings. It is up to the researcher to determine what the limit of missing entries would deem a dataset incomplete.
External Validity				
Timeliness, Currency, and Time Period	• Timeliness measures whether data are up to date and the extent to which the age of the data is appropriate. • Time period of when data was collected needs to be accurately reported.	4, 34 – 36, 40, 41	5, 6, 35, 36, 45, 46	Using blood pressure readings taken in the 1970s to answer a question about today's population would not be timely. However, these readings would be timely if examining blood pressure as a trend across time. Data collected in 2005 would not be considered current because it is more than 15 years from 2023. Some data becomes out of date faster than others depending on how fast the topic being studied is expected to change.

Accessibility, Obtainable, Access Security	• Data are easily accessible, usable and retrievable. • Data are available for download or from another research team. • Data accessibility also refers to access security, interpretability and understandability, concise and consistent presentation, timeliness, and amount of data.	5, 8 – 10, 14, 16, 18, 19, 39 – 41	4, 8, 10 – 12, 16, 17, 20 – 22, 26 28 – 34, 41, 45, 46	For example, due to the time and efforts required to get appropriate authorization and permission, some computerized data can be considered inaccessible. Data that is easy to download would be accessible, but it may be less secure. On the other hand, data can be considered to have high access security when working with information like individual patient health information (e.g., the Health Insurance Portability and Accountability Act (HIPAA) is a federal law that protects sensitive patient health information from being disclosed).
Relevancy	• Data are applicable or pertinent to the task of data user.	7, 12, 26-33	9, 14, 19, 21, 22, 37, 45, 46	Political affiliation is not relevant to the GES Community Health Study while air quality is.
Spatial Scale & Scalability Includes geographical correlation and scalability, granularity	• Data has a scale of which measurements were collected (e.g., population level, community level). • Ability to downscale data to different spatial scales data is linked between the defined area of study and where data was collected.	26, 27, 32, 33, 37, 40, 41	27, 28, 29, 37, 45, 46	Data can be collected and presented at different geographic scales from state-wide to census-tract levels.
Comparability Also referred to as scalability and generalizability	• Comparability refers to the capacity to make meaningful comparisons across datasets. • Geographical correlation means data is linked to a defined area of study.	26, 27, 32, 33	37, 43 – 46	Data collected regarding air quality measurements in Wisconsin cannot be used to make conclusions about Colorado, rather scientists can use it to compare the two locations.
Interpretability & Ease of Understanding Understandability also falls under accuracy	• Metrics and data definitions should have the right amount of information to be interpretable. • Data is presented in a way that is easy to comprehend.	20, 24, 25, 40, 42	20 – 25, 28, 29 42, 45, 46	Data that uses a lot of codes but does not have a key to what the codes mean is difficult or impossible to understand.

Rubrics

Literature Assessment

Document Basics

1) Reviewer Name [select one]
    a. [list of ENVIRONS members]
2) Date of Assessment [date response]
3) Document Title [short response]
4) Date Published [short response]
5) Publisher (News source, Journal, Agency) [short response]
6) Author(s) [short response]

Screening – Topic

7) Is the topic relevant to the GES Health Study? (Error on the side of yes) [select one]
    a. Yes [proceed to Q8]
    b. No [proceed to Q12]

Screening – Source Type

8) Is the source: peer reviewed journal article, final report from a government agency, or a court document? If a dataset, is the publisher a trusted data source (e.g., government agency)? [select one]
    a. Yes [proceed to Q15]
    b. No [proceed to Q9]

Screening – News Media

9) Is the source news media? [select one]
    a. Yes [proceed to Q10]
    b. No [proceed to Q11]

Screening – News Media Primary Source

10) Does the news media source reference a primary source of data or literature? [select one]
    a. Yes [exclude the source, proceed to Q14]
    b. No [use caution, proceed to Q15]

Screening – Objectivity

11) Review the source for objectivity. Is the source objective? [select one]
    a. Yes [proceed to Q15]
    b. No [exclude the source, proceed to Q13]

Exclusion – Topic

This source will be excluded due to not having topical relevance to the GES Health Study.

12) Describe why the source is not topically relevant to the GES Health Study. [long response]

Exclusion – Objectivity

This source will be excluded due to a lack of objectivity.

13) Describe why the source is not objective. [long response]

Exclusion – News Media

This source will be excluded in preference of the primary data source or literature.

14) Please provide locating information for the primary data source or literature. (E.g., title, author, URL, or description). [long response]

Highlighted Document Information

15) Is this document peer reviewed? [select one]
    a. Yes
    b. No
    c. Don't know
    d. Other [fill in]
16) Type of document [select multiple]
    a. Peer reviewed journal article
    b. Technical document
    c. News media
    d. Court document
    e. Other [fill in]
17) Funding [select multiple]
    a. AHRQ (Agency for Healthcare Research and Quality)
    b. Foundation/Private
    c. International government
    d. NASA
    e. NCAR (National Center for Atmospheric Research)
    f. NIH
    g. NSF
    h. State/local government
    i. US DOT
    j. US EPA
    k. Not indicated
    l. TPF (U.S. FHWA Transportation Pooled Fund)
    m. NIEHS (National Institute of Environmental Health Sciences)
    n. Other [fill in]
18) Does the highlighted document information support inclusion? [select one]
    a. Yes
    b. No
19) Comments about the highlighted document information. [long response]

Document Overview

20) Was the question or objective sufficiently described? [select multiple]
    a. Yes
    b. No
    c. Other [fill in]
21) Type of study (check all that apply). [select multiple]
    a. Epidemiology study (exposure --> outcome)
    b. Experimental
    c. Exposure study
    d. Modeling (e.g., mathematical, spatial, simulation)
    e. Observational
    f. Opinion/Editorial
    g. Qualitative study
    h. Review
    i. Not a study
    j. Other [fill in]
22) If it is a qualitative study, was it guided by a theoretical framework? [select multiple]
    a. Yes
    b. No
    c. NA
    d. Other [fill in]
23) Are the conclusions presented in the document supported by the results? [select multiple]
    a. Yes
    b. No
    c. Other [fill in]
24) Does the document overview support inclusion? [select one]
    a. Yes
    b. No
25) Comments about document overview. [long response]

Document Relevancy

26) Does the study area presented in this document cover GES? [select multiple]
    a. Yes
    b. No
    c. Other [fill in]
27) Can the results be applied to my population of interest? Can the results be applied to GES? [select multiple]
    a. Yes
    b. No
    c. NA/Unable to assess
    d. Other [fill in]
28) Is the exposure in this study (or document) relevant to GES? [select multiple]
    For example, PFAS has not been mentioned by the community as a concern, while air quality has been mentioned several times.
    a. Yes
    b. No
    c. Maybe
    d. NA/Unable to Assess
    e. Other [fill in]
29) What is the environmental risk factor or measurement? (Select all that apply) [select multiple]
    a. Air quality
    b. Alcohol/tobacco
    c. Arsenic
    d. Black carbon
    e. Built Environment
    f. Cannabis/Marijuana
    g. Community safety
    h. Connectivity/Mobility
    i. Goods and Services
    j. Indoor air
    k. I-70
    l. Lead
    m. Mobile air sources
    n. Noise
    o. Odors
    p. Ozone
    q. PM
    r. Soil Quality
    s. Superfund sites
    t. Water quality
    u. Zoning
    v. Other [fill in]
30) Is the outcome in this study (or document) relevant to GES? [select multiple]
    For example, asthma has been mentioned several times by the CC as a large concern.
    a. Yes
    b. No
    c. Other [fill in]

31) What is the outcome being measured? (Select all that apply) [select multiple]
    a. Allergies
    b. Asthma
    c. BMI
    d. Blood lead levels
    e. Cancer
    f. Cardiovascular health or disease
    g. Diabetes
    h. Eye irritation
    i. Mental health
    j. Respiratory health or disease
    k. Social determinants of health
    l. Other [fill in]
32) Does the document relevancy support inclusion? [select one]
    a. Yes
    b. No
33) Comments about the document relevancy. [long response]

Contextual Features

34) Is the time period of the study or data used in the document listed? [select multiple]
    a. Yes
    b. No
    c. Other [fill in]
35) What is the currency of the document based on when the document was originally published? [select multiple]
    a. less than 3 years difference to year of review
    b. less than 6 years difference to year of review
    c. less than 10 years difference to year of review
    d. less than 15 years difference to year of review
    e. age is unknown or more than 15 years of difference to year of review
    f. Other [fill in]
36) What is the currency of the data used in the document? [select multiple]
    Note: (1) Based on when the data were collected. (2) For ACS or other ranges, use the end date.
    a. less than 3 years difference to year of review
    b. less than 6 years difference to year of review
    c. less than 10 years difference to year of review
    d. less than 15 years difference to year of review
    e. age is unknown or more than 15 years of difference to year of review
    f. Other [fill in]
37) If applicable: Is the coordinate system well defined, including spatial extent, spatial resolution, boundary, and scale? Evaluate the following statements. (Select all that apply) [select multiple]
    Definitions: The spatial extent is the allowable range for x and y coordinates. The spatial extent is the geographic area that the raster data covers. Geographical boundaries can be edges of neighborhoods defined by socio-economic status, employment and deprivation; zones of population mixing in population genetics; the edges of disease clusters in public health; places where environmental exposures are changing.
    a. The coordinate system is well defined.
    b. The information includes spatial extent.
    c. The information includes spatial resolution.
    d. The information includes a spatial or geographical boundary and scale.
    e. NA
    f. Other [fill in]
38) Is the data collection method or tool being used to collect the data fine-tuned or exact enough to register the expected change? [select multiple]
    For example, a yardstick may not be a precise enough tool to measure a change of a few millimeters.
    a. Yes
    b. No
    c. NA
    d. Other [fill in]
39) Does it appear that sensitive information has been protected? [select multiple]
    a. Yes
    b. No
    c. Other [fill in]
40) Do the contextual features support inclusion? [select one]
    a. Yes
    b. No
41) Comments about the contextual features. [long response]

Final Comments

42) Is further review or digging into the sourced/referenced information needed? [select multiple]
    a. Yes
    b. No
    c. Maybe
    d. Other [fill in]
43) Key words. [short response]
44) Comments about the document. [long response]
45) Should this document be included or excluded from the GES health study? [select one]
    a. Included
    b. Excluded
46) What are your reasons for including or excluding this document? [long response]
47) Summary. Provide a technical summary of the document. What were the findings? What are the limitations relevant to how we can use it? [long response]
48) What is your 3-4 sentence summary for the community? [long response]

Data Assessment

Dataset Basics

1) Reviewer Name [select one]
    a. [list of ENVIRONS members]
2) Date of Assessment [date response]
3) Dataset Title [short response]
4) Data Source [select multiple]
    a. CDPHE
    b. Census/ACS
    c. Denver Open Catalog
    d. DRCOG
    e. US EPA
    f. Other [fill in]
5) Period for which data are being reported. [short response]
6) Date data was last updated [short response]
7) Author(s) [short response]
8) Type of data format available. [short response]

Screening – Topic

9) Is the topic relevant to the GES Health Study? (Error on the side of yes) [select one]
    a. Yes [proceed to Q10]
    b. No [proceed to Q14]

Screening – Source Type

10) Is the source: peer reviewed journal article, final report from a government agency, or a court document? If a dataset, is the publisher a trusted data source (e.g., government agency)? [select one]
    a. Yes [proceed to Q17]
    b. No [proceed to Q11]

Screening – News Media

11) Is the source news media? [select one]
    a. Yes [proceed to Q12]
    b. No [proceed to Q13]

Screening – News Media Primary Source

12) Does the news media source reference a primary source of data or literature? [select one]
    a. Yes [exclude the source, proceed to Q16]
    b. No [use caution, proceed to Q17]

Screening – Objectivity

13) Review the source for objectivity. Is the source objective? [select one]
    a. Yes [proceed to Q17]
    b. No [exclude the source, proceed to Q15]

Exclusion – Topic

This source will be excluded due to not having topical relevance to the GES Health Study.

14) Describe why the source is not topically relevant to the GES Health Study. [long response]

Exclusion – Objectivity

This source will be excluded due to a lack of objectivity.

15) Describe why the source is not objective. [long response]

Exclusion – News Media

This source will be excluded in preference of the primary data source or literature.

16) Please provide locating information for the primary data source or literature. (E.g., title, author, URL, or description). [long response]

About the Data Producer

17) Is the data producer a government department or agency, academic or research institution, or private company? [select multiple]
    a. Government Department or Agency
    b. Academic or research institution
    c. Private Company
    d. Non-profit group
    e. Other [fill in]
18) Does the literature agree that the indicator is a valid and logical measure for the stated result? [select multiple]
    For example, a valid measure of overall nutrition is healthy variation in diet; age is not a valid measure of overall health.
    a. Yes
    b. No
    c. NA/Unable to assess
    d. Other [fill in]
19) Does the data measured in this dataset add value to the GES Community Health Study? [select multiple]
    For example, air pollution is within the scope of the study, while political affiliation is not.
    a. Yes
    b. No
    c. Maybe
    d. Other [fill in]
20) Is there contact information available to ask questions about the dataset? [select multiple]
    a. Yes
    b. No
    c. Other [fill in]

21) Does the data producer information support inclusion? [select one]
    a. Yes
    b. No
22) Comments about the data producer. [long response]

About the Metadata and Information Available

23) Are metadata or overall information about the dataset available at the same time as the data are available? [select multiple]
    a. Yes
    b. No
    c. NA
    d. Other [fill in]
24) Does the metadata or information available include variable descriptions and definitions? [select multiple]
    a. Yes
    b. No
    c. NA
    d. Other [fill in]
25) Does the metadata or information available include descriptions of methods for data collection in the production of the data? [select multiple]
    a. Yes
    b. No
    c. NA
    d. Other [fill in]
26) Do you expect the dataset to be available one year from now? [select multiple]
    a. Yes
    b. No
    c. Other [fill in]
27) If applicable: Is the coordinate system well defined, including spatial extent, spatial resolution, boundary, and scale? Evaluate the following statements. (Select all that apply) [select multiple]
    Definitions: The spatial extent is the allowable range for x and y coordinates. The spatial extent is the geographic area that the raster data covers. Geographical boundaries can be edges of neighborhoods defined by socio-economic status, employment and deprivation; zones of population mixing in population genetics; the edges of disease clusters in public health; places where environmental exposures are changing.
    a. The coordinate system is well defined.
    b. The information includes spatial extent.
    c. The information includes spatial resolution.
    d. The information includes a spatial or geographical boundary and scale.
28) Does the metadata and available information support inclusion? [select one]
    a. Yes
    b. No
29) Comments about the metadata and information available. [long response]

Data Accessibility

30) Evaluate the accessibility of the data. (Select all that apply) [select multiple]
    a. Data are properly stored and readily available.
    b. To your knowledge, there are procedures or safeguards in place to minimize data transcription errors.
    c. To your knowledge, there are mechanisms in place to prevent unauthorized changes to the data.
    d. Other [fill in]
31) Is it easy to retrieve or read the data into your work environment? [select multiple]
    a. Yes
    b. No
    c. Other [fill in]
32) Is it easy for you to process or manipulate the data in your work environment? [select multiple]
    a. Yes
    b. No
    c. Other [fill in]
33) Does the data accessibility support inclusion? [select one]
    a. Yes
    b. No
34) Comments about data accessibility. [long response]

Contextual Features

35) Is the time period of the data listed? [select multiple]
    a. Yes
    b. No
    c. Other [fill in]

36) What is the currency of the data based on the year the data represent? [select multiple]
    Note: (1) Based on when the data were collected. (2) For ACS or other ranges, use the end date.
    a. less than 3 years difference to year of review
    b. less than 6 years difference to year of review
    c. less than 10 years difference to year of review
    d. less than 15 years difference to year of review
    e. age is unknown or more than 15 years of difference to year of review
    f. Other [fill in]
37) Is the geographical coverage of the data adequate for your purposes? [select multiple]
    a. Yes
    b. No
    c. Other [fill in]
38) Do the variables that are most important have enough valid values for your purposes? [select multiple]
    Note: Look at map of data to see if GES has valid values.
    a. Yes
    b. No
    c. Other [fill in]
39) Evaluate the following sentences. (Select all that apply) [select multiple]
    a. Records are internally consistent for your purposes.
    b. Variables follow standard formats.
    c. Data is recorded with sufficient detail to measure relevant indicators.
    d. There are accuracy indicators for the variables of interest.
    e. There is no evidence of bias.
    f. The margin of error is less than the expected change being measured.
40) Is the data collection method or tool being used to collect the data fine-tuned or exact enough to register the expected change? [select multiple]
    For example, a yardstick may not be a precise enough tool to measure a change of a few millimeters.
    a. Yes
    b. No
    c. NA
    d. Other [fill in]
41) Does it appear that sensitive information has been protected? [select multiple]
    a. Yes
    b. No
    c. NA
    d. Other
42) Are there unique identifiers in the dataset? [select multiple]
    For example, identifiers can include a sample ID, serial number, EIN (Employer Identification Number), business license number, or object ID.
    a. Yes
    b. No
    c. Other [fill in]
43) Are there matching variables such as age, sex, industry, or occupation? [select multiple]
    a. Yes
    b. No
    c. NA
    d. Other [fill in]
44) Does the population covered by the data align with what you need? [select multiple]
    a. Yes
    b. No
    c. Maybe
    d. Other [fill in]
45) Do the contextual features support inclusion? [select one]
    a. Yes
    b. No
46) Comments about contextual features. [long response]

Final Comments

47) Key words. [short response]
48) Comments about the dataset. [long response]
49) Should this dataset be included or excluded from the GES health study? [select one]
    a. Included
    b. Excluded
50) What are your reasons for including or excluding this document? [long response]
51) Summary. Provide a technical summary of the document. What were the findings? What are the limitations relevant to how we can use it? [long response]
52) What is your 3-4 sentence summary for the community? [long response]

THE ABC'S OF GES: THE STATE OF HEALTH AND ENVIRONMENT

GES Community Health Study

In response to Deliverable 2.2 Health Impact Assessment

January 31, 2024

ENVIRONS

Colorado State University

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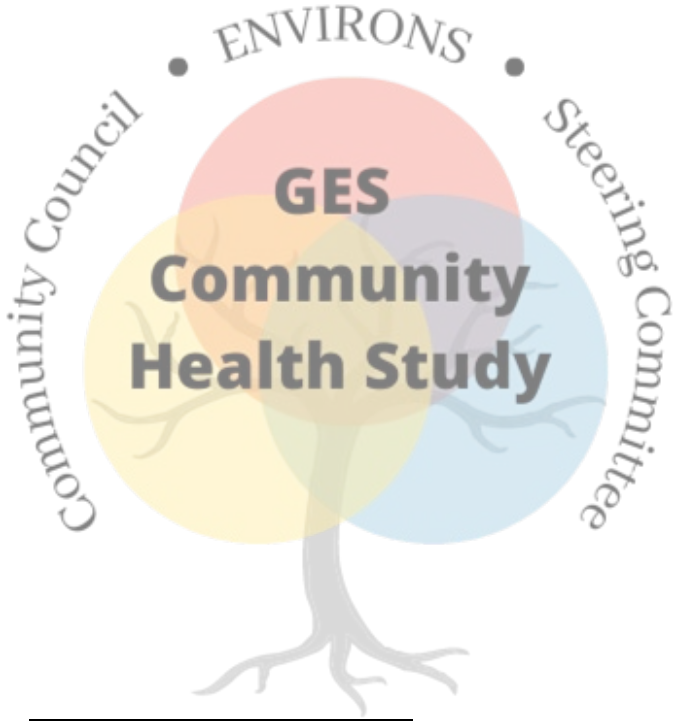

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COMMUNITY RELEVANT SUMMARY

Purpose: This report, *The ABCs of GES: the State of Health and Environment*, provides a summary of what is known about environmental conditions and health in the Globeville, Elyria, and Swansea neighborhoods compared to the rest of Denver as of January 2024 using data that have been collected from previous studies, projects, or public health surveillance programs.

Importance: This report is intended to be used by community members, neighborhood organizations, and government agencies as a reference regarding the current environmental conditions and human health trends in GES.

Important Findings:

Health

- **Health at Birth**: Compared to the Denver average, GES residents had a greater rate of risk factors like gestational diabetes during pregnancy and congenital abnormalities. However, the low birthweight and preterm birth rate in GES was about the same as the Denver average.
- **Death**: Between 2017-2021, the overall rate of death in GES was 24% higher than the Denver average. When specifically evaluating cancer, there was no evidence that GES had a higher rate of death.
- **Respiratory**: There is evidence that the rate of adult asthma hospitalizations is significantly greater in GES than the Denver average.
- **Cardiovascular**: There is no evidence that strokes, hypertension, or high cholesterol are more prevalent in GES than the Denver average.
- **Obesity and Diabetes**: Compared to the Denver average, GES has a higher percentage of adults who are obese, overweight, or have type II diabetes.
- **Disabilities**: A greater percentage of GES residents have a disability than the overall Denver population.
- **Health Behaviors**: GES residents have health behaviors similar to those of the overall Denver population, but there is a greater percentage of uninsured people and a greater percentage of people who are not up to date on preventative healthcare.

Environment

- **Air**: Air quality in GES is similar to the rest of Denver. There is no evidence of air pollution above health limits except for occasional short-term events.
- **Built Environment:**
    - Compared to the rest of Denver, GES residents have less access to healthy food and higher access to marijuana.
    - GES residents have similar access to parks and recreation facilities. However, the usability of parks is limited by concerns about safety, access, odors, and noise, which are worse in GES than in the rest of Denver.
    - GES has less tree canopy coverage than the rest of Denver, which is correlated with hotter streets.
- **Soil**: Soil quality is similar to the rest of Denver. Regarding Superfund site activities, there are very few properties left that have not been remediated. There is no evidence that soil contamination has directly caused health problems in GES.

Changes since the 2014 Health Impact Assessment

- Many of the issues that were identified in 2014 continue to be issues today.
- Some of the 2014 recommendations were incorporated into plans for neighborhood projects. However, the long-term follow-through and impact are unclear.
- Government agencies should re-evaluate the efforts to address the health and environmental concerns in GES and provide a report or press release on these efforts in a clear and concise format.

INSIGHTS FROM THE COMMUNITY COUNCIL

The following points were summarized based on our conversations with the Community Council and from community meetings. The Community Council consists of 6 residents, two from each neighborhood in GES. Members of the Community Council act as the Globeville, Elyria, and Swansea neighborhood representatives and liaisons.

Social Determinants of Health

- **Demographics:** Data regarding demographics and socioeconomic status may not fully reflect trends in the communities because they are a few years old. Since the most US Census data release, many long-time residents have moved out due to the rising cost of living. This could mean that there has been a decrease in the Hispanic/Latino population and people under the age of 25.
- **Education:** Community members recognize the need to increase educational attainment, but it has been challenging. Residents have attempted to open childcare facilities but faced multiple barriers, including the high cost of buying or renting a building, which prevented them from being successful. While youth in these communities graduate high school at the same rate as the Denver average, there are few opportunities for them afterward, which leads to them ending up in bad situations. However, many GES residents have their kids in Head Start programs, and many adults have attended GED courses.
- **Employment and Income:** Community members have a difficult time finding well-paying jobs. This is made more difficult by bias against Hispanics and Latinos, which limits the opportunities for advancement to high-level management and director positions. Many industrial companies do not promote from within and instead hire people who don't live in GES for upper-level positions. GES residents also face employment competition from the influx of recent migrants from Venezuela who are often willing to do the same jobs at a lower wage. This creates an environment where both the GES residents and migrants lose.
- **Housing**: Low incomes for residents impact housing in GES, making overcrowding common. With the rising cost of rent, it is common for multiple families to share one small house to be able to afford it. In addition, the removal of houses during the Central-70 project forced families to move in together. Again, the data included in this report likely do not capture this recent trend because they are old and housing costs have increased a lot in the past few years.
- **Health Behaviors:**
    - Health behavior data may estimate the use of marijuana to be lower than it actually is.
    - GES residents are probably getting more exercise than what is reflected in the health behavior data because many people work in labor and warehouses.
    - Only a few people who have lived in GES for a long time still go to Tepeyac Community Health Center. It seems like mostly new residents or people who live outside GES use the clinic. Some residents report being denied because their income is too high, yet they still can't afford groceries.
    - The similar rate of receiving an annual checkup in GES and Denver may be because residents can get discounted care even when they don't have health insurance.

Health

- The statistics about mortality and chronic disease confirm a hard reality that GES residents already know: that they have worse health, and this is at least in part because of the environment they live in. This is also scary because it impacts themselves and their families.
- Some people choose to engage in risky behaviors on top of environmental exposures during pregnancy, such as smoking, drinking, and using drugs.
- The cancer statistics do not align with the lived experience of residents that there is a very high number of people who get cancer, which residents believe is from living close to major sources of pollution. The Community Council believes that the currently published cancer studies from the early 2000s are unacceptable to use for cancer comparisons because they are now very old and potentially outdated. The cancer death rates presented in this report use death certificate data between 2017-2021.

Environment

- **Air**: Community Council members are still concerned about the air quality in GES, which leads them not to use parks and greenspaces. Some community members report that their children's asthma is worse in GES than elsewhere in Denver because of the air quality.
- **Built Environment**:
    - For most of GES, it is a 30-minute walk to get to a grocery store, which is significantly more than the 10-minute standard used by Denver. There are only three markets in GES where residents can buy food. This is less than Denver's database because some markets closed during COVID.
    - Some residents who tried to plant their own trees received citations from the city for unknowingly planting the wrong type of tree or planting it too close to buried utility lines.
    - Traffic accident and crime statistics confirm what residents experience. There is a lot of crime and car crashes. Not many people walk or bike in the neighborhoods, which is probably why there are fewer crashes involving bicyclists and pedestrians.
    - Streets continue to be very dark. The streetlights that are present are small and do not provide enough light for the whole block.
    - The city could better support residents in trying to improve their neighborhoods.
- **Odor**: Community Council members have personally called to report nuisance odors more times than what is presented in the 311 odor complaint data.
- **Noise**: Community Council members have indicated that GES is noisy compared to other parts of Denver due to the highways and trains and report being awakened by trains multiple times every night.
- **Soil**: There is hesitation in believing the soil data because of mistrust of government, and the residents believe more properties refused cleanup than what is recorded for each site. Residents also have concerns about how soil was tested and how effective soil replacement has been in the long-term, leading to additional concerns about planting trees and using soil for backyard gardening.
- **Water**: GES residents don't recreationally use the South Platte River, so the water quality and safety of the river are not a primary concern. Denver Water lead pipe replacements have been welcomed in GES, but some repairs are slow. Often, residents don't receive water testing results. Residents also expressed interest in cost assistance to update water fixtures within the home.

EXECUTIVE SUMMARY

Globeville, Elyria, and Swansea (GES) are three of Denver's oldest neighborhoods. Residents in these three neighborhoods have been impacted by a host of environmental pollution over time, which greatly affects the health and well-being of the GES community. This report aims to characterize the current state of health and environment in Globeville, Elyria, and Swansea, and when possible, draw connections between the two.

We used the 2014 health impact assessment titled, "How Neighborhood Planning Affects Health in Globeville and Elyria Swansea" published by Denver's Department of Public Health and Environment as our starting point. We conducted a review of literature, in the form of peer-reviewed scientific journal articles, technical documents, and news media to describe established associations between environmental exposures and specific health outcomes. We primarily used publicly available data to compare health outcomes in GES and Denver as a whole and assess the strength of the evidence. Finally, we evaluated the recommendations presented in the 2014 report based on our findings and community input.

Overall, our findings were mixed when comparing the state of health and environment between GES and the Denver average. For social determinants of health, we found that GES has a lower rate of educational attainment, higher cost of housing burdens, and mixed trends around substance use. We also found that GES has higher rates of adverse health outcomes compared to the Denver average, including risk factors during pregnancy, congenital abnormalities, all-cause mortality, chronic respiratory diseases, diabetes, and obesity. However, there is some evidence to suggest other health outcomes are comparable to the rest of Denver, such as cardiovascular disease and mental health outcomes. For environmental quality, we found that GES has worse exposure to noise pollution and odors, mainly due to where the community is located and the large industrial presence. Air quality generally follows regional trends and falls below health-based thresholds except for occasional short-term events when air quality may exceed these thresholds. Considering the built environment, it has been well documented that GES is significantly impacted by decreased access to goods and services, and our findings support this conclusion. Specifically, there is a lack of healthy food access and tree cover, and greenspaces remain underused due to safety concerns. GES has a higher rate of traffic accidents and crime than Denver. Conversely, there is evidence to suggest that soil quality and water quality are comparable to the rest of Denver. Most of the properties in GES that fall within the two Superfund sites have been sampled and remediated as necessary. Denver Water is currently working on updating the water infrastructure to provide safer water to the city and is prioritizing GES. The final part of our report provides an overview of the status of the 2014 recommendations, highlighting areas where more work is required to accurately evaluate the state of health and environment in GES.

It is our hope that these findings can be used in partnership between government agencies and community members to better engage and produce change for the residents of GES.

RESULTS AT A GLANCE

Table 1 highlights the results of our evaluation of the strength of evidence for social determinants of health. An explanation of how the strength of evidence was determined can be found in **Appendix 1**.

Table 1. Evaluation of the strength of evidence for social determinants of health results. Strength of evidence is only provided when multiple data sources are available.

VARIABLE	GES COMPARED TO DENVER	STRENGTH OF EVIDENCE
Education		
Adult educational attainment rate	Lower	Consistent
High school graduation rate	Similar	--
Access to early childhood education	Mixed	--
3rd graders reading below grade level	Higher	--
Employment and Income	Lower	Consistent
Housing		
Housing cost burden	Higher	--
Housing quality	Lower	Consistent
Health Behaviors		
Tobacco use	Higher	Limited
Alcohol use	Similar	Consistent
Marijuana use	Similar	--
Leisure time Physical activity	Lower	--
Vaccine use	Similar	--
Clinical Care		
People without health insurance	Higher	Consistent
Annual health check-up	Similar	--
Delaying medical care due to cost	Higher	--
Up to date on core preventative services	Lower	Consistent

Table 2 highlights the results of our evaluation of the strength of evidence for specific indicators of health, disease, and mortality. An explanation of how the strength of evidence was determined can be found in **Appendix 1**.

Table 2. Evaluation of the strength of evidence for specific indicators of health, disease, and mortality results. Strength of evidence is only provided when multiple data sources are available.

OUTCOME	GES COMPARED TO DENVER	EVIDENCE STRENGTH
Health at Birth		
Birth and Fertility Rate	Higher	Consistent
Risk factors during pregnancy	Higher	Consistent
Low birth weight and preterm births	Similar	Consistent
Congenital abnormalities	Higher	--
Mortality		
All-cause mortality	Higher	--
Mortality from cardiovascular disease, cancer, or injuries	Similar	--
Chronic Respiratory Diseases		
Respiratory diseases prevalence	Higher	Consistent
Adult asthma prevalence	Slightly higher	Limited
Adolescent asthma prevalence	Slightly higher	--
Asthma hospitalizations	Higher	--
COPD prevalence	Slightly higher	--
Cardiovascular Diseases		
Cardiovascular disease prevalence	Similar	Consistent
Strokes prevalence	Similar	--
Hypertension prevalence	Similar	--
High cholesterol prevalence	Similar	--
Obesity and Diabetes		
Obesity and overweight prevalence	Higher	Consistent
Adult obesity and overweight prevalence	Higher	Consistent
Adolescent obesity and overweight prevalence	Higher	Consistent
Diabetes prevalence	Higher	Consistent
Diabetes hospitalizations	Higher	--
Cancer Prevalence	Lower	--
Mental Health		
Poor mental health	Similar	Consistent
Depression and anxiety prevalence	Similar	Consistent
Frequent mental distress	Higher	--

OUTCOME	GES COMPARED TO DENVER	EVIDENCE STRENGTH
Additional Health Outcomes		
Blood-lead levels	Mixed	--
Influenza hospitalizations	Higher	--
Disabilities prevalence	Higher	Consistent
COVID-19 mortality	Higher	--

Table 3 highlights the results of our evaluation of the strength of evidence for environmental factors. An explanation of how the strength of evidence was determined can be found in **Appendix 1**.

Table 3. Evaluation of the strength of evidence for environmental factors results. Strength of evidence is only provided when multiple data sources are available.

VARIABLE	GES COMPARED TO DENVER	STRENGTH
Air Quality	Similar	Consistent
Built Environment		
Food Access	Lower	Consistent
Marijuana Access	Higher	--
Alcohol Access	Similar	--
Greenspace, Parks, and Recreation Access	Mixed	--
Urban Heat Island/Hot Streets	Higher	--
Community Safety		
Traffic Accident Rate	Higher	--
Crime Rate	Higher	Consistent
Connectivity And Mobility	Lower	Consistent
Odor	Higher	--
Noise	Higher	--
Soil Quality	Similar	--
Water Quality	Mixed	--

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LIST OF ACRONYMS, DEFINITIONS, AND DESCRIPTIONS

Health Study Teams

CC	Community Council: Resident collaborators part of the research team conducting the health study, can answer questions about the Community Council's role in the study and membership ges.commcouncil@gmail.com.
SC	Steering Committee: Stewards of the Central 70 settlement agreement to ensure it is carried out appropriately, approve invoices, deliverables, and can answer questions about the settlement geshealth.steercomm@gmail.com.
ENVIRONS	Research team conducting the health study, can answer questions about the health study, geshealthstudy@gmail.com.

List of Acronyms

AirToxScreen	Air Toxics Screening Assessment; AirToxScreen is a national model that predicts the risk from air toxics in the United States.
As	Arsenic; a metal that is toxic. There are many naturally occurring sources of As.
ASARCO	American Smelting and Refining Company.
ATSDR	Agency for Toxic Substance and Disease Registry; ATSDR is a federal public health agency within the US Department of Health and Human Services. The agency focuses on minimizing human health risks associated with exposure to hazardous substances.
BC	Black carbon; a type of particulate matter air pollution.
BMI	Body mass index; BMI is used as a measure to screen for obesity and overweight. It is calculated by dividing a person's weight by their height.
BZ	Benzene; a type of air toxic.
CCoD	City and County of Denver.
Cd	Cadmium; a metal that is toxic.
CDC	Centers for Disease Control and Prevention; the CDC is the national public health agency of the United States.
CDOT	Colorado Department of Transportation; the principal department of the Colorado state government responsible for maintaining interstates and highways in Colorado.
CDPHE	Colorado Department of Public Health and Environment; CDPHE is the principal department of Colorado state government responsible for public health and environmental regulations.
Central 70	The Central 70 Project; this is the official name for the expansion of interstate 70.
CI	Confidence interval; expressed as a range, the CI is a mathematically calculated range where the true value is likely to be in.
CO	Carbon monoxide; a type of air pollutant.
CPD	Denver Department of Community Planning and Development.
CSU	Colorado State University.
CVD	Cardiovascular disease.
CW Montero	Office of Councilwoman Judy H. Montero. It is important to note that CW Montero was in office at the time of the 2014 HIA.

DEH/DDPHE	Denver Department of Public Health and Environment; the city department responsible for public health and environmental regulations, serves a similar function as CDPHE, but at a local level. It is important to note that some literature uses DEH to represent DDPHE.
Denver	City and County of Denver.
DPD	Denver Police Department.
E. coli	*Escherichia coli*; a bacteria (germ) that can sometimes cause disease. It is a good indicator of other pathogens (germs) that may be present.
Environmental Covenant	Environmental Covenant refers to a restriction placed on a property by CDPHE to restrict future use of the site. Land use restrictions may be used to ensure the cleanup remedy adequately protects human health and the environment when a contaminated site is not cleaned up completely.
EPA (US EPA)	United States Environmental Protection Agency; the primary agency of the United States government tasked with environmental protection.
FHWA	Federal Highway Administration; the division of the United States Department of Transportation that specializes in highway transportation.
GES	Globeville, Elyria, and Swansea neighborhoods.
H_2S	Hydrogen sulfide; a type of air pollutant.
HAP	Hazardous air pollutants; a group of air pollutants that do not fall under the NAAQS but are known to cause serious health effects and are regulated under the Clean Air Act.
HI	Hazard index; an HI is a way to assess if there is a risk of health effects from chemical exposures. A value less than 1 indicates that health effects are not expected. A value greater than 1 indicates that there may be a risk of health effects and further investigation is needed.
HIA	Health Impact Assessment; a process that usually produces a report describing how a proposal will impact health.
MRL	Maximum risk levels; an MRL is an estimate of the amount of a chemical a person can eat, drink, or breathe each day without a detectable risk to health. MRLs are set by ATSDR.
NAAQS	National Ambient Air Quality Standards; The Clean Air Act requires EPA to set NAAQS for carbon monoxide (CO), lead (Pb), ground-level ozone (O_3), nitrogen dioxide (NO_2), particulate matter (PM), and sulfur dioxide (SO_2).
NGOs	non-governmental organizations.
NO_x and NO_2	Nitrogen oxides and nitrogen dioxide, respectively; types of air pollutants. NO_2 is a specific type of NO_x and is used in NAAQS as a representative of NO_x.
NPL	National Priorities List.
NWC	National Western Center.
O_3	Ozone; a type of air pollutant.
OCP	Odor Control Plan.
OED	Denver Office of Economic Development.
OU	Operable Unit; During Superfund cleanup, a site can be divided into a number of distinct areas depending on the complexity of the problems associated with the site. These areas called operable units may address geographic areas of a site, specific site problems, or areas where a specific action is required.
Pb	Lead; a toxic element that can come from many sources, including air, water, and soil.
PM	Particulate matter; PM contains microscopic solids or liquid droplets that can be inhaled and cause serious health problems. Some particles less than 2.5 micrometers in diameter can get deep into your lungs and some may even get into your bloodstream.

ppm	Parts per million; this is equivalent to 1 drop in 10 gallons.
ppb	Parts per billion; this is equivalent to 1 drop in 500 barrels.
PW	Denver Department of Public Works.
RSEI	Risk-Screening Environmental Indicators Model; RSEI is a national model that helps determine the risk from chemicals released by industrial facilities.
RTD	Regional Transportation District; the public transit system that operates buses and trains in the Denver metropolitan area.
SDOH	Social determinants of health; As defined by the Healthy People 2030 goals, social determinants of health are the "conditions in the environments where people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks."
SMR	Standardized mortality rate; a value that compares the rate of death in a population to the expected rate of death. Values greater than 1 indicate that the rate of death is higher than expected.
SO_x and SO_2	Sulfur oxides and sulfur dioxide, respectively; types of air pollutants. SO_2 is a specific type of SO_x and is used in NAAQS as a representative of SO_x.
VB/I-70	Vasquez Boulevard and Interstate 70 Superfund site; this Superfund site was created to remediate soil contamination primarily from historic smelting activities. The site includes two commercial/industrial areas as well as residential properties in all or part of the following neighborhoods: Cole, Clayton, Swansea/Elyria, southwest Globeville and northern Curtis Park.
VOCs	Volatile organic compounds; VOCs are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects.

1. INTRODUCTION

The residents of Globeville, Elyria, and Swansea (GES) have long fought to bring awareness to the environmental hazards of the GES environment. In response to the Central Interstate-70 expansion project (referred to as Central 70 project), multiple neighborhood organizations joined together in 2017, and with the support of the Colorado Sierra Club, filed a lawsuit against the expansion (referred to as the Central 70 settlement).[1] The lawsuit was settled, and funds were designated for the creation of a comprehensive health study in the neighborhoods.[1,2] The Central 70 settlement outlines that the health study must provide decision-makers with the information required to make policy without recommending any policy itself. This is a nuanced and challenging requirement to adhere to and is often disheartening to community members and partners who wish to see this study result in actionable change. Nevertheless, we hope the approach we take in this report to assess the current state of health and environment in GES, as an update to the 2014 Health Impact Assessment (HIA) conducted by Denver,[3] will provide a useful tool for community members, partners, and decision-makers.

Health Impact Assessments

Traditionally, a health impact assessment (HIA) focuses on one project or new policy to predict potential benefits and impacts on health. For example, in 2020, researchers conducted a greenspace health impact assessment to estimate annual premature mortality burden for adults in Philadelphia.[4] An HIA is a combination of procedures, methods, and tools to systematically judge the potential effects of a policy, plan, program, or project on the health of a population, and the distribution of those effects within the population.[5] There are two main types of health impact assessments, qualitative and quantitative. Both follow 6 overarching steps for completion: 1) screening, 2) scoping, 3) appraisal, 4) recommendations, 5) report, and 6) monitoring and evaluation. ENVIRONS used these 6 steps as the starting point for the 2023 HIA.

Screening. ENVIRONS adapted a screening checklist[6] and assessment tool[7] used by other organizations such as the Minnesota Health Department and the University of New South Wales to conduct the screening step of this HIA. The outcome of the screening process along with the outline of the Central 70 settlement and GES Community Health study contract resulted in defining the context for this 2023 HIA, which is to serve as a review of the 2014 Health Impact Assessment "How Neighborhood Planning Affects Health in Globeville and Elyria Swansea."[3] Recalling the Central 70 settlement's prohibition against identifying or recommending policy, we have taken an analytical approach to evaluating the 2014 HIA recommendations. The 2014 HIA contains many recommendations, which if implemented would largely be policy-based. This 2023 HIA assesses the status of the 2014 recommendations from a factual standpoint, whether they have been implemented or not, and when feasible, provides community members, partners, and decision-makers with an update regarding the suggested interventions. The recommendations contained in this HIA can inform future policy decisions **(see Recommendations)**. However, we have avoided, as prohibited, discussion of what policy-making entities should do prospectively.

Scoping. The second step of a health impact assessment is to conduct a scoping review to determine the boundaries of what will be done, which health determinants and outcomes should be evaluated, and the methods for analysis, sources of data, and strategies for engaging with the involved community partners. ENVIRONS created a scoping worksheet[8] and toolkit[9] adapted from the Wisconsin Public Health Association and Human Impact Partners to further outline the scope of this deliverable. Many of the sources of data were identified in Phase 1 of the GES Community Health study, along with each dataset being evaluated in Phase 2 Deliverable 2.1.

Appraisal. The appraisal step of an HIA is to create a profile of current conditions and evaluate the potential health impacts. To complete this process, ENVIRONS used a variety of databases[a] to accurately characterize the state of

[a] Explanations of the main data sources are in **Appendix 1**.

health and environment in GES relative to the Denver average. We used the Denver average as a comparison to better understand GES within the regional context of the city. We believe this will provide meaningful context for grassroots organizers and local and state health officials. Further, all environmental justice is local, and each environmental justice community has unique burdens and impacts. Even within Colorado, environmental justice communities have a wide range of experiences and exposures. Comparing two environmental justice communities does not recognize the uniqueness of each individually. Similarly, comparing GES to communities nationwide may mask significant exposures or impacts that would be overshadowed by a few extreme measures nationwide. By comparing GES to the Denver average, we are able to highlight the environmental and health characteristics of GES that require action while centering the lived experience of residents, which is inherently based on local experiences and comparisons. Additionally, as part of the appraisal process, we evaluated the status of the 2014 HIA recommendations.

2. WHO IS GES?

Globeville, Elyria, and Swansea are some of the oldest neighborhoods in Denver, originally settled in the late 1800s by European immigrants to work in rail and smelting industries. By the end of World War II in 1945, most European settlers and war refugees had left the area, and Latino and African American service members relocated to the area in search of more stable employment. Over time, GES residents would face continuous changes, ongoing presence of environmental cleanup activities, big investor interest, and industrial encroachment. (A more complete history of GES is reported in Deliverable 1.4[a]).

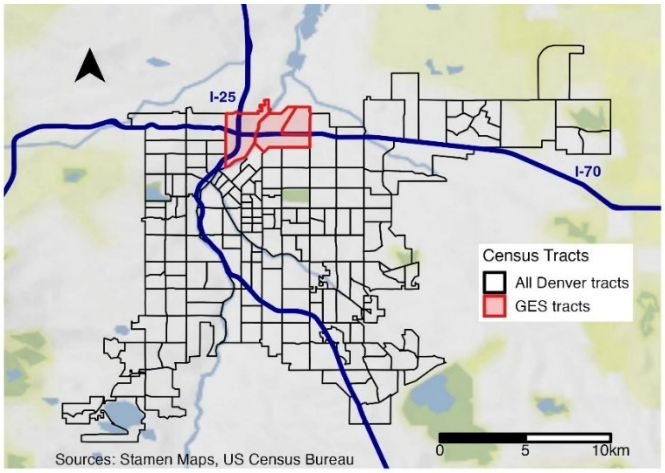

Figure 1. Globeville, Elyria, and Swansea neighborhoods in relation to the Denver area.

But who is GES today? Globeville, Elyria, and Swansea neighborhoods cover four-square miles in northeast Denver, Colorado **(Figure 1)**. GES boasts a colorful and proud cultural community with European, Latino, and Hispanic roots. When asked, GES residents enjoy their neighbors, are proud of how GES helped shape Denver, and a strong community cohesion is ever present.[10,11] Over the course of the GES Community Health Study, ENVIRONS has had the privilege of spending time with community members, hearing their stories, listening to their concerns, and where possible, trying to make the connections between health and the environmental impacts GES face.

2.1. SOCIAL DETERMINANTS OF HEALTH

The 2014 HIA acknowledged that biology and genetics account for only 30% of one's health status, while 70% of health outcomes are attributable to social determinants of health (SDOH). Despite this acknowledgment, the HIA did not evaluate many important health-influencing factors in GES, including education, employment, and health behaviors.[3] As defined by the Healthy People 2030 goals, social determinants of health are the "conditions in the environments where people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks." **Figure 2**[12] shows five broad categories of social determinants of health as defined by Healthy People 2030. In this report we assess education, employment and income, housing, health behaviors, and access to clinical care for residents in GES using the best available data, then briefly explore how each of these is connected to health. SDOH are not the primary focus in the GES Community Health Study and will not appear in the Exposure Outcome Matrix (Deliverable 2.3; February 2024) or the Cumulative Risk Assessment (Deliverable 2.4-2.6; January

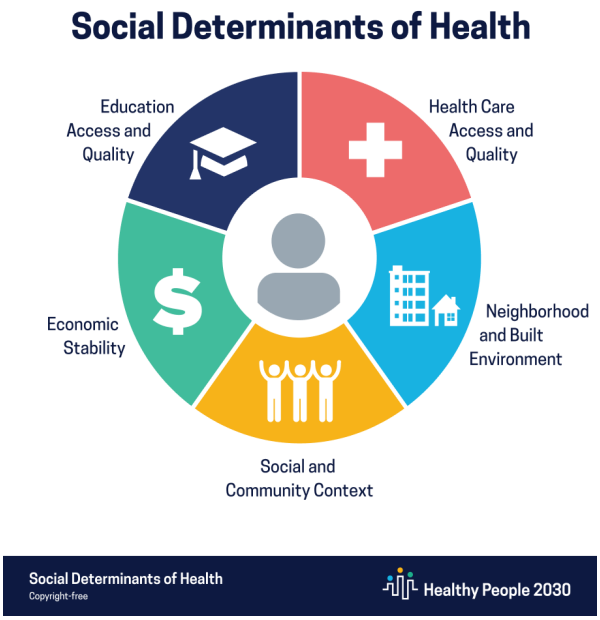

Figure 2. Social determinants of health.

[a] Deliverable 2.1 can be accessed at https://www.geshealthstudy.org/products.

2025). However, we have included a descriptive analysis of them in this report to provide the most complete update to health and environment in GES as possible, recognizing that the SDOH are interconnected with how the chemical, physical and built environments impact health.

2.2. DEMOGRAPHICS

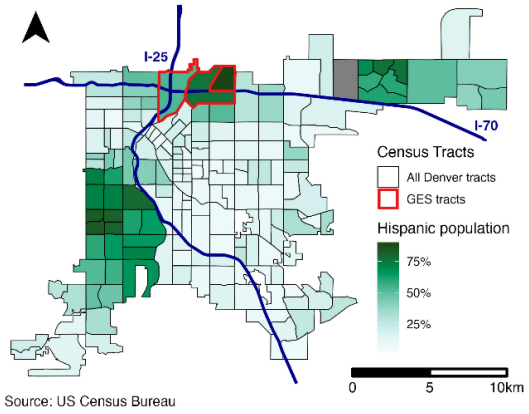

Figure 3. Hispanic/Latino population in Denver, Colorado, 2017-2021 5-year estimates.

Current demographic data indicate the GES community is predominantly Hispanic/Latino. Specifically, Elyria and Swansea neighborhoods have one of the highest Hispanic/Latino populations in Denver: roughly 72% compared to 29% in Denver **(Figure 3)**. Approximately 27% of GES residents were born outside of the United States and 17% of adults have limited English proficiency. GES is also significantly younger than the rest of Denver, with 25% of GES's population is under 18 years old, while only 19% of Denver's population is under 18.[13] Evidence supports that across the United States, Hispanic/Latino residents are disproportionately exposed to high levels of ambient air pollution, particularly in comparison to White populations.[14] Further, limited English proficiency results in challenges in economic opportunities, educational opportunities, obtaining appropriate health care, as well as others.

2.3. EDUCATION

Educational achievement gaps are a major contributor to health disparities. There is consistent evidence that educational attainment rates among adults above 25 years old are lower in GES than in Denver on average. From 2017-2021, the percentage of the population above age 25 without a high school diploma in GES was estimated to be 39.4%, compared with 10% in Denver.[15] During the same time period, the estimated population over age 25 with a bachelor's degree or higher in GES was 17.9%, compared to 52.5% in Denver.[16] Educational attainment not only influences life expectancy, but also impacts employment, income, and other social determinants of health.[17] Without access to quality education, including vocational schools and certificate programs, poor education can cyclically contribute to numerous interconnected barriers to health.

While the percentage of the population without a high school diploma includes older adults and those who have moved or migrated to GES, high school graduation rates within GES present a slightly different narrative. In 2018, an estimated 77-86% of Denver Public Schools (DPS) high school students living in Globeville graduated in four years, and 66-76% of high school students living in Elyria-Swansea graduated in four years.[15] These graduation rates are strong in comparison to the overall four-year graduation rate in Denver of 70%. High school graduation is predictive of employment, income, drug and alcohol abuse, and teenage pregnancy.[15] Further, employment rates for individuals with a high school diploma are twice as high as those who do not complete high school.[15]

Educational attainment of parents also impacts children. Children with parents of low educational attainment are at a higher risk for numerous barriers to well-being, including a higher risk of living in poverty.[15] In Denver, an estimated 14% of children are born to women without a high school diploma or GED, compared to 23-30% in Globeville and 31-37% in Elyria-Swansea.[15] Women without a high school diploma may include women who have immigrated and older women.

These data suggest an opportunity to improve access to contraception and family planning resources in GES, and that one potential outcome could be greater high school retention rates. Further, more women graduating high school may lead to improvements across the outcomes of many other social determinants of health.

Another important educational social determinant of health is early childhood education (ECE). The first five years of a child's life are some of the most critical for human development.[15] Enrollment in quality preschool leads to higher high school graduation rates, higher income, higher likelihood to become an adult homeowner, fewer interactions with law enforcement, and higher rates of health and well-being.[15] One of the biggest threats to ECE is access and availability. As of 2021, there is evidence that childcare capacity in Globeville is meeting community demand, but the situation is different in Elyria-Swansea. Childcare capacity refers to the population of children under age 10 compared with available childcare slots in licensed childcare centers. As of 2021, Globeville's childcare capacity was approximately 110% and Elyria-Swansea's childcare capacity was at 16%, qualifying the Elyria-Swansea neighborhood as a childcare desert[a].[18] The burden of inequitable distribution of childcare is compounded when we consider other factors. Low-income families may be more likely to rely on public transportation, have two working parents, or have inflexible job schedules due to immigration status, job classification (e.g., service industry jobs), and other factors.[15]

Another key indicator in educational attainment is third grade reading level. After third grade, public school curriculum transitions from learning to read towards reading to learn. Children who have not achieved a third-grade reading level at this juncture may be more likely to fall behind in the years ahead. In Globeville, there is evidence that 70% of third grade students are reading below grade level, compared to 55% in Elyria-Swansea and 37% in Denver.[18]

There is ongoing legislation being considered that influences education and health in GES. With the recent passing and implementation of the Healthy School Meals for All initiative, all students in Colorado will have access to free school breakfast and free school lunches.[19] Pairing access to education with quality food may contribute to improved health outcomes through greater school attendance and improved childhood nutrition in GES, which has limited access to healthy, affordable food **(see Access to Goods and Services)**.

Improving access to and quality of education in GES has the potential to improve community health outcomes. Adults and children alike experience better health outcomes when access to ECE, primary, secondary and tertiary education, as well as vocational schools and training centers are available. In the wake of the COVID-19 pandemic, addressing the achievement gap and inequitable access to educational opportunities is as important as ever. Without quality, affordable, proximate education facilities, GES residents will continue to face a disproportionate burden in fulfilling this basic health need.

2.4. EMPLOYMENT & INCOME

Socioeconomic factors such as income and employment affect and influence health. The 2014 HIA presented the average household income for Elyria and Swansea as $44,700 and Globeville's household income as $39,200, which were both lower than Denver's median income of $73,100. There was no detailed information on employment status in 2014 HIA. Still, employment and economic status greatly impact economic opportunities and are some of the strongest predictors of health in the United States.

[a] According to the 2019 Status of Denver's Children, "childcare deserts are defined as any census tract with more than 50 children under age five that contains either no childcare providers, few options, or more than three times as many children as licensed childcare slots."

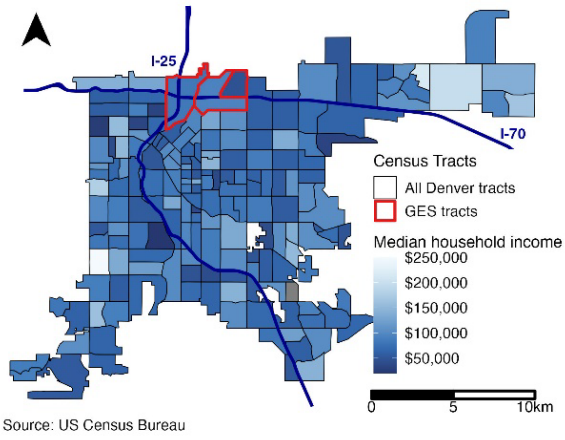

Figure 4. Median household income in Denver, Colorado, 2017-2021 5-year estimates.

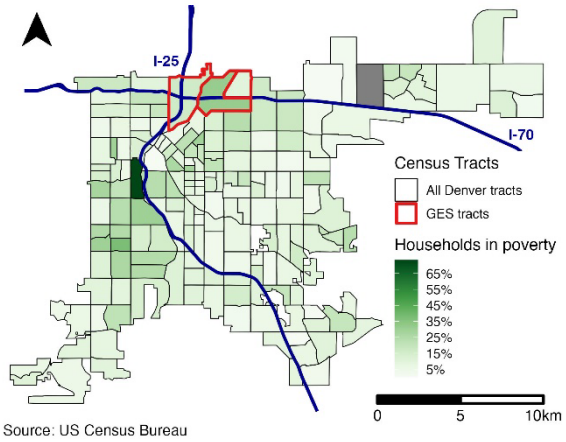

Figure 5. Household in poverty in Denver, Colorado, 2017-2021 5-year estimates.

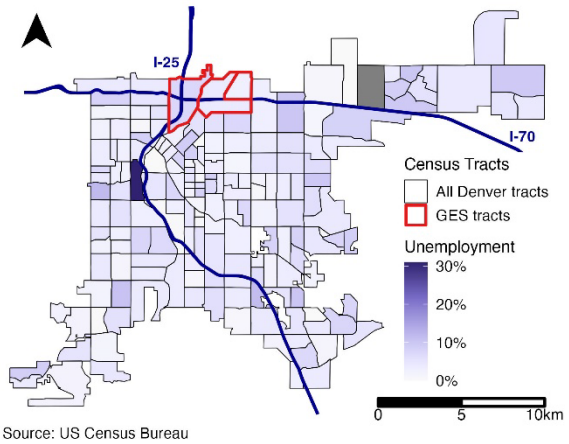

Figure 6. Unemployment rate in Denver, Colorado, 2017-2021 5-year estimates.

Employment and income are important social determinants of health because they can contribute to better health and economic opportunities. There is consistent evidence that median household income is lower in GES than the Denver average. However, the income disparity is less than reported in 2014, which may be partially because of gentrification, with higher-income households pushing out lower-income households from the area. This is anecdotally supported by the lived experience of residents who share that rising rents have caused families to move elsewhere, such as Montbello and Green Valley Ranch. The 2021 American Community Survey found that the median household income in Globeville is $67,917, $60,556 in west Elyria-Swansea, and $48,920 in east Elyria-Swansea, which is substantially lower than the median household income in Denver of $78,177 **(Figure 4)**. We see the same pattern in the percentage of households that are below the poverty level in 2021. In GES, 18.1% of households were estimated to be below the poverty level and 11% of households in Denver overall were estimated to be below the poverty level **(Figure 5)**.[16] These economic characteristics impact GES residents who face barriers to maintaining good health through limitations of employment and low economic opportunity.

Low employment has been an issue in the GES community as many families find it difficult to find jobs that pay enough to provide for their families.[15] In 2021, the unemployment rate in GES was estimated to be 5.1%, compared to Denver's unemployment rate of 4.6% **(Figure 6)**. While that is not a big difference in percentage, residents have reported that they lack the necessary skills, education, and resources to compete for industry jobs.[10] Low income, high poverty, and employment challenges create a financial burden on residents to meet basic needs such as paying rent or their mortgage and buying groceries, leaving fewer resources (time, money, and energy) for recreation and leisure. Low income is associated with worse mental health, poorer nutrition, and decreased access to medical care.[20]

2.5. HOUSING

Accessible and safe housing is an important social determinant of health. Families who are involuntarily displaced from their homes experience detrimental impacts to their physical and mental health, disrupted family life, broken social networks, and damage to well-being.[21] GES residents face displacement from rising housing costs as redevelopment of the River North (RiNo) art district threatens gentrification for GES. There is limited evidence that suggests GES residents have a higher housing cost burden than other parts of Denver, as measured by the percentage of housing use where the annual cost of housing is greater than 30% of income. In GES, it is estimated that over a third (38.7%) of housing units are cost-burdened, while overall in Denver 34.4% are cost-burdened **(Figure 7)**. However, the data available to measure housing cost burden are a poor indicator because they are summarized as a five-year average from 2017-2021 and do not accurately reflect the rapid increase in housing costs in recent years. Additionally, the GES Coalition for Health and Housing Justice conducted a survey in 2017 in GES on living conditions and found that out of survey respondents, 51% of renters don't have a lease and 61% of renters earn less than $25,000 a year.[21] The lack of leases signifies that families in GES are more vulnerable to evictions, forced relocation, and homelessness. Further, data show that the percentage of housing units occupied by owners in Denver is 49.6% and only 45.2% in GES.[16] These data demonstrate that there are fewer resources for people in GES to purchase a home or find secure and affordable leases, resulting in high levels of housing insecurity.

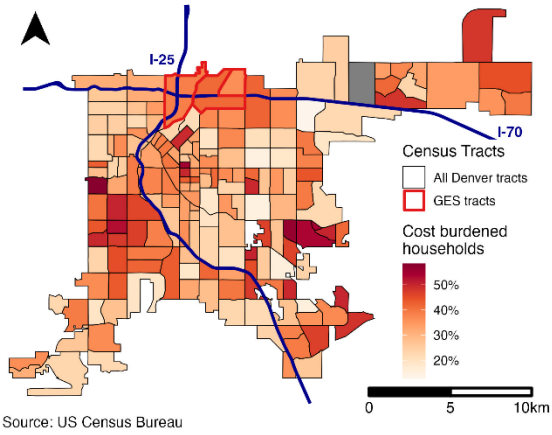

Figure 7. Cost burdened households in Denver, Colorado, 2017-2021 5-year estimates.

There is also consistent evidence that housing quality in GES is worse than the Denver average. In GES, 78.5% of households are estimated to have been built before 1980 compared to 61.5% in Denver. The median year houses were built in Globeville is 1946 and 1951 in Elyria-Swansea, which is much older than the Denver median year built of 1968 **(Figure 8)**. This is not surprising given that the GES neighborhoods are some of the oldest in Denver, dating back to the early 20th century, and many residents take pride in the nature of their homes. However, in Denver, houses built before the 1950's are at the greatest risk of having lead service lines, and houses built before 1986 may have internal lead pipes, solder, and fixtures. Houses built before 1978 may also have lead paint, with older houses having a greater chance of having lead paint.[22] These are all potential sources of lead exposure, and a study of childhood blood lead levels in the Denver metro area found that housing age was associated with elevated blood lead levels.[23] Older houses are also more likely to have asbestos, poor insulation, and lack air conditioning.[24] Poor insulation and lack of air conditioning is of concern as heatwaves in Denver become more frequent and more intense with climate change. Both Globeville and Elyria-Swansea neighborhoods were identified by Denver's office of Climate Action, Sustainability, and Resilience (CASR) as priority neighborhoods for heat vulnerability.[25] As another measure of housing quality, 8% of housing units in GES are estimated to be overcrowded, more than double the 3.1% Denver average.

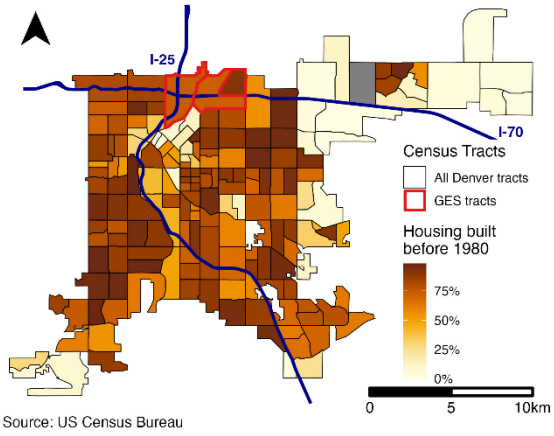

Figure 8. Housing built before 1980 in Denver, Colorado, 2017-2021 5 - year estimates.

Physical housing characteristics can directly impact health, as mentioned previously, and are a critical factor in overall health as people spend the majority of their time indoors.

Housing insecurity, displacement, and high housing cost burden negatively impact mental health, which may be worsened by co-occurring employment insecurity.[24,26] Like other social determinants of health, access to affordable and secure housing is a product of systems of inequality, which is visible in the historical practice of redlining.[27] Redlining was a practice by the Home Owner's Loan Corporation (HOLC), a government sponsored organization, that graded communities based on their perceived risk.[28] In effect, communities of color where often graded as high risk which resulted in an inability of people of color living in those neighborhoods to secure mortgages. This practice was initiated in the 1930s, and while redlining is prohibited under the Fair Housing Act of 1968, there are still negative impacts to this day.[27] The effects of redlining on people's well-being can be seen in many neighborhood conditions as outlined in the built environment section of this report.

2.6. HEALTH BEHAVIORS

As with all SDOH, health behaviors are largely produced by structural inequities, not individual choices. Structural factors afford unequal levels of access to health-supportive resources for different communities. When it comes to health behaviors, structural barriers to health may include lack of access and time for purchasing healthy food or safe places to exercise **(see Access to Goods and Services)**, or lack of educational resources and support regarding substance use.

Based on available data, substance use in GES is approximately the same as the Denver average. There is limited evidence that tobacco use is slightly higher in GES than the Denver average. In 2021, tobacco use in Globeville adults over 18 was estimated to be 18.9%, and in Elyria-Swansea it was 17.2%, as compared to 13% in Denver.[29] Beyond impacting the physical health of tobacco users and those exposed to second-hand smoke, exposure to tobacco and toxic substances during pregnancy can also impact childhood development before birth, with possible adverse outcomes in academic, social, and physical life.[18] However, there is no evidence that binge drinking in adults is greater in GES than in Denver. Binge drinking in Denver was estimated to be 22.2%, compared to 21.0% in Globeville and 20.5% in Elyria-Swansea.[29] Marijuana use in adults between 2014-2017 in Denver was estimated to be 17.1%, whereas in Globeville it was 18.5% and in Elyria-Swansea it was 13.4%.[29] In all, the picture of substance uses in GES as compared to Denver is mixed, with estimated rates of alcohol consumption and marijuana use showing strong community health habits in the face of structural barriers to well-being.

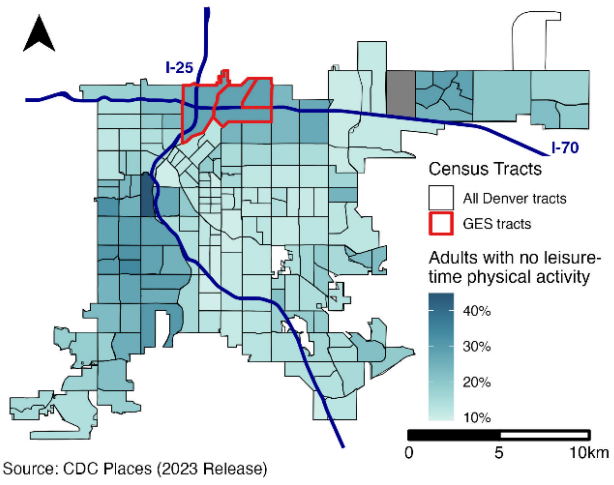

Figure 9. Adults with no leisure time physical activity in Denver, Colorado, 2021 BRFSS.

Self-reported physical activity in adults is an area of opportunity to improve access and resources for healthy behaviors in the GES community as there is evidence to suggest that the number of people who engage in physically active lifestyles is lower than the Denver average. In 2021, 83.6% of Denver adults were estimated to maintain a physically active lifestyle outside of their work setting. In Globeville and Elyria-Swansea the same year, 72.6% and 71.8% of adults, respectively, reported an active lifestyle **(Figure 9)**.[29] In this survey, active lifestyle was defined as participation in physical activity like running, calisthenics, golf, gardening, or walking. It is worth noting that physical activity was only measured outside of an individual's regular job. If physically demanding jobs like house cleaning and construction are factored in, as well as walking commutes to and from work or the bus, we may see different levels of physical activity reported by GES residents.

Vaccine uptake is another important health behavior that demonstrates access to care, health communication (including in the appropriate language), and overall trust in the health system. While there aren't data available for all vaccination rates in GES, pairing influenza vaccination information with local demographics can provide some insight into this health behavior. Between 2014-2017, flu vaccination rates in GES were comparable to Denver. In Globeville, 42.7% of adults received their flu vaccines and in Elyria-Swansea 46.2% of adults were vaccinated against the flu. Denver's overall flu vaccination rate at the time was 44.0%.[29]

While flu vaccine disparities appear not to be a health concern in GES, the flu vaccine rates of 42.7-46.2% rates are still well below the Healthy People 2030 goal of 70%.[12] Additionally, uninsured individuals and persons reporting less than $35,000 annual household income are less likely to be vaccinated for influenza, as are individuals who are physically inactive and who smoke cigarettes.[30] The relationship between other social determinants of health and the uptake of flu vaccinations demonstrates the interconnected relationship between these risk factors, and the need for ongoing health communications efforts to reach the uninsured and those whose first language is not English. Further, because vaccination rates are strongly associated with insurance status, it's possible that flu vaccine status indicates other vaccination uptake rates. In the US, flu, pneumococcal, Tdap, herpes zoster and HPV vaccination is two to five times higher among those with insurance compared to those without.[30]

Vaccination rates (for hepatitis A, hepatitis B, pneumococcal, and Tdap) are notably higher in US born individuals as compared to foreign born residents, with some exceptions. Hispanic foreign-born individuals in the US have the lowest vaccination rates for multiple of these vaccines. This disparity may be especially pertinent to the GES community. This trend is a window into the broader reality that foreign-born adults face barriers to receiving appropriate care, including lack of linguistically and culturally appropriate healthcare messaging/resources, socioeconomic stressors, lack of health insurance, citizenship status, and lack of healthcare education.[31]

2.7. CLINICAL CARE

Access to quality clinical care does not just influence vaccination rates. Access to and utilization of available care is an important social determinant of health that influences all health behaviors, health care utilization, and health outcomes. Further, this care must be considered trustworthy and language-appropriate for the community served in order to effectively meet community health needs.

Availability of care must be also paired with widespread health insurance coverage. In GES, there is consistent evidence that the uninsured population is significantly higher than the uninsured population of Denver. In 2021, it was estimated that 12.4% of Denver adults were uninsured, in Globeville, 28.3% of the population was uninsured, and in Elyria-Swansea, 33.6% of the people were without insurance.[29] GES is also categorized as a Medically Underserved Area (MUA), which is a geographic with a shortage of primary care health services **(Figure 10)**.

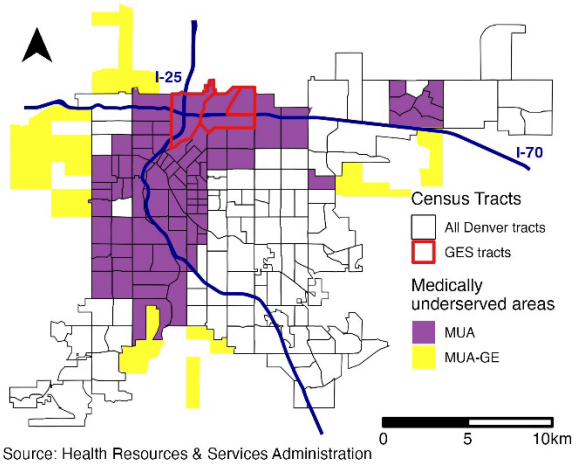

Figure 10. Medically underserved areas in Denver, Colorado 2021.

Despite the challenges of being a medically underserved area with high uninsured rates, GES residents are utilizing many healthcare services with similar frequency as the rest of Denver, although there are some differences for specific preventative services. For example, in 2021, an estimated 61% of Denver residents had an annual health check-up, compared to 57.3% of Globeville and 59.2% of Elyria-Swansea residents.[29] This demonstrates that, despite facing

increased barriers to care, the GES community is prioritizing annual health checkups similarly to the rest of Denver. However, both Denver and GES annual health check-up rates are low, demonstrating room for improvement in the preventative care sector. With higher utilization rates, many negative health outcomes can be detected and delayed or and prevented altogether. Delayed medical care due to cost represents a similar context: 17.5% of residents in Globeville and 18.9% of residents in Elyria-Swansea were estimated to have delayed their medical care due to high costs, compared with 14.7% of Denver residents.[32] Finally, there is consistent evidence that the use of core preventative services among older men and women (ages 65+) in GES is substantially lower than in Denver.[29] In Globeville, it was estimated that only 32.9% of older women and 35.1% of older men were up to date on core preventative services in 2021, and Elyria-Swansea was similar at 33% and 35.6%, respectively. These are substantially lower than the 43.7% of older women and 48.4% of older men who were up to date on core preventative care in Denver as a whole.[29] These data demonstrate a clear need for affordable care across both Denver and GES.

3. INDICATORS OF HEALTH, DISEASE, AND MORTALITY IN GES

Exposures from the physical, social, and built environment can have synergistic impacts on health that span all manner of diseases and outcomes. In our assessment of the current state of health in GES, we considered several health measures such as birth outcomes, death rates, chronic diseases, and more. We compared the rates of these health outcomes in GES to the Denver average. We found that GES has higher rates of some respiratory diseases, obesity, diabetes, disabilities, and notably, a higher rate of overall mortality. Conversely, cardiovascular diseases, mental health, and cancer were similar to the Denver average. However, this method of comparison masks potential differences between GES and the most affluent neighborhoods in Denver, which could highlight more significant differences in health outcomes among various populations in Denver.

On a population scale, the largest impact from environmental exposures on health tends to be on chronic diseases. The pyramid of effects from air pollution illustrates that the more severe outcomes, like death and hospitalization, occur in a relatively small number of people **(Figure 11)**.[33] In contrast, less severe but more widespread impacts, such as worsening chronic diseases or decreasing lung function, affect more people. However, collecting data on these more common outcomes can be challenging. The most comprehensive health data available are through birth and death records, which are collected by the state health department for every birth and death. Hospitals also collect information on who they provide care to, but in Colorado, these data are managed by the Colorado Hospital Association and are expensive to obtain. In Colorado, hospitalization data for a few key diseases are available through the state health department. There are limited sources of data available for health outcomes that do not primarily result in hospitalization or death. The primary resource available for this information is the Behavioral Risk Factor Surveillance System (BRFSS), which uses telephone surveys to estimate the number of people who have different risk factors and health outcomes. However, because GES is a relatively small area, these data can be limited. (A full discussion of data sources and limitations is provided in **Appendix 1**)

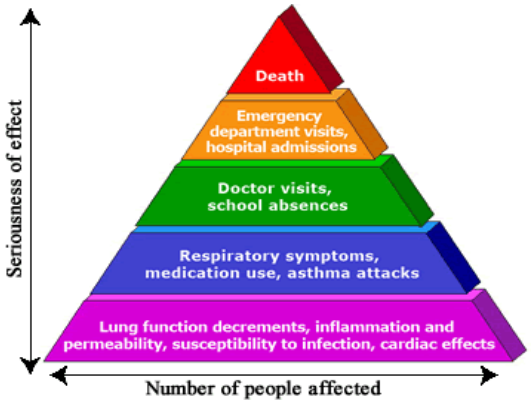

Figure 11. Pyramid of effects from air pollution.

3.1. HEALTH AT BIRTH

Health at birth is an important predictor of childhood success and long-term health.[34,35] Babies born with low birthweight[a] are at a greater risk of premature death within 28 days, stunted growth, and lower IQ. Health risks associated with premature birth (before 37 weeks gestation) or low birthweight can carry into adulthood, resulting in a higher risk of obesity, diabetes, asthma, and cardiovascular disease.[35–37] Mothers who have diabetes or hypertension during pregnancy are at a greater risk of developing complications throughout the pregnancy and experiencing maternal or fetal death. Infants born from mothers with hypertension are more likely to be born with low birthweight, putting them at risk of additional long-term effects.[38,39]

Despite how critical these outcomes are to overall health, health at birth and related pregnancy risk factors were not assessed in the 2014 HIA. We used birth record data from 2017-2021 to assess selected birth outcomes and pregnancy

[a] Low birthweight is defined as <2,500 g or 5.5 lbs.

risk factors in GES compared to Denver **(Appendix 2)**. We found that the total birth rate in GES was slightly higher than the Denver average (13.66 per 1,000 compared to 12.35) and the fertility rate among females ages 15 to 44 was substantially higher (60.00 compared to 49.94 births per 1,000). Additionally, there is evidence that teen fertility rate is substantially higher in GES at 33.96 births per 1,000 females aged 14-17 in Globeville and 23.08 in Elyria-Swansea, compared to only 10.14 in Denver.[40]

The rate of gestational diabetes and hypertension was substantially higher in GES compared to the Denver average. In GES, 139.34 births per 1,000 live births were associated with gestational hypertension, compared to only 116.49 on average in Denver. Similarly, 92.90 of every 1,000 live births involved gestational diabetes, compared to just 58.28 in Denver. Health at birth in GES was similar to the Denver average and there was no evidence of a difference in the rate of low birth weight and preterm births **(Figure 12)**. However, the rate of congenital abnormalities at birth was higher in GES (133.88 per 1000 live births) than the Denver average (119.14 per 1000 live births). There were too few cases of eclampsia, HELLP [a] syndrome (hemolysis, elevated liver enzymes, low platelet count syndrome),[41] and infant mortality to compare GES to Denver.

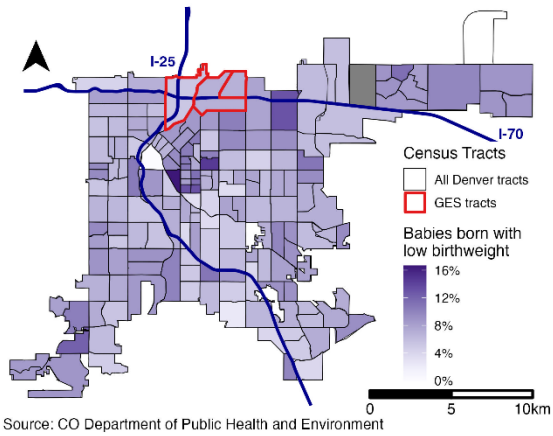

Figure 12. Babies born with low birthweight in Denver, Colorado, 2015-2019.

Health at birth has been associated with environmental and social exposures. For example, exposure to particulate matter and ozone can increase the risk of premature birth and low birthweight, as can extreme heat.[42] A study conducted in Denver in 2019 found that adverse birth outcomes are associated with cumulative exposure to both social and environmental stressors.[43] However, the study concluded that the impact of cumulative social exposures had a greater impact on birth outcomes than environmental exposures. Research into the connection between environmental exposures and congenital abnormalities has been conducted across a wide range of possible exposures. In general, results have been mixed and inconsistent, and vary based on the specific abnormality. A 2016 literature review study found that parental exposure to some chemicals in the workplace has been consistently associated with congenital abnormalities.[44] However, it is impossible to determine what associations would be relevant to GES without knowing which specific congenital abnormalities are elevated.

3.2. MORTALITY

Comparing the rate of death (mortality rate) from different causes is a common way to assess the health of an area, but unfortunately, it is the worst outcome and too late for interventions. To compare mortality rates, we obtained death records from Colorado Department of Public Health and Environment (CDPHE) for specific causes of death from 2017-2021. We used these data to calculate a standardized mortality ratio (SMR), which compares the mortality rate in GES to the mortality rate in Denver **(Table 4)**. Values greater than 1 indicate that there is a higher rate of death in GES than what would be expected if GES looked like Denver as a whole. We found that the overall mortality rate in GES was 24% higher than the Denver average (SMR: 1.24). This indicates that there is a higher rate of death in GES than the Denver average. There is weak evidence that the mortality rate from cardiovascular disease in GES was 21% higher than the

[a] HELLP syndrome usually develops before 37 weeks gestation but can also occur after delivery.

Denver average (SMR: 1.21). However, there is no evidence of an increased mortality rate from cancer or injury in GES compared to Denver. Based on data from CDPHE, there is no evidence that motor vehicle accidents or suicide mortality was greater in GES than the Denver average between 2015-2019.[40]

The Centers for Disease Control and Prevention (CDC) estimated that life expectancy at birth in Globeville and Elyria-Swansea from 2010-2015 was lower than the average for the state of Colorado. The average life expectancy in Colorado was 80.5 years, compared to 72.8 years in Globeville and 76.2 years in Elyria-Swansea. Unfortunately, there were no estimates provided for the City and County of Denver. This means that from 2010-2015, GES residents could expect to live 4-6 years less than the average Colorado resident. More recent data are unavailable, but the higher mortality rate in GES from 2017-2021 aligns with these statistics. Overall, there is evidence that GES residents are more likely to die at a younger age than other residents in Denver and Colorado.

Table 4. Denver-wide mortality rate and standardized mortality ratios for all-cause mortality and specific causes of death for GES and Denver excluding GES, 2017-2021.

CAUSE	DENVER MORTALITY RATE DEATHS PER 100,000	GES STANDARDIZED MORTALITY RATIO (95% CI)	DENVER EXCL. GES STANDARDIZED MORTALITY RATIO (95% CI)
All-cause Mortality	794.51	1.24 (1.10 - 1.37)	1.00 (0.98 - 1.01)
Cardiovascular (CVD) Mortality	197.04	1.21 (0.93 - 1.49)	1.00 (0.97 - 1.02)
Cancer Mortality	142.64	1.02 (0.73 - 1.31)	1.00 (0.97 - 1.03)
Injury Mortality	108.68	1.15 (0.82 - 1.48)	1.00 (0.96 - 1.03)

3.3. CHRONIC DISEASES

RESPIRATORY DISEASES

Throughout the GES Community Health study, community members have raised concerns about respiratory health, particularly asthma. The 2014 HIA reported adolescent asthma-related emergency department visits in Globeville and Elyria-Swansea were greater than in Denver. Presently, there is limited evidence to suggest that the prevalence of adult asthma is greater in GES than the Denver average. The CDC estimated adult asthma prevalence in 2021 to be 10.9% in Globeville and 10.3% in Elyria-Swansea, which is only slightly higher than the Denver average of 9.7%. However, there is evidence that asthma hospitalizations are significantly greater in GES than Denver. From 2015-2019, the asthma hospitalization rate was 1,008 per 100,000 people in Globeville and 1,141 per 100,000 people in Elyria-Swansea, compared to 725 per 100,000 people in Denver **(Figure 13)**.[40] There are limited data on adolescent asthma, which suggests that there may be a slightly higher prevalence in Globeville (14.2%) and Elyria-Swansea (14.4%) than in Denver (12.6%). However, these data, obtained from CHORDS in 2019-2020, has multiple limitations that increase our uncertainty in these estimates **(Appendix 1)**.[45] Additionally, there is evidence that the rate of adult chronic obstructive pulmonary disease (COPD) is slightly higher than the Denver average. The CDC estimated that in 2021 the prevalence of COPD was 5.7% in Globeville and 5% in Elyria-Swansea, while the Denver average was 4.4%.[29]

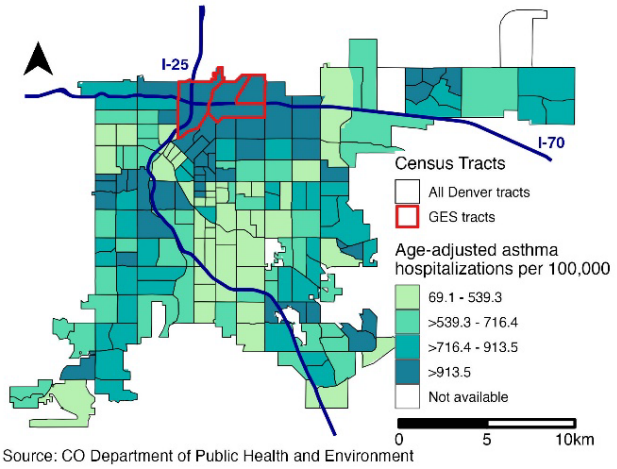

Figure 13. Age-adjusted asthma hospitalizations in Denver, Colorado, 2015-2019.

The association between air pollution and the development and exacerbation of asthma, particularly in adolescents, has been extensively studied.[46] There is strong evidence that early childhood exposure to air pollution, as well as maternal exposure during pregnancy to air pollution, are risk factors for adolescent asthma. However, evidence connecting air pollution to adult asthma is weaker. Air pollution can also exacerbate asthma, resulting in increased emergency department visits and hospitalizations. The effect of air pollution on asthma may be worse in individuals who are overweight or obese. Exposure to high ozone concentrations has also been associated with the progression of asthma to COPD. Individual behaviors, such as smoking, can also increase the risk of adolescent asthma. Prenatal maternal smoking and exposure to secondhand smoke during infancy can increase the risk of developing asthma. Smoking effects can be intergenerational, and some evidence suggests that grandmothers smoking while pregnant is linked to asthma development in the grandchild, even if the mother does not smoke.[46] There is also evidence to suggest that outdoor air pollution is related to the development of COPD, but more definitive evidence indicates that air pollution is associated with the exacerbation of COPD. Extreme heat has also been associated with increased mortality from COPD, which is a prominent concern for urban heat islands and climate change. Similar to asthma, smoking is a major risk factor for development of COPD.[47] In sum, residents of GES experience multiple risk factors that may contribute to the elevated rate of asthma exacerbations, including hotter streets **(see Urban Heat Islands/Hot Streets)**, higher rates of obesity, and potentially slightly higher use of tobacco products.

CARDIOVASCULAR DISEASES

Heart disease is the leading cause of death in the United States, and major risk factors include high blood pressure (hypertension), high cholesterol, diabetes, and obesity or overweight.[48] At the time of the 2014 HIA, Denver City Council District 9, which includes GES, ranked fourth highest in the number of cardiovascular deaths per 100,000 residents compared to other Denver City Council Districts. Evidence suggests that there may be higher mortality from cardiovascular disease (CVD) in GES compared to the Denver average. However, additional research would be required to confirm this. There is no evidence that strokes, which are a specific type of cardiovascular disease, are more prevalent in GES than in Denver as a whole[a].[29] The evidence indicates that GES has a similar prevalence of hypertension and high cholesterol than the Denver average. According to the CDC, across Denver and in GES, roughly 23% of people have hypertension, and 30% have high cholesterol.[29] While positive that GES does not have a higher prevalence than Denver, these statistics show an alarming prevalence of cardiovascular disease risk factors in GES.

[a] Stroke prevalence (%) from PLACES (2023 release) in Denver: 2.2 (95% CI 1.9, 2.5); Globeville: 2.6 (95% CI 2.3, 2.9); Elyria-Swansea: 2.7 (95% CI 2.4, 3.0).

Exposure to environmental factors such as air pollution, noise, high temperature, light pollution, and the built environment can increase the risk of developing cardiovascular diseases. Long-term exposure to particulate matter ($PM_{2.5}$) is associated with an increased risk of developing many cardiovascular diseases. Short-term exposure to high concentrations of particulate matter and ozone is associated with an increased risk of death from cardiovascular diseases. Exposure to loud ambient noise levels can also increase the risk of cardiovascular disease by disturbing sleep and increasing stress. Similarly, there is emerging evidence that light pollution can increase the risk of chronic diseases, including cardiovascular diseases, by disturbing circadian rhythms.[49] Access to greenspace, healthy sources of food, and living in a walkable environment can be protective against hypertension, obesity, and cardiovascular disease.[50] In GES, limited access to healthy food, perception of danger at parks, lack of a walkable environment, noise, and hotter streets are risk factors that GES residents experience **(see Built Environment)**.

OBESITY AND DIABETES

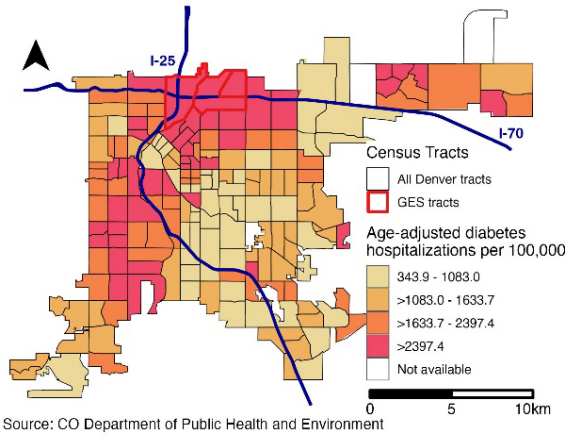

Figure 14. Age-adjusted diabetes hospitalizations in Denver, Colorado, 2015-2019.

Obesity and overweight[a], as measured by body mass index (BMI),[51] are critical risk factors for cardiovascular diseases, diabetes, musculoskeletal disorders, and some cancers.[52] There is consistent evidence that the prevalence of overweight and obesity in adults and adolescents is higher in GES than the Denver average. The CDC estimates that in 2021, 22% of adults in Denver were obese, compared to 26.9% in Globeville and 26.7% in Elyria-Swansea.[29] These estimates are lower than data based on health records, which show that 32.6% of Denver adults were obese in 2019-2020, compared to 39.6% in Globeville and 44.5% in Elyria-Swansea. Similarly, 64.9% of adults in Denver were overweight or obese, while 71% and 77% were in Globeville and Elyria-Swansea, respectively.[45] Older health record data from 2014-2016 have similar but slightly lower percentages of adults with obesity and overweight. While limited, health record data indicate that there is a greater prevalence of adolescent obesity and overweight in GES than the Denver average. From 2019-2020, 22.3% of children in Globeville and 28.3% in Elyria-Swansea were obese, and 37.6% in Globeville and 45% in Elyria-Swansea were overweight or obese, while the prevalence in Denver was 19.7% and 35.2%, respectively.[45]

Obesity and overweight increase the risk of type-II diabetes. There is consistent evidence that diabetes prevalence and hospitalizations from diabetes are higher in GES than the Denver average. The most recent data estimate that 9.9% of adults in Globeville and 9.8% in Elyria-Swansea have diabetes compared to only 6.8% in Denver overall. These estimates are lower than health records data, which indicate that 13% of adults in Globeville and 14.2% in Elyria-Swansea have diabetes, compared to 9.8% in Denver.[45] The diabetes hospitalizations rates in GES provide a starker contrast to Denver: the rates in Globeville and Elyria-Swansea are 2,435 and 3,211 hospitalizations per 100,000, respectively, compared to 1,626 hospitalizations per 100,000 in Denver **(Figure 14)**.[40] Across obesity, overweight, and

[a] According to the World Health Organization obesity in adults is defined as a BMI greater than 30 and overweight in adults is defined as a BMI greater than 25.

diabetes, Globeville and Elyria-Swansea are consistently higher than the Denver average, and Elyria-Swansea is higher than Globeville. There is an urgent need in GES, and in Denver generally, to address the obesity epidemic.

The development of obesity, and consequently diabetes, is influenced by many factors, including diet, exercise, genetics, environmental exposures, and the built environment.[52] Highlighting the connection to the built environment, there is robust evidence that neighborhoods that are highly walkable and have more greenspaces encourage physical activity and are associated with lower levels of obesity and diabetes. Further, neighborhoods with a low density of fast-food restaurants have lower rates of obesity and diabetes.[53] Air pollutants have also been associated with adolescent and adult obesity and overweight, specifically particulate matter, nitrogen dioxide, sulfur dioxide, and ozone.[54,55]

3.4. CANCER

The 2014 HIA outlines the results of early 2000's cancer cluster studies in North Denver. These cluster studies assessed cancer rates around the Vasquez Boulevard and Interstate 70 Superfund Site (VB/I-70). Importantly, cluster studies are often more difficult to conduct than other study types due to the relatively small number of cases and many potential causes of cancer, which limits the confidence of findings. A 2003 study, which examined cancer rates between 1982 and 1998, found that the VB/I-70 area had a higher-than-expected cancer rate compared to the rest of the Denver metropolitan area.[56] However, study results also indicate that there was no relationship between arsenic exposure and these cancers, citing that other socioeconomic and environmental factors like air quality or work environment are more likely drivers. Additionally, a technical report published in 2002 established that cancer risk related behaviors like not wearing sunscreen and smoking were higher in North Denver.[57] Both the 2003 cluster study and the 2002 technical report draw on data over 20 years old, ranging from 1982-1998 in the cluster studies and 1998-2000 in the 2002 report. As a result, these studies provide important historical context for cancer rates and cancer studies in North Denver, but they are not strong indicators of the state of cancer in GES today. As described in earlier sections, both environmental risks and health behaviors like tobacco use have evolved over time, as have their corresponding cancer risks.

Today, there are updated data on crude cancer mortality and crude cancer prevalence compared to the 2014 HIA (see **Box 1** for definitions of the cancer measures). From 2017-2021, cancer mortality (deaths) from all cancers in GES was neither substantially nor significantly higher than in Denver **(see Mortality)**. Despite availability of new data from GES, the data are limited due to the low number of cases of death from cancer in the neighborhood, meaning that there are not enough cases to delve into specific cancer types. In short, there are simply not enough cases of death from cancer to draw conclusions. It is also difficult to make conclusions about the cause of cancer due to the complex, multifactorial pathways between exposure and disease. With these complex cancer pathways and limited current data, it is not possible to determine any causal relationships between environmental exposures, behaviors and genetics to cancer rates or cancer mortality.

Box 1. Cancer prevalence, incidence, and mortality defined.

Cancer prevalence, cancer incidence, and cancer mortality are all different things, each with a distinct causal pathway.

Cancer mortality refers to the overall number of deaths due to cancer in a specific time frame, often described as a rate.

Cancer incidence refers to the percentage of the population who are newly diagnosed with cancer within a specific time period. Cancer prevalence refers to the percentage of the population who have ever been diagnosed with cancer, new and preexisting cases.

There is evidence that the percentage of people who have ever been diagnosed with cancer (excluding skin cancer) is lower in GES compared to Denver. However, we need to consider the age of the population before making conclusions. GES has a younger population than Denver, and cancer is more common in older populations **(see Demographics)**. If cancer prevalence estimates were adjusted for age, we may find that the data reveal a different story about the differences between cancer in GES and Denver. Unadjusted for age, the estimated cancer prevalence in Denver was 5.3% compared to 3.6% in Globeville and 3.9% in Elyria-Swansea.[29]

GES community members continue to voice concerns about the possibility for neighborhood environmental pollutants to cause cancer in their community. As aforementioned and evident in Deliverable 2.1, limited data present challenges to understanding the full scope of cancer in the GES neighborhood, as does the complexity in determining causality in all cancers. While there are no data to confirm GES residents are at higher risk for cancer or death by cancer, many of the present environmental and socioeconomic factors have been associated with cancer in other communities. Further studies would be required to understand the full picture in GES.

3.5. MENTAL HEALTH

Throughout the GES Community Health Study, we have heard community concerns about mental health and well-being. Similar to what was presented in the 2014 HIA, residents report decreased mental well-being due to strong odors from industrial operations, perceptions about crime and resident safety, and perceptions of lingering pollution despite past environmental cleanup. People exposed to adverse conditions like poverty, disability, and inequality are at higher risk of poor mental health and well-being.[58] Despite this, there is no evidence that depression, anxiety, or suicide, are more common in GES than the Denver average. However, there is evidence that experiencing frequent mental distress[a] is more common in GES than the Denver average. In 2021, the estimated prevalence of frequent mental distress among adults in Denver was roughly 15.2% compared to Globeville at 20.8% and Elyria-Swansea at 18.1% **(Figure 15)**.[29] Even though the rate of poor mental health in GES is not worse than the Denver average, there is still reason to be concerned. The CDC estimates that over 20% of adults in GES and Denver experience depression.[29] Additionally, it may be more difficult for GES residents to access mental health services due to overlapping barriers relating to transportation, insurance, availability of mental health providers nearby, childcare, cost, and time.

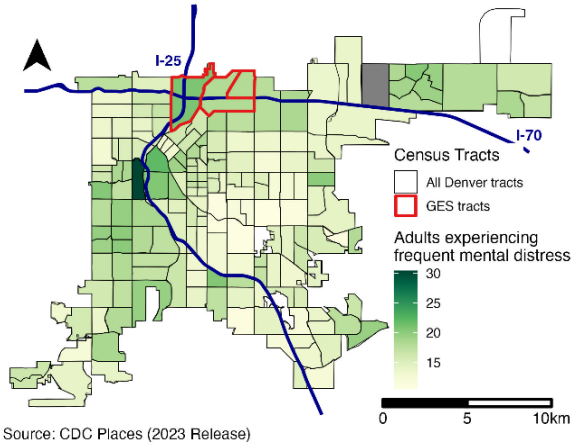

Figure 15. Adults experiencing frequent mental distress in Denver, Colorado, 2021 BRFSS.

[a]Frequent Mental Distress is defined as experiencing more than 14 mentally unhealthy days within the past 30 days in which mental health was "not good." Health conditions for measuring mental health include stress, depression, and problems with emotions.

3.6. ADDITIONAL HEALTH OUTCOMES

ELEVATED BLOOD LEAD LEVELS

Exposure to environmental sources of lead can result in elevated blood lead levels. This is primarily a concern in children, who are the most susceptible to the effect of lead and more likely to be exposed to lead through hand to mouth behaviors. In children, lead can cause developmental and growth delays, hearing and speech problems, difficulty learning, and other serious health effects including death. There is no safe level of lead.[59,60] In Colorado, only children who are at high risk of lead exposure or are enrolled in Medicaid are recommended to be tested for blood lead levels, which limits the availability of data, making it difficult to compare testing rates between areas. However, we can compare the percentage of children who are tested who have elevated blood lead levels[a].[61] From 2017 to 2021, Globeville and the west side of Elyria-Swansea[b] had similar rates to Denver of elevated blood lead levels among children who are tested at about 3%. However, close to 8% of children on the east side of Elyria-Swansea[c] who are tested have elevated blood lead levels.[59]

Two previous studies have assessed the risk factors contributing to elevated blood lead levels in Denver. In 2005, researchers collected blood samples from roughly 1,000 children living within the Vasquez Blvd. and I-70 (VB/I-70) site boundary. Sample results found that the blood lead concentrations were higher than the national average. However, comparing the elevated levels to soil lead concentrations and housing characteristics showed that blood lead levels were associated with lead-based paint and not soil lead exposure.[62] Similarly, a 2017 study used 2010-2014 blood lead level testing data to evaluate risk factors associated with elevated blood lead levels.[23] Results from this study indicated that lead exposure risk was associated with socioeconomic status, demographics, and housing characteristics, but not proximity to lead-related Superfund sites, Toxic Release Inventory facilities, or major roads.[23] As discussed in the housing section, older homes are more likely to have lead-based paint and lead plumbing, and houses in GES tend to be significantly older than houses in the rest of Denver. Families living in older homes should ensure their children are tested for lead and have their homes evaluated for sources of lead.

INFLUENZA HOSPITALIZATION RATE

There is evidence that the rate of hospitalization for influenza in GES may be higher than the Denver average, however, there is substantial uncertainty in these data[d]. In Denver, approximately 68 per 100,000 people were hospitalized for influenza from 2015-2019. However, that rate was 97 in Globeville and 117 in Elyria-Swansea.[40] Risk factors for influenza hospitalization include existing respiratory diseases such as asthma, cardiovascular diseases, obesity, premature birth, smoking, and lower education status. In addition, children under 5 and adults over 65 are more likely to be hospitalized.[30,63,64] Many of these risk factors are more common in GES, so a higher rate of influenza hospitalizations is not unexpected.

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[a] The CDC blood lead reference value is 3.5 ug/dL.

[b] Census tract FIPS: 08031003501

[c] Census tract FIPS: 08031003502

[d] Data for GES have large confidence intervals. Rates are as follows (95% CI): Globeville, 97.22 (44, 150.43); Elyria-Swansea, 116.5 (62.96, 170.02); and Denver, 67.86 (64.97, 70.74).

DISABILITIES

The American Community Survey (ACS) and the Behavioral Risk Factor Surveillance System (BRFSS) both collect data on the percentage of the population that has different types of disabilities. These sources use the same questions; however, the results are different nationally and in GES. We believe that the BRFSS data are more likely to represent the actual percentage of adults with disabilities as this questionnaire is specifically tailored for health research and the ACS is not. Using CDC BRFSS data, there is consistent evidence that a greater percentage of adults in GES (34% of adults in Globeville and 32% in Elyria-Swansea) have a disability compared to the Denver average (22%), and national average (27%).[29] This trend is consistent for disabilities related to vision, mobility, independent living, cognitive disability, and to a lesser extent, hearing. Of the individual disability types, cognitive disability is the most common at 19.7% in Globeville and 17.5% in Elyria-Swansea compared to only 11% in Denver.[29] Further, the CDC estimates that 13.6% of adults in Globeville and 13.2% in Elyria-Swansea suffer from frequent physical distress, compared to only 9.2% in Denver.[29]

Nationally, individuals with a disability are more likely to be unemployed, have a lower individual and household income, live in poverty, and have less education.[65] These factors may be both a cause and result of disability. For example, individuals who have less education are more likely to work in labor and construction, which may put them at an increased risk of a workplace injury that leads to disability. However, having a disability may also limit the ability of individuals to pursue education and obtain higher paying jobs. In GES, individuals with disabilities may face additional difficulties in everyday life including poor connectivity and sidewalk infrastructure and limited access to goods and services nearby.

COVID-19

COVID-19 continues to have a substantial impact on the population of Denver and on residents in GES more specifically. The first case confirmed of COVID-19 in the state of Colorado was identified on March 5, 2020,[66] but evidence compiled later that year suggested the virus was spreading throughout the Front Range earlier than originally thought.[67] Since the start of the pandemic in 2020, there have been more than 1.8 million reported cases of COVID-19 in Colorado (2020 population: 5.77 million), a number that likely underestimates the true number of cases as at-home testing has become more widely available in recent years.[68] More than 14,000 people died due to the disease across the state.[68]

Notably, the burden of COVID-19 has not been equally distributed among different populations within Denver, particularly during the earliest months of the pandemic when vaccines and many treatment options were not available. A report from the first 7 months of the pandemic (March-October, 2020) found that the majority of adults COVID-19 cases (55%), hospitalizations (62%) and deaths (51%) were among Denver residents who identify as Hispanic or Latino, despite this group making up only 25% of the Denver population.[69] Hispanic residents in Denver were more likely than non-Hispanic residents to report factors that contributed to the spread of the disease, including larger household sizes with more contact with people infected with COVID-19, working in essential industries, working while ill, and delaying testing after the onset of symptoms.[69]

We compared COVID-19 mortality, which represents the most severe outcome associated with the disease, for GES neighborhoods against COVID-19 mortality for Denver as a whole. As with the other mortality outcomes, we used the standardized mortality ratio (SMR) to compare the age-adjusted mortality rate of GES to Denver for adults ages 18 and older. We relied on mortality data from 2020 and 2021 provided by CDPHE as these data were the most recent finalized

data available. Due to small sample sizes, the confidence intervals around the SMRs are wide and should be interpreted with appropriate caution.

Based on our estimated SMRs, COVID-19 mortality was higher than expected in GES when compared to Denver as a whole **(Table 5)**. When considering the full period for which we had mortality data (2020-2021), the COVID-19 mortality rate for adults in GES was twice that of adults in Denver as a whole. When examining the data by year, this increase in mortality is primarily due to deaths that occurred in 2020; the SMR for GES relative to Denver in 2020 is 2.20 (95% CI: 1.05 – 3.35). In 2021, when vaccines became more widely available and other treatment options became available, the SMR for GES remained high (1.84), but due to the lower number of deaths that occurred in Denver County in 2021, this estimate is more uncertain.

Table 5. Denver-wide mortality rate and standardized mortality ratios for COVID-19 mortality for GES and Denver excluding GES, 2020-2021.

YEAR	DENVER MORTALITY RATE DEATHS PER 100,000	GES STANDARDIZED MORTALITY RATIO (95% CI)	DENVER EXCL. GES STANDARDIZED MORTALITY RATIO (95% CI)
2020-2021	84.20	2.05 (1.20 - 2.91)	0.99 (0.93 - 1.05)
2020	103.69	2.20 (1.05 - 3.35)	0.99 (0.91 - 1.07)
2021	64.74	1.84 (0.57 - 3.12)	0.99 (0.89 - 1.09)

4. ENVIRONMENT

4.1. AIR

Air quality is one of the primary, if not the foremost, concern GES residents have shared regarding the environment. Residents fear that degradation of air quality from nearby sources such as the Suncor petroleum refinery, Cherokee Generating Station, Interstates 25, 70, and 270, freight rail, truck routes, and industrial facilities, are leading to high rates of illnesses in the community. The 2014 HIA reported that, in general, air quality in GES is similar to other parts of Denver except for occasional "upset events." Our findings, discussed in this section, support this conclusion, but we acknowledge that there are major limitations in the available data that prevent accurate estimates of personal exposures.

Air pollution is a complex mixture of compounds, and assessing overall air quality typically involves separating mixtures into parts, then examining individual compounds to determine if they are above or below regulatory standards. In this report, we follow this approach as there are no well-defined methods for assessing the impact of the entire mixture. We have divided air pollutants into two primary categories: criteria pollutants – those pollutants that are regulated nationally by the National Ambient Air Quality Standards (NAAQS)[70] – and air toxics. Our approach to both criteria pollutants and air toxics focuses on monitoring data, which provide pollutant concentrations at a specific time and location but are limited to locations where monitors are installed. Another approach to assessing air quality is through modeling, which estimates pollution levels across an area based on known sources of pollution and how pollution spreads. While modeling can provide estimates of air pollution across a larger area, it may not accurately reflect the true concentration of a pollutant due to assumptions made during the process. We used models to complement measurement data, but we have relied on measurement data to draw most conclusions. Air quality is often assessed at the regional level (e.g., Colorado's Front Range) however, air quality can be worse in close proximity to a source of pollution. In this study, we did not attempt to determine the impact of individual sources on overall air quality or health outcomes.

General Weather Patterns

Weather, or meteorology, is important in understanding air quality. Weather patterns help determine how pollution spreads, who it impacts, and how it interacts with other pollutants. In Globeville, wind is typically mild and blows from the southwest following the South Platte River more often than from other directions (about 20% of the time).[71,72] This means that GES is often downwind of downtown Denver, Interstate 70 (I-70), Interstate 25 (I-25), and the Purina pet food factory, but upwind of Suncor, Cherokee Generating Station, and other industrial facilities to the north in Commerce City. However, sometimes the wind does blow in reverse (about 10% of the time) or in other directions, bringing emissions from those facilities into GES. Air quality varies seasonally in the region due to changes in chemical reactions and sources of pollutants. Carbon monoxide, nitrogen dioxide, and sulfur dioxide are worst in the winter, while ozone is worst in the summer. Particulate matter remains relatively constant across seasons except for exceptional events like wildfires in the summer.[72] Temperature inversions are another event that impact regional air quality. These events frequently occur along the Front Range in the winter and trap pollutants near the surface, resulting in poor air quality and visible haze.

Mobile Sources of Pollution

Sources of pollution are divided into two categories, mobile and stationary. By definition, mobile sources move and include cars, trucks, and trains. In GES, mobile sources of concern include Interstates 70, 25, and 270; heavy truck traffic; and heavy freight trains. Vehicles emissions contain multiple pollutants such as nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter (PM), and volatile organic compounds (VOCs) such as benzene.[73,74]

Pollution from interstates can be elevated near the road but generally dissipates and reaches background levels within a few hundred meters of the roadway.[73] Prior to the Central 70 project, a study conducted by the Denver Department of Public Health and Environmental (DDPHE) found that in GES, there was 30-80% more black carbon downwind of the interstate. However, when averaged for the whole day, including when the wind changed directions, being close to the interstate was associated with about 15% more black carbon, a component of diesel exhaust. The study was unable to make conclusions about VOC concentrations near the interstate. Overall, this study shows that some pollutants are more concentrated close to the interstate, but this may have changed with the Central 70 project.[75] Mobile sources are also considered in the national Air Toxics Screening Assessment (AirToxScreen) conducted by the EPA and discussed later in this section.[76]

Box 2. Criteria pollutants, primary sources, and associated health effects.

Criteria pollutants are a set of six pollutants that fall under the National Ambient Air Quality Standards.

Carbon Monoxide (CO): Carbon monoxide is a gas released by something burning. Fossil fuels (like gasoline) used in vehicles are the biggest source of carbon monoxide in the environment. At high levels usually observed outdoors, carbon monoxide exposure can cause fatigue and chest pain in people with heart disease. At extreme levels, usually only observed indoors, exposure can cause dizziness, confusion, and death.[77]

Lead (Pb): Historically, the primary source of lead in the air was the use of leaded automobile gasoline. However, leaded gasoline is no longer used in the US and the level of lead in the air nationwide has decreased by 98% between 1980 and 2014. Lead as an air pollutant is no longer a major concern, though other sources of exposure, such as lead paint, still exist. Lead can impact many organ systems, and critically, can damage the brains of children leading to reduced intelligence quotient (IQ).[78]

Nitrogen Dioxide (NO_2): Nitrogen dioxide gas is released through the burning of fossil fuels in cars, trucks, and at power plants. NO_2 exposure can cause lung irritation and aggravate respiratory diseases like asthma and COPD. Long term exposure can contribute to the development of asthma.[79]

Ozone (O_3): Ground level ozone is a harmful gas formed by a chemical reaction between nitrogen oxides (NO_x) and other volatile organic compounds (VOC) in the air. In the upper atmosphere, ozone protects against harmful ultraviolet radiation, but at ground level breathing ozone is associated with negative health effects. Ground level ozone is related to the burning of fossil fuels, which releases the chemicals that react to form ozone. Increased ozone exposure can irritate the lungs, causing coughing, difficulty breathing, worsen lung diseases like asthma, and cause premature death.[33,80] The Colorado Front Range is a severe nonattainment area for ozone.[81]

Particulate Matter less than 10 µm (PM_{10}) and Particulate Matter less than 2.5 µm ($PM_{2.5}$): Particulate matter is a mixture of fine solid particles or liquid droplets suspended in the air that can be made up of a wide range of chemicals and materials. Particulate matter can be released directly from burning, grinding activities (construction or roadway dust), or formed in the air from reactions between many different chemicals. Particulate matter is categorized by size as less than 10 µm in diameter and less than 2.5 µm in diameter. Both are small enough to be inhaled and are many times smaller than a grain of sand. Increased particulate matter exposure can cause coughing, aggravated asthma, decreased lung function, heart attacks, and in extreme cases, premature death.[82]

Sulfur Dioxide (SO_2): Sulfur dioxide is a gas released into the air from the burning of fossil fuels, particularly at coal-fired power plants. Sulfur dioxide exposure can cause difficulty breathing, aggravate asthma, and contribute to the formation of particulate matter pollution.[83]

We recognize that there are many questions regarding the impact of the Central 70 project on air quality. Unfortunately, we are unable to address the impact of the project in this study because the Central 70 settlement agreement prohibits separately analyzing the impact of the project. We direct readers to the Social Justice and Environmental Quality – Denver research group from the University of Colorado, Boulder, which used personal monitors to assess the impact of construction on air quality and disruptions to life. Additionally, Denver Department of Public Health and Environment Division of Environmental Quality is a valuable resource.

Stationary Sources

Stationary sources of air pollution are facilities that release pollutants, such as power plants and factories. Stationary sources near GES include the Suncor petroleum refinery, Philips 66 terminal, Cherokee generating station, Nestle Purina PetCare factory, and many other industrial facilities. Stationary sources are included in the AirToxScreen and Risk-Screening Environmental Indicators (RSEI), which are discussed later in this section.

CRITERIA POLLUTANTS

National Ambient Air Quality Standards

There are six "criteria pollutants" that fall under the National Ambient Air Quality Standards (NAAQS). Each criteria pollutant has a concentration level, called a standard, that must be met for a region to be within regulation. If a region does not meet the standards, it is designated as "nonattainment" by the EPA, the state must create a plan and take action to improve air quality. Attainment and nonattainment designations are provided individually for each criteria pollutant. **Box 2** presents a summary of the criteria pollutants, their primary sources, and associated health effects.

CDPHE monitors the criteria pollutants at air monitoring stations all over Colorado, many of which are located along the Front Range, however, not all locations monitor all seven criteria pollutants **(Appendix 3, Figure 39)**. There is one monitoring station in Globeville just north of the I-25 and I-70 intersection, which only monitors NO_2 and $PM_{2.5}$. Other monitoring stations that record all the criteria pollutants (besides lead, which is no longer measured in Colorado) are the La Casa station located just west of Globeville in Sunnyside, and CAMP station located in central downtown Denver. In Commerce City, the Welby station monitors all but $PM_{2.5}$ and the Birch Street station monitors only $PM_{2.5/10}$.[72] Recently, CDPHE collected air quality data from January 2023 through May 2023 at Lorraine Granado Park. In addition to CDPHE's monitoring efforts, DDPHE operates an air monitoring station at Swansea Elementary that includes $PM_{2.5/10}$, NO_2, and CO. For $PM_{2.5/10}$, NO_2, and CO, which have monitoring data from within GES, we have compared these data to other monitors in the Denver metro area. Criteria air pollutants tend to follow regional trends, so when data are not available from within GES, we have used the data from nearby monitors as the best available data representative of GES. Detailed data summaries are available in **Appendix 3**. Based on our analysis, we conclude:

- There is no evidence that criteria pollutants exceed NAAQS more often in GES than other parts of the Denver metropolitan area.
- The monitoring at Swansea Elementary (SAMS) and Lorraine Granado Park reported median concentrations of NO_2 that were less than half of the median concentrations at monitoring sites elsewhere in Denver, including the I-25 Globeville monitor. The I-25 Globeville monitor consistently records higher NO_2 concentrations than other

monitors elsewhere in the Denver metro[a]. However, these values are still below the NAAQS and other short- and long-term health-based thresholds[b]. This suggests that residents in GES who live near the I-25 Globeville monitor may be exposed to higher concentrations of NO_2 than residents in other parts of Denver, but residents who live more centrally in GES may be exposed to lower concentrations. In all cases, NAAQS and other health-based thresholds were not exceeded.

- SO_2 is higher at the Welby monitor in Commerce City than other monitors in the Denver metropolitan area. While generally well below short- and long-term health-based thresholds[c], the 3-year average maximum value is above the ATSDR acute MRL **(see Box 3)**. This suggests that the Welby location experiences periodic episodes of high SO_2. If the wind blows from the northeast to the southwest, as it does occasionally, this could bring higher concentrations of SO_2 into GES.
- Median $PM_{2.5}$ concentrations measured at Swansea Elementary, Lorraine Granado Park, and I-25 Globeville were the same as other monitors in the region and are below NAAQS. The maximum concentration and upper range of concentrations at Swansea Elementary and Lorraine Grando Park are higher than what is reported through the EPA Air Quality System; however, this is likely due to inclusion of exceptional events like wildfires that are removed from the EPA-sourced data.
- Median PM_{10} concentrations at Swansea Elementary and Lorraine Granado Park were about half of the concentration at other monitoring sites in the Denver metro area. However, the highest PM_{10} concentrations at these sites are higher than other monitoring sites in Denver, which may also be the result of nearby construction

Box 3. Health Based Reference Concentrations

Agency for Toxic Substances and Disease Registry (ATSDR) Maximum Risk Levels (MRL): An MRL is an estimate of the amount of a chemical a person can eat, drink, or breathe each day without a detectable risk to health. MRLs are developed for health effects other than cancer. Concentrations exceeding MRLs do not mean health problems will definitely occur, but that there is increased risk and further investigation is needed. MRLs are developed for three different time periods based on the length of time people are exposed to the chemical: acute (about 1 to 14 days), intermediate (from 15-364 days), and chronic (exposure for more than 364 days).

EPA Acute Exposure Guideline Levels (AEGL): AEGLs represent concentrations of airborne chemicals at which health problems may occur for the most susceptible populations (elderly and children). There are three different levels for each chemical based on the severity of effects: one (least severe, discomfort and irritation), two (irreversible or long-lasting effects), and three (life-threatening or death). We used level one (AEGL-1) values as they are the most protective of health. AEGLs are also assigned for different lengths of exposure to the chemical, ranging from 10 minutes to 8 hours. We used 1-hour values as these correspond to the measurement periods used across our data.

EPA Integrated Risk Information System (IRIS) Reference Concentration (RfC): The concentration at which there is not expected to be adverse health effects over a lifetime of exposure.

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[a] Comments from reviewers suggest that this may be because of a higher density of heavy-duty vehicles on I-25 north of I-70 and because the monitor is placed at the end of an on-ramp, which requires vehicles to accelerate, producing more emissions.

[b] EPA AEGL-1 (60 min) for NO_2 is 0.5 ppm

[c] ATSDR Acute MRL for SO_2 is 10 ppb, and the EPA AEGL-1 (60 min) is 200 ppb

resulting in isolated instances of extremely high PM_{10} values. The median PM_{10} concentrations are far below the NAAQS.

- CO concentrations at monitors near GES follow regional trends and are below the NAAQS.
- O_3 concentration at monitors near GES follow regional trends, which includes multiple NAAQS exceedances each year.
- Our analysis is limited because the criteria pollutant monitoring network is not designed to identify variations in pollutants at a small geographic scale. Consequently, determining if GES experiences air pollution at different rates compared to other areas in the region is difficult with these data. Further, regional monitors may not be representative of what people breathe (personal exposures).

AIR TOXICS

Air toxics are a broad class of chemicals that can cause negative health impacts. In Colorado, the largest source of air toxics is wildfires, followed by other natural sources. Human activities contribute about 20% of the overall air toxics statewide.[83,84] Within the human activity category, the largest contributors are industrial activities (39%) and mobile emissions (34%). Air toxics are of concern in GES because of the presence of heavy industrial activity (e.g. Suncor, Cherokee Generating Station, others), interstates, and heavy rail. We assessed air toxics through a combination of modeling and measured data, as previously described.

Table 6. Summary of 2019 AirToxScreen results for Globeville and Elyria-Swansea.

RISK	GLOBEVILLE	ELYRIA-SWANSEA
Total Cancer Risk (per million)	36.93	39.2
Non-cancer effects		
Total Respiratory HI	0.61	0.61
Total Neurological HI	0.04	0.04
Total Liver HI	0.01	0.01
Total Developmental HI	0.15	0.13
Total Reproductive HI	0.17	0.16
Total Kidney HI	0.01	0.01
Total Ocular HI	0	0
Total Endocrine HI	0	0
Total Hematological HI	0	0
Total Immunological HI	0.05	0.05
Total Skeletal HI	0	0
Total Spleen HI	0	0
Total Thyroid HI	0.01	0.01
Total Whole-body HI	0	0

*HI = hazard index, a hazard index of 1 or lower means air toxics are unlikely to cause adverse noncancer health effects over a lifetime of exposure

Air Toxics Models

There are two primary models that assess air toxics, the Air Toxics Screening Assessment (AirToxScreen) and the Risk-Screening Environmental Indicators (RSEI) Model, both of which are conducted by the EPA for the entire country. AirToxScreen is a tool that uses data obtained from natural and human-related sources of emissions in an attempt to capture all sources of air toxics. It models how the emissions mix, react, and spread to predict the concentration of air toxics at the census tract level. Using these concentrations, the screening tool calculates cancer and non-cancer risks assuming long-term exposure. However, it should be noted that AirToxScreen is a tool intended to help public health agencies identify chemicals of concern so that appropriate follow-up testing can be conducted. Results from AirToxScreen alone cannot be used to determine if there is a true health hazard.[76,84] **Tables 6, 7,** and **Figure 16** show the 2019 AirToxScreen results for GES. Hazard index (HI) values **(Table 6)** below 1 indicate that health thresholds are not exceeded, and adverse non-cancer effects are not expected. All individual chemicals were

predicted to have concentrations substantially below the threshold for non-cancer health effects. Likewise, combined hazard indexes for individual body systems were below 1, indicating that there is likely no risk of adverse health effects.

Of system-specific hazards, the respiratory hazard was the closest to exceeding 1, though it was still substantially below that threshold. Within the respiratory hazard, the largest contributor was diesel particulate matter (PM), which accounted for approximately 30% of the overall hazard **(Figure 16).** Again, it is important to note that the individual hazard index for respiratory effects from diesel PM individually falls well below the threshold of 1. All other system-specific hazards were far below 1.

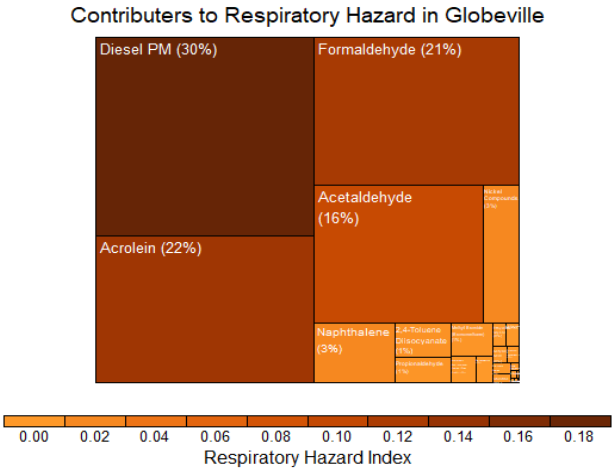

Figure 16. Top contributors to respiratory hazard in Globeville from 2019 AirToxScreen. Results for Elyria-Swansea are nearly identical.

AirToxScreen also reports the predicted excess cancer risk from chemical exposures. In GES, the predicted excess risk of cancer from air toxics was approximately 40 in one million (**Table 6**). This means that out of one million people, it is expected there would be 40 extra cases of cancer in addition to the background rate of cancer caused by other factors or chance. This falls within EPA's range of acceptable risk and is in line with the excess cancer risk from air toxics in other parts of the Denver urban area.[85] The excess cancer risk in GES primarily resulted from formaldehyde and benzene, which contribute to about 40% and 10% of the excess risk, respectively **(Table 7)**. Motor vehicle exhaust and industrial activities can contribute to both formaldehyde and benzene.[86,87]

The Risk-Screening Environmental Indicators (RSEI) model is similar to AirToxScreen but only includes industrial facilities (these are also included as one component of AirToxScreen). Further, RSEI considers chemical releases to both water and air. By using industrial facilities' toxic release data, RSEI can predict how chemicals will spread in the environment, estimate their potential toxicity, and provide a score for the risk in an area as compared to other areas. Like AirToxScreen, RSEI is intended as the first step in identifying areas of potential risk. For our analysis, we used the toxicity-weighted concentrations, which incorporate chemical releases, environmental spread, and the toxicity of each chemical, but do not factor in the population density of the area. This approach provides a better understanding of burden rather than risk management.[88] In the Denver metro area, toxicity-weighted concentrations are driven by

Table 7. The top 10 chemicals identified in the 2019 Air Toxics Screening Assessment contributing to cancer risk in Globeville and Elyria-Swansea. The percentage contribution to the overall excess cancer risk is in parenthesis.

GLOBEVILLE	ELYRIA-SWANSEA
1. Formaldehyde (43.43%) 2. Benzene (13.17%) 3. Ethylene Oxide (7.72%) 4. Carbon Tetrachloride (7.15%) 5. Naphthalene (5.44%) 6. Acetaldehyde (5.16%) 7. 1,3-Butadiene (4.95%) 8. Chromium Vi (Hexavalent) (2.77%) 9. Nickel Compounds (2.42%) 10. Arsenic Compounds (Inorganic Including Arsine) (2.36%)	1. Formaldehyde (40.57%) 2. Benzene (11.77%) 3. Chromium Vi (Hexavalent) (11.48%) 4. Carbon Tetrachloride (6.74%) 5. Ethylene Oxide (5.67%) 6. Naphthalene (4.92%) 7. Acetaldehyde (4.81%) 8. 1,3-Butadiene (4.33%) 9. Nickel Compounds (2.89%) 10. Arsenic Compounds (Inorganic Including Arsine) (2.01%)

emissions to the northwest of the city. As such, GES and other northwest neighborhoods have higher concentrations compared to neighborhoods to the southeast. However, it is important to note that this is not a direct result of industrial activity within GES.

Air Toxics Measurements

There are limited GES data available for most of the chemicals that were flagged in AirToxScreen, with many only monitored at one station in central Denver. From this list, we selected benzene for further follow-up. In addition, we assessed hydrogen sulfide (H_2S) and sulfur dioxide (SO_2) based on a recommendation from CDPHE Air Quality and Health Unit, as these chemicals were flagged in a 2023 EPA review of Suncor.[89] Benzene, H_2S, and SO_2 have been directly monitored in or near GES. However, formaldehyde, which AirToxScreen flagged as the largest contributor to cancer risk, is only monitored at one site in central Denver among the data sources included in this report. Therefore, we are unable to assess monitoring data for formaldehyde. Diesel PM, the largest contributor to respiratory hazard is discussed in the following section with black carbon. Detailed tables by monitoring site for each chemical are available in **Appendix 3**. Key findings include:

- Benzene concentrations were generally below health thresholds[a] for both short- and long-term exposure, however, there were rare instances of benzene concentrations measured above short-term thresholds **(Figure 17)**.
- Between June 2019 and June 2023, the Swansea Air Monitoring Station recorded seven hours where the benzene concentration was above the ATSDR minimum risk level **(see Box 3)**[b]. It is possible that these are aberrant measurements due to some local event such as a car idling near the monitor.
- Median benzene concentrations at monitors in central Denver and Brighton were about 10x higher than concentrations measured at stations in or near GES, but still below both short- and long-term health thresholds.
- Hydrogen sulfide concentrations measured by Boulder AIR during Cultivando's air monitoring project in Commerce City near GES were generally below health thresholds for both short- and long-term exposure[c]; however, there were rare instances of hydrogen sulfide measured above short-term thresholds.
- Sulfur dioxide concentrations measured by Boulder AIR during Cultivando's air monitoring project in Commerce City near GES were all below short- and long-term health thresholds[d]. Cultivando's findings are similar to those measured by CDPHE at sites that report to the EPA.
- Current methods to assess the risk from exposure to multiple chemicals simultaneously assume an additive effect between chemical risk (e.g., a chemical with a toxicity of two plus another chemical with a toxicity of two results in a mixture with a toxicity of four). This approach is limited in that it does not account for the potential for chemicals to act synergistically (e.g. a chemical with a toxicity of two plus another chemical with a toxicity of two results in a mixture with a toxicity of ten), which may result in misidentifying the health risk of a chemical mixture.[90]

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[a] ATSDR acute MRL for benzene is 9 ppb, the chronic MRL is 3 ppb, the EPA IRIS RfC is 9 ppb, and the EPA AEGL-1 (60 min) is 52 ppm.

[b] These hours ranged from 10-16 ppb. Hourly measurements were calculated as the average of two 30-minute samples within the hour. For each of the seven hours, only one of the 30-minute samples was elevated, and these were in the range of 21-32 ppb.

[c] The EPA AEGL-1 (60 min) for H_2S is 510 ppb, the ATSDR acute MRL is 70 ppb, and the EPA IRIS RfC is 14 ppb.

[d] The EPA AEGL-1 (60 min) for SO_2 is 200 ppb, and the ATSDR acute MRL is 10 ppb.

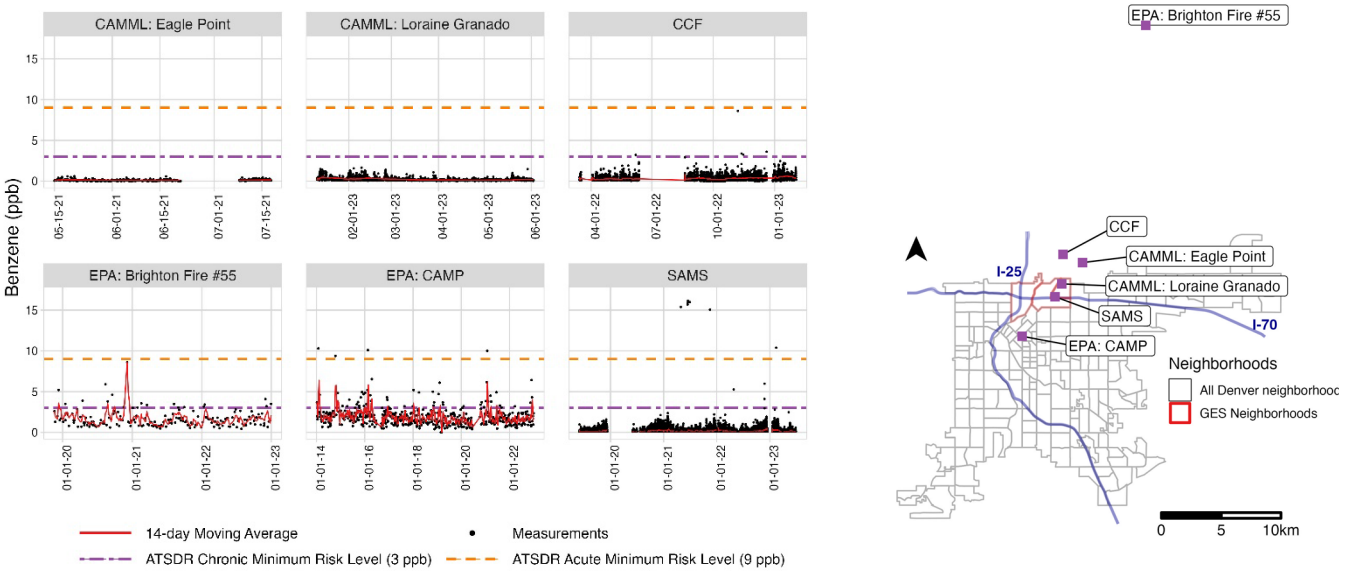

Figure 17. Hourly benzene measurements for sites near GES (left) and map of measurement sites (right), 2020-2023. A 14-day moving average (solid red line) has been calculated to compare against the ATSDR acute MRL (dashed yellow line), which is for exposures of 14 days or less. Graphs show data for benzene, but similar patterns were observed for other pollutants. More detail regarding frequency and duration of monitoring is available in **Appendix 3.**

Black Carbon

Black carbon is an emerging air pollutant of concern due to its potential health effects.[91] Black carbon is a type of particulate matter that comes from combustion processes like the burning of fossil fuels or biomass burning.[92] In Denver, most of the black carbon in the air is due to traffic emissions and wildfires. Black carbon from on-road traffic sources like diesel trucks tends to be highest near major roadways, leading to the highest exposures occurring closest to the road.[93–95] Black carbon from wildfire smoke tends to be more widespread and impacts an entire region at once.[96,97] Research into the health effects of black carbon is still in the early stages. However, there are some suspected health effects associated with black carbon exposure. When black carbon is inhaled, it can cross into the blood stream and cause potential health problems.[98,99] These health problems include exacerbation of cardiovascular and respiratory diseases, particularly in older adults.[100,101] Notably, there is currently no health-based concentration standard for exposure to black carbon in the ambient air. Therefore, we cannot determine the quality of air in GES compared to Denver based on ambient black carbon concentrations.

Monitoring data for black carbon in Denver are limited. Black carbon measurements are collected routinely by CDPHE at the I-25 Denver site located at 913 Yuma Street in Denver. This monitoring location, which was established in 2013, is designated as a “near road” site and is primarily used to monitor NO_2 concentrations from on-road traffic sources, but also measures

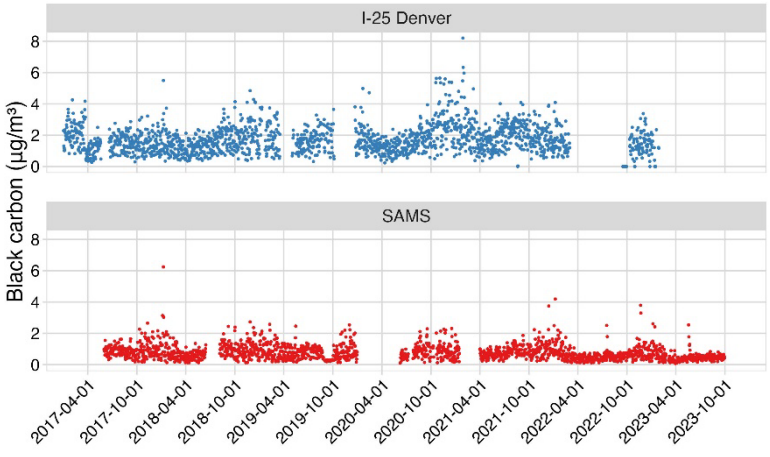

Figure 18. Daily 24-hour black carbon concentrations measured at the I-25 Denver near-road monitoring site and the Swansea area monitoring site, 2017-2023.

Table 8. Summary of 24-hour black carbon concentrations (µg/m^3) measured at the I-25 Denver monitoring site and the Swansea area monitoring site (SAMS), 2017-2023.

SITE	MIN	Q25	MED	MEAN (SD)	Q75	Q95	Q99	MAX
I-25 Denver	0.0	1.1	1.6	1.7 (0.9)	2.2	3.3	4.6	8.2
SAMS	0.1	0.4	0.7	0.8 (0.5)	1.0	1.6	2.3	6.2

Q25-Q99: The respective percentile. E.g. Q25 is the 25th percentile of values.

Min, Med, and Max: The minimum, median, and max values, respectively.

SD: Standard deviation

black carbon. Black carbon concentrations have also been measured at the Swansea Area Monitoring Station (SAMS) since 2017. Like the I-25 Denver site, the SAMS site is also meant to measure air pollutant concentrations due to traffic sources. These data are managed by DDPHE and are available from 2017 through 2023. Trends showing the concentrations recorded at these two locations over time suggest that black carbon concentrations measured at the SAMS location are generally lower than those measured at the I-25 Denver site **(Figure 18)**. Between 2017 and 2023, the average 24-hour concentration at the I-25 Denver location (1.7 µg/m^3, standard deviation = 0.9 µg/m^3) is more than twice the average 24-hour concentration at the SAMS location (0.8 µg/m^3, standard deviation = 0.5 µg/m^3) **(Table 8)**.

Starting in 2018, a group of investigators from Colorado State University led by Dr. Sheryl Magzamen developed a model to estimate black carbon concentrations in Denver.[93] The purpose of the model was to estimate black carbon concentrations in areas where monitoring data were not available. Between 2018 and 2020, the team collected more than 700 weekly measurements of black carbon from sites all over the city. These sites were chosen to be representative of the sources of black carbon (e.g., high-traffic roadways) and places where black carbon concentrations would be lowest (e.g., parks and other green spaces where pollution could settle). These measurements were combined with data on related air pollutants (i.e., particulate matter and nitrogen dioxide) as well as land use characteristics to develop a prediction model. The model was used to estimate weekly and annual black carbon concentrations across Denver. **Figure 19** shows the predicted annual black carbon concentrations in 2018. Consistent with known sources in the area, predicted black carbon concentrations in Denver tend to be highest near major roadways, including where the I-25 and I-70 freeways intersect in Globeville.

Previous Air Toxics Assessments

There have been multiple air toxic assessments conducted in the GES or Commerce City-North Denver area. Most recently, Cultivando hired Boulder AIR to conduct air monitoring and analyze the data from a stationary monitor (included here as CCF) and a mobile monitor. The assessment by Boulder AIR, which has not been peer-reviewed, concluded that Commerce City experiences greater variability and has higher and more frequent spikes of many air pollutants than other parts of the Front Range, specifically Broomfield.[102] Measurements of wind speed and direction that occurred at the same time as high pollution events helped identify the Robert W. Hite Wastewater Treatment Facility as a likely source of hydrogen sulfide, and Suncor as a source of benzene.

In the early 2000's DDPHE conducted a series of air toxics assessments and found that the mean concentration of many air toxics was greater in Swansea (measured at Swansea Elementary School) than other locations in Denver. This included formaldehyde, acetaldehyde, acetone, benzene, and xylene. The 4-hr median concentrations of these

pollutants were below health-based thresholds at the Swansea site [a] . Notably, the current benzene concentrations measured at Swansea Air Monitoring Stations are 4x lower than in 2005-2006[b], representing a significant reduction in benzene since then.[103] In conjunction with the Central-70 project, DDPHE also modeled benzene concentrations for the year 2030 and found that benzene would be reduced compared to pre-construction, largely due to improvements in cleaner fuel. That model predicted benzene concentrations of approximately 0.2 ppb at Swansea Elementary School,[104] which is the same as the measured 24-hour mean from the Swansea Air Monitoring Station in 2022.

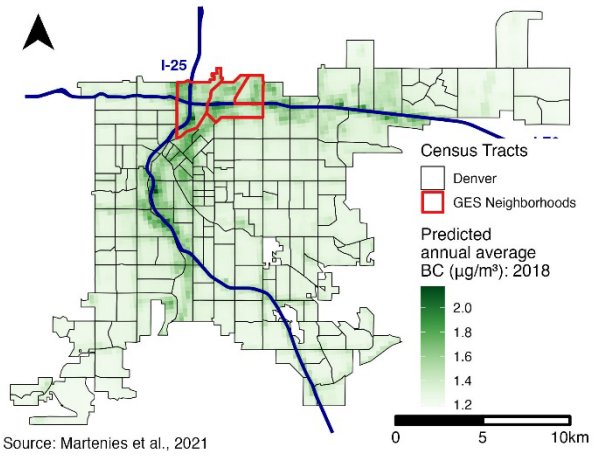

Figure 19. Map showing the predicted annual mean black carbon concentrations for a 250 m grid covering the city and county of Denver in 2018.

CDPHE also studied air toxics in Denver in the early 2000s, including at Swansea Elementary. Sampling was done for a large number of toxic air pollutants including VOCs, aldehydes, and metals.[105] A risk analysis published in 2006 using data from 2002-2003 showed that no chemical individually reached the level of risk for cancer or non-cancer health effects.[105] However, the Swansea site had an excess cancer risk of 100 cases per one million individuals, driven by benzene, arsenic, and crotonaldehyde. Considering multiple chemical exposures simultaneously, Swansea and central Denver had a risk of respiratory effects, while Swansea, central Denver, and Commerce City had a risk of neurological effects. At Swansea, the primary contributors to the respiratory and neurological risks were manganese, 1,2,4-trimethylbenzene, formaldehyde, and acetaldehyde. Again, it is notable that the mean concentration of benzene at the Swansea station was approximately 4 times higher[c] than the current mean from 2019-2021.

Additionally, CDPHE's Toxicology Program reviewed air quality data collected around Suncor Refinery between 2012-2016. Measured levels of VOCs were below health guideline levels for all 5 years, and cancer risk estimates for benzene and ethylbenzene were less than one in ten thousand, which was considered an acceptable risk. During this sampling campaign, sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) were below EPA NAAQS at all locations near Suncor.[106]

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[a] 4-hr median concentrations were as follows:

Formaldehyde: 2.36 ppb (EPA AEGL-1 60 min: 900 ppb; ATSDR acute MRL: 40 ppb; ATSDR chronic MRL: 8 ppb)

Acetaldehyde: 1.34 ppb (EPA AEGL-1 60 min: 45 ppm; EPA IRIS RfC: 5 ppb)

Acetone: 1.56 ppb (EPA AEGL-1 60 min: 200 ppm; ATSDR acute MRL: 8 ppm)

Benzene: 0.56 ppb (EPA AEGL-1 60 min: 52 ppm; ATSDR acute MRL: 9 ppb; ATSDR chronic MRL: 3 ppb; EPA IRIS RfC: 9 ppb)

Xylene: 1.71 ppb (EPA AEGL-1 60 min: 130 ppm; ATSDR acute MRL: 2 ppm; ATSDR chronic MRL: 50 ppb; EPA IRIS RfC: 20 ppb).

[b] The median 1-hour benzene concentration was 0.41 ppb, compared to 0.1 ppb presently.

[c] The mean concentration from 2002-2003 was 0.9 ppb (converted from 2.8 µg/m^3 at STP). The mean concentration from 2019-2023 was 0.2 ppb (data not shown in **Table 17**).

4.2. BUILT ENVIRONMENT

Zoning is an important characteristic impacting environmental quality and lived experience in GES. The three neighborhoods are classified as residential areas, but a large percentage of the land area is zoned for industrial use. One driver of this disparity is historical redlining, a racially discriminatory practice implemented under the Home Owners' Loan Act of 1933 before the suburban development boom.[107] Residential Security Maps were used to rank (A, B, C, D) and color-code neighborhoods on a spectrum of most desirable (A), still desirable (B), declining (C), and hazardous (D).[28,108] The Home Owners' Loan Corporation (HOLC) grade D, or hazardous, areas were deemed off-limits for mortgage loans further intensifying racial residential segregation boundaries.[109,110] While the policy was outlawed in the 1960s,[111] these practices still influence urban areas today, with documented adverse social and environmental health outcomes like high unemployment, poverty, and residential vacancies **(Figure 20)**.[108,112,113]

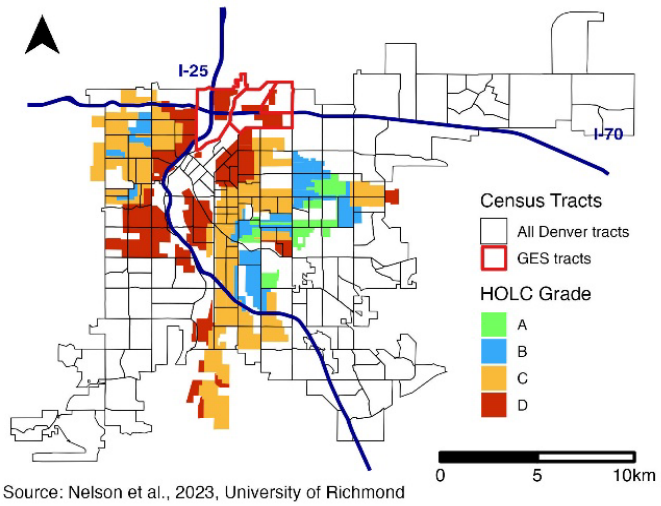

Figure 20. Former HOLC redlining status in Denver, Colorado by 2023 census tracts.

In GES, areas zoned for residential use are often surrounded by areas zoned for industry **(Figure 21)**. Even if not directly adjacent, these residential zones are located very close to industrial areas and are separated by small, mixed-use zones. The presence of heavy industrial zones close to residential areas presents a risk of pollution and exposure from stationary sources, which include factories, power plants, refineries, dry cleaners, and construction and/or shipping facilities. The closeness of industry to residential areas has increased community concern about noise, air quality, odor, and overall appearance from proximity to I-25 and I-70, visible plumes, and landfills. Impacts of zoning can also be seen through limited access to goods and services and the impaired connectivity and mobility of the community.

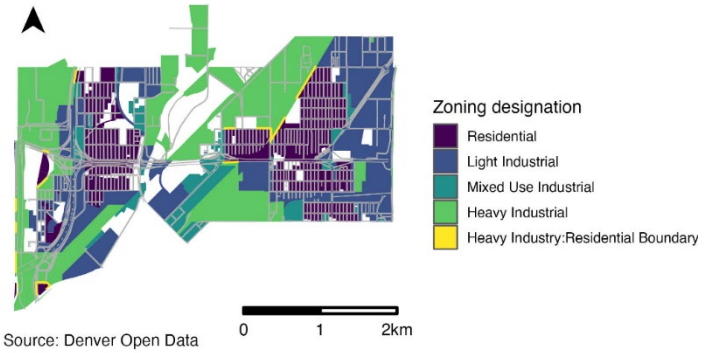

Figure 21. Summary of 2023 zoning designations in GES showing the boundary between residential and heavy industrial zoned areas

ACCESS TO GOODS AND SERVICES

The noticeable lack of retail businesses and the resulting limited access to goods and services is a prominent feature of GES. Goods and services are part of the built environment and include the businesses and facilities residents need to interact with as part of daily life, such as grocery stores, childcare, banks, recreation centers, and retail stores. Although the connection between these and health may not be immediately apparent, like other parts of the built environment, access to goods and services can shape health behaviors that impact health outcomes. This section

focuses on access to food, alcohol, marijuana, and recreation, which either appeared in the 2014 HIA or have been raised as community concerns. Other aspects of goods and services are discussed in separate sections as appropriate.

FOOD ACCESS

Limited access to healthy foods is at the forefront of the goods and services discussion in GES and is a major concern for residents. The 2014 HIA extensively discussed this issue, which persists today. According to the 2014 HIA, GES residents must often travel up to twice as far as the average Denver resident to reach a full-service grocery store. This problem is compounded by a high dependence on public transportation by GES residents, lack of produce and staples at convenience stores, and high SNAP eligibility, resulting in high rates of food insecurity: about 34% in GES compared to 16% statewide.[3]

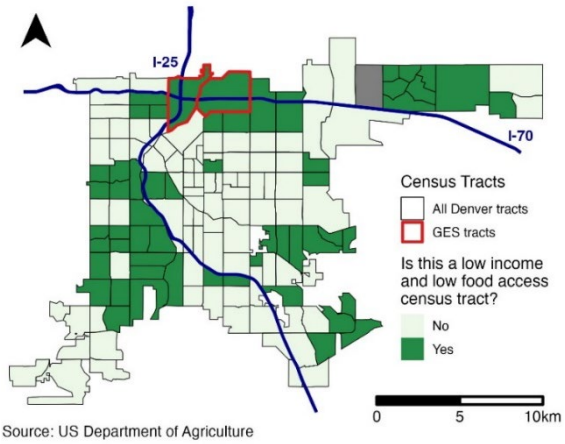

Figure 22. Low income and low food access in Denver, Colorado, 2019.

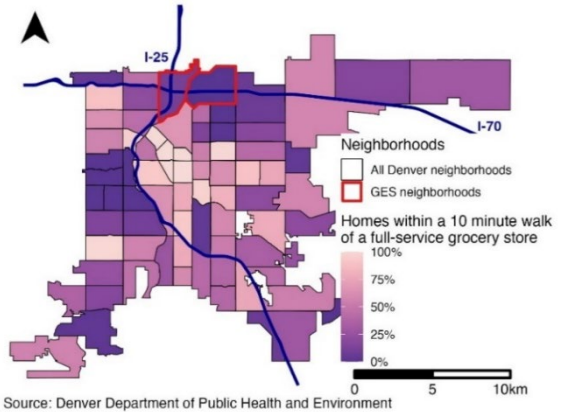

Figure 23. Homes within a 10-minute walk of a full-service grocery store in Denver, Colorado, 2021.

Presently, GES continues to have low access to healthy food options; as a hub of industrial activity, there are at least 19 food production, processing, and storage facilities, yet there are no full-service grocery stores.[114] Based on mapping activities conducted during Phase I of the GES Community Health Study, residents indicated that the most common location for grocery shopping is at the shopping center located in Commerce City at Vasquez Blvd. and I-270. Natural Grocers is the nearest grocery store just outside of Globeville in the Five Points neighborhood. However, as a premium retailer, it may not be affordable for many GES residents. Furthermore, in 2019 the USDA classified the GES census tracts as low income and low access (LILA) based on the percentage of residents in the census tract with low income who live more than 0.5 miles from the nearest grocery store **(Figure 22)**.[115] In 2021, Denver likewise found GES to have among the lowest access to full-service grocery stores among Denver neighborhoods. The analysis found that only 10.5% of residents in Globeville and 0% in Elyria-Swansea live within a 10-minute walk of a full grocery store, compared to a city-wide population-weighted average of 42.1% **(Figure 23)**.[116] Impaired connectivity and limited mobility, including a high dependence on public transportation, further compound the scarcity of retailers offering a full selection of health food **(see Connectivity and Mobility)**. These analyses confirm and support the lived experiences of residents, who cite limited access to food as a top concern.

To address the scarcity of healthy food in GES, the East Denver Food Sovereignty Initiative has begun development of a co-op model grocery store located in the Elyria neighborhood following multiple years of planning.[117,118] In the meantime, GES residents can benefit from food boxes offered by various neighborhood organizations and the Huerta Urbana pay-what-you-can market organized by the Focus Points Family Resource Center.[119] Additionally all students in Denver are now eligible for free meals.[19]

Research into the connection between the food environment and diet or health outcomes has been ongoing for decades, and results have generally been mixed.[120,121] The 2014 HIA cited multiple studies that indicated increased availability healthy food and grocery stores was associated with decreased rates of obesity, diabetes, and mortality, while increased prevalence of convenience stores was associated with higher BMI among students. Recent literature reviews have found that there is not consistent evidence of an association between food deserts (i.e., lacking access to grocery stores) and health. However, this is complicated by many other neighborhood characteristics, such as walkability.[53,122] One study that accounted for walkability found that the likelihood of obesity was 13% lower and BMI was about one point lower in neighborhoods with the greatest access to healthy food outlets, such as grocery stores, compared to those with the least access.[53,122] While the evidence regarding food deserts is inconsistent, there is strong evidence that food swamps, or areas with more unhealthy food options (like fast-food) than healthy options, are associated with increased obesity and overweight.[53,121] We are unable to compare how food access in GES compares to the rest of Denver through the lens of food swamps because the open access data of food locations exclude fast food and convenience stores. However, our observation of multiple fast-food chains while working in the neighborhood, combined with the documented lack of full-service groceries, suggests that GES is a food swamp as well.

MARIJUANA ACCESS

The 2014 HIA includes a quote from a GES resident that "There are more marijuana stores than grocery stores..."[3(p47)] While quoted, the 2014 HIA does not further describe access to marijuana in GES, which is unsurprising as recreational sales only began in January 2014 following legalization in 2012.[123]

We found that access to marijuana retail is above the Denver average in Globeville but not in Elyria-Swansea. However, the ratio of marijuana stores (presently) to food markets and grocery stores (data from 2021) shows that GES has more marijuana stores than food markets and grocery stores. Globeville has 3.5x more marijuana stores than food markets or grocery stores, while Elyria-Swansea has 1.75 marijuana stores for each food market or grocery store **(Figure 24)**. Additionally, GES is included in the highest category of access to cultivations **(Figure 25)**. While individuals do not purchase directly from cultivations, the presence of cultivation sites is related to nuisance odors and neighborhood perceptions.

Marijuana outlet density has been reported to have associations with increased use[124–126] and increased use during pregnancy.[127] Research on the long-term health effects of marijuana is still developing, however, marijuana use has been associated with multiple health outcomes including worsening of chronic bronchitis, development of COPD, low birthweight following maternal use, learning impairment, schizophrenia development, exacerbated bipolar disorders, increased suicide, and increased

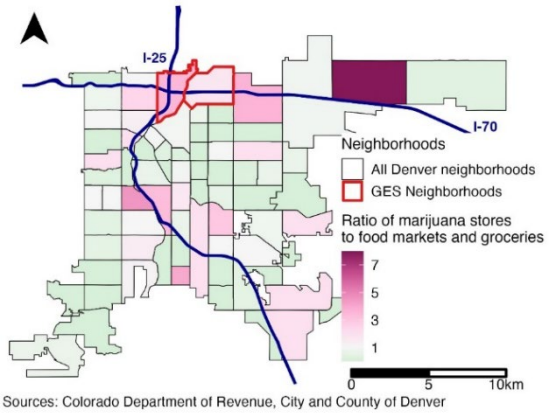

Figure 24. Ratio of marijuana stores (2023) to food markets and groceries (2021) in Denver, Colorado.

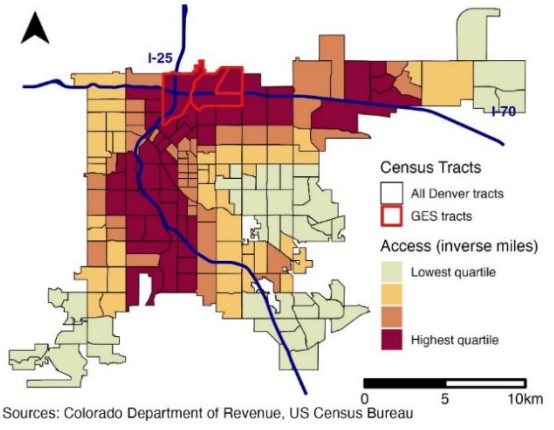

Figure 25. Access to marijuana cultivations in Denver, Colorado, 2023.

social anxiety disorder.[128] Further, marijuana retail density has been associated with cannabis-involved pregnancy hospitalizations and increased cannabis abuse/dependance hospitalizations.[129–131] In Colorado, three studies have found an association between increased access to marijuana and crime.[132–134]

ALCOHOL ACCESS

Relatedly, we have heard concern from residents about the access to liquor stores and alcohol. We found that Globeville and Elyria-Swansea have similar or lower access to off-premises liquor sales (including grocery stores, convenience stores, drugstores, and liquor stores) than Denver's average. This is likely an extension of the overall lack of access to goods in GES. There is mixed evidence that increased access to alcohol results is associated with increased use and there does appear to be a consistent association between access to alcohol and health.[135,136] Studies have reported that higher alcohol retail density is associated with decreased life expectancy and increased mortality, and reduced densities of alcohol outlets are protective of self-reported health in disadvantaged areas.[137,138] Increased access to alcohol has also been associated with increased neighborhood crime.[139–144] Long term health risks from excessive alcohol consumption include hypertension, heart disease, stroke, liver disease, cancers, depression, and anxiety.[145–147] Since access to liquor in GES is not substantially different from the Denver average, it is unlikely to be a primary contributor to physical health disparities, but still contributes to the lived experience of residents.

GREENSPACE, PARKS, AND RECREATION ACCESS

Parks, community gardens, and other natural spaces are often referred to as "greenspaces."[148] Access to these parks and recreational facilities is not limited in GES; however, community members have raised concerns regarding the usability, particularly of outdoor parks. The 2014 HIA reported that both Globeville and Elyria-Swansea meet minimum standards from Denver Parks, and GES had eight parks covering 97 acres of parkland. In 2023, according to Denver's park map, there are now eleven parks covering 113 acres of parkland in GES.[149] The total greenspace area expanded because of the addition of Platte Farm Open Space (7 acres), I-70 Cover Park (5 acres), and the 51st and Broadway Park (1 acre). However, the park dataset has a significant limitation as some known greenspaces located in GES, such as Riverside Cemetery and Riverfront Open Space, are not included in the count.

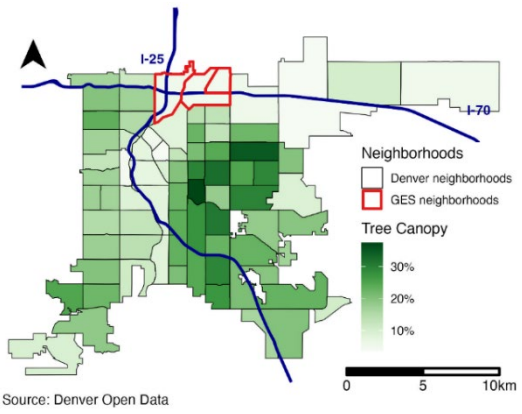

Figure 26. Percent tree canopy in Denver, Colorado, 2020. A lighter color indicates less tree canopy coverage.

Denver has 31 city-owned recreation centers, 4 of which are located in GES (Globeville, 5090 Broadway, Swansea, Johnson).[150] The Globeville Center is contracted to be run by Birdseed Collective, a local non-profit. Argo Park and the Swansea Recreation Center have outdoor pools, but the outdoor pool at Swansea Recreation Center is in the design phase to be replaced with an indoor pool, a long-requested amenity by residents. The indoor pool is expected to be completed in 2025.[151,152] The only other neighborhoods to have more than one designated recreation center are Five Points, Gateway - Green Valley Ranch, and Northeast Park Hill.

Tree canopy coverage is an important measure of greenspace that can impact the health of a community. According to the latest available data from 2020, Denver has a tree canopy

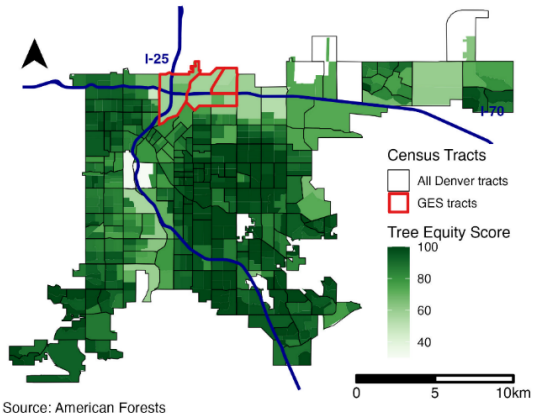

Figure 27. Tree Equity Score in Denver, Colorado, 2020. The score ranges from 0-100. The lower the score, the greater priority for tree planting.

coverage of 11%, while GES only has about 5% **(Figure 26)**.[153] This is concerning because low tree canopy coverage has been linked to higher temperatures,[154] poorer air quality,[155] and overall worse health conditions.[156] Another method to measure tree coverage is through a tree equity score which factors in environmental aspects such as surface temperature and heat index, as well as social features like demographics. American Forests' Tree Equity project provides access to tree equity score data for major US cities.[157] The score is derived by comparing existing tree coverage to the desired goal for the neighborhood and assigning a priority score based on factors such as race, income, employment, age, heat island severity, and health. Combining these measures results in a score ranging from 0 to 100, with 100 indicating the most equitable tree coverage. Denver's tree equity score is 90, while GES's score ranges between 60 and 75 **(Figure 27)**.[157]

Access to greenspace, parks, and recreational facilities have been found to be essential for mental and physical well-being. They provide a space for social interaction and physical activity, which can help reduce mental stress and improve respiratory and cardiovascular health.[158,159] Additional research suggests that proximity to parks and recreational centers is associated with increased physical activity levels and lower weight status.[53,120] However, overall access to greenspaces, parks, and recreational facilities in GES varies based on how it is measured. While the number of parks and recreational facilities is on par with city-wide standards, tree coverage and equity are lacking compared to Denver. Despite having a representational number of parks and recreational facilities, some GES residents are hesitant to use them due to concerns regarding safety, health, and odors. The perceived high prevalence of homelessness and drug paraphernalia (such as needles) in the parks is a significant concern. Nuisance odors are also frequent in the parks, which discourages residents from using them. Some community members fear that their children's health may be impacted by the surrounding air and soil quality and, therefore, choose to go to parks in other parts of Denver. It is important to note that not all community members share these concerns, and perceptions of parks vary greatly. More community engagement is necessary to fully understand the barriers to greenspace and park usage.

URBAN HEAT ISLAND/HOT STREETS

A major concern related to the built environment in GES is the urban heat island effect. The urban heat island effect occurs when paved surfaces like streets, sidewalks, and parking lots that are concentrated in an urban area retain heat over the course of a day, resulting in temperatures that are hotter than those in the surrounding suburban and rural areas. The urban heat island effect is linked to several adverse health outcomes related to heat exposure, including exacerbations of existing cardiovascular disease, heat stroke, and mortality.[160] Across the United States, Black and Brown communities are more likely than White communities to experience higher temperatures due to the urban heat island effect.[161,162] These same communities are also less likely to have access to the types of housing and resources (e.g., air conditioning, green space) needed to mitigate the urban heat island effect.[163,164] As outlined elsewhere in this report, tree canopy coverage, which is helpful for mitigating the urban heat island effect, is lower in GES (5%) compared to Denver as a whole (11%).

In 2021, the Denver Department of Transportation and Infrastructure Office of Green Infrastructure conducted an analysis ranking streets in Denver based on their long-term surface temperatures.[165] In their analysis, they combined

remote sensing data of land surface temperatures recorded during July and August for a 20-year period (2000 – 2019) with road network data to estimate the long-term summertime temperature of each road segment. These road segments were then ranked based on these long-term average temperatures. **Figure 28** shows the percentile ranks for each road segment in Denver. Higher percentile ranks represent higher summertime temperatures.

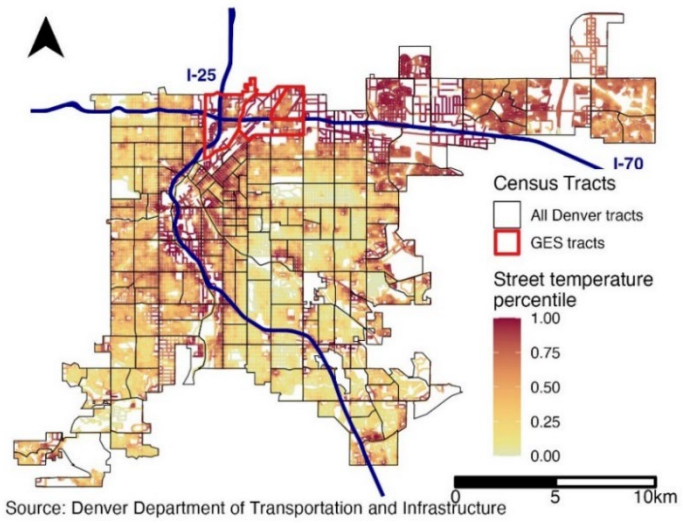

Figure 28. Relative ranking of Denver street segments based on long-term average land surface temperatures measured during July and August, 2000-2019. Higher percentiles correlate with hotter surface temperatures. Note: This figure excludes the census tract containing the Denver International Airport; street temperatures in this census tract are among the hottest 25% of streets in Denver.

Based on these data, there is evidence that surface temperatures for GES streets are hotter than in other areas of the city, but we do not know the extent of this difference. The street temperature data indicate that the hottest streets in the city are located along the I-25 and I-70 corridors, which include the neighborhoods of Globeville, Elyria, and Swansea **(Figure 28)**. Other Denver neighborhoods with high concentrations of hot streets include Five Points, Union Station, Auraria, and Sun Valley. The lowest street temperatures are located on the east and south sides of the city. Because the street data are available only as relative rankings, we are not able to estimate the difference in summertime street temperatures between these three neighborhoods and Denver as a whole. It is also important to note that the land surface temperature data were summarized at the street level and may not fully reflect the urban heat island effect in all areas (e.g., in areas where street density is lower but other heat sinks are present).

COMMUNITY SAFETY

Community safety, or lack thereof, is tied into multiple aspects of this report, including the use of parks, connectivity and mobility, physical activity, mental health, and other downstream health effects. The 2014 HIA recognized these linkages too and attributed perceptions of high crime and fear in GES at the time to pedestrian and cyclist accidents, graffiti, vandalism, and lack of street lighting. However, in 2014 reported crime in GES was lower than in surrounding areas at the time, despite many areas lacking street lighting. Low reported crime may have partially been an artifact of GES residents not reporting crime out of fear of police or feeling that the police would not respond in a timely manner.[3] Many of the same perceptions are still prevalent today, especially regarding the use of parks, which some residents have reported they avoid out of fear of crime, drugs, and people experiencing homelessness.

TRAFFIC

Traffic safety is a prominent concern in GES due to the heavy business and freight traffic through residential neighborhoods. Fast speeds on north-south arterials (e.g., Washington St., Brighton Blvd., and Vasquez Blvd.) present a hazard to pedestrians, bicyclists, and other road users. Limited sidewalk and bicycle lane networks **(see Connectivity and Mobility)** add to the danger through the lack of safety features between road users and high-speed vehicles.

Denver Police Department publishes detailed records of all traffic accidents that city police services respond to or that are reported to the city. From these data, we found that Globeville and Elyria-Swansea have a higher rate of traffic accidents than Denver as a whole. However, both neighborhoods have a significantly lower rate of accidents that involve bicyclists or pedestrians **(Table 9)**.[166] Traffic accidents in GES cluster around interstate interchanges, which serve as a connection between the north and south sections of the neighborhoods. The low rate of bicycle and pedestrian-involved accidents could be due to less infrastructure supporting biking and walking in these neighborhoods, which results in lower overall road usage by bicyclists and pedestrians, rather than the roads being safer for these users. A greater in-depth analysis of the factors associated with traffic accidents in GES would be required to identify the exact factors associated with the higher rate of accidents and potential solutions.

Table 9. Traffic accidents for Globeville, Elyria-Swansea, and Denver, Colorado.

MEASURE	GLOBEVILLE	ELYRIA-SWANSEA	DENVER TOTAL
Rate of Traffic Accidents in 2022 (count)	11.20 (477)	7.28 (359)	6.39 (16,263)
Rate of Traffic Accidents Involving a Bike or Pedestrian in 2022 (count)	0.09 (4)	0.10 (5)	0.21 (514)
Rate of Traffic Accidents in the Last Five Years (count)[A]	55.42 (2,360)	40.48 (1,997)	34.87 (88,732)
Rate of Traffic Accidents Involving a Bike or Pedestrian in the Last Five Years (count)[A]	0.66 (28)	0.47 (23)	1.17 (2,983)

All rates per roadway mile.

[A] Five-year period from September 2018 to September 2023

CRIME

A second direct measure of community safety is the amount of crime reported to police. Denver Police Department maintains detailed data on every crime reported and substantiated. In contrast to the 2014 HIA, which reported lower crime in GES than in surrounding areas, in 2022, GES had a higher rate of crime compared to surrounding neighborhoods and Denver as a whole **(Table 10).**[167] This was true across all crime categories. The rate of crimes

Table 10. Crime rates by category for GES and Denver, 2022.

MEASURE	GES	DENVER TOTAL
Rate of Crimes Against Persons[A] (count)	240.74 (258)	116.89 (8,262)
Rate of Crimes Against Property[B] (count)	1,319.40 (1,414)	802.70 (56,735)
Rate of Crimes Against Society[C] (count)	118.50 (127)	78.78 (5,568)
Rate of Other Crimes (count)	130.63 (140)	78.14 (5,523)
Rate of Total Crimes (count)	1,809.27 (1,939)	1,076.52 (76,088)

All rates per 10,000 population. Population from 2017-2021 5-year estimates.

[A] Crimes against persons includes murder, assault, sex offenses, kidnapping, and intimidation.

[B] Crimes against property include arson, bribery, burglary, forgery, criminal mischief, embezzlement, extortion, fraud, larceny, motor vehicle crimes, and robbery.

[C] Crimes against society includes drug and narcotic violations, gambling, child pornography, prostitution, weapon law violations, disorderly conduct, family offenses, liquor law, and violation of court order.[168]

against persons in GES, which includes murder, assault, sex offenses, and kidnapping among others, was more than double the rate for Denver as a whole.

Crime rates in GES have consistently been higher than the Denver average in all categories over the past five years (2018-2022) **(Figure 29)**. During this time, the rate of crime against persons and property has increased substantially in both Denver and GES, while the rate of crime against society and other crimes has decreased slightly. Interestingly, crimes against persons and property, and other crimes had a noticeable uptick in 2020 corresponding to the onset of the COVID-19 pandemic. In GES, the increase in crimes against persons in 2020 was substantially greater than the increase observed in Denver as a whole and the rate of crimes against persons has remained at an elevated level.

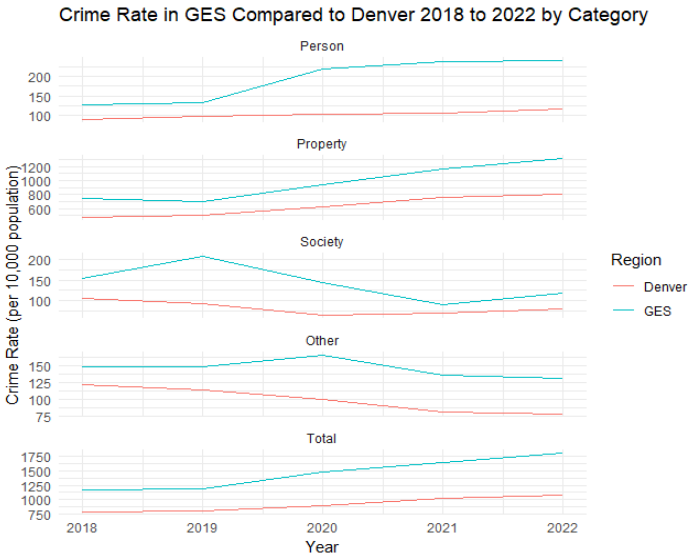

Figure 29. Crime rates by category in Denver and GES, 2018-2022.

There are many possible reasons why reported crime is higher in GES other than there actually being more crime. Just as the 2014 HIA suggested that the lower crime rate in GES could be the result of residents hesitating to report crime, the inverse could be true now and residents in GES may be more likely to report crime than in other parts of the city. It is also possible that there are more police patrols in GES than in other parts of the city so the likelihood of an individual being caught for a crime is higher. However, both of these possibilities conflict with the lived experiences of residents who report that they often do not report crime to the police because, in their experience, the police are slow to respond or do not respond at all. This observation, coupled with the 2014 HIA suggestion that GES residents do not report all crime that occurs, indicates it is possible that the rate of crime in GES is higher than what we have reported here.

STREETLIGHTS

Streetlights are an important factor in deterring crime,[169,170] and GES residents report a lack of streetlights on roads and in alleys as contributing to the perception of danger at night in GES. This issue was highlighted in the 2014 HIA through a streetlight survey performed by Denver Police that identified many streets in GES that lacked or had insufficient lighting. Maps of these areas are available in the 2014 HIA, which also recommended installing new streetlights and encouraging residents to turn on porch lights. Despite these recommendations, residents continue to report inadequate streetlighting, partially

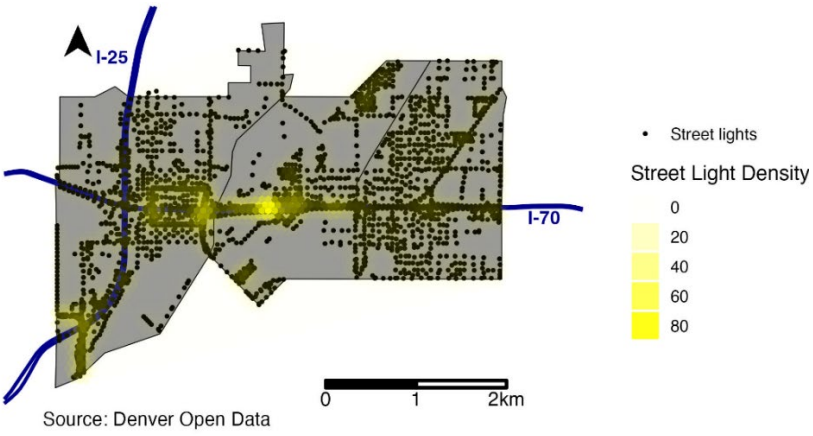

Figure 30. Street light density in GES census tracts, 2019.

due to long delays in repairing non-functional lights. Using data from Denver on the location of streetlight poles in 2019, we mapped streetlights in GES **(Figure 30)**.[171] However, it is difficult to assess lighting conditions exclusively from the location of light poles, as this does not account for the quality of the lighting or other possible obstructions. From 2014-2019, 100 streetlights have been installed in GES. However, from manual comparison it appears that many of the areas identified in the 2014 streetlight survey have not received new lights. In residential areas, many of which were labeled as needing additional lighting in the 2014 survey, there is often only one light at intersections and one light halfway down the block on residential streets and alleys. Based on residents' continued reporting of inadequate lighting, this low-density lighting may not be sufficient in GES.

OTHER COMMUNITY SAFETY CONCERNS

In 2019, Denver built the 47th and York St. Pedestrian bridge over the Union Pacific Railroad tracks in Elyria-Swansea to provide east-west connectivity. This project cost $12 million dollars and was projected to provide a safe railroad crossing for 100 students per day walking to and from Swansea Elementary.[172] However, instead of using the bridge, many people cross the tracks through holes in the fence below[a]. Community members say that the hole is fixed periodically but is made again in less than a day. Possible reasons for the low usage of the bridge include the long ramps or stairs to ascend/descend (there are no elevators), the presence of drug paraphernalia, drug use, and people experiencing homelessness. Regardless of the causes, people, including children, continue to unsafely cross the rail tracks outside of a crossing zone in an area with frequent trains, some of which are operated remotely.

CONNECTIONS TO HEALTH

Community safety is directly related to health through accidents and injuries and indirectly through neighborhood disorder and effects on mental health. Unsafe environments can result in increased injuries and fatalities, such as in the case of traffic accidents and certain crimes that result in physical harm to the victim. High rates of crime can also be indicative of social and physical neighborhood disorder[b], which increases stress and depression, and lowers general mental health.[173] Poorer mental health is in turn related to increased substance use and lower general health.[173] It is also possible that fear of crime adds a barrier to physical activity, resulting in worse health outcomes. Scientific support for the association of crime on physical activity is not definitive,[173,174] however, we have heard support for this association in the lived experiences of residents who relate that the parks in GES are unsafe and avoid them for this reason.

CONNECTIVITY & MOBILITY

Connectivity and Mobility in GES are a major focus of the Globeville Neighborhood Plan,[10] Elyria-Swansea Neighborhood Plan[11] and National Western Center Master Plan,[175] the North Denver Cornerstone Collaborative,[176] and

[a] This has been noted by the Community Council, members of community organizations that work directly adjacent to the bridge, and has been observed by the research team while touring the neighborhood.

[b] Neighborhood disorder is the terminology used in social science literature. We encourage interested readers to explore O'Brian et al. (2019) as a starting point.

a key component of the 2014 GES Health Impact Assessment. Mobility is defined as the ability to safely move around one's community using public transit, private vehicles, bicycles, or foot.[3] Connectivity refers to the ease and intuitiveness of traveling directly between places. Community mobility depends on neighborhood connectivity both within the neighborhood and in ease of access to locations outside of neighborhood boundaries.

WALKABILITY

Connectivity and mobility are key environmental drivers of a healthy community, of which walkability is a critical factor. Walkability refers to the pedestrian experience, including sidewalk availability, quality, safety (distance from the street), lighting, and connection/proximity to destinations like schools, work, parks, retail shops, grocery stores and public transit.[177] In 2023, as reported in the 2014 HIA, GES residents continue to voice poor walkability, disconnectedness, and lack of safe conditions in parks and underpasses as points of concern and priority. They also voice concerns surrounding safe, walkable access to local schools, parks, and grocery stores, and the challenges of flood-prone streets and sidewalks, lack of lighting near sidewalks, chronic odor, heavy industrial activity, and physical barriers imposed by interstates, railroads, and busy thoroughfares **(Figure 31)**.

Figure 31. Image of the wall around I-70 as viewed from the north side of the interstate in Globeville, 2022. I-70 and I-25 divide GES into quadrants and are a physical barrier to connectivity.

According to EPAs Walkability Index, which groups walkability by block groups ranked on a score from 1-20, the Denver median walkability score is 10.67.[178] Globeville's block groups range from 7.2-9.5 on the walkability score, and Elyria-Swansea ranges from 4.3-13.7 **(Figure 32)**. This evidence suggests that GES has similar walkability when compared to the Denver average, however, the lowest score for walkable blocks in GES is 4.3, which is well below the Denver average of 10.67. Irrespective of the walkability score, the lived experience of community members demonstrates real and perceived challenges to connectivity in their neighborhoods. Without the perception of a safe, walkable neighborhood, neighbors will continue to live without experiencing the benefits of walking in their neighborhoods.

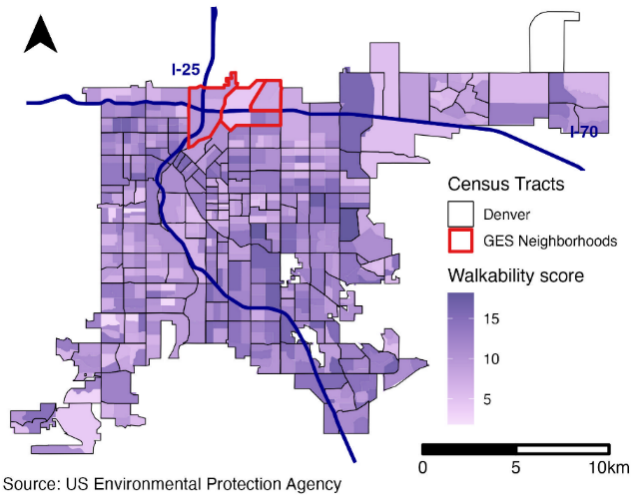

Figure 32. National Walkability Index score in Denver, Colorado, 2023. The US EPA Walkability Index characterizes 2019 census block groups based on their relative walkability, which is dependent on built environment characteristics that influence the likelihood of people using walking as a mode of transportation.

When a neighborhood is more walkable, community members can stay active and therefore healthier, which leads to reductions in obesity and diabetes.[53,177]

Walkability also improves human and environmental health by reducing pollution from commuters and private motor vehicles. Finally, walkability can help improve a sense of community, which in turn improves mental health due to neighborly encounters during walks to local neighborhood destinations.[179,180] Limited connectivity, mobility, and walkability can contribute to the underutilization of community destinations and businesses that are difficult to reach. This impacts both the current economy and prospects for future economic and resource development.[11,181] The 2014 HIA describes, and current residents continue to voice concerns about, this lack of neighborhood destinations.

Water quality, noise and air quality are all directly tied to connectivity and mobility as well. In GES, lack of adequate drainage systems leads to flooding on roads, sidewalks and bike paths, and compromises water quality in the South Platte.[182,183] Flooding of the South Platte also renders the South Platte River Trail unusable for bikers and walkers. Noise and air quality in GES are negatively impacted by factors like large trucks on neighborhood roads where specific truck routes don't exist, multiple freight train lines which splice the neighborhoods, and the I-70 "Mousetrap."[10,11] As referenced in this HIA, all these factors contribute to individual and community physical and mental health outcomes and behaviors—including respiratory and cardiovascular impacts, reduced physical activity, mental health implications, and more.

EXISTING INFRASTRUCTURE AND TRANSIT RESOURCES

The existing infrastructure in GES includes bus routes, light rail routes, an Amtrak line, bike lanes, bikeshare and scooter access, walking paths, and the South Platte River Trail. Despite the availability of transit, there is still underutilization and a lack of effective implementation across all modes of transit and transit infrastructure. Both data and neighborhood perspectives confirm that while improvement efforts have occurred, they are not always successful, or community led.

While current RTD Bus routes exist in GES, there is a lack of bus lines that provide east-west connectivity in and between Globeville and Elyria-Swansea neighborhoods.[184] This connection is important as some resources are only in one of the neighborhoods, such as the library, which is currently only in Elyria, and educational resources at CSU Spur, which has no bus service. However, a strength of the bus system is that lines and routes can be adapted according to community need and demand. The bus system also continues to provide reduced fares, including discounted fares for youth below 19 including the new Zero Fare for Youth program (Sept 2023 – Aug. 2024), discounted fares for adults 65+, discounted fares for Medicare recipients, discounted fares for individuals with disabilities, and the LiVE program for individuals between ages 20-64 who are at least 185% below the federal poverty level and meet other requirements.[185] While north-south connectivity is critical for neighbors to access the Downtown Denver area, without east-west connectivity the neighborhoods remain fractured and cut off from important resources.

The RTD Light Rail, on the other hand, is more costly and complex to modify than bus routes. Despite this, three new GES-accessible RTD Light Rail transit lines and four stations have been developed since the 2014 HIA. While the additional Light Rail infrastructure provides better connectivity to Downtown Denver and Denver International Airport, community members still voice ongoing challenges with accessing the Light Rail. Throughout GES and Denver alike, sidewalks are frequently missing or deficient in width near Light Rail stops, which can be a deciding factor in whether residents utilize Light Rail services.[186] One Light Rail stop, implemented near the National Western Stock Show Complex, is frequently cited as difficult to access and as designed to service the Stock Show, rather than support neighborhood connectivity. It is advertised as an "Entertainment" Light Rail stop.[187] The RTD Light Rail offers the same selection of discounted fares as the RTD Bus, but the issue of fare availability and resource utility remains, as does education about discounts and benefits available to community members. Finally, while enhancing connectivity to

some extent, the new Light Rail additions do not solve east-west connectivity challenges in GES, leaving room for ongoing transit developments to address community needs.

Additionally, safe biking infrastructure is lacking in GES compared to other neighborhoods **(Figure 33)**.[188] There is a lack of protected bike lanes in GES compared to other areas of the city, which is likely a product of the broader issue of neighborhood fragmentation from the "Mousetrap" (e.g., junction of I-25 and I-70) and various industrial sites. The lack of official bike lanes is in stark contrast to nearby RiNo and Downtown neighborhoods.[188] Other potential microconnectivity resources in GES are city biking and scootering programs. Although Denver's city bike-share and scooter programs through Lyft and Lime have expanded in recent years, data from 2018-2023 demonstrates that the lack of connectivity is visible in public bike and scooter usage in GES.[189] The lack of bicycle and scooter usage in the area surrounding the "Mousetrap" feature illustrates the lived experiences of GES community members who are unable to conveniently navigate the area. While the Lime Access program provides free, unlimited 30-minute bike and scooter rides to qualifying applicants[190] and discounted Opportunity Area Pricing in both Globeville and Elyria-Swansea,[191] ridership in those areas remains low.[189] The inconsistency between affordability and use exemplifies the need for community-informed interventions, as well as ongoing construction to ensure better connectivity to promote use of existing microtransit resources. Accessible bicycle paths and well utilized bikeshare and scooter programs not only increase neighbors' mobility, but they also have the potential to reduce air and noise pollution and enhance community physical activity. As such, they support multiple environmental, behavioral and social determinants of health.

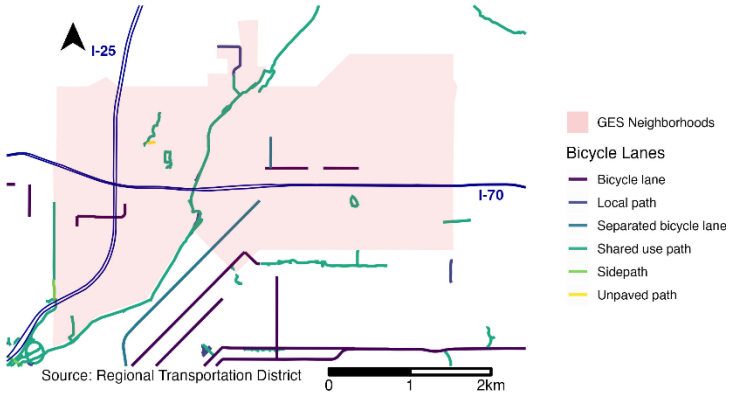

Figure 33. Existing bicycle infrastructure in GES census tracts, 2023.

Box 4. Key concerns reported in the 2014 HIA and GES Neighborhood Plans.

- Disconnected neighborhood due to three railroad lines, South Platte River, I-70 and I-25, and large dead-end industrial sites peppered through the neighborhoods.
- Lack of sidewalks, broken sidewalks, and lack of separated bike lanes, as well as lack of lighting.
- Lack of business and service destinations within GES.
- Inconvenient or disconnected public transit options, and lack of basic transit amenities like benches and shelters at bus stops.
- Unsafe, unclean and unmaintained underpasses below major roads, I-70 and I-25.
- Poor drainage systems leading to frequent street and sidewalk flooding.
- Large trucks on neighborhood roads, and the need for specific truck routes.
- Superblocks
- Despite proximity to downtown Denver, it is difficult to get there on any type of transit including foot, bicycle, car, public transit.
- Lack of East-West connectivity between Globeville and Elyria-Swansea
- Need for safer, more connected access to school zones. (Lack of access to local public schools due to I-70 and lack of sidewalks.)

RECENT DEVELOPMENTS

The 2014 Health Impact Assessment, recent Globeville and Elyria-Swansea neighborhood plans, as well as other recent neighborhood analyses have each identified or quantified economic, industrial, and environmental challenges associated with disconnected, unsafe, and inadequate infrastructure. Community concerns have also been acknowledged and documented. **Box 4** outlines some historically identified issue areas by legislators and community members. These challenges represent disproportionate burdens that GES neighbors bear on a day-to-day basis. These burdens do not exist independently, but rather are intertwined with social and environmental determinants of health to contribute to community wellbeing. **Box 5** identifies some areas of growth that have been made since the 2014 HIA, in response to many of the public concerns. Although many concerns remain, and connectivity is an ongoing community challenge, the City of Denver has invested in local development, and there is evidence of progress in the areas of connectivity and mobility. Where new infrastructure is developed, there is an ongoing need to ensure it continues to be well integrated into the existing bus routes, sidewalk network and broader systems of mobility in GES.

While the Department of Transportation and Infrastructure (DOTI) has made measurable progress on various connectivity-related issues in GES, the projects do not always factor in community members' top priorities. Centering

Box 5. Recent Developments in Connectivity and Mobility for GES.

- **Three transit lines with four new stations in the area**: Due to progress by the North Denver Cornerstone Collaborative, Globeville is now served by the 41st Avenue and Fox Street stations on the Gold Line, and Elyria-Swansea is served by stations at 38th and Blake and 40th and Colorado on The East Rail Line, with service to Denver International Airport and Downtown Denver Union Station. Finally, the North Metro Rail Line has a new station at the National Western Stock Show.[187,192]
- **Sidewalk Gap Program:** Funded primarily from the Elevate Denver Bond, the Sidewalk Gap Program was passed in 2017. It is an effort to fill in existing gaps in sidewalks, and it earmarked $17 million specifically for GES neighborhoods (out of $47.7 million total). These funds have been used to construct sidewalks along Jackson St., Josephine St., Thompson Ct., 52nd Ave., Cook St., and 46 Ave.[193]
- **Denver Deserves Sidewalks and Ordinance 307:** In 2022, voters passed this ballot initiative which makes sidewalk construction and maintenance the responsibility of the city, and residents pay an associated fee. Historically, maintaining sidewalks was the responsibility of adjacent property owners in Denver. This has the potential to improve sidewalk conditions throughout GES, despite a possible additional financial burden of maintenance fees.[193]
- **Denver Connector Microtransit Program**: This free, on-demand rideshare program started in Montbello in 2021 and was expanded to GES in 2022. The pilot will continue for two years before reevaluation. Rides are available between 6:00am-8:00pm Monday-Friday, with services available in English and Spanish. On-demand vehicles include wheelchair accessible vans, hybrids, and electric cars, which allow for greater access with minimal environmental harm.[194]
- **44th Avenue and Broadway Project:** This project, scheduled for completion in 2024, will improve pedestrian experience, aesthetic, access and safety along 44th Avenue between Delaware Street and Broadway. The project is located in the critical "Mousetrap" feature of GES, which has chronically impeded neighborhood connectivity and mobility.[195]
- **Brighton Boulevard Construction**: In 2015, The North Denver Cornerstone Collaborative and the city of Denver announced plans to invest $26 million into this three-mile street (which intersects the GES neighborhood), thereby developing it into a major connective gateway into River North and Downtown Denver.[196]

community members' concerns when developing community infrastructure can contribute to positive health outcomes including progress in physically active lifestyles and choosing active modes of transportation, as well as improved sense of community-efficacy and trust in local government's ability to support community needs. Efforts to enhance mobility and connectivity by the Denver city government have been robust, but education and communication regarding these efforts to GES community members may be lacking, resulting in some residents not being aware of recent projects.

Finally, growth in connectivity and mobility has the potential to increase gentrification in the GES neighborhood. Development may promote community mobility and movement but reduce a sense of belonging and psychological connectedness if community members feel that ongoing development is pricing out or pushing out community members who call GES home. This persistent threat to community stability and identity will be an ongoing consideration as infrastructure and connectivity in GES improves.

4.3. ODOR

Odor pollution is a recurring concern for GES community members. The 2014 HIA states that the odors in GES are a nuisance that can interfere with quality of life and hinder outdoor activities. Although odors do not have long-term direct effects on physical health, they can cause distress and reduce the desire to go outdoors.[197] Severe odors can have short-term effects such as headaches and irritation of the eyes or throat, though the effects stop when exposure is no longer present.[71] In 2014, GES consisted of 70% commercial or industrial businesses compared to the Denver average of 35%.[3] Many residents who live close to GES industries have reported experiencing unpleasant odors and have made complaints to the city about these odors. The 2014 HIA stated that in 10 years (2004-2014), there were 983 odor complaints made to Denver with over one-third coming from GES and many more have been made to date. However, residents still experience nuisance odors to this day.

Community members have mentioned odor as a nuisance that contributes to a perceived lower quality of life in GES compared to other neighborhoods in Denver. Current concerns from GES community members are odors from marijuana grow facilities, two major highways, railyards, and commercial and industrial businesses.[198] Denver Department of Public Health and Environment (DDPHE) regulates nuisance odors, conducts investigations, and gives citations if necessary. The narrative (Deliverable 1.4) highlights that community members often feel ignored by city officials due to a perceived lack of response to 311 reports.

In 2022, there were a total of 74 complaints, 22 of which originated in GES. Of the 22 complaints from GES, 20 were about the strong smell of the Purina factory, one related to marijuana odors near Colorado Blvd. and I-70, and one stated a bad licorice smell outside of their home in Elyria-Swansea. All the complaints made about Purina and marijuana odor were followed up by the city with a status of "service completed". The complaint over licorice odor had a status of case closed because there was no response from the person who made the complaint. At the time of writing this report, we received odor complaint data for January and February 2023. These data included a total of 13 odor complaints, with two of those coming from Elyria-Swansea. Both complaints were about the Purina factory and stated that the smell was very strong. The odor complaints records indicate that the biggest source of odor around GES are factories such as Purina and the many marijuana cultivation centers in GES. DDPHE reports that the number of odor complaints has decreased since peaking in 2015 and that odor complaints related to marijuana have decreased substantially since that time.

ODOR COMPLAINT PROCESS

Denver Department of Environmental Health is responsible for regulating odors. There are several scenarios in which a facility may be required to submit an odor control plan (OCP). First, if a facility receives five or more complaints from separate households or businesses within a 30-day period, it must submit an OCP. One main limitation of this however is that the requirement can only be applied to facilities located within the city boundary. As GES is proximate to CCoD's border with Adams County, residents are frequently downwind from industrial processes that generate odors outside the city limits. There are no pathways to remediate odors that originate from outside of the county. Second, during site inspections, an investigator may use a portable device called the Nasal Ranger to identify and measure odor intensity. This instrument calculates odor strength using a "dilution to threshold ratio." The standard for requiring a facility to submit an OCP is a one-to-seven dilution threshold. Third, facilities that conduct pet food manufacturing, marijuana growing, processing, or manufacturing, rendering and meat byproduct processing, asphalt shingle and coating materials manufacturing, petroleum refining, sewage treatment, and wood preservation are required to submit OCPs.

City and County of Denver have a template for marijuana cultivation centers and marijuana-infused products which describes what the facilities need to include in their odor control plan. It must include the floor plan of the facility and specify the locations where odor emitting activities occur. It must include a description of the odor emitting activities or processes that happen at the facility, the sources and locations of the odors, and lastly the phases of odor emitting activities such as specifying the frequency and duration of odor emissions. There is a section to describe their odor mitigation process where they have to detail the administrative and engineering controls that the facility implements or will implement to control odors. In the administrative controls section, it asks for details of building management responsibilities, staff training procedures, and recordkeeping systems and forms. The engineering controls section asks for evidence that all engineering controls for odor mitigation were installed and operational and that they are sufficient and effective to mitigate odors from all odor sources. After the odor control plan is submitted and approved, the facility should include a comprehensive timeline for design, review process, installation, and operation of their odor mitigation processes from their control plan. After everything is purchased and installed, facilities will go through inspections and approvals by City agencies. Finally, the odor control plan should include a mechanism, and responsible staff, for receiving odor complaints and how they will be handled and recorded. The odor control plan has been in place since 2017 and is the only odor control system that the City and County of Denver have in place.

Denver Department of Environmental Health (DDPHE) says that they investigate a complaint as soon as one is received. In order for a complaint to be counted towards the 5 or more complaints within 30-days, the complainant needs to provide their name, address, and phone number, time and date of observations, and a description of the nuisance odor which includes a description of the estimated location or source of complaint and wind or weather condition at the time, if possible. Denver Department of Public Health and Environment Division of Environmental Quality will then investigate and evaluate the complainant's validity on a case-by-case basis. DDPHE inspectors are certified by the state to make a qualitative assessment of odor intensity and source. Factors DDPHE inspectors evaluate are weather conditions on the day of the complaint, the proximity of the suspect facility to the complaint location, and the suspect facility activities at the time of the complaint. If the suspect facility already has an odor control plan in place, the inspectors will determine if the facility is in compliance of its odor control plan. If the facility is within compliance, DDPHE will work with the facility on a case-by-case basis to determine if the facility's mitigation efforts are effective and appropriate. If a facility is found to be out of compliance with its odor control plan, DDPHE may cite the facility for violating the requirements.

4.4. NOISE

Noise is unwanted and disturbing sound that can affect the well-being of people. The EPA considers noise exceeding 55 decibels outdoors and 45 decibels indoors as an annoyance that can interfere with daily activities. The 2014 HIA identifies the contributors to exceeding the EPA noise thresholds as train horns, train engines, industrial operations, and the parts of I-70 that run through the neighborhoods. When the 2014 HIA was written, residents expressed experiencing distress about excessive noise in the neighborhood and mentioned their concerns during the community involvement portion of drafting both the Globeville and Elyria-Swansea Neighborhood Plans in 2015.[10,11]

Loud noises, particularly generated by industry and trains, can impact the mental well-being of residents, including increasing anxiety and stress.[197] Excessive noise can damage health depending on its intensity, duration, and type of noise. Long-term exposure to moderate noise levels can impact sleep quality and school and work performance.[3] Health studies suggest that there is a higher risk for cardiovascular disease in people who are chronically exposed to high levels of road or air traffic noises.[199] Negative health impacts from excessive noise start to occur at 50 dB and increase as ambient noise increases. This relationship is thought to occur as noise-induced stress worsens biological risk factors such as blood pressure, blood flow, sugar levels, and fats.[199]

As discussed previously and in the Narrative (Deliverable 1.4), zoning in GES presents challenges as industrial zones are located directly adjacent or in close proximity to residential zones, and many residential zones are immediately next to interstates. The Federal Highway Administration guidelines indicate that traffic noise is not a serious problem for people who live more than 500 feet away from heavily traveled freeways, however, there are residential areas of GES that are within 500 feet of I-25 and I-70.[200] Further, a map of transportation-related noise from the US Department of Transportation shows that most of GES experiences elevated levels of noise **(Figure 34)**.

Community members have indicated an interest in having noise barriers installed throughout GES. However, CDOT only builds noise barriers required by Federal regulation Title 23 Code of Federal Regulation Part 772 [23 CFR 772]. CDOT conducted a noise impact study as part of the planning process for the Central 70 project, which resulted in requiring a noise barrier to be installed in Elyria from Brighton Blvd. to York St. on the north side of the highway.[201] A visual check confirmed that this barrier was installed. The noise impact assessment considered the feasibility and reasonableness of noise barriers. However, the federal guidelines used in the traffic study were based on a residential noise limit of 66 dB, which is substantially louder than what the EPA considers irritating. These studies were based on models, while actual measurements of noise and potential impacts in GES are lacking.

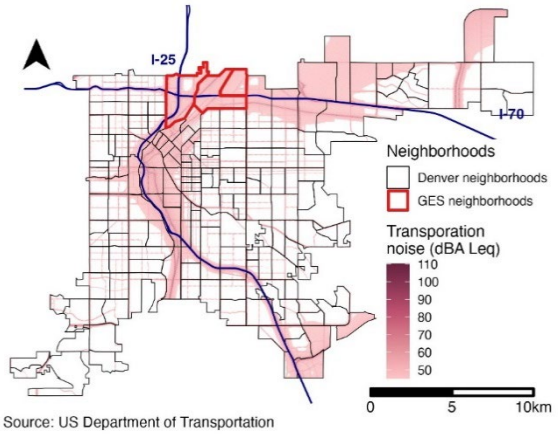

Figure 34. Modeled transportation related noise in Denver, Colorado, 2020.

NOISE COMPLAINT PROCESS

Noise complaints can be made to DDPHE through an online form or by calling 311. When complaints of excessive noise are received by DDPHE, an inspector is assigned to investigate it. If the complaint is legitimate, then the individual, company, or organization determined responsible for the source of the noise receives a verbal or written warning of the

violation requiring them to reduce noise to a legal level. If the noise source does not comply with the warning, an administrative citation or court summons is issued. If found guilty, a fine of up to $5,000 per incident can be levied by the court. DDPHE's Division of Environmental Quality processes these complaints and needs specific information to be provided in order to properly process and address the complaints. To be investigated, complaints need to contain the complainant's name, address, phone number and email, incident address, incident date and time, and a description of the activity causing the offending noise. If complaining about construction, delivery trucks, or trash truck noise there is more required information to include in the complaint. The additional information wanted for these noise complaints includes the date and day of the week that the offending noise occurred, the complete name of each of the businesses creating the noise, and the time of day or night that the offending noise occurred. If complaining about delivery truck noise, DDPHE would also like to have the complete name and address of the business receiving the delivery in addition to the delivery company's name. Without all of the information mentioned, the complaints cannot be processed or addressed.

As demonstrated through the 311-complaint data, and as we have heard from residents, noise complaints may not be accurately reported. There is a need for consistent data collection on sound levels in GES to demonstrate if noise levels are higher than in other parts of Denver. Further research and community engagement are required to gain a better understanding of the burden of excessive noise in GES. Additional future research should include a study focusing on how the I-70 cap park mitigates noise levels in GES.

4.5. SOIL AND SUPERFUND SITES

Soil contamination has been a major concern throughout the GES Community Health Study. The primary concern is exposure to contaminated soil due to historical smelting operations. There is also confusion about Superfund site remediation activities. The Globeville, Elyria, and Swansea neighborhoods have a history of housing various industrial operations, including smelting plants like the Omaha-Grant, Argo, and Globe Plants. These plants refined metals such as gold, silver, copper, lead, and zinc, causing soil contamination in parts of GES. Two sites that have undergone extensive soil cleanup by either the state of Colorado or EPA are the American Smelting and Refining Company (ASARCO) Globe Plant and Vasquez Boulevard and Interstate 70 (VB/I-70) site. Contamination concerns for the ASARCO site are arsenic, lead, cadmium, and zinc, while the VB/I-70 site contamination concerns are arsenic and lead in soil, and cadmium in groundwater near the old Argo smelter site. Further details about potential health risks associated with exposure to elevated levels of these metals can be found in the health sections of this report. According to CDPHE and EPA reports, any remaining exposure risk is low, with almost all residential properties being tested, and remediated when required for both ASARCO and VB/I-70. The following sections describe the remediation actions taken for ASARCO and VB/I-70 operable units. Additional information regarding water concerns and superfund activities is highlighted in the water section of this report.

ASARCO

The American Smelting and Refining Company (ASARCO) Globe Plant operated from 1886 to 2006. The Globe Plant was established in the 1880s to refine silver and gold. In 1901, the Globe Plant converted to lead smelting with operations continuing through the late 1910s. Between 1919 and 1926, ASARCO produced arsenic followed by cadmium until 1993. In 1983, Colorado sued ASARCO and in 1993 a consent decree was signed, a court-ordered settlement requiring ASARCO to provide funds for the remediation of the Globe Plant site. The ASARCO plant, which was roughly 86 acres, was divided into four operable units (OUs) which further defined the boundaries of where cleanup actions needed to

take place **(Figure 35)**.[3] OU1, OU2, and OU4 primarily deal with issues specific to the ASARCO smelter site itself, and OU3 focuses on the offsite soil contamination in nearby residential and commercial areas.

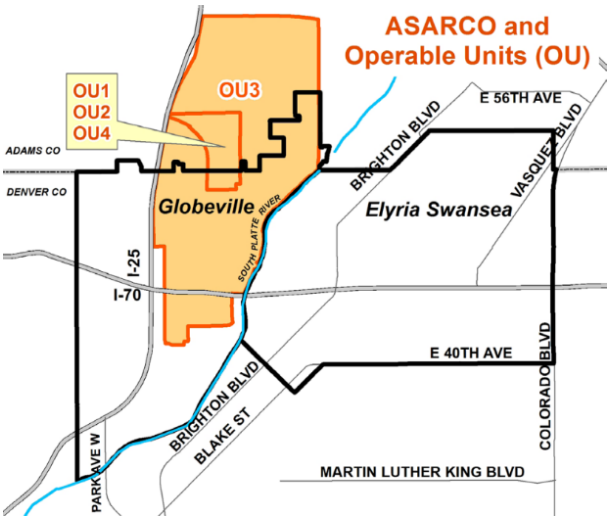

Figure 35. Map of ASARCO Operable Units. Figure from Denver Department of Environmental Health. *How Neighborhood Planning Affects Health in Globeville and Elyria Swansea.*; 2014.

OU1 – Former Neutralization Pond. Contaminated sediments were excavated and consolidated on the property. These sediments were combined with other ongoing activities within the site boundary, like soils from OU2 and OU4. Much of the work for the former neutralization pond occurred before 2005, and any remaining exposure risk is considered low.

OU2 – Groundwater and Surface Soils. Contaminated surface soils were combined with removed sediments from OU1 and OU4. To prevent further groundwater contamination, water was captured, treated, and moved off-site. The remaining cadmium plume is slowly moving offsite and will be treated naturally through this process. In anticipation of the plume's movements, CDPHE monitors the groundwater status and will be legally responsible if contamination levels become actionable. DDPHE monitors the South Platte River in several places, one of which is located roughly one-half mile downstream from OU2 **(see Water)**. Sample monitoring efforts have not indicated an increase in cadmium related to ASARCO OU2.[3] As of October 2022, the cleanup of the former sedimentation pond, industrial drainage ditch, and retention ponds have been completed.

OU3 – Community Soils. The majority of community soils (OU3) were remediated between 1994 and 2002. Cleanup activities included sampling residential properties, schools, parks, and commercial properties. **Figure 36** outlines the number of residential properties sampled and cleaned up under state action and class action settlements. Clean up steps included removing twelve inches of soil in yards with sample concentrations above naturally occurring

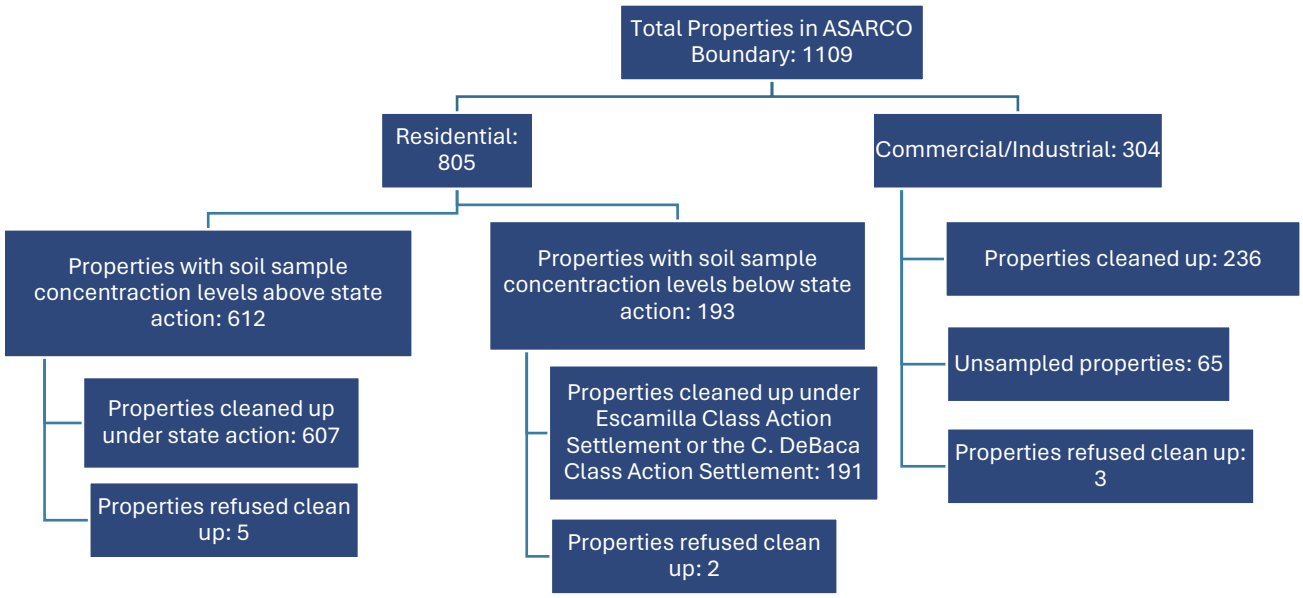

Figure 36. Status and count of residential soil remediation in the ASARCO Operable Unit 3 – Community Soils, as of 2023.

background levels. The removed soil was replaced with clean fill. For vegetable gardens, a similar process occurred but 18 inches was removed. Similarly, all contaminated schools, parks, and commercial or industrial properties in the area received soil remediation if they allowed access. Only a few residential and commercial properties refused access for the initial sampling or cleanup.

Any remaining exposure risk to potentially contaminated soil is considered low. The 7 residential properties that refused sampling or soil cleanup have a Notice of Environmental Conditions on their property documenting the potential of contamination. For commercial and industrial properties, 65 remain unsampled, mainly due to existing physical barriers like a paved parking lot, or the freight railroad track going over the property.

OU4 - ASARCO Globe Plant site. The Globe Site consists of 78 acres containing residential and commercial properties and 53 current and former manufacturing facilities. While some of these properties have been cleaned up, when this is unable to take place properties are placed under an Environmental Covenant. ASARCO OU4 was able to achieve regulatory closure in June 2015.

VASQUEZ BOULEVARD AND INTERSTATE 70 (VB/I-70)

Historically, the Vasquez Boulevard and Interstate-70 (VB/I-70) Superfund site was a major smelting center for the Rocky Mountains and the West. Boundaries for VB/I-70 include the former Omaha-Grant smelter and the former Argo smelter, both of which began operating in the 1870s. Today the VB/I-70 Superfund site covers approximately 4 square miles in North Central Denver, Colorado. The site spans a number of neighborhoods, including Swansea, Elyria, Clayton, Cole, and portions of Globeville and Five Points.[202] There are over 4,000 residential properties within the site boundaries. The site also contains a number of schools, parks, and playgrounds, as well as commercial and industrial properties. VB/I-70 was listed on the National Priorities List in 1999 and divided into three operable units (OUs) **(Figure 37)**.[3] OU1 consists of residential properties, schools, and parks. OU2 and OU3 are non-residential, commercial, and industrial properties.

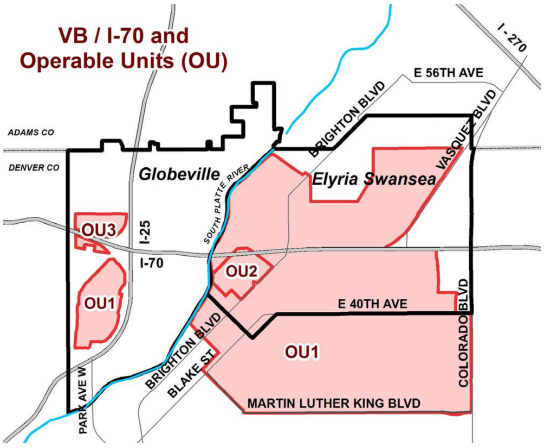

Figure 37. Site boundary for Vasquez Blvd. and I-70 Superfund Site. This site is next to ASARCO Superfund site. Figure from Denver Department of Environmental Health. *How Neighborhood Planning Affects Health in Globeville and Elyria Swansea*.; 2014.

OU1 – Residential yards, parks, and schools. There are approximately 4,470 residential properties, 10 schools, and 7 parks in VB/I-70 Operable Unit 1 (OU1).[203] Sampling and clean-up actions have been taking place since 1998. Extensive soil sampling of the majority of the residential properties was conducted in 1999 and 2000. EPA set remedial action levels at 70 milligrams per kilogram (mg/kg) arsenic and 400 mg/kg lead to identity properties with yard soil concentrations that equaled or exceeded the action levels[a].

[a] Numerous public comments on the OU1 Proposed Plan released in May 2002 requested that EPA lower the soil concentration cleanup levels from 540 ppm to 400 ppm for lead and from 240 ppm to 70 ppm for arsenic to be consistent with those adopted for the ASARCO OU4 Globe Site. In May 2003, an addendum was made to reflect these changes.

In 2000, CDPHE collected blood samples from preschool children to test for blood lead levels. Results from this sampling campaign found that roughly 10% of the 86 children tested had blood lead levels above 10 µg/dL (the action level set by the CDC).[204] However, it was not possible to determine how much lead contamination in residential soils contributed to these blood lead levels. A cancer study was conducted in 2003 by CDPHE to investigate cancer cases of residents living within the VB/I-70 boundary. Researchers used cancers reported to the Colorado Cancer Registry between 1982 and 1998. The study found that while the census tracts within VB/I-70 had higher rates of multiple cancers, there was no relationship found between arsenic exposure and these cancers. The study does acknowledge that the higher rates of various cancers are likely due to socioeconomic and environmental factors, including, but not limited to, air quality, race, work environment, and access to medical care.[56] Also in 2003, The Agency for Toxic Substance and Disease Registry (ASTDR) conducted a public health assessment regarding lead and arsenic in the residential soils of VB/I-70.[204] Results from this assessment indicated that soil arsenic levels at many (but not all) of the properties in the VB/I-70 study area were safe for children and adults with typical soil intake levels. However, it is important to note that cases of arsenic poisoning may be missed because typical symptoms include nausea and vomiting.

In 2005, CDPHE investigated children's exposure to soil contaminated with lead and arsenic. Results indicated that blood lead concentrations were similar to those reported in other urban areas with houses painted with lead-based paint. These findings suggest that exposure to contaminated soil during normal outdoor play has not resulted in lead exposures that are unusually high compared to US children. Results do suggest direct soil ingestion may have resulted in elevated blood lead levels in a few children.[62] In 2009, EPA conducted the first Five Year Review of the remedy for OU1 where results indicated that the cleanup was not protective of human health for properties where EPA was not granted access from the property owner to either sample or cleanup despite EPA contacting the owners numerous times.[203] In the fall of 2012, a final residential property investigation on outstanding properties was conducted. During this effort, soil sampling was completed for approximately 63 out of 155 remaining residential yards. Twenty-two residential yards and one garden site were identified as candidates for remediation. From the 2012 investigation, it was determined that it was not cost-effective to keep options for sampling and cleanup for unaddressed properties open, therefore Environmental Covenants were placed on these properties.

Table 11 summarizes the number of properties that received soil cleanup by year. Soil sampling as part of the remedial action that took place between 2005 and 2015 addressed a total of 382 properties, with most of the soil sampling being conducted in 2005 and 2006. A total of 31 properties were identified as requiring soil removal because the lead and/or arsenic concentrations exceeded the action level(s). Additionally, as part of the clean-up process, EPA sampled exterior lead-based paint at properties that had received soil removal due to lead concentration; 312 properties meet this criterion. From that, 128 properties had peeling lead-based paint that could cause recontamination of the soil, so exterior lead-based paint abatement was conducted.

In 2019, EPA removed OU1 from the National Priorities List, meaning no further response is required to protect human health or the environment. As of September 2019, 10 residential properties within OU1 have a Notice of Environmental Conditions and 43 have a Notice of Potential Environmental Conditions.[205]

Table 11. Number of residential properties remediated each year in the VB/I-70 Superfund site.

YEAR	NUMBER OF PROPERTIES REMEDIATED
1998 – 2003	48
2003	133
2004	326
2005	212
2006	65
2008	3
2013	21
2014	4
2015	2

OU2 – Former Omaha Grant Smelter. OU2 is a non-residential commercial and industrial area that includes the Denver Coliseum, a portion of Globeville Landing Park, and surrounding businesses. In 2009, EPA conducted a baseline human health screening assessment that indicated arsenic and lead in soil were of concern. Also, in 2009, EPA published an ecological risk assessment, reporting that deep soil samples under the Pepsi Co. bottling and commercial buildings along Brighton Blvd. had lead, zinc, and arsenic concentrations that could be harmful to plants.[206] However, water and sediment in the South Platte downriver of OU2 were about the same as upriver and did not have arsenic, lead, cadmium, or zinc at concentrations dangerous to aquatic life (see **Water** for more information regarding the water testing associated with OU2). The start of remediation of OU2 took place between 2016 and 2018 as part of the Globeville Landing Outfall Project. CDPHE reports that their Superfund program's current focus is on the remaining parts of OU2, including the National Western Center.

OU3 – Former Argo Smelter. The majority of the OU3 area is paved and has been extensively redeveloped since the smelter stopped operating. Today it is a commercial area northwest of the I-25 and I-70 interchange. A feasibility study was conducted in 2007, but since then EPA has been waiting on more funds to conduct remediation.

4.6. WATER

The 2014 HIA focused on potential outdoor exposures related to water quality. Mainly, exposure to bacteria in surface water when participating in recreation activities along the South Platte River (SPR) and Heron Pond, the two large water bodies located within or near GES. At that time, the 2014 HIA identified that upstream pollution in Denver results in poorer water along the South Platte through GES, and that Heron Pond water quality is impacted by runoff from the ASARCO Globe facility site.[3] Contrasting this, community members have expressed more concern regarding drinking water quality in their homes than water quality in streams and ponds.

SURFACE WATER

South Platte River

The South Platte River is facing water quality issues and has been listed as an impaired water source for drinking due to high levels of arsenic concentration. This issue starts upstream of Denver at Chatfield Reservoir.[207] However, data from DDPHE indicates that the annual mean arsenic concentrations have remained relatively stable along the South Platte River since 2014.[208] The South Platte River also commonly exceeds standards for E. coli, nitrogen, and phosphorus. E. coli is a pathogen that can cause severe illness or infection and is used as an indicator for the presence of other pathogens.[209] The concentration of E. coli varies by season and is highest in the summer and fall, and excluding seasonal fluctuations, E. coli concentrations have not changed significantly since 2014.[209] Arsenic and E. coli concentrations slightly increase as the water flows through Denver, with the highest median concentrations generally found in Globeville.[208]

Nitrate and phosphorous are nutrients that can lead to algae blooms, which can harm aquatic life. These nutrients have higher concentrations downstream of the South Platte Renewal Partners Wastewater Treatment Plant located on Denver's southern border.[209] Denver Water's 2021 Water Quality scorecard rated the South Platte River as poor for direct contact activities like swimming, but good for fishing. However, the same report recommends against consuming fish from any tributaries of the South Platte River.[209]

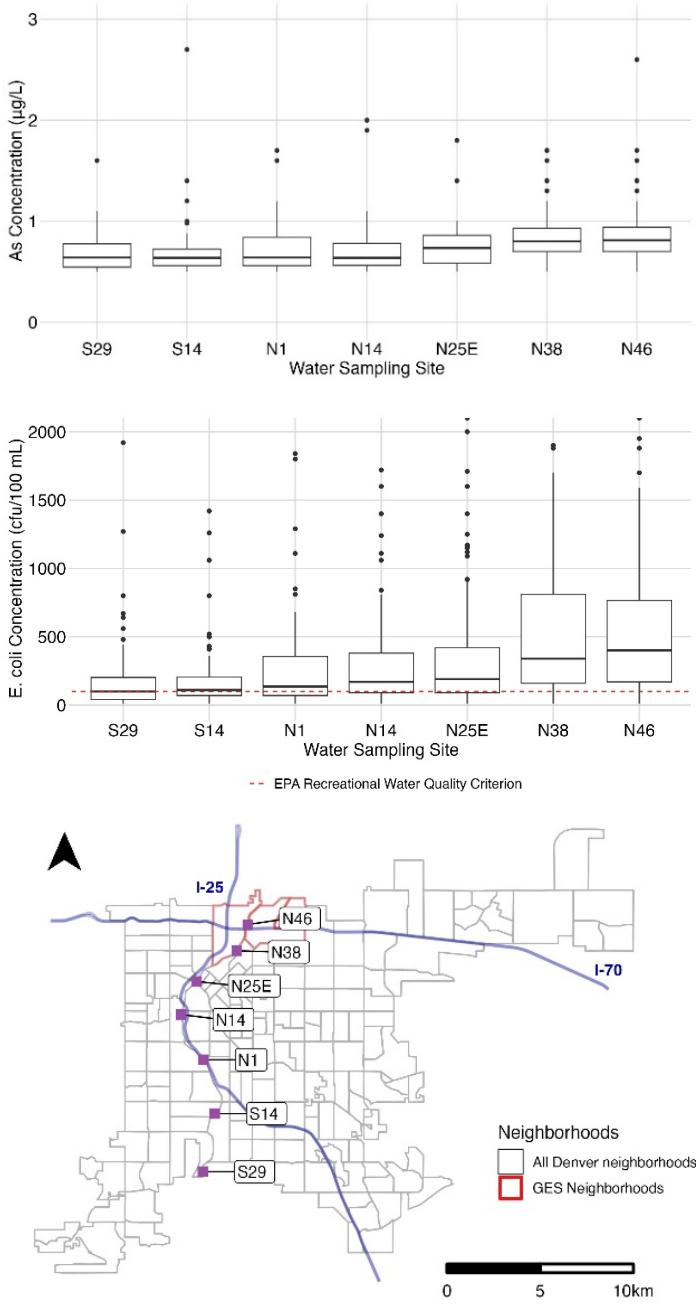

Figure 38. Water quality trends along the South Platte River through Denver 2014-2022 for arsenic (top) and E. coli concentrations (middle) with accompanying map of testing sites (bottom). The South Platte River flows south to north. Thus, the graphs show water quality progression through Denver from left to right.

In 2009, EPA published a screening ecological risk assessment (animals and plants) for VB/I-70 Operable Unit 2 (OU2) site based on previous studies conducted as part of the remediation efforts.[206] OU2 includes the area underneath the Denver Coliseum, Pepsi Co. bottling facility, Globeville Landing Park, and the South Platte. (See **Soil and Superfund Sites** section for more information regarding VB/I-70 OU2). Both surface water and river sediment were assessed for metals (arsenic, cadmium, copper, lead, zinc) upstream and downstream from OU2 (downstream is north towards Globeville) using data from a 2005 sampling effort. EPA concluded that arsenic, lead, cadmium, and zinc concentrations were about the same up and downstream of OU2, and that the concentrations are not dangerous to aquatic life. This was interpreted to mean that groundwater discharge from OU2 was not impacting the water quality of the South Platte River. This conclusion continues to be supported by water quality testing, which does not show an increase in arsenic from the sampling site upstream of OU2 at the RiNo Art Park (N38) to downstream of the site near the National Western Center (N45) **(Figure 38)**.

While the South Platte River does have water quality concerns relating to arsenic and E. coli, these do not present a large health risk. GES residents obtain drinking water from Denver Water (see below), and the remaining risk of exposure to either contaminant would occur while participating in recreational activities such as swimming, bathing, and fishing. However, the South Platte River is not currently used for recreational activities, and thus the exposure risk is minimal.

Heron Pond

The only other major body of surface water in GES is Heron Pond. Water quality in Heron Pond is not regularly reported and has only been tested a few times in the last decade. Formal reports are not available for Heron Pond, but information on existing conditions is available in the park's master plan and DDPHE shared their findings from these tests with the ENVIRONS team.[210] Metal concentrations were found to be relatively low, and since the pond is too shallow for swimming, the overall health risk is minimal. Metals in the sediment from smelting activities are overlayed with a capping layer of decades of road dust and runoff. For this reason, dredging has not been done as that will make the water quality worse.

GROUNDWATER

GES is located within the Denver aquifer, south of the Upper Arapahoe aquifer and north of the lower Dawson aquifer, all of which are part of the Denver Basin Aquifer System. The Denver aquifer has water levels that rise and fall with seasonal conditions, such as drought. However, direct everyday exposure to untreated groundwater is low within the GES communities. There is more potential of water exposure through surface water recreation along the South Platte River and Heron Pond, or through treated drinking water supplied to homes by Denver Water.

DRINKING WATER

Residents have expressed multiple concerns about drinking water throughout the GES Community Health study period, mainly that the drinking water is unsafe and contaminated. Denver Water's drinking water supply originates from surface water, mainly rain and snow precipitation.[211] Although rare, drinking water supplies are at risk for a variety of contaminants such as viruses from agricultural livestock operations, naturally occurring metals, stormwater runoff containing chemicals, or even petroleum related contaminants from gas stations.[212] However, Denver Water publishes an annual water quality report which provides information on potential contaminants and the potential level of risk. To ensure water leaving the treatment facility meets regulatory levels, Denver Water follows an extensive testing program which collects samples daily, weekly, and monthly.[212]

According to the annual water reports, water leaving Denver Water's treatment facilities is safe for human consumption. Unfortunately, this comes with one major caveat. Water can become contaminated after it leaves a treatment plant. The primary concern for GES is the introduction of lead into the drinking water supply. Lead in drinking water is caused by lead service lines, which connect the water main under the street to an individual house's plumbing system. Houses built before 1951 are at the highest risk of having lead service lines in Denver. Another potential source of lead in drinking water is from lead solder used to connect pipes, which was common before 1987. Denver Water started the Lead Reduction Program in 2020, which focuses on replacing lead service lines on a neighborhood-by-neighborhood basis as well as individual properties that pose a higher risk of exposure, like schools and daycare facilities. Residents can search to see if their property is suspected or known to have lead service lines here. The Lead Service Line Replacement initiative is estimated to be completed by 2035. As of June 2022, Denver Water reported 12,381 lead service lines had been replaced.[213] Other components of the Lead Reduction Program include increasing the pH level of the water, developing a publicly available inventory of customer-owned lead service lines, and a filter program. Denver Water reported that by increasing the pH and alkalinity, lead levels had decreased by 60%, meaning that these efforts have brought the lead concentration down well below EPA's action level[a].[213]

[a] Denver Water 90th percentile lead was 3.9 ppb in 2022. The EPA action level for lead is 15 ppb.

5. RECOMMENDATION EVALUATIONS

There were 36 recommendations presented in the 2014 HIA. Recommendations were split into two categories a) Health Recommendations to Be Included in the Globeville and Elyria Swansea Neighborhood Plans and b) Health Recommendations that Can Be Addressed by Other Means (by the City of Denver, private sector, or nongovernmental organizations). For each listed recommendation, lead agencies and partners were assigned. However, there is one large issue with this – what happens to recommendations assigned to a lead agency whose primary mission does not revolve around health in all policies and principles? There were 26 recommendations identified to be included in the Globeville and Elyria-Swansea neighborhood plans and 10 recommendations identified that can be addressed by other means. The following table provides an evaluation of the 2014 recommendations. Many of the 2014 recommendations contain action words like explore, prioritize, improve and promote. These recommendations are difficult to evaluate as there are no definitive deliverables, products, or project completions to assess. From a community standpoint, how are community members supposed to hold the lead agencies accountable if efforts are only internal and not provided publicly? Therefore, we propose that the lead agencies assigned to each recommendation provide reports or news press releases on the status of work to the community on a regular basis. In **Table 12**, we provide some examples of questions heard from community members that should be addressed by the lead agencies.

Table 12. Current status and evaluation of recommendations from the 2014 HIA, as of December 2023.

SECTION OF REPORT	# IN 2014 HIA REPORT	LEAD AGENCY	RECOMMENDATION	2023 EVALUATION
Air Odor Noise	1.a	CPD	Minimize negative environmental impacts on residential neighborhoods from industrial uses through methods such as land use designation, zoning, buffering, and other means	There are continuous updates to zoning and land use designations. However, residents still experience negative impacts from proximity to industrial uses including impacted air quality, noise, and odor.
Connectivity and Mobility	2.a	CPD	Prioritize street infrastructure improvements, including sidewalks, bike lanes, bus stops furnishings, and intersection crossings, to achieve the goals of the 2014 City Council Priorities, Denver Moves (2011) and the Strategic Transportation Plan (2008).	There have been multiple infrastructure improvements (outlined in Connectivity and Mobility) including approval of funding specifically for sidewalks in GES. However, residents continue to report that there are areas that lack sidewalks and that bus routes, and stops do not adequately serve the community. A greater in-depth analysis of the factors associated with traffic accidents in GES would be required to identify the exact factors associated with the higher rate of accidents and potential solutions.
Connectivity and Mobility	3.a	CPD	Connect streets as prioritized in the Globeville and Elyria Swansea Neighborhood Plan "Street Grid Connectivity Map."	The Street Grid Connectivity Map, available in the Globeville Neighborhood plan, identifies adding connectivity between Washington St. and the South Platte River towards the National Western Center. This has been partially achieved with the connection of 51st Ave to the National Western Center. However, 49th St remains unconnected. Additionally, the plan recommends connecting 49th and 50th streets from Pearl west to the railroad, then creating bike and pedestrian paths over the railroad to connect to what is now the Platte Farm Open Space. As of 2023, this has not been completed.

SECTION OF REPORT	# IN 2014 HIA REPORT	LEAD AGENCY	RECOMMENDATION	2023 EVALUATION
Community Safety	4.a	DPD	Explore measures to reduce the incidence of pedestrian and bicycle injury crashes at locations where multiple crashes have occurred. Such locations may include 'gateway intersections' such as 47th & York and 47th & Brighton Blvd. in Elyria Swansea, and 45th & Washington and 51st & Washington in Globeville.	Despite having a lower rate of pedestrian and bicyclist crashes than the Denver average, there is still room for improvement to reach Denver's Vision Zero goal. A preliminary hotspot analysis shows pedestrian and bicyclist-involved crashes occur frequently at 45th and Washington and along Brighton Blvd (data not shown). A greater in-depth analysis of the factors associated with traffic accidents in GES would be required to identify the exact factors associated with the higher rate of accidents and potential solutions.
Noise	5.a	DEH	Noise in residential areas and schools near major roadways and highways should be mitigated to no more than 55 decibels, where feasible.	The Central 70 project used the federal guidelines of 66 decibels to determine where noise barriers were required, resulting in noise barriers only being recommended in Elyria from Brighton Blvd. to York St. on the north side of the highway. There have been no other efforts to mitigate noise to our knowledge.
Noise	6.a	DEH	Sound walls or other noise mitigation measures are recommended along major roadways and highways where sound levels at schools and homes are expected to increase by 5 decibels or more, or exterior noise levels are expected to be 55 decibels or greater, or interior noise levels are expected to be 45 decibels or greater. Community preferences regarding aesthetic qualities of sound mitigation should be considered.	The Central 70 project used the federal guidelines of 66 decibels to determine where noise barriers were required, resulting in noise barriers only being recommended in Elyria from Brighton Blvd. to York St. on the north side of the highway. Prior to construction, storm windows were installed by CDOT in homes in Elyria and Swansea near the construction and in Swansea Elementary to mitigate noise.[201] There have been no other efforts to mitigate noise to our knowledge.
Noise	7.a	PW	Explore solutions to reduce the health impacts from trains. These could include "Quiet Zones" (intersections specifically designed so that trains do not have to sound horns).	Train noise continues to be a persistent problem. Using the railroad crossing locator app from the Federal Railroad Administration, no freight train crossings in GES are designated as quiet zones. Only A-line crossings in Elyria-Swansea are designated as quiet zones.
Community Safety	7.a	PW	Explore solutions to reduce the health impacts from trains. This could include grade separation of trains from other modes of transportation (i.e., roads constructed over or under tracks to eliminate the need for trains to sound horns at these crossings and to aid in the prevention of people and trains crossing paths). One intersection to explore for potential modification includes the train crossing at 47th St. & York St.	A pedestrian and cyclist bridge was built over the railroad at 47th and York to facilitate safe crossing, particularly for school children heading to Swansea Elementary. However, many pedestrians continue to cross at grade-level by climbing through the fence because the bridge lacks an elevator and there can be drug paraphernalia or people experiencing homelessness on the bridge. We do not know of other mitigation efforts to reduce the health impact from trains.
Odor	8.a	CPD	Mitigate the odors and emissions from marijuana grow facilities in residential neighborhoods through methods such as land use designation, siting, buffering, or other means.	DDPHE has put an odor complaint process in place to identify odor events and has worked with marijuana facilities on the implementation of odor control strategies. Marijuana odor complaints have greatly reduced since 2014, which may be due to these efforts or residents not reporting odors when they do occur. Further research and community outreach efforts are required to ensure odors are being properly mitigated.

SECTION OF REPORT	# IN 2014 HIA REPORT	LEAD AGENCY	RECOMMENDATION	2023 EVALUATION
Connectivity and Mobility	9.a	CPD	Improve connectivity to parks, trails and recreation, especially to the South Platte River trails and parks.	There have been multiple projects to increase park access in Globeville. These include the Platte Farm Open Space north of Argo Park and the Riverfront at the National Western Center. In addition, the Heron Pond-Heller Open Space and Carpio Sanquinette Park redevelopment project is in progress. These efforts have increased access to greenspace in Globeville and improved connectivity to the South Platte trail. In Swansea, the Central-70 project included construction of a new 5-acre cover park that connects the north and south sides of the neighborhood.
Access to Goods and Services	10.a	OED	Incentivize development of retail goods and services, including grocery stores.	Despite periodic news stories of potential progress on a new grocery store, this has not yet been realized within GES. In fact, residents report decreased access to food and services from demolition of some stores during the Central 70 project and a marijuana dispensary taking over the location of a convenience store. Some questions that remain unanswered include 1. What type of incentivization does this recommendation entail? 2. Are developers incentivized monetarily in this effort? If so, where does this funding come from?
Air Connectivity and Mobility Community Safety	11.a	CW Montero	Review truck routes in the neighborhoods to improve environmental quality, safety and connectivity. Examine current truck routes, particularly adjacent to schools; explore potential modifications as necessary; and make any needed changes to the City truck route ordinance for consistency with state regulations.	The Washington St study identified potential truck routes with the input of community members and local businesses.[214] However, we are unclear on the implementation of the proposed routes. It is important to note that Councilwoman Montero was in office at the time of the 2014 HIA, the appropriate lead agency in 2023 is Denver City Council District 9.
Connectivity and Mobility	12.a	CPD	Improve access and connectivity to and through residential neighborhoods and the redeveloped National Western Center.	Connectivity to the National Western Center has been improved with the completion of 51st from Washington over the South Platte. The I-70 cover park provides some increased connectivity in Swansea. This recommendation still stands, as a large part of the National Western Center is still under construction. CPD should be involved in the connectivity and mobility efforts throughout the redevelopment project.
Connectivity and Mobility	13.a	PW	Implement “Complete Streets” including sidewalks for all new and redesigned streets, to provide safe and convenient access for all users (per existing City Policy #26, adopted May 2011).	Complete streets elements are included in the preferred alternative for the Washington St redevelopment.[214] However, construction is not expected to start until 2025. Starting in Elyria, Brighton Blvd through the River North District has been redeveloped and includes complete streets elements such as improved bike and pedestrian facilities.[215]

SECTION OF REPORT	# IN 2014 HIA REPORT	LEAD AGENCY	RECOMMENDATION	2023 EVALUATION
Connectivity and Mobility	14.a	CW Montero	Improve connectivity and safety in School Zones. Improvements could include analyzing current School Zones and making modifications as necessary, including Safe Routes to School best practices.	The 47th and York pedestrian bridge was designed in part to provide safer access to Swansea Elementary. However, as discussed previously, the bridge is often not used. The I-70 cover park in Swansea connects directly to the school and may provide a safer route from the south side of the interstate than what was available before. In 2021, the Denver Safe Routes to School Action Plan identified Swansea Elementary as the fourth highest priority school in Denver, yet no additional plans or assessments have been conducted since then that we could find.[216] A future study assessing the potential change in connectivity and safety related to the I-70 cover park should be conducted. It is important to note that Councilwoman Montero was in office at the time of the 2014 HIA, the appropriate lead agency in 2023 is Denver City Council District 9
Community Safety	14.a	CW Montero	Improve connectivity and safety in School Zones. Improve education and outreach about safety in School Zones to residents, drivers and schoolchildren, particularly in alignment with the upcoming I-70 reconstruction.	In 2021, the Denver Safe Routes to School Action Plan identified Swansea Elementary as the fourth highest priority school in Denver, yet no additional plans or assessments have been conducted since then that we could find.[216] Community members can request Safe Routes to School assistance, including education on best practices, by calling 311 and stating that their question is related to Safe Routes to School.[216] A greater in-depth analysis of the factors associated with traffic accidents in GES would be required to identify the exact factors associated with the higher rate of accidents and potential solutions. It is important to note that Councilwoman Montero was in office at the time of the 2014 HIA, the appropriate lead agency in 2023 is Denver City Council District 9.
Community Safety	15.a	DPD	Install new or upgraded street lighting per the recommendations of the Denver Police Department lighting survey, particularly along new sidewalks, to increase safety and reduce crime. Encourage residents' use of porch lights at night with education and outreach efforts.	From 2014-2019, 100 streetlights were installed in GES. However, residents still report that streets and alleys remain dark. Community Council members who reviewed this recommendation believed that existing streets and sidewalks should be prioritized rather than new streets. Further, they could not recall any outreach efforts to increase the use of porch lights and questioned the shifting of responsibility onto residents without financial support to pay for the porch lights or electricity.
Access to Goods and Services	16.a	DEH	Promote new sources of healthy foods within the redeveloped National Western Center, such as grocery stores, farmers markets, and community gardens	The National Western Center is currently under redevelopment where a portion of the efforts are designed to aid in improving access to goods and services in and around GES. There is currently a café on the CSU Spur campus that is primarily used by campus staff and visitors and small garden plots that are used in research and outreach by CSU Spur. This recommendation still stands. DDPHE should be involved in efforts in addressing access to goods and services throughout the National Western Center redevelopment project.

SECTION OF REPORT	# IN 2014 HIA REPORT	LEAD AGENCY	RECOMMENDATION	2023 EVALUATION
Access to Goods and Services	17.a	DEH	Implement a "healthy corner store retail program" in the neighborhoods, similar to the Philadelphia model, to add healthy foods to existing convenience and corner stores.	A healthy corner stores program was implemented in 2016 that worked with corner stores to expand the selection of healthy food available. This program included at least three stores in GES.[217] However, it is unclear the current state of the program. Denver is also part of the Food in Communities collaborative that works to address food insecurity and increase the availability of healthy foods, though the impact of this in GES is unclear.[218] To date, there has still been no new development of grocery stores located within GES.
Access to Goods and Services	18.a	CPD	Promote mixed use development to support a variety of commercial and retail businesses and services throughout the community and around new rail stations.	We are unaware of efforts to support increased mixed use or improve access to goods and services beyond what has been discussed regarding food access. Some questions that remain unanswered include 1. What type of incentivization does this recommendation entail? 2. What does promotion mean when discussion mixed use development?
Access to Goods and Services	19.a	CPD	Develop a flexible market space that can support a variety of neighborhood goods and services and culturally relevant activities.	The National Western Center 2015 Master Plan includes year-round flexible market space. This has yet to be realized and the National Western Center is still being developed.[175] The new CSU Spur campus next to the National Western Center hosts activities open to the public.
Access to Goods and Services	20.a	Parks	Increase the tree canopy cover and green infrastructure as prioritized in the Denver Urban Forestry Program and The Game Plan, including planting street trees, to improve environmental quality.	As part of the Central 70 Settlement, funds were allocated to tree planting campaigns. Additionally, multiple organizations have conducted tree planting projects in GES. However, it is unclear what resources are available to support residents in taking care of the provided trees. Continuous monitoring should be done to verify the health of the trees. Future research should be conducted to evaluate how these trees impact the overall tree canopy in GES.
Community Safety	21.a	DPD	Enforce regulations regarding graffiti, vandalism, public drug use, stray animals and property maintenance to increase safety.	Based on crime data, there is enforcement of these laws to some degree in GES, but we are unable to assess if laws are enforced to a different extent in GES compared to the rest of Denver. Community members report observing drug use and paraphernalia in public spaces such as parks.
Community Safety	22.a	DPD	Increase education and outreach to citizens about pedestrian safety, in anticipation of increased pedestrian activity with the redevelopment of the National Western Center and other projects.	We are not aware of any pedestrian safety outreach that has occurred. The National Western Center is currently under redevelopment. This recommendation still stands. DPD should be involved in efforts in addressing pedestrian safety throughout the National Western Center redevelopment project.

SECTION OF REPORT	# IN 2014 HIA REPORT	LEAD AGENCY	RECOMMENDATION	2023 EVALUATION
Soil	23.a	DEH	Work with community partners to provide education to residents about best practices for backyard gardening.	Residents report that they have received some education on backyard gardening, though we are unclear on who provided the education or when. CSU Spur has provided some resources such as a rain barrel workshop that was open to the public. Increasing backyard gardening is not a substitute for increasing access to healthy foods at a grocery store, and residents in GES face additional time and cost barriers to gardening. DDPHE should continue to work with community partners to provide backyard gardening information. Specifically, there are community concerns with regards to health and safety due to lingering fears of soil contamination.
Air Odor Noise	24.a	DEH	DEH staff should continue to participate in public sector development projects in Globeville and Elyria Swansea, including the I-70 reconstruction, to help anticipate health and environmental conditions of concern such as those identified in the HIA.	DDPHE has continued to participate in community projects and plans, including monitoring air quality throughout the Central-70 project.
Air Odor Noise	24.a	DEH	DEH staff should continue to participate in public sector development projects in Globeville and Elyria Swansea, including the National Western Center, to help anticipate health and environmental conditions of concern such as those identified in the HIA.	The redevelopment of the National Western Center is underway and Denver Department of Environmental Health is listed as a partner on the Master Plan.[175] DDPHE should continue its efforts to be involved in projects around GES.
Water Soil	25.a	DEH	Encourage developers to use low impact development and green infrastructure techniques in new development and redevelopment in the Globeville and Elyria Swansea neighborhoods to enhance water quality in each basin. Examples include the use of bioretention (rain gardens), bioswales, or vegetated buffer strips to minimize directly connected impervious areas. Roadway and alley projects should include 'green street' techniques such as stormwater planters, stormwater curb extensions, tree trenches, and permeable pavers.	The Denver Green Building Ordinance was approved by voters and went into effect in 2018. It requires that new buildings larger than 25,000 square feet install a cool roof and choose from a variety of options to reduce their environmental impact.[219] Beyond this we are unaware of what efforts have been made to encourage developers to implement green infrastructure. Some questions to note include: 1. What efforts are used in "encouraging" developers to use low impact development and green infrastructure technology? 2. How have these efforts in encouragement taken place? 3. Were developers incentivized (monetarily or otherwise) in this effort?
Water	26.a	DEH	Implement recommendations from the River North Greenway Master Plan to improve water quality (where possible, use existing park areas without affecting existing uses, to incorporate water quality treatment features such as wetlands, to restore wildlife habitat along the river or in Heron Pond).	The Denver Department of Transportation Division of Green Infrastructure was involved in the River North and Brighton Blvd development project and implemented green infrastructure such as streetside stormwater planters.[220] Additionally, the Globeville Landing Outfall project improved stormwater drainage and water quality.[221]

SECTION OF REPORT	# IN 2014 HIA REPORT	LEAD AGENCY	RECOMMENDATION	2023 EVALUATION
Air	1.b	DEH	In advance of the I-70 reconstruction project through Globeville and Elyria Swansea: a. DEH should work with CDOT and CDPHE to define types of air pollution monitoring CDPHE that can be done to determine a community baseline. b. DEH should work with CDOT and other stakeholders to recommend air quality mitigation measures that may be required during the reconstruction of I-70, including upgrading the heating/ventilation/air conditioning (HVAC) system at Swansea Elementary School to improve indoor air quality.	DDPHE conducted air monitoring at Swansea Elementary prior to, during, and following construction of the Central-70 project. In addition, CDOT implemented air quality monitoring that alerted the contractor whenever high concentrations of PM_{10} were detected in order to take corrective action.[222] The HVAC system at Swansea Elementary was upgraded along with doors and windows to mitigate air pollution and noise infiltration. Houses near the construction were provided with air conditioning units, attic insulation, storm windows, and improved weatherization.[222] The Central 70 project was completed; however, results of this recommendation should be provided to the community, including the methods and results for determining the community baseline.
Noise	1.b	DEH	In advance of the I-70 reconstruction project through Globeville and Elyria Swansea: c. The City should work with CDOT to mitigate noise impacts of the I-70 reconstruction during the construction period.	Doors and windows were upgraded at Swansea Elementary to mitigate noise infiltration and houses near the construction were provided with attic insulation, storm windows, and improved weatherization.[222]
Air Odor	2.b	DEH	Explore the feasibility of an environmental plan review process prior to approval of future development applications in order to minimize conflicts between industrial and residential uses.	We are unable to find requirements for environmental review of general development, except in the case of odor, which requires that specific odorous industries such as pet food manufacturing, marijuana cultivation, rendering, and others submit an odor control plan.[223]
Air	3.b	DEH	Continue to improve the City's air quality through specific actions including: a. DEH should update its community air pollution modeling assessment to a 2011 baseline and make projections for a future year (such as 2025). b. DEH should work with CDPHE and EPA to establish an additional air quality monitoring station in Globeville or Elyria Swansea by 2015, with a goal of quantifying near-highway pollution separately from the I-70 project.	In 2016, DDPHE independently conducted air pollution modeling for the year 2035 factoring in changes from the Central 70 project. In addition, DDPHE has conducted other air toxics, personal exposure, and wind-tunnel studies.[104,224,225] DDPHE established the Swansea Air Monitoring Station (SAMS) at Swansea Elementary to monitor pollution before, during, and after construction. Monitoring at this site began in late 2017 and ended in December 2023.[226] This project was in direct connection to the Central 70 project and therefore does not necessarily achieve the aim of this goal. However, the I-25 Globeville monitor run by CDPHE began operation in 2015 and does meet the aim of this goal.[72] Additional monitoring locations should be installed to better address the air pollution distribution in the GES area.

SECTION OF REPORT	# IN 2014 HIA REPORT	LEAD AGENCY	RECOMMENDATION	2023 EVALUATION
Odor	4.b	DEH	Analyze the distribution of current marijuana grow facilities and determine any excessive odor burdens generated by such facilities in Globeville and Elyria Swansea, and make recommendations to mitigate odor impacts as needed, including best management practices and technologies.	The Denver Revised Municipal Code requires that the Department of Excise and Licensing annually determine neighborhoods that have an undue burden of marijuana cultivations and dispensaries (separately) and restricts new facilities from being licensed in these neighborhoods. Neighborhoods of undue burden are defined as the top five neighborhoods with the most facilities in each category.[227]
Odor	5.b	NGOs	Advocate for further research on the potential human health impacts from marijuana grow facilities, as such impacts are unknown. Concerns include emissions to air, odors, mold, and discharges to the water system.	The cannabis industry has been identified as a source of VOCs that contributes to the formation of ozone. DDPHE and CDPHE have created best practice guidelines for reducing the air quality impact from cannabis, many of which correspond to odor reduction as well.[228] Further questions surrounding this recommendation include: 1. How will these future research projects be funded? 2. How will CCoD provide support to the community in researching potential impacts from marijuana grow facilities?
Odor	6.b	DEH	Address nuisance odors through specific actions including: a. DEH should work with City agencies, other government, non-profit, community, and industry partners to form a long-term steering committee to implement solutions to reduce odors, potentially including recommendations for local and state policy changes. b. DEH should create and lead a community partnership of interested organizations to pursue funding for research on manufacturing processes that produce odors, and odor monitoring technologies to address nuisance odors in Globeville and Elyria Swansea. c. DEH should continue its work with the Northeast Metro Pollution Prevention Alliance (NEMPPA) to cooperate on potential solutions for odor reduction from industries located outside of City boundaries.	The Denver nuisance odor ordinance was updated in 2016 and expands what businesses are required to submit an odor control plan. These include certain odorous industries, many of which are pertinent to the odors in GES, and businesses that receive five complaints within 30 days. We are unaware of odor-related partnerships, and odors from sources outside of GES continue to be an issue.[229]
Water	7.b	DEH	DEH should partner with other agencies and organizations to improve education and outreach to businesses and residents related to water quality in Globeville and Elyria Swansea, including providing information to developers about City regulations for stormwater runoff and fugitive dust and dirt.	We are unaware of what outreach has been conducted regarding water quality. This recommendation is on-going as redevelopment of areas in and around GES is currently underway.

SECTION OF REPORT	# IN 2014 HIA REPORT	LEAD AGENCY	RECOMMENDATION	2023 EVALUATION
Soil	8.b	DEH	DEH should work with the EPA to continue to take steps to remove the residential portion (Operable Unit 1) of VB/I-70 from the Superfund site (i.e., de-list OU1), as the remedy has been completed.	VB/I-70 Operable Unit 1 (OU1) was removed from the National Priorities List in 2019.
Community Safety	9.b	DPD	The City and private developers should work together to encourage crime prevention and safety through the use of environmental design principles for new development and redevelopment, including large projects such as the National Western Center.	We are unaware of what outreach has been conducted regarding crime prevention. Residents continue to report crime and the fear of crime as major concerns.
	10.b	NDCC	The City, private developers and community partners should continue and strengthen bilingual and culturally appropriate outreach and communication with residents about upcoming construction and development projects, as these communities have historically experienced negative environmental impacts from previous decisions.	We have observed that local and state agencies often have interpretation available at meetings. However, not all written materials are translated into Spanish. Often large reports that are relevant to the community are not translated, such as neighborhood plans and study reports, including the 2014 HIA, which only had the executive summary translated. Community members continue to cite inaccessibility of information as an issue.

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APPENDIX 1. EXPLANATION OF DATA SOURCES

MAIN DATA SOURCES

Data for each section were collected from multiple sources and compared to determine the strength of evidence for whether GES differs from the rest of Denver. In some cases, the data sources have similar estimates for an indicator, and at other times, there are substantial differences, stemming from the methodology used to generate the data. This is particularly true of data sources that publish estimates, such as the small area estimates from CDPHE and CDC. This section provides a brief description of the main data sources used in this report to help explain why values for a given indicator (e.g., rate of tobacco use) may be different based on the source of the data.

American Community Survey (ACS)

ENVIRONS primarily relied on the American Community Survey 5-year estimates from the US Census Bureau as our source for baseline demographic and socioeconomic data. The American Community Survey provides important socioeconomic, educational attainment, housing, and other data beyond the basic demographics collected by the decennial census. Unlike the decennial census where everyone is counted, the ACS surveys a small percentage of the population each year and asks more detailed questions. 5-year estimates are generated using survey data for 5-year periods, allowing there to be enough responses to calculate estimates for small areas, like census tracts.[230] Additionally, the ACS survey implements an important weighting procedure to correct for people who do not respond to the survey.[231] Non-response rates were higher for the 2020 census compared to previous census years.[232] Therefore, ACS data, which include more variables of interest and accounts for non-response bias, provide the best demographic and socioeconomic data for the Denver metropolitan area.

CDPHE Community Level Estimates

CDPHE Community Level Estimates are generated from models that predict (model) the prevalence of health conditions and access among adults (age 18+) for each census tract in Colorado. The most recent data release from 2019, uses 2014-2017 Colorado Behavioral Risk Factors Surveillance System data. The predicted prevalence is based on the relationship between age, race, gender, poverty, education, location, and health conditions or risk behavior indicators, and applied to the population for each census tract in Colorado based on the 2013-2017 ACS.[233] This model type is called a small area estimate (SAE), which is the same as CDC PLACES. The estimates are based on statistical models and are not direct survey results. This means that there is a greater potential for values to be different from what the true value in the community is, however, this is still an important data source because it allows us to compare small geographic areas, such as GES, which would not be possible from survey data alone. While PLACES and CDPHE Community Level Estimates are both based on BRFSS and ACS data, the calculated values differ based on the exact methods used by each organization and the year of BRFSS or ACS data included.

CDC Population Level Analysis and Community Estimates (PLACES)

Similar to CDPHE Community Estimates, the CDC PLACES data are small area estimates that, for the 2023 release, use 2020 or 2021 BRFSS survey data in combination with 2015-2019 ACS socio-demographic characteristics.[29,234] The same limitation applies to these data as CDPHE Community Level Estimates; these values are calculated from a statistical model and are not direct survey results and there is a greater potential for these values to be different from what the true value in the community is. While PLACES and CDPHE Community Level Estimates are both based on BRFSS and ACS data, the values calculated may be different based on the exact methods used by each organization and the year of BRFSS or ACS data included. However, it is important to note that these data are based on more recent survey data than CDPHE Community Level Estimates. In this report, we use both PLACES and CDPHE Community Level

Estimates along with other sources when available to describe if there is a consistent relationship between GES and Denver among the sources.

Colorado Health Observation Regional Data Service (CHORDS)

CHORDS was an initiative by healthcare providers and public health organizations in metro Denver, Larimer, and Weld Counties to track health measures through electronic health records. Electronic health records were shared by participating healthcare providers to a central database that then calculated rates for health measures based on the total number of people who sought care at a participating provider.[235] This initiative recently stopped operating, and the most recent data available through a web map is from 2019-2020. Requests by our team to access the datafiles underlying the web map were denied, so where included, CHORDS data have been manually recorded from the web map.[235]

These data have significant limitations based on who received care from participating healthcare providers. During a mapping activity, community members stated they seek medical care from participating providers like Denver Health, Children's Hospital Colorado, Kaiser Permanente Colorado, and Tepeyac Community Health Center.[45] Exact data about how people are included in the care-seeking population compared to the whole county population are no longer provided, and our request for this information was denied. Some sense of how well these data represent the full population of GES can be found on the web maps, which, for each census tract, show the number of care-seeking individuals by health condition, the total number of care-seeking individuals, and the total population (the source of population data is not stated). For example, in Globeville from 2019-2020, there were 124 care-seeking adults with asthma, 1,534 adults who received care from a participating provider, and a total adult population in Globeville of 3,459. The rate for adult asthma in Globeville in this time period was calculated as 124/1,534 x 100 = 8.1%. This percentage may be incorrect, however, depending on whether the 1,534 adults who received care are representative of the entire 3459 adult population. It is likely that individuals who are sick or have a health condition are more likely to seek care than those who are healthy, meaning that the reported rates may be higher than the true rate. This is especially true for adults, who, unlike kids, are less likely to go to the doctor for a wellness check when there are no obvious issues. Other important considerations are that individuals who have lower income, lack health insurance, or are undocumented may be less likely to seek care while also being more likely to have poorer health,[236] resulting in the calculated percentage being lower than it actually is. This second concern is pertinent to GES which has a lower median income and a larger uninsured population than other parts of Denver.[236] Many of the healthcare providers who participated in CHORDS serve low-income and uninsured populations, which may lessen the effect of this issue.[45]

Overall, CHORDS is a useful source because it is based on actual counts of individuals with specific health outcomes. However, we must be mindful of the potential reasons that the data may not reflect actual rates of health outcomes in the community. Without the greater level of detail that is no longer provided, it is difficult to assess exactly how the reported data differ from the true rates. For this report, we use CHORDS data to complement other sources when possible

CDPHE Vital Statistics

Vital statistics data refers to birth and death records, which are collected for every birth or death in the state by CDPHE.[237] These data provide detailed information at the "book ends" of life, and due to the rigor in which these data are reported, they are high quality and complete. However, they are also limited in certain regards. Birth records collect information at the time of birth, so health outcomes that are not apparent at birth are not collected well. Death records record the main cause of death and may not include contributing factors. For example, extreme heat increases the risk of heart attacks, but the cause of death will likely be recorded as a heart attack, not the heat stress that contributed. Additionally, death records do not represent conditions that don't often cause death, such as asthma. Both birth and

death records are also limited for rare outcomes in that too few cases make it difficult or impossible to compare the rate between GES and other locations with certainty. To minimize this, we have combined vital statistics for a five-year period of 2017-2021 and only included outcomes with a high number of cases.

STRENGTH OF EVIDENCE

We created three categories to use when determining the level of evidence (**Table 13**). This allowed us to be able to better characterize the overall picture without diminishing each entry when there were multiple sources of information or datasets.

Table 13. Strength of evidence.

STRENGTH OF EVIDENCE	EXAMPLE INTERPRETATION	CRITERIA
Consistent evidence	"There is consistent evidence that there is a difference (include directionality)."	• Substantial differences • Data sources agree on directionality • Minimal to no overlap in confidence intervals
Limited evidence	"There is limited evidence that there is a difference (include directionality)."	• Data sources do not agree on directionality • Some overlap in confidence intervals
No evidence	"There is no evidence that there is a difference."	For more than one data source: • Difference in estimates is small • Large overlap of confidence intervals For one data source: • Data source indicates there is not a difference
Evidence (general)	"There is evidence that there is a difference."	Only 1 data source • Substantial differences • Minimal to no overlap in confidence intervals

APPENDIX 2. BIRTH OUTCOMES

Birth outcomes were calculated using birth records from 2017-2021. Population data from the 2017-2021 ACS.

Table 14. Birth outcomes, 2017-2021.

OUTCOME	GES	GLOBEVILLE	ELYRIA-SWANSEA WEST	ELYRIA-SWANSEA EAST	DENVER
Birth Rate[A]	13.66 (12.67 - 14.65)	12.03 (10.52 - 13.55)	17.52 (15.43 - 19.62)	12.19 (10.59 - 13.79)	12.35 (12.23 - 12.46)
Fertility Rate[B]	60.00 (55.65 - 64.35)	50.79 (44.38 - 57.2)	79.59 (70.08 - 89.1)	54.48 (47.31 - 61.64)	49.94 (49.47 - 50.41)
Gestational hypertension[C]	139.34 (126.54 - 152.14)	145.23 (122.53 - 167.92)	141.26 (120.03 - 162.5)	130.63 (108.01 - 153.25)	116.49 (114.95 - 118.02)
Gestational diabetes[C]	92.9 (70.82 - 114.98)	87.14 (49.87 - 124.41)	96.65 (59.5 - 133.81)	94.59 (54.14 - 135.05)	58.28 (56.01 - 60.54)
Low birthweight births[C,D]	94.26 (72.02 - 116.5)	78.84 (43.39 - 114.29)	118.96 (99.22 - 138.7)	81.08 (43.62 - 118.54)	98.77 (95.82 - 101.72)
Preterm births[C,E]	98.36 (75.64 - 121.08)	112.03 (91.72 - 132.35)	96.65 (59.5 - 133.81)	85.59 (47.1 - 124.07)	91.62 (88.78 - 94.46)
Congenital abnormalities at birth[C]	133.88 (121.29 - 146.47)	103.73 (84.09 - 123.38)	156.13 (134 - 178.27)	139.64 (116.38 - 162.9)	119.14 (117.59 - 120.7)

Parenthesis show 95% CI

[A] Birth rate per 1,000 population

[B] Fertility rate per 1,000 females age 15-44

[C] Rate per 1,000 live births

[D] Births < 2,500 g (5.5 lbs.)

[E] Births before 37 weeks of gestation have been completed

APPENDIX 3. AIR QUALITY SUPPLEMENTAL DATA

These tables present more detailed summaries of air quality for criteria and non-criteria pollutants that informs the conclusions in **Section 4.1 Air**.

Figure 39 shows the locations of air monitoring sites that report to the EPA to complement data from these monitors **(Table 15)**.

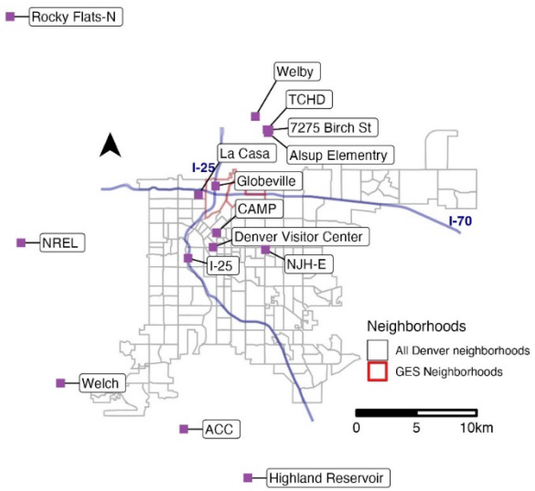


Figure 39. Map of air quality sites in the Denver Metro that report to the EPA.

Table 15. Summary of National Ambient Air Quality Standards from EPA reporting monitors near GES, 2020-2022 means.

PARAMETER	STANDARD	SITE	POC	EX	Q10	Q50	MEAN	Q75	Q95	Q99	MAX	UNITS
CARBON MONOXIDE	CO 1-hour 1971	CAMP	2	0.00	0.17	0.26	0.32	0.36	0.67	1.15	2.62	ppm
	CO 1-hour 1971	I-25	1	0.00	0.20	0.37	0.44	0.52	0.97	1.48	2.56	ppm
	CO 1-hour 1971	La Casa	1	0.00	0.14	0.22	0.28	0.32	0.64	1.00	1.74	ppm
	CO 1-hour 1971	Welby	1	0.00	0.13	0.20	0.29	0.34	0.73	1.08	1.81	ppm
	CO 8-hour 1971	CAMP	2	0.00	0.20	0.30	0.32	0.37	0.60	0.97	1.97	ppm
	CO 8-hour 1971	I-25	1	0.00	0.23	0.40	0.44	0.50	0.87	1.17	2.00	ppm
	CO 8-hour 1971	La Casa	1	0.00	0.20	0.23	0.28	0.30	0.57	0.87	1.40	ppm
	CO 8-hour 1971	Welby	1	0.00	0.13	0.20	0.29	0.37	0.63	0.90	1.27	ppm
Nitrogen dioxide (NO2)	NO2 1-hour 2010	CAMP	1	0.00	15.17	29.17	30.85	39.77	54.07	66.93	77.90	ppb
	NO2 1-hour 2010	Globeville	1	0.00	28.07	43.53	43.19	50.77	62.87	73.10	81.67	ppb
	NO2 1-hour 2010	I-25	1	0.00	22.60	36.53	36.61	43.67	54.47	65.70	74.77	ppb
	NO2 1-hour 2010	La Casa	1	0.00	15.47	29.77	30.38	38.17	50.33	60.73	67.80	ppb
	NO2 1-hour 2010	Rocky Flats-N	1	0.00	2.33	5.37	7.06	8.60	18.73	30.93	40.07	ppb
	NO2 1-hour 2010	Welby	1	0.00	14.13	35.07	33.02	42.10	52.03	59.63	69.87	ppb
	NO2 Annual 1971	CAMP	1	0.00	5.10	11.33	14.81	18.77	38.40	51.40	77.90	ppb
	NO2 Annual 1971	Globeville	1	0.00	7.90	22.97	24.81	34.63	49.03	59.33	81.67	ppb
	NO2 Annual 1971	I-25	1	0.00	7.37	18.63	20.85	28.30	43.10	51.93	74.77	ppb
	NO2 Annual 1971	La Casa	1	0.00	3.83	11.40	15.10	21.20	39.03	46.93	67.80	ppb
	NO2 Annual 1971	Rocky Flats-N	1	0.00	0.17	1.60	2.54	3.07	8.17	16.03	40.07	ppb
	NO2 Annual 1971	Welby	1	0.00	2.70	9.90	15.35	24.80	41.40	48.97	71.87	ppb
Ozone	Ozone 8-hour 2015	CAMP	6	8.00	0.02	0.04	0.04	0.05	0.07	0.07	0.08	ppm
	Ozone 8-hour 2015	Highland Reservoir	1	19.33	0.04	0.05	0.05	0.06	0.07	0.08	0.09	ppm
	Ozone 8-hour 2015	La Casa	1	14.33	0.03	0.05	0.05	0.06	0.07	0.08	0.08	ppm
	Ozone 8-hour 2015	NREL	1	32.00	0.04	0.05	0.05	0.06	0.08	0.08	0.09	ppm
	Ozone 8-hour 2015	Rocky Flats-N	1	29.00	0.04	0.05	0.05	0.06	0.07	0.08	0.09	ppm
	Ozone 8-hour 2015	Welby	2	15.33	0.03	0.05	0.05	0.06	0.07	0.08	0.08	ppm
	Ozone 8-hour 2015	Welch	1	8.00	0.03	0.05	0.05	0.05	0.06	0.08	0.09	ppm
PM_{10} Total	PM10 24-hour 2006	7275 Birch St	1	0.00	14.00	31.00	33.96	43.00	69.50	91.50	109.00	$\mu g/m^3$
	PM10 24-hour 2006	CAMP	1	0.00	15.33	28.00	31.08	38.67	58.67	79.00	79.00	$\mu g/m^3$

PARAMETER	STANDARD	SITE	POC	EX	Q10	Q50	MEAN	Q75	Q95	Q99	MAX	UNITS
	PM10 24-hour 2006	CAMP	2	0.00	14.33	26.00	29.00	35.00	58.00	69.33	69.33	µg/m³
	PM10 24-hour 2006	La Casa	1	0.00	10.33	19.67	22.40	29.00	44.67	57.67	64.67	µg/m³
	PM10 24-hour 2006	La Casa	2	0.00	11.33	20.33	23.41	30.33	47.00	62.67	62.67	µg/m³
	PM10 24-hour 2006	TCHD	1	0.00	14.00	31.00	36.63	48.00	81.00	108.00	139.00	µg/m³
	PM10 24-hour 2006	Welby	2	0.00	13.33	32.00	35.93	49.67	75.33	94.00	94.00	µg/m³
	PM10 24-hour 2006	Welby	3	0.00	12.00	30.33	34.16	45.67	76.00	88.67	96.00	µg/m³
$PM_{2.5}$ - Local Conditions	PM2.5 24-hour 2012	7275 Birch St	2	0.50	4.55	8.45	9.74	11.55	20.55	32.40	32.40	µg/m³
	PM2.5 24-hour 2012	7275 Birch St	3	1.50	3.55	6.75	8.02	9.45	17.25	28.35	40.95	µg/m³
	PM2.5 24-hour 2012	ACC	1	0.33	2.30	4.53	6.09	7.33	15.57	28.73	34.90	µg/m³
	PM2.5 24-hour 2012	CAMP	1	0.67	3.00	5.97	7.40	8.93	17.93	28.17	33.73	µg/m³
	PM2.5 24-hour 2012	CAMP	2	0.67	3.27	6.30	7.57	8.40	19.33	29.93	29.93	µg/m³
	PM2.5 24-hour 2012	CAMP	3	2.67	3.50	6.67	8.47	10.60	19.27	32.00	37.80	µg/m³
	PM2.5 24-hour 2012	Globeville	3	3.00	4.37	7.77	9.30	11.37	19.93	32.77	37.90	µg/m³
	PM2.5 24-hour 2012	I-25	1	1.00	4.60	8.00	9.45	11.50	20.07	31.53	31.53	µg/m³
	PM2.5 24-hour 2012	I-25	3	0.67	3.57	6.47	7.86	9.80	17.10	27.67	31.97	µg/m³
	PM2.5 24-hour 2012	La Casa	1	0.33	2.80	5.70	7.25	8.40	18.10	29.60	33.93	µg/m³
	PM2.5 24-hour 2012	La Casa	3	4.33	3.70	6.43	8.23	9.47	18.80	34.00	43.57	µg/m³
	PM2.5 24-hour 2012	NJH-E	3	6.00	3.83	6.37	8.56	10.00	19.93	34.80	45.97	µg/m³
	PM2.5 24-hour 2012	TCHD	2	1.00	3.70	6.70	9.66	11.90	25.00	41.30	41.30	µg/m³
	PM2.5 24-hour 2012	TCHD	3	2.00	3.60	7.30	8.99	11.10	20.50	34.40	37.10	µg/m³
	PM2.5 Annual 2012	7275 Birch St	2	N	4.55	8.45	9.74	11.55	20.55	32.40	32.40	µg/m³
	PM2.5 Annual 2012	7275 Birch St	3	N	3.55	6.75	8.02	9.45	17.25	28.35	40.95	µg/m³
	PM2.5 Annual 2012	ACC	1	N	2.30	4.53	6.09	7.33	15.57	28.73	34.90	µg/m³
	PM2.5 Annual 2012	CAMP	1	N	3.00	5.97	7.40	8.93	17.93	28.17	33.73	µg/m³
	PM2.5 Annual 2012	CAMP	2	N	3.27	6.30	7.57	8.40	19.33	29.93	29.93	µg/m³
	PM2.5 Annual 2012	CAMP	3	N	3.50	6.67	8.47	10.60	19.27	32.00	37.80	µg/m³
	PM2.5 Annual 2012	Globeville	3	N	4.37	7.77	9.30	11.37	19.93	32.77	37.90	µg/m³
	PM2.5 Annual 2012	I-25	1	N	4.60	8.00	9.45	11.50	20.07	31.53	31.53	µg/m³
	PM2.5 Annual 2012	I-25	3	N	3.57	6.47	7.86	9.80	17.10	27.67	31.97	µg/m³
	PM2.5 Annual 2012	La Casa	1	N	2.80	5.70	7.25	8.40	18.10	29.60	33.93	µg/m³
	PM2.5 Annual 2012	La Casa	3	N	3.70	6.43	8.23	9.47	18.80	34.00	43.57	µg/m³

PARAMETER	STANDARD	SITE	POC	EX	Q10	Q50	MEAN	Q75	Q95	Q99	MAX	UNITS
	PM2.5 Annual 2012	NJH-E	3	N	3.83	6.37	8.56	10.00	19.93	34.80	45.97	$\mu g/m^3$
	PM2.5 Annual 2012	TCHD	2	N	3.70	6.70	9.66	11.90	25.00	41.30	41.30	$\mu g/m^3$
	PM2.5 Annual 2012	TCHD	3	N	3.60	7.30	8.99	11.10	20.50	34.40	37.10	$\mu g/m^3$
Sulfur dioxide	SO2 1-hour 2010	CAMP	1	0.00	0.27	0.87	1.16	1.43	3.07	5.47	6.00	ppb
	SO2 1-hour 2010	La Casa	1	0.00	0.33	0.90	1.21	1.50	3.47	5.67	8.80	ppb
	SO2 1-hour 2010	Welby	2	0.00	0.50	1.67	1.88	2.53	3.97	5.60	15.17	ppb

POC: Unique identifier for equipment. Useful when there are multiple monitors for the same parameter at one site.

EX: For the NO_2 annual standard, the number of years from 2020-2022 that exceeded the standard. For the $PM_{2.5}$ annual standard, whether the three year mean from 2020-2022 exceeded the standard (Y = yes, N = no). For all other standards, the 3-year mean number of annual NAAQS exceedances.

Q10-Q99: The 3-year mean of the respective percentile. E.g. Q10 is the mean the 10th percentile of values from 2020-2022.

MIN, MEAN, MED, MAX: The 3-year mean of the minimum, mean, median, and max values, respectively.

Table 16. Summary of criteria pollutants from non-EPA-reporting monitors near GES.

PARAMETER	SITE NAME	DATE RANGE	N	MIN	Q25	MED	Q75	Q95	Q99	MAX	UNITS
CO	SAMS	06/01/17 – 09/30/23	42417	0.0	0.2	0.3	0.4	0.8	1.3	3.4	ppm
NO_2	Lorraine Granado	01/11/23 – 06/02/23	3046	1.4	7.2	13.2	25.3	43.9	53.2	68.5	ppb
	SAMS	06/01/17 – 09/30/23	39875	0.0	7.2	13.5	25.6	43.9	55.0	94.2	ppb
$PM_{2.5}$	Lorraine Granado	01/11/23 – 06/02/23	3018	0.4	3.7	5.9	11.4	28.0	70.6	119.3	$\mu g/m^3$
	SAMS	06/01/17 – 09/30/23	44939	0.0	3.8	6.5	11.2	23.9	42.1	311.3	$\mu g/m^3$
PM_{10}	Lorraine Granado	01/11/23 – 06/02/23	3018	0.4	8.3	14.9	27.8	51.8	77.1	135.8	$\mu g/m^3$
	SAMS	06/01/17 – 09/30/23	44871	0.0	9.2	18.6	35.6	87.9	169.3	1506.4	$\mu g/m^3$
SO_2	CCF	12/22/21 - 11/03/22	5775	0.2	0.2	0.2	0.8	1.9	3.6	7.0	ppb

Q25-Q99: The respective percentile. E.g. Q25 is the 25th percentile of values.

Min, Med, and Max: The minimum, median, and max values, respectively.

Table 17. Summary of benzene concentrations (ppb) from monitors near GES.

SOURCE	SITE NAME	DATE RANGE	FREQUENCY	DURATION	N	MIN	Q25	MED	Q75	Q95	Q99	MAX
CAMML	Eagle Point	05/14/21 - 07/17/21	Hourly	45 minutes	994	0.0	0.0	0.1	0.1	0.3	0.4	0.6
	Lorraine Granado	01/11/23 - 06/02/23	Hourly	45 minutes	3075	0.0	0.1	0.1	0.2	0.6	1.1	1.7
Boulder AIR	CCF	03/14/22 - 02/02/23	Hourly	10 minutes	4590	0.0	0.1	0.2	0.5	1.0	1.5	8.6
EPA	CAMP	01/07/14 - 12/31/22	6 days	3 hours	513	0.0	1.2	1.6	2.3	3.9	6.4	10.3
	Brighton Fire #55	11/19/19 - 12/31/22	6 days	3 hours	184	0.4	0.9	1.4	1.9	3.5	5.3	8.6
SAMS	SAMS	06/01/19 - 06/30/23	Hourly*	60 minutes	26020	0.1	0.1	0.1	0.1	0.5	1.0	16.1

Q25-Q99: The respective percentile. E.g. Q25 is the 25th percentile of values.

Min, Med, and Max: The minimum, median, and max values, respectively.

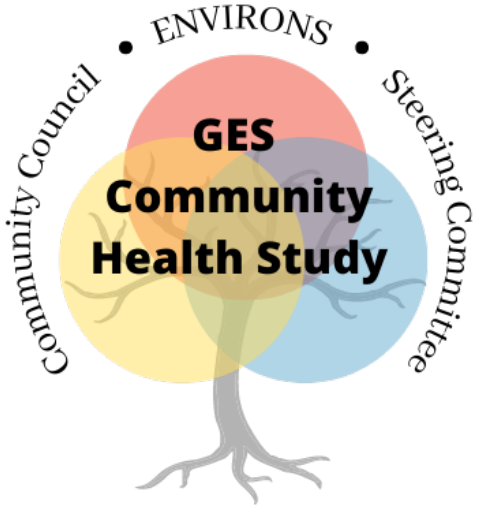
* Data was provided as two 30-minute samples for each hour and was aggregated to 1-hour increments by taking the mean of the two half-hours within each hour. This was done to match the hourly frequency of other data.

Table 18. Summary of hydrogen sulfide concentrations (ppb) from monitors near GES.

SOURCE	SITE NAME	DATE RANGE	FREQUENCY	DURATION	N	MIN	Q25	MED	Q75	Q95	Q99	MAX
Boulder AIR	CCF	12/22/21 - 02/02/23	Hourly	10 minutes	8001	0.2	0.5	1.1	2.6	8.7	21.6	77.7

Q25-Q99: The respective percentile. E.g. Q25 is the 25th percentile of values.

Min, Med, and Max: The minimum, median, and max values, respectively.



Exposure Outcome Matrix

GES Community Health Study

In response to deliverable 2.3

February 29, 2024

Revised April 19, 2024

ENVIRONS

Colorado State University

COMMUNITY RELEVANT SUMMARY

Purpose: The purpose of this diagram is to visualize how environmental exposures (e.g. pollutants) are connected to adverse health outcomes, and to inform the Community Environmental Burden Assessment process (deliverables 2.4-2.6).

Importance: This diagram visualizes how environmental exposures (e.g. pollution) can lead to differences in health between GES and the Denver average. Residents can use this matrix to understand which environmental exposures are connected to illnesses they are interested in, or the other way around. It is also used to identify which combination of environmental exposures and health outcomes will be included in the Community Environmental Burden Assessment.

Summary:

There is not one take-away from this Matrix. Rather, it is meant to demonstrate the variety of pathways that begin with the neighborhood environment and culminate in community members' health outcomes. When viewing the Exposure Outcome Matrix, we encourage users to explore how their family's health is connected to the built environment, air pollution, walkability, and other environmental factors.

This matrix includes all exposures identified in our previous report, *The ABC's of GES: The State of Health and Environment*, that have a high level of evidence from other studies connecting them to a health outcomes and all health outcomes we found associated with them, though some have been grouped together to make the matrix more readable.

General observations from the matrix include:

- There are more connections between air pollutants and health outcomes than components of the built environment (like heat, noise, odor, and walkability). One reason for this is that air pollution is easier to measure and calculate how it is connected to health than the built environment.
- Cardiovascular diseases (relating to heart illnesses), respiratory diseases (relating to lung illnesses), and death from these diseases are connected to more environmental exposures than other health outcomes.

Understanding the Exposure Outcome Matrix:

- Rows represent individual environmental exposures and columns represent health outcomes.
- Grey boxes at the intersection of an environmental exposure (row) and health outcome (column) indicate that previous studies have found that the environmental exposure is likely to contribute to that health outcome.
- The color of the health outcome indicates if GES is better, similar, or worse than the Denver average for that health outcome. This helps identify the environmental exposures that may be associated with health differences between GES and the Denver average.
- Dark grey boxes within the blue outlined area (top left) indicate that combination of environmental exposure and health outcome will be considered in the Community Environment Burden Assessment.
- Grey boxes outside of this area (bottom and right sides) will not be included in the Community Environmental Burden Assessment. Further described in Deliverable 2.4, this is because either the data are not detailed enough or the connection between exposure and outcome are not well-defined.

INTRODUCTION

This deliverable, the Exposure Outcome Matrix, is designed to illustrate the relationship between environmental exposures (e.g., air pollution), health outcomes, and health disparities that are relevant to the Globeville, Elyria, and Swansea (GES) neighborhoods based on rigorous studies in other locations. In addition, the matrix is used in the scoping portion of Deliverable 2.4: The Planning, Scoping, and Problem formulation of the Community Environmental Burden Assessment (CEBA).

Scope

The Exposure Outcome matrix visualizes the environmental exposures in GES and health outcomes that have associations reported in meta-analyses[1]. The focus is on physical (e.g., air pollutants) and built environment (e.g., greenspace/greenness) exposures that were identified in *The ABC's of GES: The State of Health and Environment* (Deliverable 2.2 Health Impact Assessment), but is limited to the environmental exposures that have associations with health outcomes reported in meta-analyses. Some components of the built environment are not included because they do not have meta-analyses supporting associations with health outcomes[2].

While the scope of environmental exposures has been limited to those from *The ABC's of GES*, health outcomes have been left broader and encompass all major associations backed by meta-analyses that we were able to find. This was done so residents can use the matrix as a tool for identifying potential environmental determinants of diseases they may be interested in beyond just the diseases we are able to include in Aim 1 of the CEBA, which is largely limited by data availability. Some health outcomes have been aggregated together to improve understandability (e.g., multiple types of heart disease are included under cardiovascular diseases and mortality).

Relation to Other Deliverables:

This deliverable builds off our previous report, *The ABC's of GES: The State of Health and Environment*, by visualizing how the environmental exposures identified in that report are connected to health outcomes. Simultaneously, this matrix refines what associations are included by requiring a higher level of evidence, a meta-analysis, than what discussions in *The ABC's of GES* are based on. Further, as a scoping tool, the matrix identifies the pairs of environmental exposures and health outcomes that will be included in Aim 1 of the analysis and risk characterization phases of the CEBA (deliverables 2.5 and 2.6, respectively). These pairs are identified in the matrix as those within the blue outlined area (top left). Pairs outside of the outlined area (bottom and right) will not be included. A comprehensive discussion on the selection of what is included or excluded from Aim 1 of the CEBA can be found in Deliverable 2.4.

[1] Meta-analyses are a type of study that analyzes the results from multiple individual studies to determine an overarching conclusion. This helps account for variability in individual studies.

[2] Of note, the neighborhood foot environment, often referred to as "food deserts" or "food swamps," is not included in the matrix because meta-analyses have failed to find associations with health outcomes. This was also noted in *The ABC's of GES: The State of Health and Environment*, but the discussion there also included individual studies to provide a broader picture of existing literature.

Exposure-Outcome Matrix for Environmental Exposures in Denver, Colorado

Globeville, Elyria, and Swansea Community Health Study

April 19, 2024

Associated Health Outcomes

Environmental Exposure		Respiratory Health: Asthma	Respiratory Health: Chronic Obstructive Pulmonary Disease (COPD)	Respiratory Health: Respiratory Disease & Mortality	Cardiovascular Health: Cardiovascular Disease & Mortality	Cardiovascular Health: Hypertension	Cardiovascular Health: Stroke & Stroke Mortality	Mental Health: Depression	Mental Health: Anxiety	Mental Health: Suicide Mortality	Birth-related Health Outcomes: Low Birthweight	Birth-related Health Outcomes: Preterm Birth	Birth-related Health Outcomes: Gestational Diabetes	Other Health Outcomes: Type 2 Diabetes	Other Health Outcomes: Elevated Blood Lead Levels	Other Health Outcomes: All Cause Mortality	Other Health Outcomes: Total Cancer Mortality	Additional Health Outcomes Not Included in the Community Environmental Burden Assessment: Respiratory Infection	Small For Gestational Age	Specific Congenital Abnormalities (Not Total)	Autism Spectrum Disorder	Alzheimer's Disease and Related Dementias (ADRD) and Parkinson's	Chronic Kidney Disease	Acute Renal Failure	Headaches	Cough/Phlegm	Cancers	Psychological Distress	Obesity
Included in Aim 1 of Community Environmental Burden Assessment	Air Pollution and Air Toxics: Benzene*																										Leukemia, lung		
	Air Pollution and Air Toxics: Black Carbon*																										Lung cancer mortality, brain tumors		
	Air Pollution and Air Toxics: Carbon Monoxide (CO)*																												
	Air Pollution and Air Toxics: Nitrogen Dioxide (NO2)*																										Leukemia, brain tumors		
	Air Pollution and Air Toxics: Ozone (O3)																												
	Air Pollution and Air Toxics: Particulate Matter (PM10)*																										Lung and breast cancer mortality		
	Air Pollution and Air Toxics: Particulate Matter 2.5 (PM2.5)																										Colorectal, liver, lung, and breast cancer mortality		
	Air Pollution and Air Toxics: Sulfur Dioxide (SO2)*																												
	Built Environment: Low Greenness/ Greenspace																												
	Built Environment: Surface Temperature/ Heat																												
	Built Environment: Noise*																												
	Built Environment: Lead Exposure Risk																												
Additional Exposures Not Included in the Community Environmental Burden Assessment Aim 1	Low Walkability																												
	Odor																												
	Neighborhood Crime																												

Health Outcome Disparities From HIA

- Worse than Denver
- Similar to Denver
- Data Not Presented in HIA or is not Available for GES

* ENVIRONS will attempt to include these exposures based on models. However, this may not be possible if models show little difference in estimated exposure levels when aggregated to the neighborhood level.

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Exposure-Outcome Matrix Description

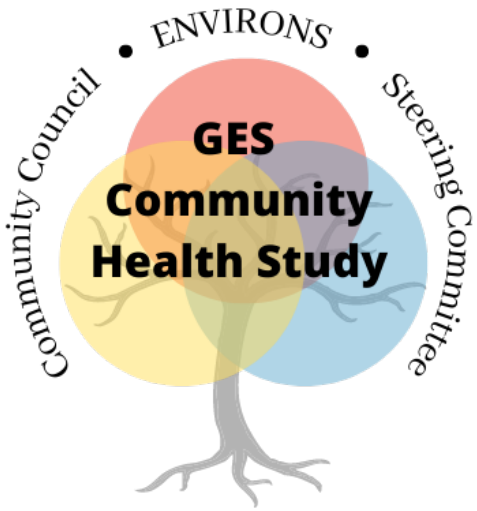
The matrix is organized as a grid. Across the top (horizontal-axis) are health outcomes and along the left (vertical-axis) are environmental exposures relevant to Globeville, Elyria, and Swansea. Each box at the intersection of a row and column is colored coded to indicate if the environmental exposure is associated with the health outcome, and if so, if that pair is included in the Community Environmental Burden Assessment (CEBA).

Exposure-outcome pairs are as follows:

- Benzene - ENVIRONS will attempt to include this exposure based on models. However, this may not be possible if models show little difference in estimated exposure levels when aggregated to the neighborhood level.
    - Included associations: asthma
    - Excluded associations: leukemia and lung cancer
- Black carbon - ENVIRONS will attempt to include this exposure based on models. However, this may not be possible if models show little difference in estimated exposure levels when aggregated to the neighborhood level.
    - Included associations: asthma, respiratory diseases and mortality, cardiovascular disease and mortality, all-cause mortality
    - Excluded associations: lung cancer mortality, brain tumors
- Carbon monoxide - ENVIRONS will attempt to include this exposure based on models. However, this may not be possible if models show little difference in estimated exposure levels when aggregated to the neighborhood level.
    - Included associations: cardiovascular diseases and mortality, low birth weight, preterm birth
    - Excluded associations: respiratory infections
- Nitrogen dioxide (NO2) - ENVIRONS will attempt to include this exposure based on models. However, this may not be possible if models show little difference in estimated exposure levels when aggregated to the neighborhood level.
    - Included associations: asthma, chronic obstructive pulmonary disease (COPD), respiratory diseases and mortality, cardiovascular diseases and mortality, hypertension, low birth weight, type 2 diabetes, all cause mortality, total cancer mortality
    - Excluded associations: small for gestational age, specific congenital abnormalities (not total), autism spectrum disorder, chronic kidney disease, leukemia, brain tumors
- Ozone (O3)
    - Included associations: respiratory diseases and mortality, cardiovascular disease and mortality, low birth weight, preterm birth, all-cause mortality
    - Excluded associations: respiratory infection, Alzheimer's disease and related dementias and Parkinson's
- Particulate matter 10 (PM10) - ENVIRONS will attempt to include this exposure based on models. However, this may not be possible if models show little difference in estimated exposure levels when aggregated to the neighborhood level.

    - Included associations: asthma, chronic obstructive pulmonary disease (COPD), respiratory diseases and mortality, cardiovascular diseases and mortality, hypertension, suicide mortality, low birthweight, preterm birth, type 2 diabetes, all-cause mortality, total cancer mortality
    - Excluded associations: respiratory infections, specific congenital abnormalities (not total), autism spectrum disorder, chronic kidney disease, lung and breast cancer mortality
- Particulate matter 2.5 (PM2.5)
    - Included associations: asthma, chronic obstructive pulmonary disease (COPD), respiratory diseases and mortality, cardiovascular diseases and mortality, hypertension, stroke and stroke mortality, depression, low birth weight, type 2 diabetes, all-cause mortality, total cancer mortality
    - Excluded associations: respiratory infections, small for gestational age, autism spectrum disorder, Alzheimer's disease and related dementias and Parkinson's, chronic kidney disease, mortality from cancers of the colon and rectum, liver, lung, and breast
- Sulfur dioxide - ENVIRONS will attempt to include this exposure based on models. However, this may not be possible if models show little difference in estimated exposure levels when aggregated to the neighborhood level.
    - Included associations: cardiovascular diseases and mortality, hypertension, low birth weight, gestational diabetes
    - Excluded associations: respiratory infections, specific congenital abnormalities (not total)
- Low greenness/greenspace
    - Included associations: cardiovascular disease and mortality, stroke and stroke mortality, depression, anxiety, low birth weight, all-cause mortality
    - Excluded associations: small for gestational age
- Surface temperature/heat
    - Included associations: respiratory diseases and mortality, cardiovascular diseases and mortality, stroke and stroke mortality, suicide mortality, type 2 diabetes
    - Excluded associations: acute renal failure
- Noise - ENVIRONS will attempt to include this exposure based on models. However, this may not be possible if models show little difference in estimated exposure levels when aggregated to the neighborhood level.
    - Included associations: cardiovascular diseases and mortality, hypertension, type 2 diabetes
    - Excluded associations: none
- Lead exposure risk
    - Included associations: elevated blood lead levels
    - Excluded associations: none
- Low walkability
    - Included associations: none
    - Excluded associations: hypertension, type 2 diabetes, obesity
- Odor

    - Included associations: none
    - Excluded associations: headaches, cough/phlegm
- Neighborhood crime
    - Included associations: none
    - Excluded associations: depression, psychological distress



Community Environmental Burden Assessment: Planning, Scoping, and Problem Formulation

GES Community Health Study

In response to deliverable 2.4

February 29, 2024

Revisions April 19, 2024

ENVIRONS

Colorado State University

COMMUNITY RELEVANT SUMMARY

Purpose: This document outlines the plan for how ENVIRONS will conduct the Community Environmental Burden Assessment (CEBA), which makes up Deliverables 2.4, 2.5, and 2.6 for the study.

Importance: This document is an essential checkpoint for the study to ensure that the Community Environmental Burden Assessment (CEBA), which is a considerable effort, is responsive to community needs, and that it is conducted in a scientifically valid way. This is also a crucial step in ensuring that all groups involved in the study agree on how the Community Environmental Burden Assessment will be conducted.

Plan Summary: The GES Community Health Study Community Environmental Burden Assessment aims to evaluate the combined human health effects of simultaneous exposure to various environmental stressors, such as air pollution, in the Globeville, Elyria, Swansea (GES) neighborhoods. This approach is different from what is used in traditional toxicology risk assessments in that we can directly calculate the number of deaths and illnesses attributed to environmental exposures, and we can include environmental exposures like heat and noise that are difficult to include in other approaches.

Aim 1: Calculate the number of deaths and illnesses in GES and other Denver neighborhoods that environmental exposures are responsible for.

- Environmental exposures that will be included are: fine particulate matter (PM2.5), ozone, neighborhood greenness (tree canopy), heat, and lead exposure risk. An effort will be made to include additional types of air pollution such as particulate matter < 10ug/m3 (PM10), nitrogen dioxide, sulfur dioxide, carbon monoxide, black carbon, and benzene. Noise may also be included. Our ability to include these additional exposures depends on the data we can access and if the data are detailed enough to show differences between neighborhoods. Only environmental exposures that have an established measure of association with a health outcome of interest will be included.
- The number of deaths and illnesses due to each environmental exposure will be calculated by comparing GES and all other City and County of Denver (CCoD) neighborhoods to the least burdened neighborhood, such as the neighborhood with the lowest concentration of air pollutants (i.e., PM2.5, ozone) or the highest tree canopy coverage. Based on how much more or less burdened GES (and other neighborhoods) are, we will be able to calculate the number of deaths and illnesses in each neighborhood that are due to residents being exposed to more of that pollutant.
- We will use the number of deaths and illnesses to calculate disability adjusted life years (DALYs) lost due to environmental exposures. This is a standard measure that combines deaths and illnesses, which we will use to calculate the combined impact from all exposures.

Aim 2: Describe the environmental exposures environmental justice communities in Denver, including GES, experience, and how these could impact health.

- Environmental justice communities in Denver will be identified using the Environmental Protection Agency (EPA) EJScreen and Colorado Department of Public Health and Environment (CDPHE) Colorado EnviroScreen tools. Utilizing the Colorado EnviroScreen and EPA EJ Screen allows us to focus on GES compared to the rest of Denver since they have detailed data at the census tracts. In addition, the data are already available to the public and can help the community use to further compare with other Denver communities. Lastly, Colorado EnviroScreen tool gives more detailed and defined information for the location selected.
- Environmental justice communities will be descriptively compared across multiple exposures including the total air pollution emissions from industrial facilities, proximity to hazardous waste facilities, proximity to contaminated (Superfund) sites, proximity to traffic, and the neighborhood walkability. These are important

exposures but cannot be included in Aim 1 due to lack of numerical measures of association with health outcomes.

- The impact of how some environmental exposures might reasonably change in the future will be discussed, including the impact of lower concentrations of two air pollutants, particulate matter 2.5 and ozone, a shift to having more electric vehicles instead of gas or diesel, increased tree coverage, replacement of lead service lines, and the impact of climate change.

Limitations:

- We are making assumptions about how multiple exposures interact with each other that may result in underestimating the number of deaths and illnesses.
- Not included in this analysis are social determinants of health; certain air toxics; food, marijuana, and alcohol access; community safety; some aspects of connectivity and mobility; odor; water quality; and soil quality. Excluding these may cause us to underestimate the number of deaths and illnesses due to environmental exposures.
- The following preceding items have been excluded from the analysis due to the following reasons: either there is no evidence that they pose an ongoing health risk for the community, data are not detailed enough (e.g., to estimate neighborhood differences), or the connections between the exposure and health outcomes are not well-defined.

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LIST OF ACRONYMS, DEFINITIONS, AND DESCRIPTIONS

Table 1. Key Definitions.

TERM	DEFINITION
Average annual daily traffic (AADT)	Average annual daily traffic measures the mean traffic volume over a year for a given location.[1]
BC	Black carbon; a component of particulate matter air pollution.
CDPHE	Colorado Department of Public Health and Environment. CDPHE is the principal department of Colorado state government responsible for public health and environmental regulations.
Census blocks	Small statistical areas bounded by features, such as streets, property lines, and railroad tracts. Census blocks serve as the basis for census tracts and are the lowest geographical area in measuring demographics of a population.[2]
Census tract	Small, relatively permanent subdivision of a city or county with a population between 1,200 and 8,000 people.[2]
CCoD	City and County of Denver.
Colorado EnviroScreen	Colorado EnviroScreen is an interactive environmental justice mapping tool and health screening tool developed for CDPHE by Colorado State University team members.[3]
Cumulative risk	The combined risks from aggregate exposures to multiple agents or stressors.
Cumulative risk assessment	An analysis, characterization, and possible quantification of the combined risks to health or the environment from multiple agents or stressors.
CVD	Cardiovascular disease.
Disability adjusted life years (DALYs)	Disability adjusted life years; A measure that combines morbidity and mortality to express the number of healthy years lost.
EPA (US EPA)	United States Environmental Protection Agency; the primary agency of the United States government tasked with environmental protection.
EPA EJScreen	EPA's Environmental Justice Screening tool is an interactive mapping and health screening tool.[4]
Exposure response	An exposure-response is a quantitative measurement of an association between an exposure (e.g., air pollution) and health effects.
Endpoints	An observable or measurable outcome that is used as an index of a stressor's effect (e.g., health outcome incidence or mortality).
Exposure pathways or route of exposure	The exposure pathway refers to how a pollutant enters a person's body. The four main routes are inhalation, ingestion, injection, and absorption through the skin.
GBD	Global Burden of Disease.
GES	Globeville, Elyria, Swansea neighborhoods.

TERM	DEFINITION
Health	Health is a state of complete physical, mental, and social well-being and not merely the absence of disease.[5]
Heterogeneity	Heterogeneity pertains to the degree of diversity, such as varying study findings. For instance, oil and vinegar can be defined as heterogeneous.
HIA	Health Impact Assessment; Deliverable 2.2.
Large quantity generator (LQG)	Large quantity generators are commercial or industrial facilities which generate (or produce) 1000 kg of hazardous waste per month. LQGs have specific federal and state regulations to follow to remain in compliance. Federal regulations are located under 40 CFR Section 262.[6]
Morbidity	Morbidity describes the effects a disease or a symptom of a disease has on a person's life.
Mortality	Death-producing characteristics of a disease (e.g., cause specific or all-cause mortality).
National Priorities List (NPL)	National Priorities List is a list of sites deemed to present known or threaten releases of hazardous substances, pollutants, or contaminants in the United States. The NPL is a primary guide for the EPA to determine which sites warrant further investigations.[7] For example, portions of Vasquez Boulevard and Interstate 70 Superfund are on the national priorities list.[8]
Neighborhood	The City and County of Denver recognizes 78 official neighborhoods. These are often made up of a collection of census tracts. For example, GES includes three census tracts.
O3	Ozone; a type of air pollutant.
PM	Particulate matter; PM contains microscopic solids or liquid droplets that can be inhaled and cause serious health problems. Some particles less than 2.5 micrometers in diameter can get deep into your lungs and some may even get into your bloodstream.
Population attributable fraction (PAF)	A measure used to define cases of a particular disease or mortality attributable to a specific exposure.
Risk Ratio, Rate Ratio (RR)	Risk ratio is an epidemiological term used to describe the measure of association. A RR compares the risk of a health event (disease or death) among two groups of people.[9]
Stressors	Chemicals, biological or physical agents that can induce adverse effects on human health.[10]
Toxic Release Inventory (TRI)	The Toxic Release Inventory (TRI) is an EPA management tool used to track certain toxic chemicals that may pose a threat to human health and the environment. Chemicals covered under TRI include cancer or chronic human health effects, and significant adverse acute human health effects, and significant adverse environmental effects. Facilities are regulated by employee size, industry type, and chemical thresholds.[11]

TERM	DEFINITION
Treatment, Storage, and Disposal Facilities (TSDF)	Treatment, storage, and disposal facilities (TSDF) is a grouped term that represents the final step in hazardous waste management. TSDFs are permitted and regulated at both the federal and state level for the treatment, storage, disposal, or recycling of hazardous waste. In practice, there are storage facilities, treatment and disposal facilities, and every other combination possible. Federal regulations for TSDFs are located under 40 CFR Part 264.[12]

Intended audience. The primary audiences of this Community Environmental Burden Assessment (CEBA) are the residents and community members of the Globeville, Elyria, and Swansea neighborhoods in Denver, Colorado. The secondary audiences are policymakers, public health practitioners, and government departments.

INTRODUCTION

This deliverable, Deliverable 2.4 Community Environmental Burden Assessment (CEBA): Planning, Scoping, and Problem Formulation, is the first step of the next two study deliverables (2.5 and 2.6). As part of a community environmental burden assessment process (**Figure 1**), this deliverable outlines the environmental exposures, health outcomes, and methodology that will be included in the analysis phase. This deliverable also highlights the main limitations associated with this approach.

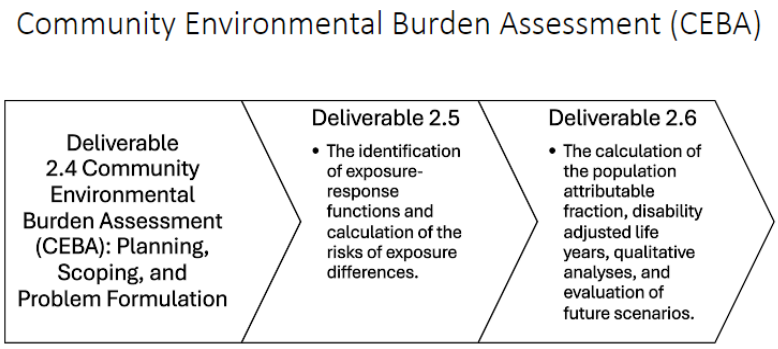

Figure 1. Community Environmental Burden Assessment Process Flow.

Our approach, outlined in detail in the following sections, uses established methods to comprehensively describe the health burdens environmental exposures, such as air pollution and proximity to hazardous waste facilities, have on Globeville, Elyria, Swansea (GES) and other neighborhoods in Denver. The design of this approach is in response to the Sierra Club v. Chao settlement agreement,[13] which calls for an assessment of how environmental exposures contribute to adverse health outcomes in GES. Unlike traditional toxicology risk assessments, we will use a burden of disease framework that allows us to calculate the number of deaths and illnesses attributed to each type of exposure, then summarize these into one metric, disability-adjusted life years (DALYs), to describe the cumulative impact that environmental exposures have in GES. Traditional risk assessments, such as those used in regulatory contexts, follow a prescribed framework based on the toxicity of a chemical, how much of the chemical is present, and the likelihood of people being exposed. The data required to conduct a toxicological risk assessment are extensive, limited to specific chemical exposures, and for the purposes of this study, unavailable to the extent required. Further, the traditional approach characterizes the risk of adverse health effects but does not quantify the number of deaths and illnesses associated with the exposure. Conversely, the environmental burden of disease approach we are following allows for the incorporation of a wider range of environmental exposures and calculation of their impact on specific diseases and mortality, which can be viewed individually by exposure or outcome, or summarized into an easily communicated metric.

Despite the greater flexibility provided by the burden of disease approach, there are still many stressors environmental justice communities face, particularly those associated with the built environment, such as the walkability of a neighborhood or the number of hazardous waste facilities, that cannot be fully accounted for in the quantitative burden assessment described here due to limited data availability. To address this limitation and acknowledge the likely impacts of these environmental stressors on the community, we will comparatively describe the impact of these additional factors on environmental justice communities in a complementary analysis that will be completed alongside the burden of disease. The focus of both analyses is on environmental exposures that evidence suggests have a disproportionate impact on GES residents. For a discussion of other factors relevant to GES (e.g., social determinants

of health, odor, and water quality) please see the health impact assessment, entitled *The ABC's of GES: The State of Health and Environment*, completed previously[1].

Community members in GES, those of other environmental justice neighborhoods in Denver, and policymakers will be able to use the findings of this analysis, the CEBA, alongside the previously published health impact assessment, to understand the impact of environmental exposures on disparate health outcomes across the City and County of Denver (CCoD). This analysis will provide the impact of environmental exposures, in real terms (i.e., the number of illnesses and deaths), by neighborhood, cause, outcome, or summarized, to facilitate community members to advocate for their community and for policymakers to create data-driven policies.

[1] *The ABC's of GES: The State of Health and Environment* can be accessed at https://drive.google.com/file/d/1X5zeZe-dITYX2soG2wS891wp51Bb9oww/view.

SPECIFIC AIMS

The study of cumulative environmental exposures within an urban environment is vital to understanding the overall health of residents. A community environmental burden assessment is a comprehensive approach to evaluating risks arising from the combined impact of multiple agents or stressors by incorporating quantitative and qualitative information to drive the understanding of relationships between these exposures and community health.[14,15]

Research on health effects from a single environmental exposure have been well established,[16] and the relationship between harmful environmental exposures and health has been studied and reported across the U.S.[17–21] However, current methodological approaches to understanding the relationship between environmental exposures and health generally focus on one pollutant at a time.[22,23] Yet, exposure is rarely limited to one stressor at a time. Applications of cumulative risk assessment methods on chemical mixtures[24–27] and indicator-based cumulative burden assessments have been slowly developed for a more refined geographical scale (i.e., regionally).[28–31] However, the assessment of cumulative environmental (chemical and non-chemical) exposures and the potential synergies among these exposures on health outcomes at a neighborhood level is not as well understood.[23,30]

The objective of the GES Community Health Study Community Environmental Burden Assessment (CEBA), is to evaluate the combined human health effects of concurrent exposure to various environmental pollutants, including chemical (i.e., air pollution) and non-chemical (i.e., built environment), in the GES neighborhood. The study intends to gather data and gain insights that will help policymakers develop evidence-based measures to address the impact of environmental pollutants on human health. The central hypothesis is that the GES neighborhoods have some of Denver's highest cumulative human health burdens and that environmental exposures contribute significantly to this burden. The specific aims of this Community Environmental Burden Assessment (CEBA), are based on the rationale that each environmental justice community exists within a local context, meaning that the challenges these communities face are unique, and must also be understood in relation and contrast to the area in which the communities are embedded. With this framework in mind, the following specific aims will be pursued to attain the overall objective of the study:

Aim 1. Quantify the excess human health burden from multiple environmental exposures in GES. We will evaluate the excess health burdens experienced by different Denver neighborhoods by utilizing publicly available health data and examining the associated environmental exposures. Our approach will be systematic and based on established literature, using linear and no-threshold exposure-response functions that account for both short- and long-term impacts of environmental exposures on health outcomes. By adopting a risk difference approach, we will estimate the impact of environmental exposure and associated health outcomes, providing a basis for comparing and ranking burden levels across neighborhoods. For this analysis, we will use the neighborhood with the lowest environmental exposure burden (such as the lowest air pollutant concentration or the highest tree canopy coverage) as a reference exposure for each environmental stressor we evaluate. To examine the excess burden impact, we will calculate both the population attributable fraction, a measure used to define cases of a particular disease or mortality attributable to a specific exposure, and disability-adjusted life years, a measure that combines morbidity and mortality to express the number of healthy years lost.

Aim 2. Qualitatively examine environmental justice neighborhoods within the City and County of Denver for present-day environmental exposures and the impact of future scenarios. We will qualitatively evaluate neighborhoods that fall under the environmental justice category, as defined by the Environmental Protection Agency (EPA) Environmental Justice Screening tool and Colorado EnviroScreen. This approach will enable us to assess the current environmental exposures in Denver's environmental justice neighborhoods and accurately capture the full range of associated impacts. By adopting this method, we aim to gain a deeper understanding of the challenges faced by environmental justice communities and to identify future scenarios that work towards creating a more equitable and sustainable environment for all.

METHODS

Our focus is based on environmental exposures identified as having a causal association with health outcomes based on existing scientific literature. Candidate health outcomes must have an established causal relationship with an environmental exposure that is supported by validated evidence of the mechanisms by which the exposure impacts health.[32] The conceptual site model (**Figure 2**) illustrates the pathways by which GES residents may encounter the environmental exposures that will be included in the Community Environmental Burden Assessment (CEBA). The conceptual site model is complementary to the Exposure Outcome Matrix (Deliverable 2.3), which illustrates the known associations between environmental exposures and health outcomes and expands on the intermediate route by which GES residents are exposed.

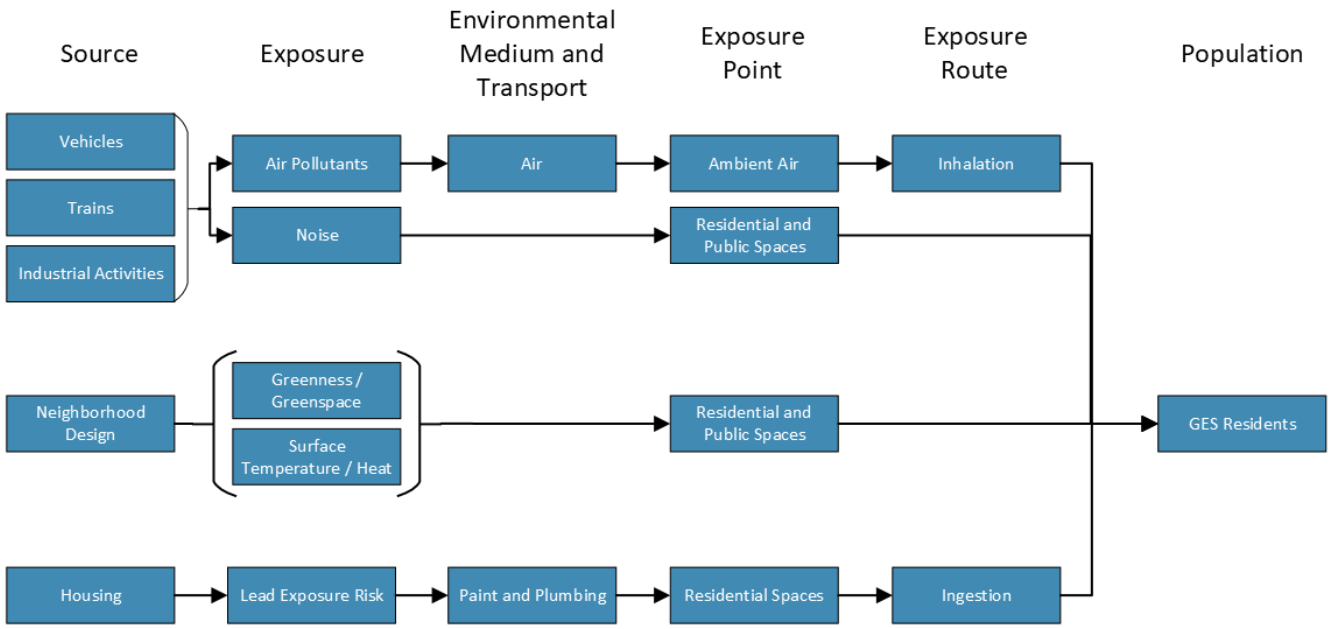

Figure 2. Conceptual Site Model

DATA

The Community Environmental Burden Assessment (CEBA) will include environmental exposures and health outcomes outlined in Deliverable 2.2's Health Impact Assessment (HIA). While Deliverable 2.2 HIA findings will serve as the primary data source, supplementary sources may be consulted as necessary. Descriptions of databases are provided in Appendix 1 of **Deliverable 2.2 Health Impact Assessment**. Statistical measures such as non-missing sample size (n), mean, standard deviation, median, maximum, and minimum will be used to concisely describe continuous variables. All statistical analyses will be conducted in R (statistical software).

POPULATION AND DEMOGRAPHIC VARIABLES

Geographical units and population data will be taken from the 2017-2021 5-year estimates from the American Community Survey by the U.S. Census Bureau.

ENVIRONMENTAL EXPOSURE VARIABLES

The utility of environmental exposure data is constrained by the geographic scale at which it is obtainable. For this analysis, we will scale environmental measurements to the neighborhood level[2], as recognized by the City and County of Denver.[33] To upscale environmental data from census block groups to neighborhoods, we will calculate the population-weighted average of the census block group measurements. Conversely, if we downscale exposure data from the state or city level to a neighborhood, we will assign the same value to the neighborhood as to the larger geographic area. Specific methodologies for calculating environmental exposure indicators used by EPA EJScreen[34] and Colorado EnviroScreen[35] can be found at https://www.epa.gov/ejscreen and https://cdphe.colorado.gov/enviroscreen. **Table 2** outlines the environmental exposures, or stressors, we have data measurements for based on monitoring data, satellite imagery, and publicly available databases. Table 2 variables are those that we will be able to use to calculate the attributable burden of health.

Table 2. Environmental Exposures (stressors).

TOPIC	DESCRIPTION OF VARIABLE	SOURCE
Particulate matter 2.5 ($PM_{2.5}$)	Annual average $PM_{2.5}$ levels in air corresponding to the year of health data.	U.S. EPA
Ozone (O_3)	Average of the annual top ten daily maximum 8-hour ozone concentrations in air (Ground-level) corresponding to the year of health data.	U.S. EPA
Trees (Greenness)	Greenness is measured by calculating the Normalized Difference Vegetation Index (NDVI) of satellite imagery.	USGS Landsat Satellite Data
Surface Temperature/Heat	Long-term average land surface temperature, remote imagery.	Denver Department of Transportation and Infrastructure
Lead exposure risk	Percent of housing units built pre-1960 as an indicator of potential lead paint exposure.	2017-2021 5-year estimates, American Community Survey

In addition to the EPA PM2.5 data, we will explore supplementing air monitoring data from Denver's Love My Air program, particularly Swansea Elementary monitoring station.[36] Denver's Love My Air program, founded in 2018, is focused around air quality monitoring (e.g., PM2.5) at partner schools.[37] Currently there are roughly 35 sites, with some monitoring data dating back to 2019. However, one limitation with using this data is ensuring the dates align with health outcome data. For some exposures (e.g., nitrogen dioxide, NO_2, sulfur dioxide, SO_2, and carbon monoxide, CO), monitoring data for Denver have limited spatial coverage, limiting our ability to interpolate measurements at the census tract level. These environmental exposure variables are outlined in **Table 3**. To address this limitation, we will explore the feasibility of using models of these exposures as proxy measurements and assess their applicability to our Community Environmental Burden Assessment (CEBA) methods.

[2] Neighborhoods, as recognized by the City and County of Denver, are aggregations of census tracts (which are in turn aggregations of census block groups) and have boundaries that generally align with those defined by the US Census Bureau.

Table 3. Environmental exposures based on models.

TOPIC	DESCRIPTION OF VARIABLE	SOURCE
Particulate matter 10 (PM_{10})	Annual average PM_{10} levels in air corresponding to the year of health data.	U.S. EPA
Nitrogen dioxide (NO_2)	Annual average corresponding to the year of health data.	U.S. EPA
Sulfur dioxide (SO_2)	Annual average corresponding to the year of health data.	U.S. EPA
Carbon Monoxide (CO)	Annual average corresponding to the year of health data.	U.S. EPA
Black Carbon (BC)	Predicted annual black carbon concentrations based on the model.	Martenies et.al., 2021 model[38]
Benzene	Annual average.	U.S. EPA
Noise	Approximate average noise energy due to transportation noise sources over a 24-hour period at receptor locations.	Bureau of Transportation Statistics, National Transportation Noise Map[39]

For Aim 2, to qualitatively compare CCoD environmental justice neighborhoods, we will calculate measures such as the proximity to hazardous waste facilities and the walkability of each neighborhood. These exposures are outlined in **Table 4.** We will rely on CDPHE's Colorado EnviroScreen and EPA's EJScreen for these variables, to allow for the use of measurements that have previously approved by these two regulatory agencies. Using these two sources for data will allow for greater comparability between the different CCoD environmental justice neighborhoods Additionally, we will explore the utility of DOTI's Open Data including "Current Sidewalks" and "Equity Index" to understand if these data sources add critical context to the primary data sources.[40–42]

Table 4. Qualitative Environmental Exposures.

TOPIC	DESCRIPTION OF VARIABLE	SOURCE
Air toxics emissions	A distance-weighted measure of estimated air toxics emissions based on reported emissions from Air Pollution Emission Notices (APENs) filed by permitted entities. Methods follow Colorado EnviroScreen.[35(p47)]	Colorado EnviroScreen
Hazardous Waste proximity	Count of hazardous waste facilities (treatment, storage, disposal facilities, TSDFs, and large quantity generators, LQGs) within 5 km (or nearest beyond 5 km), each divided by distance in kilometers. Methodologies for calculating environmental exposures are presented in EPA EJScreen.[34]	Colorado EnviroScreen, EPA EJScreen
Proximity to Toxic Release Inventory (TRI) Facilities	Proximity to Toxic Release Inventory (TRI) facilities measurements will be calculated as the percent area of each neighborhood that falls within the 1-mile buffer of toxic release inventory sites. This percentage area presents the magnitude of impact by point source pollution sites. The main limitation of this approach is that when the percentage of the area falls within the 1-mile buffer zone, the resulting measurement may underestimate the true impact of the point source pollution sites.[43]	TRI Data and Tools for Advanced/Customized Analysis
Proximity to National Priorities List (NPL) sites	Count of proposed or listed national priority list (NPL), also known as Superfund sites, within 5 km (or nearest one beyond 5 km), each divided by distance in kilometers methodologies for calculating environmental exposures are presented in EPA EJScreen.[34]	Colorado EnviroScreen; EPA EJScreen
Traffic proximity	Count of vehicles, measured as average annual daily traffic (AADT) at major roads within 500 meters, divided by distance in meters (not km) as detailed in EPA EJScreen methods.[34]	Colorado EnviroScreen; EPA EJScreen
Walkability	The Walkability Index dataset characterizes every Census 2019 block group in the U.S. based on its relative walkability. Walkability depends upon characteristics of the built environment that influence the likelihood of walking being used as a mode of travel. The Walkability Index is based on the EPA's previous data product, the Smart Location Database (SLD).[44,45]	US EPA Walkability Index

In accordance with the study contract, the purpose of Deliverable 2.2 Health Impact Assessment (HIA) was to provide an "opportunity to evaluate and discuss community concerns that cannot be addressed in Deliverables 2.4-2.6 [CEBA]." This inherently recognizes that not all environmental exposures discussed in the HIA can be included in the CEBA, due to the more stringent requirements in the CEBA process regarding environmental exposure data and defined associations with health outcomes. Environmental exposures from Deliverable 2.2 that are excluded from this analysis include:

- Social determinants of health, including education, employment and income, health behaviors, access to clinical care, and housing except lead exposure risk, have been excluded because there are not defined exposure-response relationships with health outcomes.
- Access to food, marijuana, and alcohol have been excluded because there are not consistent measurements of exposure, nor are there defined exposure-response relationship with health outcomes.
- Community safety has been excluded because there are not consistent measurements of exposure, nor are there defined exposure-response relationship with health outcomes.
- Connectivity and mobility, except walkability, has been excluded because there are not consistent measurements of exposure.
- Odor has been excluded because of the lack of objective measures of odor at a city-wide level and there is not an established exposure-response relationship with health outcomes.
- Soil quality, including potential contamination, has been excluded because site records indicate that nearly all residential properties have been remediated and there is not data to suggest that soil presents an ongoing exposure risk to GES residents (see Deliverable 2.2, Section 2.5).
- Water quality, including surface water and drinking water, have been excluded because there is no evidence to suggest that these present ongoing health risks to GES residents (see Deliverable 2.2, Section 2.6).

HEALTH OUTCOME VARIABLES

We will include health endpoints that were discussed in Deliverable 2.2 Health Impact Assessment **(Table 5).** We recognize that some environmental exposures included in this analysis have been associated with health outcomes that are not included. However, this has been done to limit the analysis to be within the scope of the GES Community Health study while focusing on health outcomes that GES residents have expressed interest in, have suitable exposure-response relationships, and account for most of the health burdens related to environmental exposures. We will use state-wide health estimates when small area estimates for Denver or GES cannot be utilized (e.g., Denver Open Data Catalog,[46] CDPHE Open Data[47]). These health outcome estimates will be sourced from the University of Washington's Institute for Health Metrics and Evaluation health data platform (https://vizhub.healthdata.org/gbd-results/). The Institute for Health Metrics and Evaluation at the University of Washington led the Global Burden of Diseases, Injuries and Risk Factors Study (GBD).[48] It is a well-known data source that provides estimates for various health factors such as all-cause mortality, deaths by cause, years of life lost due to premature mortality (YLLs), years lived with disability (YLDs), and disability-adjusted life years (DALYs). GBD uses data from different sources, such as hospital records, clinical trials, surveys (e.g., American Community Survey), disease registries, and epidemiological surveillance records.[48] GBD provides the most recent (2019) measurements for many health outcomes rather than predicted model estimates.

Table 5. Health Outcomes.

TOPIC	DESCRIPTION	SOURCE
All-cause mortality	Death from any cause	GBD; 2017-2021 Death Records
Asthma	Adult asthma incidence Childhood asthma incidence	GBD; CDC 2023 PLACES
Cancer	All-cause cancer incidence All-cause cancer mortality	GBD; 2017-2021 Death Records
Cardiovascular diseases (CVD)	CVD mortality CVD incidence	GBD; 2017-2021 Death Records; CDC PLACES
COPD	Chronic obstructive pulmonary disease incidence	GBD; CDC 2023 PLACES
Diabetes	Type II diabetes incidence	GBD; CDC 2023 PLACES
Hypertension	Incidence of high blood pressure (140/90 mmHg or higher)	GBD
Low birthweight	Incidence of infants born weighing 5.5 pounds (2500 grams) or less	GBD; 2017-2021 Birth Records
Preterm birth incidence	Incidence of infants born alive before 37 weeks of pregnancy are completed	GBD; 2017-2021 Birth Records
Respiratory disease mortality	Death from an acute or chronic illness affecting the respiratory system	GBD; 2017-2021 Death Records
Stroke	Incidence, mortality	GBD; CDC 2023 PLACES
Obesity	Incidence of adults with a BMI greater than 30	GBD

AIM 1 ANALYSIS PLAN

Aim 1 will quantitatively evaluate excess health burdens experienced by different Denver neighborhoods by utilizing publicly available health data and examining the associated environmental exposures. Aim 1 follows a burden of disease framework (**Figure 3**), which outlines how to characterize excess cases of mortality and illnesses. To achieve this aim, the following key steps will be taken.

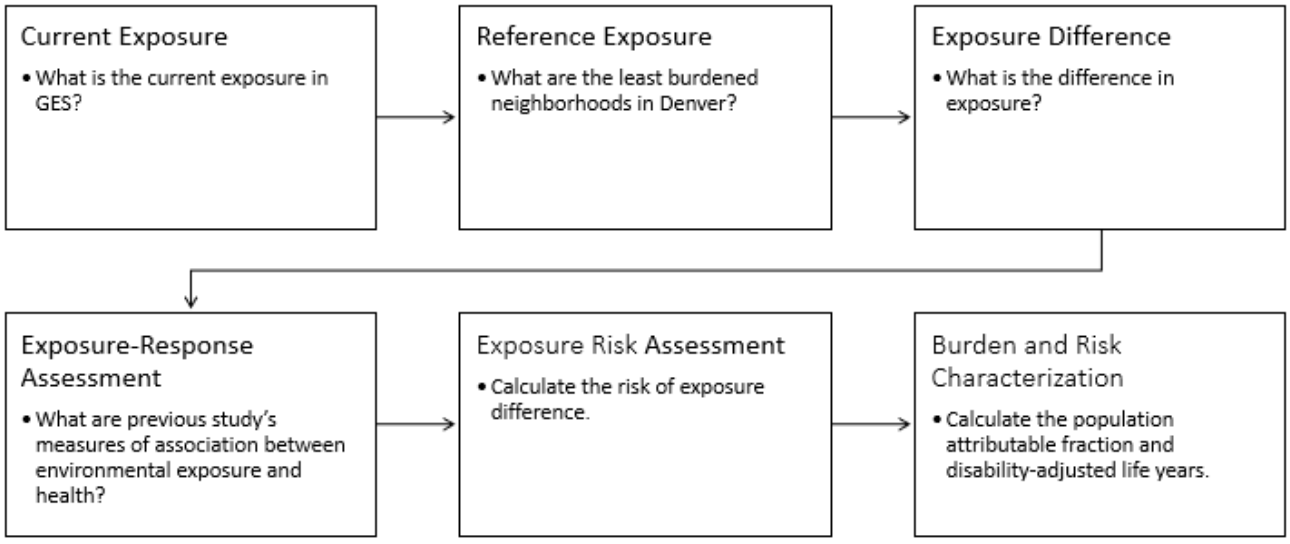

Figure 3. Aim 1 Process Flow.

CURRENT EXPOSURE

Environmental exposure data (**Table 2**) will be gathered for the GES neighborhoods and documented in a database.

REFERENCE GROUP

The reference neighborhood will change based on the environmental exposure being evaluated. For this analysis, the reference value for each environmental exposure (**Table 2**) will be the neighborhood with the lowest exposure (e.g., lowest air pollutant concentration or highest tree canopy coverage).

EXPOSURE DIFFERENCE

Environmental exposures will be numerically compared to calculate the difference in exposure between GES and the neighborhood with the lowest environmental exposure burden **(Equation 1)**.

Equation 1.

$$Difference\ in\ exposure = GES\ neighborhood\ exposure - Reference\ neighborhood\ exposure$$

EXPOSURE-RESPONSE ASSESSMENT

The exposure-response assessment, sometimes called the dose-response assessment in toxicological risk assessments, uses quantitative relationships between environmental exposures and health outcomes. A primary source for exposure-response functions is EPA's Benefits Mapping and Analysis Program (BenMAP), which uses air monitor data and population baseline incidence rates to calculate an effect estimate for particulate matter ($PM_{2.5}$) and ozone.[32] We will also largely rely on one umbrella meta-analysis, which collected effect estimates from over 100 meta-analyses on 69 environmental exposures and 83 diseases or causes of death.[49] Further exposure-response functions will be identified by using a systematic approach. We will utilize recognized literature to apply linear and no-threshold exposure-response functions that pertain to both short- and long-term impacts of the health outcomes (**Table 5**) connected to environmental exposures.

To consider using a meta-analysis study's exposure-response function, the study must meet the inclusion criteria presented in Deliverable 2.1 Data and Literature Evaluation. Some of these measures include study periods, exposure estimates, type of study, health endpoint, risk estimate reported, study population, and geographical location. Full descriptions of inclusion criteria are presented in **Deliverable 2.1**. Preference will be given to meta-analyses and large cohort studies that are more recent or present multiple pollutants. The selected exposure-response functions for our analysis will be recorded in a database that documents the environmental exposure or risk factor, the exposure unit, the type of scientific study design utilized, the study's population or age group, the risk estimate, and heterogeneity statistics.

EXPOSURE RISK ASSESSMENT

Risk calculations will be applied to the population of interest, GES, using the identified exposure-response risk estimates using **Equation 2**.

Equation 2.

$$Risk\ of\ exposure\ difference = e^{(ln(Exposure-Response)*(\frac{Exposure\ Difference}{Unit\ of\ Risk}))}$$

Where: e = mathematical function representing the natural exponent. "e" is a number approximately equal to 2.71828.

Ln = mathematical function representing the natural logarithm. Ln can also be represented as base-e log.

Exposure-Response = exposure-response functions documented in the previous step.

Exposure Difference = Equation 1.

Unit of Risk = how the environmental exposure is being measured. For example, many air pollution studies based exposure on per 10 ug/m^3.

BURDEN AND RISK CHARACTERIZATION

The final phase of the Community Environmental Burden Assessment (CEBA) is burden and risk characterizations, which will be addressed in Deliverable 2.6. We will characterize the risk of exposure by calculating excess deaths, excess cases of disease, and disability-adjusted life years.

POPULATION ATTRIBUTABLE FRACTION

The population-attributable fraction (PAF) is an epidemiological measurement that defines the number of cases of a particular disease or mortality attributable to a specific exposure.[50,51] The PAF is a measure of potential impact used to quantify the effect on a population as a whole of specific environmental exposures. **Equation 3** illustrates the formula to compare the number of cases or deaths attributable to environmental exposure due to the location of residency. The final PAF measurement can be interpreted as the number of expected deaths or cases of illness due to the difference in environmental exposure. For example, if we are considering PM2.5 and all-cause mortality, the PAF can be interpreted as the number of expected deaths related to the difference of exposure to PM2.5.

Equation 3.

$$PAF = Rate * AF * Pop$$

Where: PAF = population attributable fraction.

Rate = background incidence or mortality rate in the reference population, least burdened neighborhood health measurements.

AF = attributable fraction of exposure population; Equation 2.

Pop = number of people exposed; population in GES of the specific age group.

DISABILITY-ADJUSTED LIFE YEARS

Disability-adjusted life years (DALYs) are a measurement used to describe the burden of disease and mortality in a specific population.[52] The use of DALYS in burden assessments was introduced by the World Bank in 1991 to provide a comprehensive burden assessment of disease and risk factors.[53] DALYS provides a standardized measure of lost life years, allowing researchers to combine environmental impacts and intervention benefits.[54] One DALY represents the loss of the equivalent of one year of full health. (Two hypothetical example calculations are in Appendix A).

Two main calculations are used to find total disability-adjusted life years (DALYs; **Equation. 4**), years life lost (YLL) for mortality, and years lived with disability (YLD) for health conditions like asthma.

Equation 4.

$$DALYS = YLL + YLD$$

Where: DALYS = disability-adjusted life years.

YLL = years of life lost; Equation 5.

YLD = years lived with disability; Equation 6.

YEARS LIFE LOST

Years life lost (YLL) represents the number of years lost to premature mortality. There are two ways to calculate years of lost life. First, as **Equation 5** illustrates, is the standard formula, where we can use the number of deaths and remaining years to standard life expectancy. To follow this calculation, we will use Colorado's 2020 life expectancy of 78.3 years as our reference.[55]

Equation 5.

$$Years\ life\ lost\ (YLL) = number\ of\ deaths * remaining\ years\ to\ standard\ life\ expectancy\ at\ age\ of\ death$$

Where: YLL = years life lost.

Number of deaths = number of expected deaths; Equation 3.

Remaining years to standard life expectancy = 78.3 years – expected age of death.

Similarly, the GBD reports the number of deaths, and years life lost, which we can use to calculate a year of life lost per death rate. We can divide the reported YLL by the number of deaths to calculate a year life lost per death rate. This rate, multiplied by our expected cases (Equation 3) will result in the number of years of life lost per death (**Equation 6**).

Equation 6.

$$YLL\ of\ our\ community\ =\ YLL/death\ rate\ *\ number\ of\ expected\ deaths$$

Where: YLL = years life lost.

YLL/death rate = years life lost per death (result from GBD statistics; for example, the YLL/death rate in Colorado for all-cause mortality in 2019 is 20.1).

Number of expected deaths = Equation 3.

YEARS LIVED WITH DISABILITY

Years lived with disability (YLD) is also referred to as years lived in less-than-ideal health. There are two ways to calculate YLD. The first method (**Equation 7**) is to include disability weight and length of disability duration. Disability weight refers to the severity of a disease ranging from 0 (perfect health) and 1 (equivalent to death). We will use the GBD disability weights from 2019.[56] These weights were collected as part of the GBD study through online and phone surveys across Europe and the US.[57]

Equation 7.

$$YLD\ =\ n\ *\ DW\ *\ L$$

Where: YLD = years lived with disability.

N = number of incident cases.

DW = disability weight; scale 0 to 1.

L = average duration of disability (years).

The second method is to use the GBD reported cases and years lived with disability to calculate a rate of years lived with disability per case of illness. We will then multiply the rate by the number of expected cases of illness in GES (**Equation 8**).

Equation 8.

$$YLD\ in\ our\ community\ =\ YLD/case\ rate\ *\ number\ of\ expected\ cases$$

Where: YLD = years lived with disability.

YLD/case rate = years lived with disability rate (result from GBD statistics; for example, the Colorado YLD/case rate for asthma in 2019 is 0.3 YLD/case).

Number of expected cases = Equation 3.

AIM 2 ANALYSIS PLAN

Our study aims to provide a comprehensive analysis of the environmental impacts on various neighborhoods in Denver. We will collect data on environmental exposures, as outlined in **Table 4**, for the neighborhoods identified as having environmental justice issues by the EPA EJScreen and Colorado EnviroScreen. Using nationally available data to highlight areas with higher environmental burdens and vulnerable populations, we will rely on the EPA EJScreen to identify Denver's environmental justice neighborhoods. However, to ensure a more detailed picture, we will use Colorado's EnviroScreen tool to further characterize the environmental burdens across Denver. By combining these two data sources, we will accurately describe the variations in environmental exposures across Denver's most affected neighborhoods. Measures for qualitative environmental exposures **(Table 4)** will include non-missing sample size (n), mean, median, maximum, and minimum to compare the variations across the environmental justice neighborhoods. Aim 2 will expand results presented in **Deliverable 2.2**, "ABC's of GES: The State of Health and Environment," by focusing on environmental justice neighborhoods and the specific burdens these communities face.

The following conditions will be explored to assess future scenarios. We will use non-environmental justice neighborhoods (as designated by the EPA's EJ Screen Tool) in Denver as the counterfactual and environmental justice neighborhoods (considered individually) as our exposure unit. The analysis of the future scenarios will identify how each hypothetical benefits environmental justice neighborhoods in Denver, particularly as compared to non-EJ neighborhoods to determine the environmental and health equity of each of the following policy prescriptions.

1. **Lower $PM_{2.5}$ standard**. On February 7, 2024, the EPA lowered the primary $PM_{2.5}$ standard from 12 $\mu g/m^3$ to 9.0 $\mu g/m^3$.[58] We will evaluate the potential impact on GES and other environmental justice neighborhoods by assuming that all neighborhoods above the new 9 $\mu g/m^3$ standard will come down to 9 $\mu g/m^3$ and all neighborhoods at or below 9 $\mu g/m^3$ will stay the same.
2. **Ozone Trend**. In 2022, the EPA classified the area as severe nonattainment for ozone (2008 standard) based on 2018-2020 ozone data.[59] Colorado's ozone state implementation plan was endorsed on October 6, 2023.[60] We will assume that the trend in ozone design values for the last ten years in the Denver region will continue for the next ten years and discuss the implications of this trend at the ten-year mark (2034).
3. **Ozone Attainment**. Ozone nonattainment varies across the Northern Front Range Metropolitan Area (NFRMA), which impacts the region's overall ozone attainment status. While some NFRMA regions may remain in Severe nonattainment, models in Denver's current State Implementation Plan predict that Denver will become in ozone attainment by 2027.[61] We will discuss possible health implications from ozone attainment within Denver addition to our discussion of the implications of maintaining the status quo for the next ten years.
4. **Increased Wildfires and Severe Weather:** We will qualitatively discuss the potential impact that an increase in wildfires could have on criteria air pollutants including PM2.5, Ozone, and CO, as well as the associated health burdens like respiratory and cardiovascular disease, DALYs, and other health impacts associated with environmental exposures from wildfires. We will also explore potential synergistic relationships between health burdens from wildfires and other social determinants of health, like housing quality. We will utilize the CDC's data on social vulnerability related to Severe Weather to inform this analysis and apply an EJ lens.[62,63]
5. **Electric Vehicle Transition.** We will discuss the implications of the electric vehicle transition on health and the environment in GES and other Denver environmental justice neighborhoods using findings from other published studies.
6. **Tree Canopy Coverage.** Using findings from other published studies, we will discuss the implications of increasing tree canopy coverage on health and the environment in GES and other Denver environmental justice neighborhoods.
7. **Denver Water Lead Service Line Replacement**. We will discuss the implications of full lead pipe service line replacements being conducted by Denver Water. The Lead Service Line Replacement initiative is estimated to be completed by 2035.

8. **Impacts of Climate Change**. We will evaluate the scenario of temperature increases due to climate change. We will use historical temperature and heat index data from the Centers for Disease Control and Prevention's National Environmental Public Health Tracking database to project future temperature increases to estimate the impacts on health.[64] We will also incorporate data and qualitative discussion from Denver's Heat Index, Drought Index, and Severe Weather Vulnerability Index.

ASSUMPTIONS AND LIMITATIONS

There are multiple limitations to this study which will impact how results are interpreted. Some environmental exposure data or health outcome data are not available at the required geographical scale, limiting the applicability of these data. The scope of our study is limited by the geographical unit of analysis, specifically neighborhoods, which correspond to a combination of census tracts. As such, we will use data that relies on census tract, city, or state-level data that are publicly available. Any reference to areas smaller than the neighborhood (e.g., census blocks, streets, or houses) cannot be provided by our analysis. Further, because we are using a neighborhood reference, we are assuming that most people spend their time in or near their places of residence; we are not including occupational exposures, which may result in underestimating the total health impacts residents experience. However, because we are not including occupational exposures for any of the neighborhoods in Denver, our ability to compare between neighborhoods should be minimally impacted by omitting occupational exposures.

This study is also limited by how we assess the impact of multiple simultaneous environmental exposures on health. In this study, we are assuming that environmental exposures interact with health independently (i.e., toxicologic independence), and that toxicities are only additive[3]. While this eases the statistical models, it will fail to calculate risk fully, meaning that we may underestimate the effect of multiple combined exposures on the health of GES residents.[65] Assuming additive impacts is a common approach in this type of analysis because currently there are no standardized methods for other approaches among the number and diversity of environmental exposures we are considering in this analysis.[66–68] When considering multiple stressors acting on the same route of exposure or mode of action, more significant uncertainties arise because there is insufficient scientific evidence of how these stressors work together to impact health. Additionally, the methodologies for understanding how historical and cultural values are incorporated into risk assessments have not been developed and will not be included in this analysis.[65,69] There are also gaps in scientific knowledge surrounding low-level exposures. This gap exists because low-level exposure risks are sometimes so small that these impacts are difficult to measure or prove through experimentation.[70] Additionally, at low exposure levels, risks are assumed to increase linearly.[70,71]

We are not able to include all potential environmental exposures in this analysis. As specified in the study contract, the focus of this analysis is on environmental exposures. The environmental exposures that will and will not be included are listed in the **Environmental Exposure Variables** section. Our method to quantitatively assess the health burden from environmental exposures requires that previous studies have reported an exposure--response relationship[4] between the environmental exposure and a specific health outcome. Due to the limitations of the current state of science, some factors of the built environment (e.g., streetlights, sidewalk conditions) do not have a defined association with specific health outcomes. Some exposures may ultimately be excluded (**Table 3**) because there is not sufficient monitoring in Denver to characterize how the exposure in one neighborhood is different than that in another. We will attempt to supplement the monitoring data with models, but this may still not indicate enough difference in exposure between neighborhoods to include in this analysis. Importantly, we are also excluding social determinants of health (e.g., education or income) because the current state of the science does not support including them in this type of analysis.[15,72–74] Excluding some environmental exposures may result in underestimating the health burden on GES residents. Finally, we are not including all possible health outcomes related to environmental exposures in this

[3] For example, we are assuming that if a person is exposed to a quarter of the amount of chemical A necessary to cause harm, and a quarter of the amount of chemical B necessary to cause harm, then the person is only exposed to half (¼ + ¼ = ½) of the amount of chemicals required to cause harm and therefor the person would not experience health effects. However, there are some cases where this may not be true and the combination of chemicals, even at levels lower than what would individually or additively cause harm, would affect the person's health.

[4] A dose-response relationship describes the change in risk of a health outcome for a given increase in the exposure. For example, an increase of X ppb of ozone increases the risk of death from heart disease by Y amount.

analysis. However, we believe that the environmental exposures and health outcomes that are included capture a large fraction of the health burden GES residents have from potential environmental exposures.

While this analysis has many limitations, it will be able to provide valuable insight into the total health burden from environmental exposures in GES and other parts of Denver. Moreover, it will allow GES residents, other Denver residents, and policymakers to understand how different neighborhoods are impacted by environmental exposures in relation to each other, enabling targeted interventions to support health among the most impacted communities.

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APPENDIX A. EXAMPLE CALCULATIONS

Hypothetical Example 1. The GBD reports 40,724 deaths from all causes, all ages, and both sexes occurred in Colorado in 2019. Using this statistic, and the reported years of life lost (822,174), we can find the years of life lost per death.

- Deaths = 40,724
- YLL = 822,174
- YLL/Death rate = 822,174 / 40,724 = 20.1 years of life lost per death

Similarly, GBD reports 67,499 cases of asthma of all ages, both sexes occurred in Colorado in 2019 with a years lived with disability equaling 21,180. Using these two statistics, we can calculate the number of years lived with disability per case.

- Asthma cases = 67,499
- YLD = 21,180
- YLD/Case rate = 21,180 / 67,499 = 0.3 YLD per case

Taking both the 20.1 Years of life lost per death and 0.3 years lived with disability and multiplying it with our hypothetical expected deaths cases (equation 3), we can calculate DALYS.

- YLL = 2.2 deaths * 20.1 YLL rate = 44.48
- YLD = 0.5 expected cases * 0.3 YLD rate = 0.15
- DALYS = 44.48 YLL + 0.15 YLD = 44.63 DALYS

Hypothetical Example 2. Consider the health outcome of stroke incidence and stroke mortality. For this example, we will use 25 as our expected cases number (n=25). To calculate the DALYS of these expected stroke cases, the following steps will be applied.

We would take the Colorado 2020 life expectancy of 78.3 years and the expected age of death due to stroke of 72.5 years to find a life expectancy reduction of 5.8 years. From Equation 3, we take the number of expected cases of stroke (25 cases), multiplied by the mortality rate (20%) and life expectancy reduction (5.8) to equal 48.6 years of life lost. (Adapted from David Rojas, ERHS560)

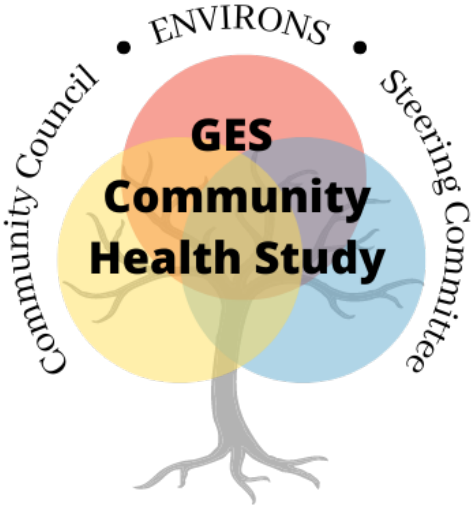
- Life expectancy reduction: 78.3 years – 72.5 years = 5.8 years
- Mortality rate 20%
- Number of expected cases of stroke (equation 3) = 25 cases of stroke
- YLL = 25 cases * 20% * 5.8 years = 48.6 years of life lost

Using the same hypothetical measurements, we can calculate years lived with disability after stroke. Using the 25 cases of stroke (n), the average duration of disability (5 years; L), and a disability weight of long-term moderate stroke survivors of 0.07, we can calculate the years lived with disability equates to 8.75 years.

- N = number of cases; 25
- DW = disability weight; 0.07
- L = average duration of disability; 5
- YLD = 25 * 0.266 * 5 = 8.75 years lived with disability

These two measurements are then added to calculate DALYS.

- DALYS = YLL + YLD
- DALYS = 48.6 years of life lost + 8.75 years lived with disability = 57.4



Community Environmental Burden Assessment:

The Exposure Response Assessment Phase

GES Community Health Study

In response to Deliverable 2.5

October 31, 2024

Resubmission December 13, 2024

ENVIRONS

Colorado State University

COMMUNITY INSIGHT

Community Insight: From the Community Council.

Hello neighbors,

As the Community Council we are writing this section to you directly. We know that there is a lot to read through and to understand in this section (Deliverable). If you are only to read one section, we request that it be our collective thoughts as your Community Council. This is our summary.

We are always searching for solutions to issues we face in our community. We also know that external groups have done local studies of our air, soil, and lived experiences. Despite the data that exists- whether it is included in this deliverable or not- we feel ignored by our local legislators, health institutions, and services. We are told time and time again that they need more evidence. Beyond the feeling of the poor air quality, we inhale every second to the crumbling sidewalks under our feet, we need to begin to understand the data that has resulted from these studies.

Our lived experience is that people's lives are shorter, our children are born with more issues, and our rates of illness are higher than the rest of Denver, and this report might not reflect that. What you will not see in this evidence is just how different these small changes in the numbers in the data feel in our daily lives. We feel as you may, that the statistics don't feel as shocking as our lived experiences. We also feel that, despite knowing that we have been studied again and again, we still need more updated information.

Still, it is important to review the data that exists and, as your Community Council, we have worked hard to understand this deliverable. Knowledge is power. Why is it powerful to our community? Often, when we are at community meetings and city officials are in front of us, we have only our lived experiences to share. By reviewing this deliverable and sharing the information from this health assessment with our neighbors, we are adding numbers to our arguments which help explain our real-life perspectives.

As you read these statistics, you'll see that the difference in numbers to the rest of Denver may be minimal in some scenarios and perhaps the assumption is that we should be "fine". However, for those of us living in the Globeville, Elyria and Swansea neighborhoods, we need city officials to understand that this is not reason enough to ignore our calls for help. While some differences in the data may seem minimal, it is substantial in the way they affect our lives.

As neighbors, we should organize in confidence around this information, ask for more studies if needed, and bring them to the attention of our elected officials, local organizations, and local health institutions. Please reach out to us or the researchers with any questions. You deserve the answers.

Sincerely,

Your Community Council

COMMUNITY RELEVANT SUMMARY

Note: This section begins the report written by the ENVIRONS research team.

Purpose: The Community Environmental Burden Assessment (CEBA) is divided across three study deliverables, Deliverables 2.4, 2.5, and 2.6, for the Globeville, Elyria Swansea (GES) Community Health Study, to ensure that the analysis is responsive to community needs and interests, and that it is conducted following scientifically valid methodology. The CEBA is a specific type of analysis that quantifies environmental exposures within and around the GES community.

Summary: Between April 2024 and October 2024, ENVIRONS team members conducted a quantitative analysis of environmental exposures across Denver, Colorado. This report, Deliverable 2.5, documents those methods and preliminary results. Environmental exposure data were obtained through the US Environmental Protection Agency (EPA) air monitoring network for 2017 through 2021. These air pollution data were spatially modeled across the City and County of Denver (CCoD) using inverse distance weighting methodology to estimate air pollution exposure levels at each neighborhood. Next, we conducted a literature review to build a database of exposure-response functions which quantify the relationship between an environmental exposure and specific health outcomes. These quantified relationships are our health effect estimates, which are presented later in this report.

There are some limitations associated with our analysis. We are making assumptions about how multiple exposures interact by assuming that simultaneous exposures are additive which may result in underestimating the number of deaths and illnesses. Additionally, by relying on the assumption that most people spend most of their time at home, we are removing occupational exposure risk. Not included in the quantitative portion of the CEBA analysis are social determinants of health (e.g., income, education level); certain air toxics, which are a broad class of chemicals that can cause negative health impacts; food, marijuana, and alcohol access; community safety (e.g., traffic, crime rates, streetlights); aspects of connectivity and mobility (e.g., connectivity refers to the ease of traveling directly between places, and can be measured as neighborhood walkability); odor; water quality; and soil quality. More information regarding these exposures is in Deliverable 2.2: *The ABCs of GES: The State of Health and Environment*.[1] These exposures have not been included in this analysis due to the lack of data availability or lack of scientific literature quantifying the relationship between exposure and health outcomes. Excluding these may cause us to underestimate the number of deaths and illnesses due to environmental exposures. As part of this deliverable, ENVIRONS and Community Council members met to discuss the analyses and preliminary results. From our conversations, the following conclusions were made:

- Industrial facilities and road traffic are two of the most common sources of air pollutants, which reflects what many community members see on a daily basis.
- The measurements of exposure levels cannot fully capture the lived experiences of the community. We acknowledge that engaging with both scientific data and personal narratives is essential for comprehensively understanding the environmental health conditions in GES. Translating exposure level measurements into everyday life can be challenging (e.g., what does a change of 10 $\mu g/m^3$ of $PM_{2.5}$ look like?). Similarly, converting lived experiences into quantitative data poses difficulties (for instance, how can we convey that data transcends mere numbers, representing real human beings who are actively living, breathing, and dreaming?). Therefore, a crucial theme throughout the GES Community Health Study has been the analysis of data and communication of findings in a manner that is accountable to both the GES community and the scientific community.
- This deliverable contributes to the overall GES Community Health Study, with its results serving as preliminary findings leading into Deliverable 2.6. Deliverable 2.6 is the third report of the CEBA, providing both qualitative and quantitative assessments of the disease burden that may be linked to environmental exposures and social determinants of health specific to the GES neighborhood.

ACKNOWLEDGEMENTS

This Deliverable was written by Community Council members and ENVIRONS. It has been reviewed by the Steering Committee.

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LIST OF ACRONYMS, DEFINITIONS, AND DESCRIPTIONS

Table 1. List of acronyms, definitions, and descriptions.

Term	Definition
CC	Community Council is a group of resident collaborators part of the research team that act as community representatives, experts, and liaisons.
CDPHE	Colorado Department of Public Health and Environment. CDPHE is the principal department of Colorado state government responsible for public health and environmental regulations.
CEBA	Community environmental burden assessment. The GES Community Health Study CEBA is comprised of Deliverables 2.4, 2.5, and 2.6.
Census blocks	Small statistical areas bounded by features, such as streets, property lines, and railroad tracts. Census blocks serve as the basis for census tracts and are the lowest geographical area in measuring demographics of a population.[2]
Census tract	Small, relatively permanent subdivision of a city or county with a population between 1,200 and 8,000 people.[2]
CI	Confidence Interval. A confidence interval, or level of significance, is the average value of the estimate plus or minus the variation of that estimate. In other words, the confidence interval describes the probability that an estimate will fall between two values centered around the mean.
CCoD	City and County of Denver.
Cumulative risk	The combined risks from aggregate exposures to multiple agents or stressors.
Cumulative risk assessment	An analysis, characterization, and possible quantification of the combined risks to health or the environment from multiple agents or stressors.
CVD	Cardiovascular disease.
Environmental justice community	Environmental justice is the idea that all people and communities have the right to live and thrive in safe, healthy environments with equal environmental protections and meaningful involvement in these actions.[3] An environmental justice community can also be identified as a disproportionately impacted community. In 2023, Colorado officially defined disproportionately impacted communities as those meeting specific criteria including low income, higher proportions of residents from minoritized race and ethnicity groups, housing cost-burdens, linguistic isolation, historical marginalization, cumulatively impacted, tribal lands, and mobile home communities.[4] This definition places emphasis on historically marginalized and cumulatively impacted communities, highlighting environmental racism and disproportionate environmental burdens.
ENVIRONS	Estudio de Nuestros Vecinos para Investigar los RiesgOs y Nuestra Salud (ENVIRONS) research team is based out of Colorado State University in Fort Collins, CO and is responsible for conducting the GES Community Health Study.
EPA (US EPA)	United States Environmental Protection Agency; the primary agency of the United States government tasked with environmental protection.
Exposure-response/Effect estimate	An exposure-response, often presented as an effect estimate (see measure of association) is a quantitative measurement of an association between an exposure (e.g., air pollution) and health effects. An exposure-response relationship describes the change in risk of a health outcome for a given increase in the exposure. For example, an increase of X ppb of ozone increases the risk of death from heart disease by Y amount.

Term	Definition
Endpoints	An observable or measurable outcome that is used as an index of a stressor's effect (e.g., health outcome incidence or mortality). In this deliverable, stressors are environmental factors and effects are health related.
Exposure pathways or route of exposure	The exposure pathway refers to how a pollutant enters a person's body. The four main routes are inhalation, ingestion, injection, and absorption through the skin.
GES	Globeville, Elyria, Swansea neighborhoods.
Health	Health is a state of physical, mental, and social well-being and not merely the absence of disease.
Heterogeneity	Heterogeneity pertains to the degree of diversity, such as varying study findings. For instance, oil and vinegar can be defined as heterogeneous.
HIA	Health Impact Assessment; Deliverable 2.2 *The ABCs of GES: The State of Health and Environment* of the GES Community Health Study.
Measure of association	A measure of association, presented as an effect estimate refers to a wide variety of statistics that quantify the relationship between environmental exposures and health outcomes, enabling comparison between different groups.
Morbidity	Morbidity describes the effects a disease or a symptom of a disease has on a person's life.
Mortality	Death-producing characteristics of a disease (e.g., cause specific or all-cause mortality).
Neighborhood	The City and County of Denver recognizes 78 official neighborhoods, including Denver International Airport (DIA). These are often made up of a collection of census tracts. For example, GES includes three census tracts.
O_3	Ozone; a type of air pollutant.
PM	Particulate matter; PM contains microscopic solids or liquid droplets that can be inhaled and cause serious health problems. Some particles less than 2.5 micrometers in diameter can get deep into your lungs and some may even get into your bloodstream.
Population attributable fraction (PAF)	A measure used to define cases of a particular disease or mortality attributable to a specific exposure.
Risk Ratio, Rate Ratio (RR)	Risk ratio is an epidemiological term used to describe the measure of association. A RR compares the risk of a health event (disease or death) among two groups of people.
SC	The Steering Committee are stewards of the settlement agreement to ensure it is carried out appropriately, including through the approval of work plans, invoices, and deliverables.
Stressors	Chemicals, biological or physical agents that can induce adverse effects on human health.

INTRODUCTION

Residents of Globeville, Elyria, and Swansea (GES) have long fought to bring awareness to the environmental hazards of the GES environment (Figure 1). In response to the Colorado Department of Transportation (CDOT) Central Interstate-70 expansion project (referred to as Central 70 project), Elyria-Swansea Neighborhood Association, Colorado Latino Forum, and Chaffee Park Neighborhood Association with support from Colorado Sierra Club, joined together in 2017, and filed a lawsuit against the expansion (referred to as the Central 70 settlement).[5,6] The lawsuit was settled, and funds were designated for the creation of a comprehensive health study in the neighborhoods.[7] The Central 70 settlement outlines that the health study must provide decision-makers with the information required to make policy without recommending any policy itself. This is a nuanced and challenging requirement to adhere to and may be disheartening to community members and partners who wish to see actionable change.

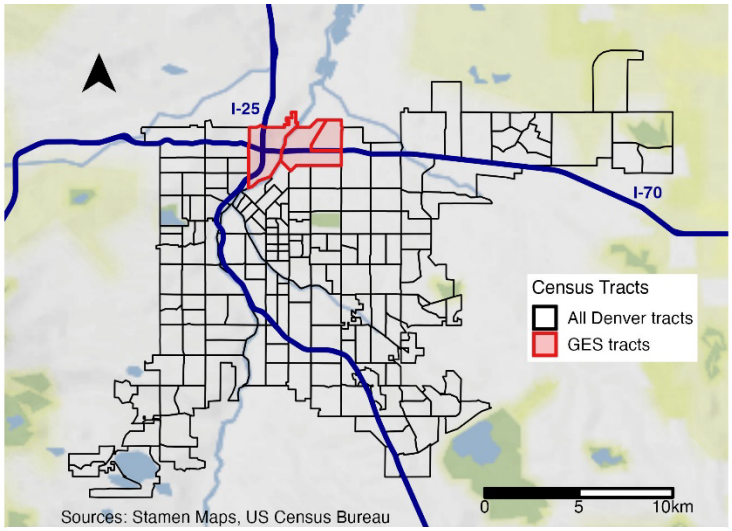

Figure 1. Globeville and Elyria Swansea census tracts in relation to City and County of Denver area.

The objective of the GES Community Health Study Community Environmental Burden Assessment (CEBA) is to evaluate the combined human health effects of concurrent exposure to various environmental pollutants, including chemical (i.e., air pollution) and non-chemical (i.e., built environment), in the GES neighborhood. The purpose of the CEBA is to underscore the critical need for environmental justice analyses at the local level, placing specific emphasis on the GES neighborhoods. Numerous studies have consistently demonstrated the stark relationship between harmful environmental exposures and the adverse health outcomes among marginalized communities.[8–10] The GES Community Health Study[11] intends to gather data and gain insights that will help policymakers develop evidence-based measures to address the impact of environmental pollutants on human health. The central hypothesis is that the GES neighborhoods have some of Denver's highest cumulative human health burdens and that environmental exposures contribute significantly to this burden. GES may experience heightened impacts due to its proximity to major interstates, Superfund sites, and extensive industrial activities. The combination of these factors could magnify the overall environmental burden on the community, thereby necessitating a comprehensive examination of these localized dynamics.

Accessibility is a top priority of the GES Community Health Study. Conversations with GES residents have underscored the importance of creating study deliverables that are accessible to the community. This includes ensuring that methods are thoroughly explained so that community members can interpret findings with ease and mobilize study findings in pursuit of actionable change. The GES Community Health Study Community Council works closely with the ENVIRONS research team to ensure that deliverables address the needs, interests, and insights of GES residents. Future study deliverables will communicate findings to the broader GES community through community meetings,

neighborhood canvassing, and discussions with community organizations and stakeholders. To return data to the GES community, all final reports, data, and methodologies will be available for public access on the CDOT website, per the settlement agreement. The GES Community Health Study aims to contribute to environmental health knowledge and call attention to gaps in data availability. All previous study deliverables are available on the GES Community Health Study website, located at https://www.geshealthstudy.org/home. We have also included a list of past study deliverables published to date (Table 2).

Table 2. GES Community Health Study Deliverables.

Deliverable	Description
Phase I	Planning and Foundations deliverables
Deliverable 1.1: ENVIRONS Questionaries	After participating in a tour of the GES neighborhoods, each ENVIRONS team member completed a questionnaire prepared by the Community Council. In addition to individual responses, a summary for the team was created.
Deliverable 1.2: Shared Operational Principles	The Community Council, ENVIRONS, and Steering Committee identified roles and defined shared values, motivations, expectations, and limitations for the study.
Deliverable 1.3: Community Engagement Plan	The Community Engagement plan was developed with the Community Council and Steering Committee. It defines how ENVIRONS will communicate with the Community Council and the Steering Committee, and outlines strategies for communicating with residents, soliciting community input, and maintaining transparency.
Deliverable 1.4: Narrative	ENVIRONS identified sources of data, literature, and on-going projects that will be used in Phase II. As part of this, ENVIRONS reviewed the materials provided in the "crowd sourced literature review" folder curated by the Steering Committee prior to ENVIRONS coming onto the study.
Deliverable 1.5: Mapping and Website	The website is available in English and Spanish, and maps are available on the Maps page.
Deliverable 1.6: Course Correction Plan	ENVIRONS worked with the Community Council and Steering Committee to create a course correction plan. This plan ensures that the study is headed in the right direction for Phase II.
Phase II	Analysis
Deliverable 2.1: Data Rubric and Literature Evaluation	ENVIRONS created a rubric to evaluate the quality of literature and data, then applied this rubric to the sources of information identified in the crowd-sourced literature folder or in the Preliminary Data Identification and Narrative.
Deliverable 2.2: The ABCs of GES: The State of Health and Environment	This report characterizes areas of community concern, provides updated data to topics identified in the 2014 Health Impact Assessment report, and evaluates the implementation of recommendations from the 2014 report.
Deliverable 2.3: Exposure Outcome Matrix	The Exposure Outcome matrix demonstrates the connections between environmental exposures in GES, health outcomes, and health disparities based on existing research. The purpose of this matrix is to visualize how environmental exposures (e.g. pollutants) are connected to adverse health outcomes.
Deliverable 2.4: Community Environmental Burden Assessment (CEBA): Planning, Scoping, and Problem Formulation	This document outlines the plan for how ENVIRONS will conduct the Community Environmental Burden Assessment (CEBA), which makes up Deliverables 2.4, 2.5, and 2.6 for the study.

The Community Environmental Burden Assessment (CEBA), comprised of Deliverables 2.4, 2.5, and 2.6, is the next key component in the GES Community Health Study.

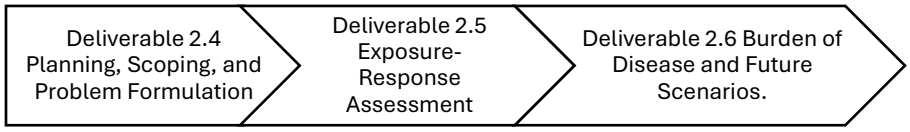

Figure 2. Deliverables 2.4-2.6 Community Environmental Burden Assessment (CEBA) Process Flow.

Deliverable 2.4 *Community Environmental Burden Assessment (CEBA): Planning, Scoping, and Problem Formulation*, served as a pivotal planning step for the GES Community Health Study.[12] This deliverable played a critical role in ensuring that the CEBA effectively responds to the specific needs of the community while adhering to scientifically robust methodologies. It provided a comprehensive outline of the proposed approach for conducting the CEBA, incorporating established analysis methods based on the burden of disease framework. This foundational work was essential for initiating the subsequent quantitative analysis, which aims to provide an in-depth understanding of the environmental health impacts on the community.

In this report, Deliverable 2.5, we address the exposure-response assessment phase of the CEBA, illustrated in Figure 2. Deliverable 2.5 outlines the methodology used to establish exposure levels of six specific air pollutants throughout the City and County of Denver. Additionally, it delves into the existing scientific literature to identify relevant health impact measurements associated with these pollutants, thereby enhancing our understanding of their potential effects on community health.

Looking ahead, Deliverable 2.6 will finalize the CEBA process flow by conducting a detailed analysis of the excess disease burden attributable to differences in exposure levels, particularly focusing on the neighborhoods of Globeville and Elyria-Swansea. This analysis will compare these areas to other neighborhoods in Denver, providing insight into the public health implications of environmental exposures and informing future interventions aimed at reducing health disparities within the community.

Most frequently, the utilization of population-attributable effect estimates is applied to broader spatial scales (e.g., global, countries, regions).[13–15] More recently, these methodologies have been applied to county, city, and census tract-level populations.[16,17] For instance, Castilo et al. employed this approach to assess intra-urban heterogeneity of fine particulate matter ($PM_{2.5}$) attributable to mortality and morbidity in Washington, DC. They found that $PM_{2.5}$ attributable health burdens are unevenly and inequitably distributed across the area.[18] Similarly, Son *et al*. investigated air pollution-mortality relationships in North Carolina, and used community-level factors to determine potential effect modifiers in the estimation of population-attributable risk.[19] Our approach uses sound methodology applied in environmental risk assessments[20,21] and environmental burden assessments[22–24] to estimate the health impacts of disproportionate environmental exposures in the Globeville, Elyria, and Swansea neighborhood compared to the least exposed neighborhood in Denver.

The assessment of attributable health burdens takes into account the many simultaneous environmental exposures experienced by environmental justice communities, which is an advantage over single- or multi-pollutant frameworks. Our assessments can account for the cumulative risks incurred by each exposure in the mixture, which may otherwise be omitted when examining one exposure at a time. We specifically target health outcomes that are well-defined and representative of broader population health. We prioritize environmental exposures that current scientific literature has established as having a causal relationship with specific health outcomes. This targeted approach, while beneficial,

does limit the spectrum of environmental exposures we can evaluate quantitatively. We are confined to those exposures that possess robust causal evidence linking them to health effects, and for which suitable monitoring data are readily available. Moreover, our analysis must adhere to definitions of environmental exposures that are consistent with established scientific standards.

In Deliverable 2.4 *Community Environmental Burden Assessment (CEBA): Planning, Scoping, and Problem Formulation*, we sought to incorporate exposures such as urban greenness (i.e. tree coverage and NDVI), surface temperature, and lead exposure risk through proxy measurements of the percentage of housing units built before 1960.[12] However, we encountered a challenge: the data available for these exposures did not align with the data descriptions employed in the scientific literature (e.g., lead exposure risk through proxy of blood lead levels, or obesity as a general concept compared to BMI measurements), ultimately resulting in their exclusion from our analysis. This discrepancy underscores the importance of data quality and definition standards in conducting meaningful environmental health assessments.

For the current analysis, we have confined our focus to the six of the criteria air pollutants, particulate matter 2.5 ($PM_{2.5}$) and 10 (PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO). Notably, some community members express primary concern over environmental exposures that go beyond these six criteria air pollutants, which presents a significant limitation of this study. (Note: airborne lead is also a criteria pollutant but has dramatically been reduced following the removal of lead from gasoline in the 1970s. As there are no active sources of airborne lead in the community, results are not presented here. However, to note, soil lead levels remain a major concern in the neighborhoods).

In Deliverable 2.4 *Community Environmental Burden Assessment (CEBA): Planning, Scoping, and Problem Formulation*, we proposed a list of candidate health outcomes that are particularly relevant to our analysis.[12] These outcomes include all-cause mortality, childhood asthma, obesity, and Type 2 diabetes. To ensure the integrity of our analysis, we emphasize that each proposed health outcome must demonstrate an established causal relationship with specific environmental exposures. This relationship should be supported by rigorous and validated evidence detailing the mechanisms through which these environmental factors influence health. Our focus on these health outcomes is intentional; it aligns with the discussions presented in Deliverable 2.1 *Data and Literature Evaluation*,[25] while also reflecting the interests and concerns expressed by community members we work with. By concentrating on these critical indicators of community health, we aim to better understand and identify the environmental factors that disproportionately affect environmental justice communities in Denver, Colorado.

As part of the larger CEBA process, Deliverable 2.5 builds upon this foundation and consists of the first four steps illustrated in Figure 3, to systematically approach the identification and analysis of these key health outcomes and their environmental determinants.

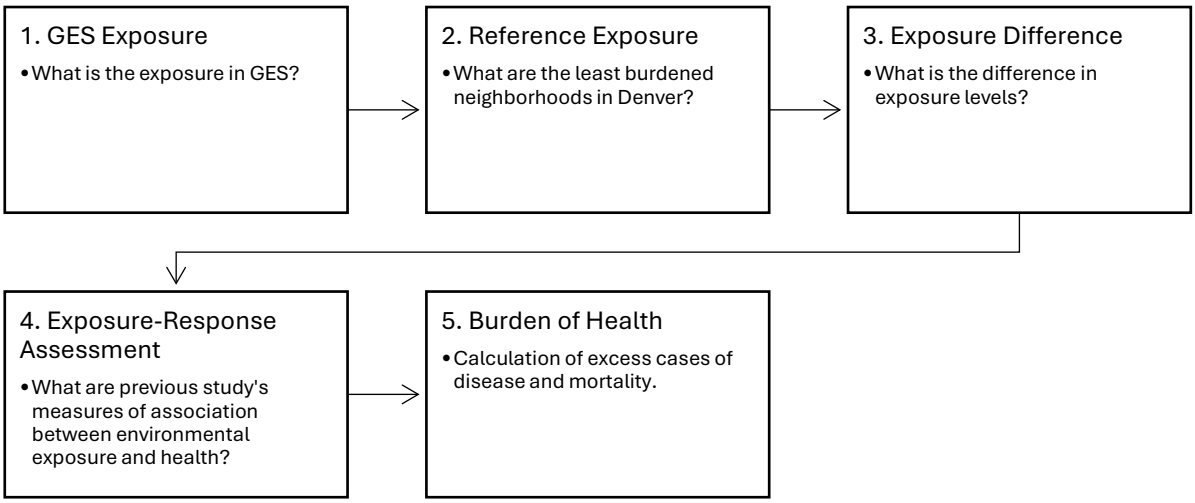

Figure 3. CEBA Aim 1 quantitative analysis process flow diagram.

EPA NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS).

The Clean Air Act mandates that the Environmental Protection Agency (EPA) establish and periodically reassess scientific evidence related to six key air pollutants: particulate matter with diameters of 2.5 micrometers or smaller ($PM_{2.5}$), particulate matter with diameters of 10 micrometers or smaller (PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO) (please see prior note regarding airborne lead). To fulfill this requirement, the EPA undertakes comprehensive scientific evaluations that analyze the latest research findings and health-related evidence. This rigorous review process helps to ascertain whether new air quality standards are necessary to safeguard public health and ensure environmental protection. The EPA's work is vital in identifying potential risks associated with these pollutants and in shaping effective policies to mitigate their impact on air quality and overall community health.

Particulate Matter 2.5 ($PM_{2.5}$) and 10 (PM_{10}). In early 2024, the EPA made significant updates to the NAAQS, specifically revising the standards for $PM_{2.5}$ by lowering the annual standard for $PM_{2.5}$ from 12 μg/m^3 to 9 μg/m^3.[26] This change reflects an evolving understanding of the health impacts associated with prolonged exposure to particulate matter, acknowledging that stricter standards may help mitigate adverse health effects on sensitive populations. The previous revision of $PM_{2.5}$ regulations occurred in 2012, indicating a substantial gap of over a decade before the latest adjustments were made.[27] It is important to note that $PM_{2.5}$ air quality standards are established based on the annual arithmetic mean concentration measured over a three-year period. This approach allows for a detailed assessment of air quality trends and variations. In conjunction with the $PM_{2.5}$ changes, the EPA chose to maintain the existing standard for PM_{10}, which is set at a 24-hour concentration limit of 150 μg/m^3. This PM_{10} standard is designed to ensure that this level of particulate matter is not exceeded more than once per year, based on an average calculated over a three-year period.

Ozone (O_3). In December 2020, the EPA conducted a review of scientific evidence concerning exposure risks associated with the current NAAQS for ozone.[28] The existing standard, established in 2015, is set at 0.070 ppm (70 ppb), which represents the fourth highest maximum daily 8-hour ozone concentration each year, averaging over three years.

Nitrogen Dioxide (NO_2). Nitrogen dioxide (NO_2) is a significant air pollutant that presents various health and environmental challenges. It is primarily produced from the combustion of fossil fuels, especially in vehicles, power generation facilities, and various industrial processes. NO_2 is a reddish-brown gas characterized by a sharp, unpleasant odor and is a major contributor to the formation of smog and acid rain. The EPA has established NAAQS for NO_2, designating a 98th percentile of 1-hour daily maximum concentrations, averaging over 3 years of 100 ppb and an annual mean concentration limit of 53 ppb.[29]

Sulfur Dioxide (SO_2). Sulfur dioxide (SO2) is a colorless gas with a pungent odor, primarily generated through the combustion of fossil fuels such as coal and oil, as well as from various industrial processes, including metal smelting and oil refining. The EPA last conducted a comprehensive review of the NAAQS for SO_2 in 2019.[30] This review aimed to assess the levels of SO_2 in the atmosphere and evaluate the effectiveness of existing regulations. Ultimately, the EPA decided to maintain the current one-hour standard of 75 ppb, which is designated as the 99th percentile of daily maximum concentrations observed over a three-year monitoring period.

Caron Monoxide (CO). Carbon monoxide (CO) is a colorless, odorless gas that is predominantly produced by the exhaust emissions of motor vehicles and various industrial processes. The EPA has established NAAQS to monitor and manage CO levels in the atmosphere consisting of two key thresholds: an 8-hour standard and a 1-hour standard.[31] The 8-hour standard is set at a maximum concentration of 9 ppm (equivalent to 9000 ppb), while the 1-hour standard permits a higher concentration of 35 ppm. Notably, both standards allow for exceedances only once per calendar year.

METHODS

SPATIAL UNIT OF ANALYSIS. For this analysis, we relied on City and County of Denver's (CCoD) definitions for statistical neighborhoods, while omitting Denver International Airport (DIA), resulting in a total of 77 neighborhoods of interest (Figure 4).[32] These statistical neighborhoods are typically a combination of census tracts. Within the neighborhood dataset, GES is divided into Globeville and Elyria-Swansea. However, we recognize that many residents view GES as three individual neighborhoods. For the purposes of this analysis, we report GES results as two spatial units, Globeville and Elyria-Swansea to match CCoD's statistical neighborhood definitions.

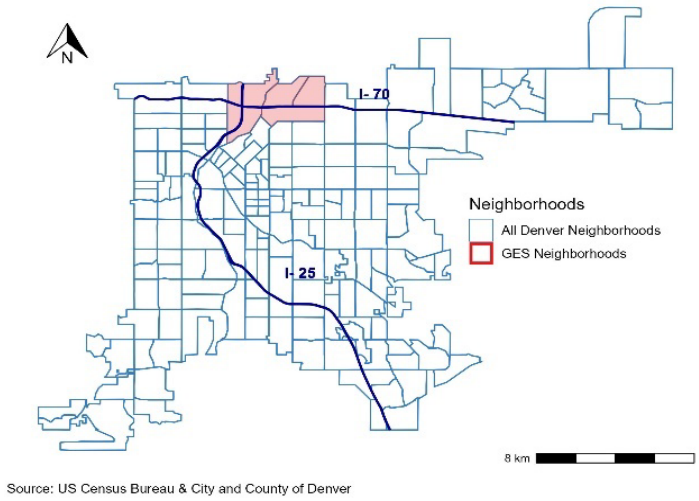

Figure 4. Denver neighborhoods.

AIR QUALITY DATA. The US Environmental Protection Agency (EPA) has established monitoring stations throughout the United States to continuously collect air quality measurements. Figure 5 highlights the EPA air monitoring stations along the Colorado front range region. Researchers utilize air quality data to develop models and conduct analyses at various geographic levels. In this study, air quality data (i.e., $PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, and CO) were acquired using the US Environmental Protection Agency (EPA) Air Quality System (AQS) application programming interface (API) through the R statistical programming language. Monitoring data for the years 2017 through 2021 for Colorado were obtained for $PM_{2.5}$ (24 - hour mean 2012 standard; micrograms per cubic meter, $\mu g/m^3$), O_3 (8- hour daily mean; parts per million, ppm), PM_{10} (24-hour mean; $\mu g/m^3$), NO_2 (1 - hour mean 2010 standard; parts per billion, ppb), SO_2 (1 - hour mean 2010 standard; ppb), and CO (8 - hour mean 1971 standard; ppm).

These data were then refined from the state level to encompass the Denver metropolitan counties, including Adams, Arapahoe, Broomfield, Denver, Douglas, and Jefferson counties. The obtained air quality data contain multiple EPA standards, which indicate the sample duration and method, resulting in duplicate entries for the same air samples. Therefore, we filtered data to one pollutant standard for our analysis by utilizing the pollutant standards that were implemented either before or during the 2017-2021 timeframe to minimize the impact of repeated measurements. Appendix A summarizes the EPA air monitoring data by pollutant and monitoring site.

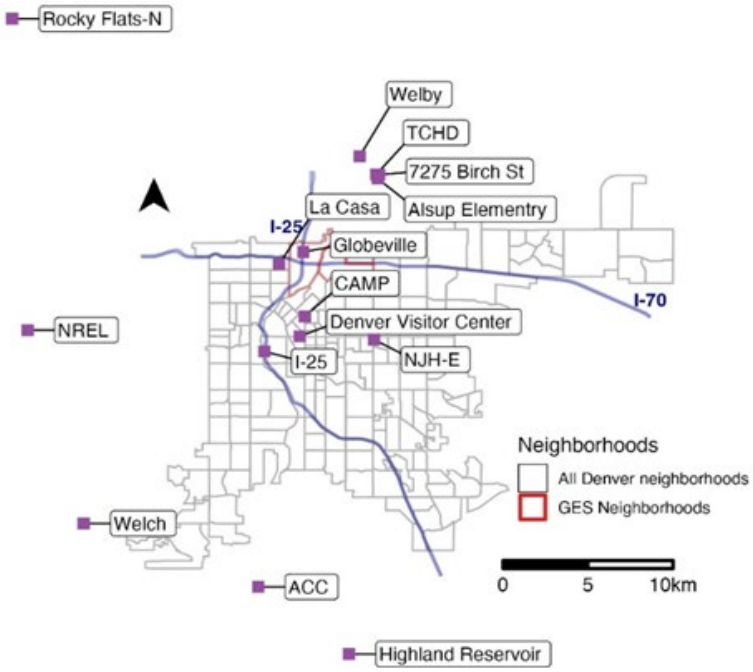

Figure 5. EPA air monitoring stations along Colorado front range region.

ESTIMATING EXPOSURE. Environmental exposure data usability is limited by the geographical scale at which it is obtainable. In this study, we addressed this limitation by scaling environmental measurements to the neighborhood level as recognized by the City and County of Denver and omitting Denver International Airport (DIA). By doing so, we aimed to capture a more granular understanding of environmental factors at a local level. Environmental exposure measurements can be obtained through two main methods: direct measurement data, which involves the collection of real-time, firsthand readings from the environment, and modeled data, which is generated using statistical or mathematical models and simulations to estimate exposure levels based on a variety of assumptions. In the realm of air pollution, the EPA has deployed air sampling equipment at various monitoring stations throughout the Front Range (Figure 5). These stations collect samples of air pollutants, such as $PM_{2.5}$ and O_3, which are validated and aggregated in a publicly accessible online database. By utilizing this data, we can model exposure levels in areas that lack air monitoring stations.

While spatiotemporal models (e.g., Martenies *et al.* 2021) offer valuable insights for assessing air exposures, they come with notable limitations. One of the primary drawbacks is that these models can be quite resource-intensive in terms of time, data collection, and computational power. Additionally, as new data becomes available or as environmental conditions change, these models can quickly become outdated, leading to inaccuracies in predictions and assessments. Although these models can be effectively utilized in specific scenarios, there is a pressing need for updated sampling campaigns that can provide additional measured data. Such campaigns would enhance our understanding of air quality and exposure levels, ensuring that our models reflect the most current conditions and trends. Previous studies have used EPA air monitoring data and inverse distance weighting (IDW) interpolation modeling which we implemented here.[33–36] Inverse distance weighting (IDW) is a technique commonly used in geographic information systems (GIS) which uses mathematical functions to predict values for locations where measurements are not available.[37–39] The underlying principle of conventional IDW assumes that the influence of a measured point location, such as an air monitoring station, diminishes as distance from that point increases. IDW operates under the assumptions of spatial autocorrelation and local pattern homogeneity.

Spatial autocorrelation refers to how values closer to each other in space are more likely to be similar, and this similarity diminishes with distance. Due to how the EPA monitors air pollution along the Colorado Front Range

(Figure 5), some air pollutants only have a few sampling locations (e.g., there are three monitors that collect SO_2 data). IDW allows us to use these limited sampling locations to estimate air pollutant exposure levels across the entire area of interest (i.e., CCoD), providing a more comprehensive view of the environmental landscape. When depending on a restricted number of sampling locations for our assessments, there is a significant risk that we might either overestimate or underestimate the actual level of exposure. This potential misrepresentation can occur due to a bias toward the nearest monitoring stations, which can result from spatial correlation.[40,41] Such bias suggests that areas closer to monitoring stations may have their exposure levels inaccurately reflected, regardless of the actual conditions in surrounding neighborhoods. Despite these challenges, our objective is to obtain exposure estimates at the neighborhood level, which necessitates the use of the data currently available to us. This approach acknowledges the complexities involved in environmental exposure assessments while striving to remain as accurate as possible within the constraints of our data collection methodology. Homogeneity of local patterns assumes that local regional trends are relatively consistent, and that large-scale global patterns are not significant for interpolation. Local pollutant concentrations are not always uniformly distributed, potentially influenced by wind, topography and local emission sources (e.g., Suncor).[42,43] IDW may not fully capture these variations, however, because we are consistent in assuming local homogeneity across all neighborhoods, this is anticipated to have minimal impacts on our model results.

We used daily average EPA air monitoring station data as our input into the IDW model to estimate the five-year weighted average air pollutant concentrations at CCoD neighborhood centroids over the duration of 2017 to 2021 (Figure 3 Boxes 1 and 2). A centroid is defined as the average geographic center of a spatial object.[44] The IDW process starts by calculating the distances between a target location (i.e., neighborhood centroids) and our known data points (i.e., air monitoring stations). Next, we assigned a weight for each point. For this analysis, an interpolation distance power (IDP) parameter of two was implemented (i.e., inverse distance squared, also referred to as a gravity model).[35,36,45–48] The inverse distance power (IDP) parameter controls how the weight of surrounding points decreases with distance. For example, an IDP of one is used when aiming for a linear decrease in weight with distance, obtaining a greater influence from distant point locations. An IDP of two is when the influence of neighboring points diminishes quadratically. An IDP of two is more commonly applied with environmental data when aiming for a more localized prediction.[49,50] Additionally, we conducted a sensitivity analysis to assess an alternative power parameter of 3. Because we did not observe meaningful differences in the root mean squared error of our estimates, we elected to use the power parameter of 2 to be consistent with other previous work. Lastly the IDW model computes a weighted average that is normalized to a value of one.[37] This ensures that the weighted averages calculated are proportionate to the data point locations and scaled to provide meaningful estimates. We assumed the air pollutant concentrations estimated at the neighborhood centroid was representative of exposures across neighborhood spatial units.

EXPOSURE DIFFERENCE. Our analysis involved comparing air pollutant concentrations to determine the differences in exposure levels between Globeville, Elyria-Swansea, and the neighborhood with the lowest environmental exposure burden (Figure 3 Box 3; Equations 1 and 2).

Equation 1. Globeville exposure difference.

$$Globeville\ exposure\ difference\ =\ Globeville\ exposure\ level\ -\ reference\ exposure\ level$$

Where reference exposure level is the least burdened neighborhood based on the air quality measurement of interest. An exposure difference greater than zero indicates that Globeville exposure levels are higher than the reference neighborhood. An exposure difference of zero indicates that Globeville exposure levels are the same as the reference neighborhood.

Equation 2. Elyria-Swansea exposure difference.

$$Elyria-Swansea\ exposure\ difference\ =\ Elyria-Swansea\ exposure\ level\ -\ reference\ exposure\ level$$

Where reference exposure level is the least burdened neighborhood based on the air quality measurement of interest. An exposure difference greater than zero indicates that Elyria-Swansea exposure levels are higher than the reference neighborhood. An exposure difference of zero indicates that Elyria-Swansea exposure levels are the same as the reference neighborhood.

EXPOSURE-RESPONSE ASSESSMENT. The exposure-response assessment, sometimes called the dose-response, or concentration-response in toxicological risk assessments, uses quantitative relationships between environmental exposures and health outcomes. An exposure-response relationship describes the change in risk of a health outcome for a given increase in the exposure. For example, an increase of *X* ppb of ozone increases the risk of death from heart disease by *Y* amount. In the exposure-response assessment step (Figure 3 Box 4), we focused on conducting a literature review of past scientific studies that report environmental exposure-response relationships with health outcomes of interest. To identify appropriate exposure-response relationships for this work, we primarily relied on meta-analyses, a type of scientific study that collects and summarizes independent scientific studies and combines their results to generate one overall effect estimate. Meta-analyses used in this study had to meet the inclusion criteria presented in the GES Community Health Study Deliverable 2.1 *Data and Literature Evaluation*.[25] Deliverable 2.1 focused on the creation of a uniform process for evaluating literature and data. We defined measures of importance such as study time periods, exposure estimates, type of study, health endpoint, risk estimate reported, study population, and geographical location.

Information Sources. A literature search was conducted in both PubMed and Google Scholar. Literature search terms included the words meta-analysis, environmental health, human health, environmental exposure, exposure-response, dose-response.

Environmental Exposure Search Terms. We used variations of the environmental exposure variables to conduct our literature search. Table 3 expands on the variations and provides a further detailed description of each variable.

Table 3. Environmental exposure search terms.

Term	Variations of Search Terms	Description of Variable
Particulate Matter 2.5 ($PM_{2.5}$)	particulate matter; particulate matter 2.5; PM2.5	Particulate matter is a complex mixture of extremely small particles and liquid droplets in the air. The composition of PM may vary depending on the season, day, or region. $PM_{2.5}$ refers to particles smaller than 2.5 microns in diameter.
Ozone (O_3)	ozone; O3	Ground-level ozone is a secondary pollutant formed through chemical reactions between nitrogen oxides (NOx) and volatile organic compounds (VOCs).
Particulate Matter 10 (PM_{10})	Particulate matter; PM10	Particulate matter is a complex mixture of extremely small particles and liquid droplets in the air. The composition of PM may vary depending on the season, day, or region. PM_{10} refers to particles smaller than 10 microns in diameter.
Nitrogen Dioxide (NO_2)	Nitrogen dioxide, NO2; NOx	Nitrogen dioxide is used as a proxy measurement for nitrogen oxides (NOx). NO_2 is primarily emitted from fuel combustion processes such as road transportation, energy generation, and domestic and industrial combustion.
Sulfur Dioxide (SO_2)	Sulfur dioxide; SO2, SOx	Sulfur dioxide is used as a proxy measurement for sulfur oxides (SOx). Coal burning is the single largest man-made source of SO_2.

Carbon Monoxide (CO)	Carbon Monoxide, CO	Carbon monoxide is an odorless, colorless gas. The largest sources of CO include cars, trucks and other vehicles, and machinery that burn fossil fuels.

Human Health Specific Terms. We used health endpoints that were discussed in Deliverable 2.2 *The ABCs of GES: The State of Health and Environment* (Table 4).[1] We recognize that some environmental exposures included in this analysis have been associated with health outcomes not included. However, this has been done to limit the analysis to be within the scope of the GES Community Health Study while focusing on health outcomes that GES residents have expressed interest in, have quantifiable exposure-response relationships, and account for most of the health burdens related to environmental exposures.

Table 4. Health Search Terms.

Term	Variations of Search Term	Description of Variable
All-cause mortality	All-cause mortality; mortality; all-cause; death; natural death	Death from any cause.
Asthma	Adult asthma incidence; childhood asthma incidence; asthma; asthma incidence	Asthma is a respiratory condition in which a person's airways become inflamed, narrow, and swollen, making breathing difficult.
Cancer	All-cause cancer incidence, All-cause cancer mortality; cancer; cancer mortality	Cancer is a disease in which abnormal cells divide uncontrollably and destroy body tissue.
Cardiovascular disease (CVD)	Cardiovascular disease; cardiovascular disease incidence; cardiovascular disease mortality; CVD mortality, CVD incidence; cardiovascular mortality	Cardiovascular disease (CVD) is a group of health conditions that impact the heart and blood vessels.
Chronic obstructive pulmonary disease (COPD)	Chronic obstructive pulmonary disease incidence; Chronic obstructive pulmonary disease mortality; COPD incidence; COPD mortality	COPD is a common lung disease that restricts airflow.
Diabetes	Diabetes; diabetes incidence; Type II diabetes; Type II diabetes incidence; T2D; T2D incidence	T2D, also referred to as adult-onset diabetes; is a medical condition that impacts how the body regulates blood glucose, also known as blood sugar.
Hypertension	Hypertension; blood pressure; BP	Incidence of high blood pressure (140/90 mmHg or higher).
Low birthweight	Low birthweight; LBW	Incidence of infants born weighing 5.5 pounds (2500 grams) or less.
Preterm birth	Preterm birth; preterm birth incidence; early birth	Incidence of infants born alive before 37 weeks of pregnancy are completed.
Respiratory mortality	Respiratory mortality; respiratory death	Death from an acute or chronic illness affecting the respiratory system.
Stroke	Stroke; stroke mortality; stroke incidence	Stroke is a type of medical emergency where the blood supply to the brain is disrupted.
Obesity	Obesity; obesity incidence; Body Mass Index (BMI); obese; overweight	Incidence of adults with a BMI greater than 30.

Eligibility Screening. Screening of results from the literature search was based on an adaptation of the 2020 PRISMA checklist.[51] The first screening check consisted of reading the abstract section of a journal article to verify the environmental exposure and the health variables matched our lists (Tables 3 and 4 respectively). Within the abstract section, readers can understand a paper's objective and glance at the results of the analysis conducted. The next step was to read the methods section of the paper. The methods sections gave us insight into how the meta-analyses were conducted. The third step consisted of reading the results section. From the results section, we were able to obtain exposure-response function information. Data from each scientific article were transcribed into a dataset, documenting measurements such as environmental exposure variable, health outcome, and measure of association effect estimates (Table 5).

Measures of Association. Epidemiology characterizes the amount and distribution of health and disease within a population.[52] Morbidity and mortality are reported in measurements of incidence and prevalence. Incidence describes the number of new cases of disease or health condition while prevalence describes the total number of cases, both existing and new.[53] To compare the risk of being diagnosed with a health condition or disease between groups of people we calculate a measure of association. Effect estimates are a combination of measures of association presented as risk ratios or odds ratios of being diagnosed with a health condition or disease in the exposed population compared to the unexposed population. We can also use an effect estimate to measure the risk or odds of disease due to the difference of exposure. Aligned with methodological best practices, this analysis assumes that odds ratios and risk ratios are both approximate measurements of risk. Therefore, we will be interpreting all effect estimates as risk of health given exposure.

Selection of Exposure-Response Functions. After eligible studies were collected into one dataset, exposure-response functions were selected based on the variables presented in Tables 3 and 4. Our literature review and final selection of exposure-response functions resulted in a dataset containing information on (1) the exposure levels in Globeville, Elyria-Swansea, (2) exposure levels in the least burdened neighborhood in Denver, and (3) literature effect estimates. In Deliverable 2.6, we will apply these effect estimates to our population based on Colorado mortality and incidence rates obtained through University of Washington's Institute for Health Metrics and Evaluation data platform.[54] The Institute for Health Metrics and Evaluation at the University of Washington led the Global Burden of Diseases, Injuries and Risk Factors Study (GBD).[55] It is a well-known data source that provides estimates for various health factors including disease incidence and mortality rates. GBD uses data from different sources, such as hospital records, clinical trials, surveys (e.g., American Community Survey),[56] disease registries, and epidemiological surveillance records. GBD provides the most recent measurements for many health outcomes rather than predicted model estimates. In doing so, we will quantify excess cases of disease and mortality in Globeville and Elyria-Swansea.

Table 5. Exposure-response function dataset variables.

Variable	Description and Rationale
Environmental risk factor	The environmental risk factor, or environmental variable, must be clearly reported for a study to remain eligible. For this analysis, the environmental risk factor variables included $PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, and CO.
Exposure unit	An exposure unit is the numerical per unit change of an environmental exposure. A study must report the exposure unit for our calculations to occur. Studies that did not report this were deemed ineligible. For example, per 10 $\mu g/m^3$ is typically used in meta-analyses.
Exposure temporality	In our analysis of neighborhoods, we have taken into account the fact that individuals tend to spend the majority of their time in or around their homes. As a result, we have given greater importance to long-term trends rather than short-term ones. It's worth noting that we have not factored in occupational exposures, which could potentially lead to an underestimation of the overall health impacts experienced by residents. However, since this consideration has been omitted for all neighborhoods in Denver, it is expected to have minimal impact on our ability to make meaningful comparisons between these areas.
Study design	Meta-analyses or large cohort studies.
Population	For many meta-analyses, the population listed is global, or general population. In some cases, there are specific age ranges presented (e.g. adults above 18 years old). Depending on the health outcome more defined populations may be used. For example, when considering preterm birth or low birth weight, the population would consist of adult women.
Geography	The geography of a meta-analysis refers to the specific populations the effect estimates are applied to. Many meta-analyses pool effect estimates to a global population, however there are some instances in which measurements are reported for North America and the United States specifically.
Health outcome	This cell documented the health outcome associated with the effect estimate. Specific health outcomes reviewed through our literature search are presented in Table 4.
Year	The year of study publication; Studies published more than 10 years ago were removed to ensure more recent study results were used.
I^2 (%)	The I^2 value is a statistical measurement used by researchers to assess the degree of heterogeneity in the effect estimate. Heterogeneity describes the degree of diversity, such as varying study findings.[57] For instance, oil and vinegar can be defined as heterogeneous. When the I^2 value is low, typically below 25%, it suggests that there is minimal variation among the study results. Conversely, a high I^2 value indicates substantial heterogeneity, meaning that the effect estimate may be influenced by factors other than chance.
Effect estimate	An effect estimate is the numerical value of the measure of association provided in the meta-analyses. Aligned with methodological best practices, this analysis assumes that odds ratios, hazard ratios, and risk ratios are all approximate measurements of relative risk. Therefore, we will be interpreting all effect estimates as risk of health given exposure.
Low and High Confidence Interval (CI)	95% confidence interval; expressed as a range, the CI is a mathematically calculated range where the true value is likely to be within. (See Table 1 for the full definition).

PARTICULATE MATTER 2.5 ($PM_{2.5}$). Our modeling results, as illustrated in Figure 6 and Table 6, indicate that Globeville and Elyria Swansea are two neighborhoods with the highest average $PM_{2.5}$ exposure levels across Denver over a five-year period from 2017 to 2021. For a full list of EPA monitoring station $PM_{2.5}$ measurements, refer to Appendix A.

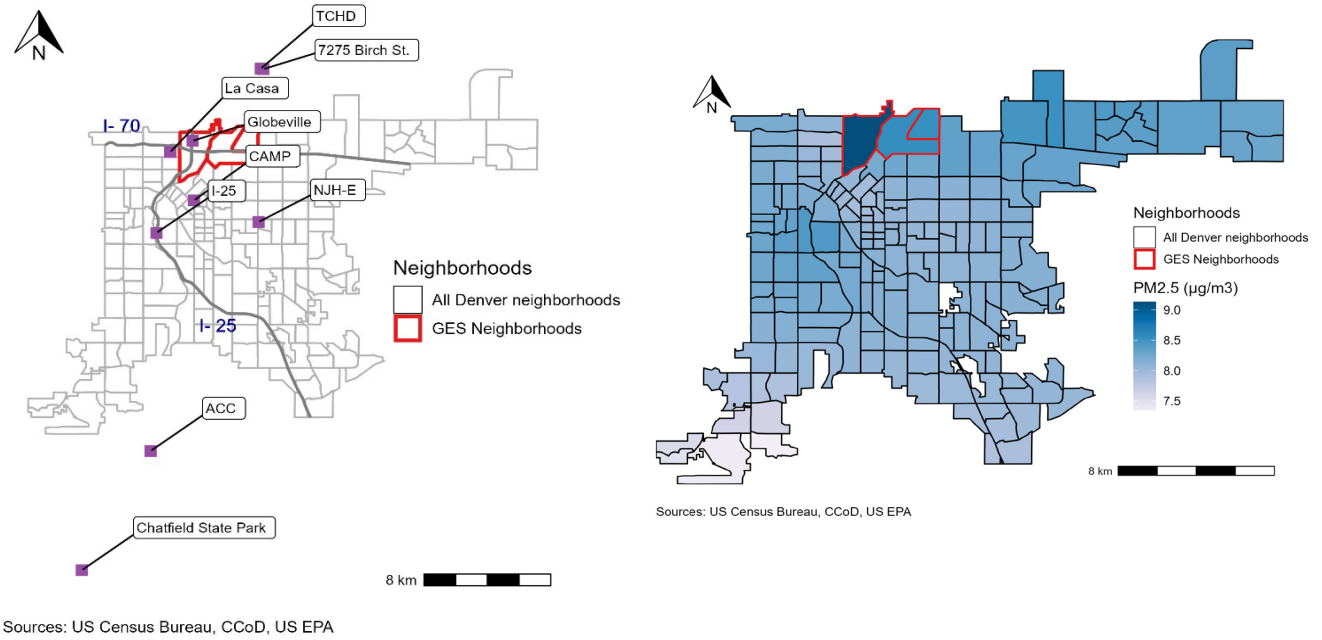

Figure 6. $PM_{2.5}$ model results. The map on the left illustrates the nine EPA air monitoring stations which collect $PM_{2.5}$ measurements. The map on the right illustrates the IDW $PM_{2.5}$ ($\mu g/m^3$) 5-year average exposure levels model estimates, 2017-2021. The darker colors indicate higher concentrations whereas the lighter colors indicate lower concentrations.

Table 6. Top five highest and bottom five lowest $PM_{2.5}$ ($\mu g/m^3$) five-year average exposure levels, 2017-2021.

Neighborhood	Maximum $PM_{2.5}$ ($\mu g/m^3$)	Neighborhood	Minimum $PM_{2.5}$ ($\mu g/m^3$)
Globeville	9.15	Marston	7.43
Elyria-Swansea	8.54	Fort Logan	7.56
Sun Valley	8.43	Bear Valley	7.86
Montbello	8.39	Harvey Park South	7.88
Central Park	8.37	Southmoor Park	7.92

OZONE (O_3). Ozone is commonly measured in parts per million (ppm), but in this analysis, we present our findings in parts per billion (ppb) to better illustrate the subtle variations in ozone exposure levels across Denver. Our examination of O_3 exposure revealed that the highest five-year average concentration was 37.28 ppb, recorded in Marston (Figure 7; Table 7). In terms of overall rankings for ozone exposure, Globeville is among the least exposed neighborhoods, with a level of 30.31 ppb, placing it 8th out of 77, and Elyria-Swansea ranks 17th out of 77, with an exposure level of 30.65 ppb. Appendix A lists the EPA monitoring station O_3 measurements in ppm for reference.

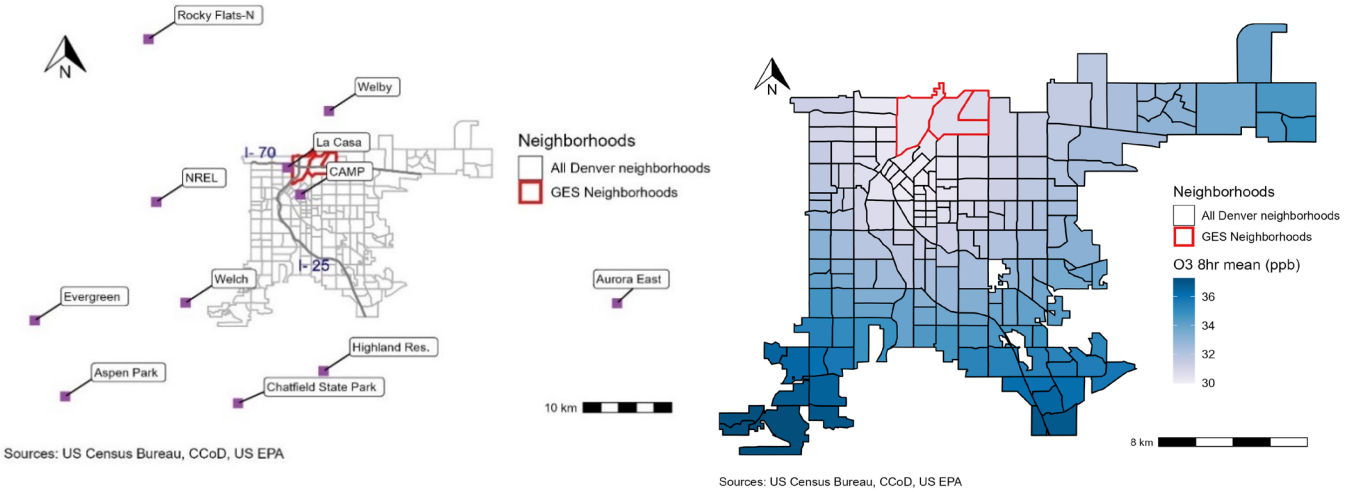

Figure 7. O_3 model results. The map on the left illustrates the EPA air monitoring stations which collect O_3 measurements. The map on the right illustrates the IDW O_3 (ppb) 5-year average exposure levels model estimates, 2017-2021. The darker colors indicate higher concentrations whereas the lighter colors indicate lower concentrations.

Table 7. Top five highest and bottom five lowest O_3 (ppb) five-year average exposure levels, 2017-2021.

Neighborhood	Maximum O_3 (ppb)	Neighborhood	Minimum O_3 (ppb)
Marston	37.28	Central Business District (CBD)	30.03
Fort Logan	36.76	Five Points	30.05
Southmoor Park	36.52	North Capitol Hill	30.07
Hampden South	36.43	Union Station	30.11
Bear Valley	36.41	Sunnyside	30.19

PARTICULATE MATTER 10 (PM_{10}). In our analysis, five-year average PM_{10} exposure concentrations range roughly between 33 µg/m^3 and 23 µg/m^3 (Figure 8; Table 8). Globeville is among the lowest exposure levels for PM_{10} (75th out of 77), or third lowest, at 25.81 µg/m^3. Conversely, Elyria-Swansea ranks 21st out of 77 neighborhoods for the highest PM_{10} exposure at 30.74 µg/m^3. For a full list of EPA monitoring station PM_{10} measurements, refer to Appendix A.

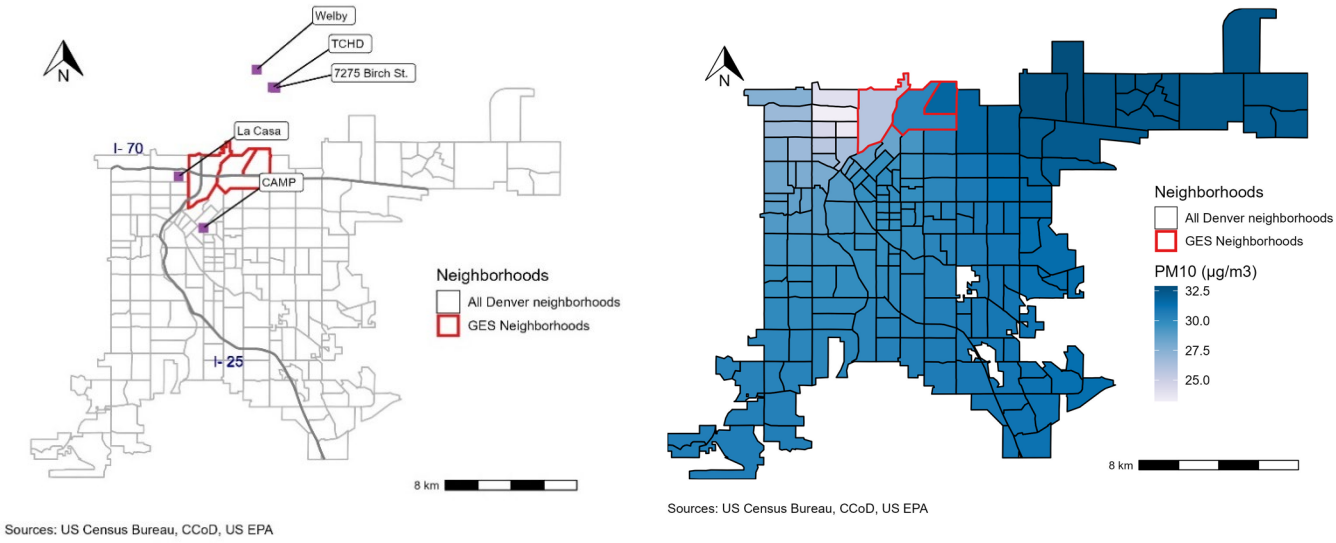

Figure 8. PM_{10} model results. The map on the left illustrates the EPA air monitoring stations which collect PM_{10} measurements. The map on the right illustrates the IDW PM_{10} (µg/m^3) 5-year average exposure levels model estimates, 2017-2021. The daker colors indicate higher concentrations whereas the lighter colors indicate lower concentrations.

Table 8. Top five highest and bottom five lowest PM_{10} (µg/m^3) five-year average exposure levels, 2017-2021.

Neighborhood	Maximum PM_{10} (µg/m^3)	Neighborhood	Minimum PM_{10} (µg/m^3)
Montbello	32.55	Sunnyside	23.33
Central Park	32.47	Chaffee Park	24.11
Gateway - Green Valley Ranch	32.36	Globeville	25.81
Northeast Park Hill	31.96	Highland	26.07
East Colfax	31.55	Berkeley	26.76

NITROGEN DIOXIDE (NO_2). In our analysis, the five-year average concentration of NO_2 exposure levels from 2017 to 2021 ranged between approximately 25 and 18 ppb (Figure 9; Table 9). Notably, both Globeville and Elyria-Swansea rank among the top ten neighborhoods with the highest NO_2 exposure levels. Specifically, Globeville has the highest recorded NO_2 exposure at 24.87 ppb, while Elyria-Swansea ranks seventh out of 77 neighborhoods, with an exposure level of 21.79 ppb. Appendix A lists the EPA monitoring station NO_2 measurements for reference.

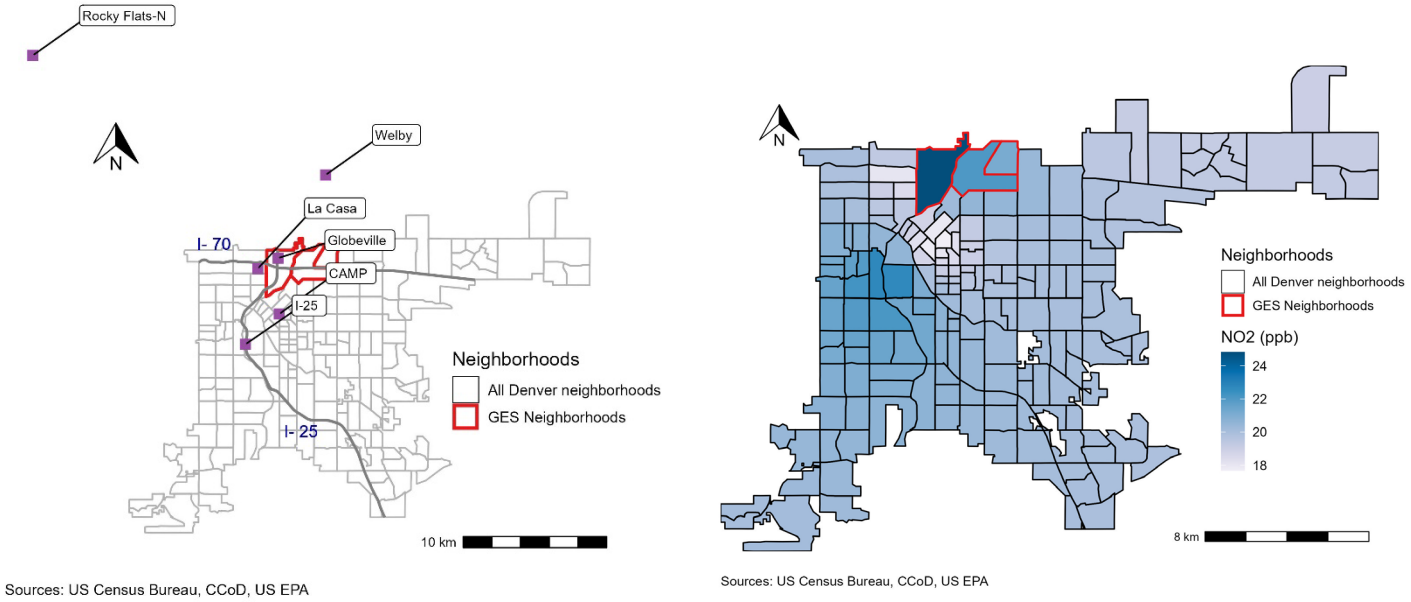

Figure 9. NO_2 model results. The map on the left illustrates the EPA air monitoring stations which collect NO_2 measurements. The map on the right illustrates the IDW NO_2 (ppb) 5-year average exposure levels model estimates, 2017-2021. The darker colors indicate higher concentrations whereas the lighter colors indicate lower concentrations.

Table 9. Top five highest and bottom five lowest NO_2 (ppb) five-year average exposure levels, 2017-2021.

Neighborhood	Maximum NO_2 (ppb)	Neighborhood	Minimum NO_2 (ppb)
Globeville	24.87	Sunnyside	18.12
Sun Valley	22.71	Central Business District (CBD)	18.25
Lincoln Park	22.28	North Capitol Hill	18.26
Valverde	22.12	Five Points	18.39
Barnum	21.95	Union Station	18.68

SULFUR DIOXIDE (SO_2). Our analysis reveals that SO_2 exposure concentration levels have fluctuated between 0.70 ppb and 0.60 ppb from 2017 to 2021 (Figure 10; Table 10). Globeville was identified as the third least exposed neighborhood, with a concentration of 0.61 ppb. In contrast, Elyria-Swansea ranked 20th out of 77 neighborhoods with the highest exposure, showing a concentration of 0.65 ppb. Notably, the difference in exposure levels between Globeville and Elyria-Swansea is quite minimal, at 0.04 ppb. Appendix A lists the EPA monitoring station SO_2 measurements for reference.

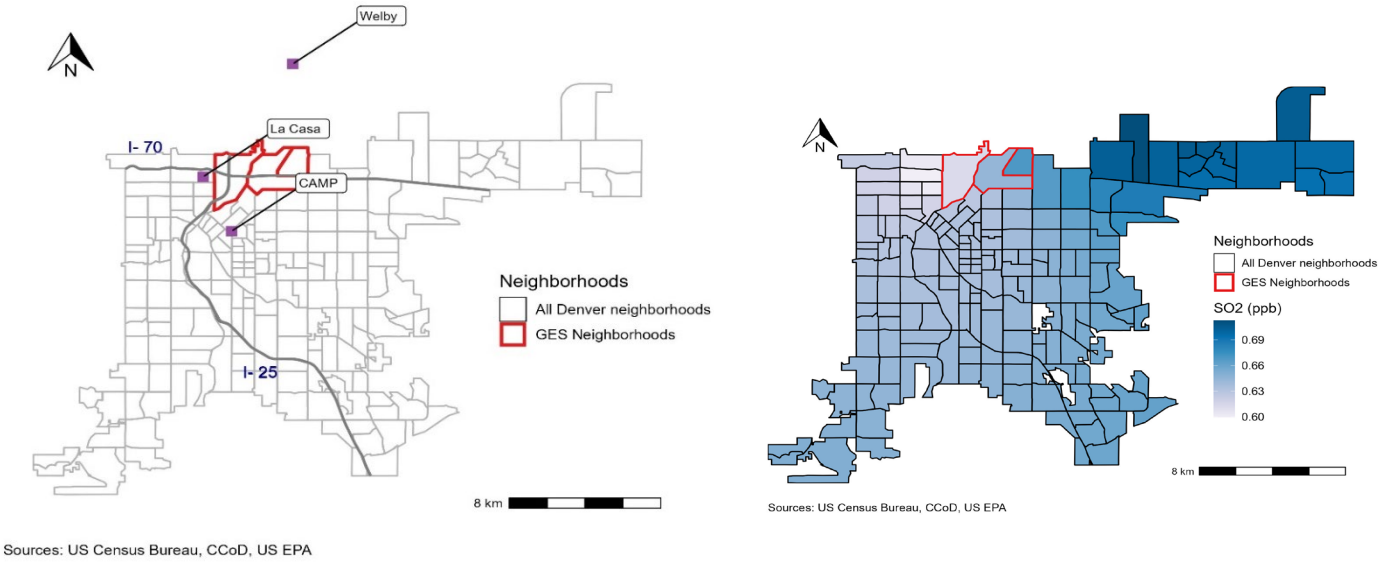

Figure 10. SO_2 model results. The map on the left illustrates the EPA air monitoring stations which collect SO_2 measurements. The map on the right illustrates the IDW SO_2 (ppb) 5-year average exposure levels model estimates, 2017-2021. The darker colors indicate higher concentrations whereas the lighter colors indicate lower concentrations.

Table 10. Top five highest and bottom five lowest SO2 (ppb) five-year average exposure levels, 2017-2021.

Neighborhood	Maximum SO_2 (ppb)	Neighborhood	Minimum SO_2 (ppb)
Montbello	0.70	Sunnyside	0.60
Gateway - Green Valley Ranch	0.70	Chaffee Park	0.60
Central Park	0.69	Globeville	0.61
Northeast Park Hill	0.67	Highland	0.62
East Colfax	0.66	Berkeley	0.62

CARBON MONOXIDE (CO). Carbon monoxide standard reporting units are typically presented as parts per million (ppm), however, we present our results in parts per billion (ppb) to emphasize the low levels of CO exposure. Our analysis indicated that CO five-year average exposure concentration levels between 2017 and 2021 ranged roughly between 470 ppb and 307 ppb. Globeville and Elyria-Swansea are among the bottom five least exposed neighborhoods (Figure 11; Table 11). Appendix A lists the EPA monitoring station CO measurements in ppm for reference.

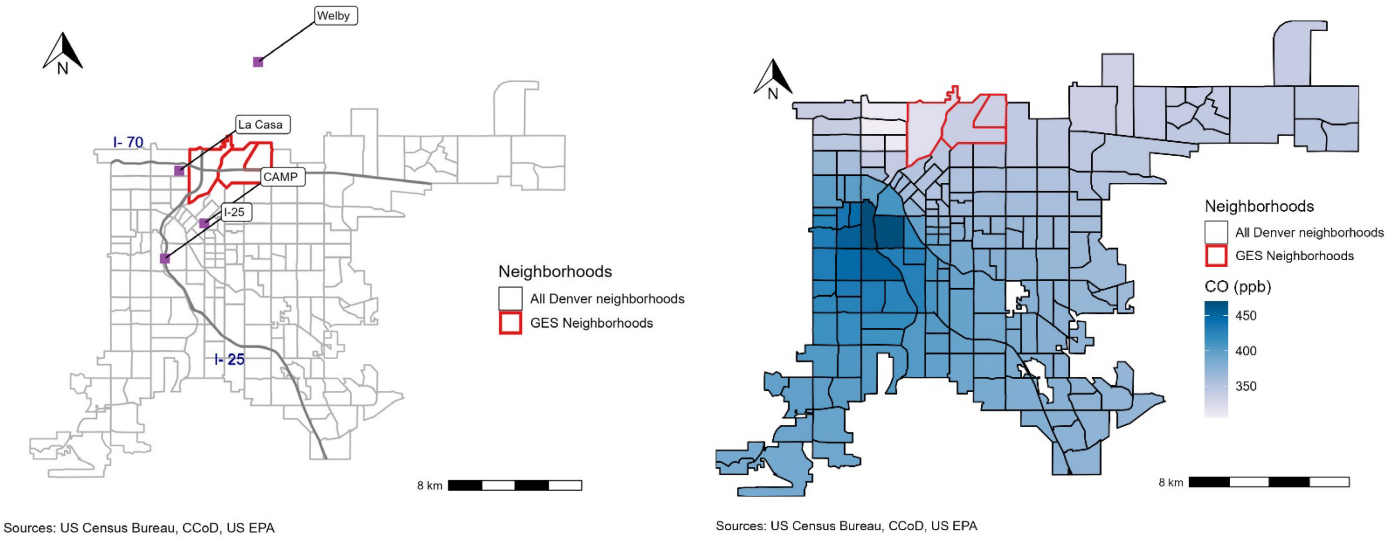

Figure 11. CO model results. The map on the left illustrates the EPA air monitoring stations which collect CO measurements. The map on the right illustrates the IDW CO (ppb) 5-year average exposure levels model estimates, 2017-2021. The darker colors indicate higher concentrations whereas the lighter colors indicate lower concentrations.

Table 11. Top five highest and bottom five lowest CO (ppb) five-year average exposure levels, 2017-2021.

Neighborhood	Maximum CO (ppb)	Neighborhood	Minimum CO (ppb)
Sun Valley	470.21	Sunnyside	307.17
Lincoln Park	458.81	Chaffee Park	309.63
Valverde	452.77	Globeville	319.66
Barnum	446.67	Elyria Swansea	337.10
Villa Park	443.21	Regis	338.19

To summarize, Globeville and Elyria-Swansea exposure levels vary by which air pollutant is being measured. Table 12 highlights Globeville and Elyria-Swansea five-year average air pollutant concentration exposure levels between 2017-2021.

Table 12. Five-year average air pollutant exposure levels in Globeville and Elyria-Swansea, 2017-2021.

Environmental Exposure	Globeville Exposure	Elyria-Swansea Exposure
$PM_{2.5}$ (µg/m^3)	9.15	8.54
O_3 (ppb)	30.31	30.65
PM_{10} (µg/m^3)	25.81	30.74
NO_2 (ppb)	24.87	21.79
SO_2 (ppb)	0.61	0.65
CO (ppb)	319.66	337.10

EXPOSURE DIFFERENCE. Our analysis involved comparing environmental exposures to determine the variance in exposure levels between Globeville, Elyria-Swansea, and the neighborhood with the lowest environmental exposure burden. The three neighborhoods with the lowest exposure levels across the six air pollutants are Marston, Central Business District (CBD), and Sunnyside, with Globeville and Elyria-Swansea also highlighted for reference (Figure 12). Sunnyside is directly west of Globeville while CBD and Marston are south, southwest of Globeville and Elyria-Swansea. While some of the exposure differences seem like small estimates, there is potential to have a larger impact later in the analysis (Table 13). For example, Marston had a $PM_{2.5}$ exposure level of 7.43 µg/m^3, resulting in an exposure difference of 1.72 µg/m^3 and 1.12 µg/m^3 for Globeville and Elyria-Swansea, respectively. However, when we compare O_3 exposure levels (Globeville, Elyria-Swansea, and CBD), the differences seem notably smaller.

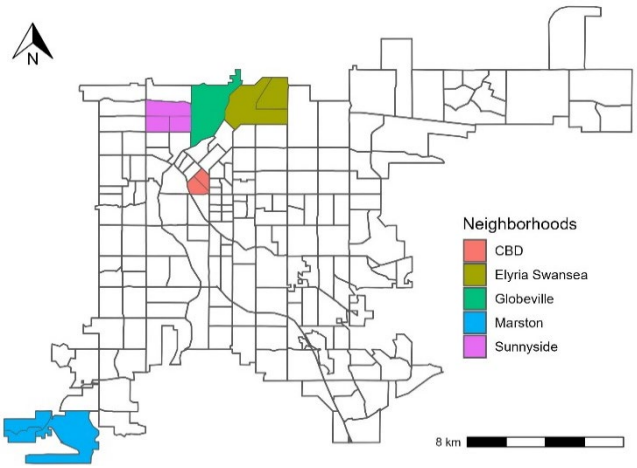

Figure 12. Neighborhoods with the lowest five-year average air pollution concentration exposure levels across the six criteria air pollutants in reference to GES, 2017-2021.

Table 13. Five-year average air pollutant concentration exposure differences between Globeville and Elyria-Swansea, and the least burdened neighborhood, 2017-2021.

Environmental Exposure	Least Burdened Neighborhood	Minimum Exposure	Globeville Exposure	Elyria-Swansea Exposure	Globeville Exposure Difference	Elyria-Swansea Exposure Difference
$PM_{2.5}$ ($\mu g/m^3$)	Marston	7.43	9.15	8.54	1.72	1.12
O_3 (ppb)	CBD	30.03	30.31	30.65	0.28	0.62
PM_{10} ($\mu g/m^3$)	Sunnyside	23.33	25.81	30.74	2.48	7.41
NO_2 (ppb)	Sunnyside	18.12	24.87	21.79	6.75	3.67
SO_2 (ppb)	Sunnyside	0.60	0.61	0.65	0.01	0.05
CO (ppb)	Sunnyside	307.17	319.66	337.10	12.49	29.93

EXPOSURE-RESPONSE ASSESSMENT. The exposure-response assessment step in our analysis consisted of a literature review to document environmental exposure and health outcome relationships. We were successful in identifying many environmental exposure health outcome pairs (e.g., air pollution and stroke mortality). From the 102 potential pairs, we identified exposure-response functions for 63 pairs, illustrated as grey cells (Table 14). A function is a quantifiable relationship between the environmental exposure and health outcome. The missing 39 exposure-health outcome pairs (illustrated in white cells) that were not identified can be attributed to (1) a lack of scientific literature (i.e. the literature search did not find articles meeting inclusion criteria), (2) if literature was available, data may be in the wrong format or missing information needed to meet eligibility requirements, and (3) not enough sufficient evidence of a relationship has been studied to confidently report a quantitative relationship between the environmental exposure and health outcome.

Table 14. Literature obtained exposure-response functions. Dark colored cells indicate an exposure-health outcome pair with an identified exposure-response function. White colored cells indicate an exposure-health outcome pair for which an exposure-response function could not be identified.

	$PM_{2.5}$	PM_{10}	O_3	NO_2	SO_2	CO
Preterm Birth Incidence[58,59]						
Low Birthweight Incidence[58,60,61]						
All-cause Mortality[10,62]						
All-cause Cancer Mortality[63]						
All-cause Cancer Incidence						
CVD Mortality[62,64]						
CVD Incidence[65,66]						
Hypertension Incidence[67]						
Stroke Incidence[68–70]						
Stroke Mortality[65,70]						
Obesity Incidence[71–73]						
Type II Diabetes Incidence[62,74]						
Respiratory Mortality[10,64,65]						
COPD Incidence						
COPD Mortality[10,64,65]						
Adult Asthma Incidence						
Childhood Asthma Incidence[66,75]						

HEALTH OUTCOMES

In Deliverable 2.2 *The ABCs of GES: The State of Health and Environment* we discussed how the largest environmental impacts on health often present as chronic health conditions.[1] Exposure to physical, social, and built environmental factors have cumulative impacts on human health. The purpose of Deliverable 2.5 is to establish environmental exposure levels in CCoD, and to identify exposure-response relationships between environmental exposures and health outcomes. The next subsections outline the risks of health incidence and mortality due to the increased exposure to the six air pollutants evaluated. Each table presents literature-identified effect estimates between specific environmental exposures and health respective by table and subsection.

In line with best methodological practices, we are assuming all measures of association (see Exposure Response Assessment subsection of methods) are all indicative of risk, meaning we will be interpreting all effect estimates, regardless if it is an odds ratio, hazard ratio, or risk ratio, as the increased risk of health due to environmental exposure. For example, in Table 15, we can interpret the effect estimates for preterm birth incidence and $PM_{2.5}$ as: The risk of preterm birth incidence increases 2% (95 CI: 0.93, 1.12) with each 10 $\mu g/m^3$ increase in exposure to $PM_{2.5}$ during the in-utero period. It is important to note that the effect estimates presented in Tables 15 through 28 are those of generalized results presented in scientific literature meta-analyses, and we do not have exact population data through which these measures were calculated.

Additionally, we chose to report effect estimates as presented in their respective meta-analyses, therefore, we did not convert exposure units to US air quality standard units (e.g., common units used for US air quality standards are $\mu g/m^3$ for $PM_{2.5}$, and PM_{10}, ppm for O_3 and CO, and ppb for NO_2 and SO_2). We did this to retain transparency and consistency across our literature review. In Deliverable 2.6, we will convert these units to match those of our air pollution estimates for calculation of excess cases of disease and mortality. Lastly, we present results that are non-significant, meaning effect estimates with a confidence interval that crosses one (e.g., for example, in Table 15 for $PM_{2.5}$ exposure and preterm birth incidence, the effect estimate 95% confidence interval is 0.93, 1.12). This was done with the goal of sharing with the community all of previous scientific analyses and meta-analyses that have been conducted on community-relevant exposure response relationships. We chose not to selectively present only statistically significant results, as that would diminish the full breadth of what data are available in the literature.

HEALTH AT BIRTH

Health at birth is a critical measuring point in one's life. We identified exposure-response functions between six air pollutants and preterm birth incidence and low birthweight incidence.

PRETERM BIRTH INCIDENCE. Preterm birth, defined as infants born alive before 37 weeks of gestation, is a significant indicator of long-term health.[58,59] As discussed in Deliverable 2.2 *The ABCs of GES: The State of Health and Environment*,[1] there was no evidence of a difference in preterm birth rates in GES compared to the rest of Denver. We identified exposure-response relationships between all six air pollutants and preterm birth incidence (Table 15).

Table 15. Preterm birth incidence effect estimates.

Environmental Exposure	Exposure Unit	Effect Estimate	Lower 95% CI	Higher 95% CI	Source
$PM_{2.5}$	Per 10 μg/m^3	1.02	0.93	1.12	Li *et al.*, 2017[58]
PM_{10}	Per 10 μg/m^3	1.05	1.02	1.07	Rojas-Rueda *et al.*, 2021[62]
O_3	Per 10 μg/m^3	1.04	1.00	1.08	Chen *et al.*, 2022[66]
NO_2	Per 10 μg/m^3	1.08	1.01	1.16	Chen *et al.*, 2022[66]
SO_2	Per 10 μg/m^3	1.20	0.95	1.52	Chen *et al.*, 2022[66]
CO	Per 1 mg/m^3	1.19	0.99	1.42	Chen *et al.*, 2022[66]

LOW BIRTHWEIGHT INCIDENCE. The incidence of low birthweight is defined as the rate of infants born weighing 5.5 pounds or less after delivery. Studies have indicated that increased maternal exposure to air pollution may raise the risk of low birthweight. In our study, we identified exposure-response functions between low birthweight incidence and all six air pollutants (Table 16).

Table 16. Low Birthweight incidence effect estimates.

Environmental Exposure	Exposure Unit	Effect Estimate	Lower 95% CI	Higher 95% CI	Source
$PM_{2.5}$	Per 10 μg/m^3	1.07	1.04	1.12	Li *et al.*, 2020[76]
PM_{10}	Per 10 μg/m^3	1.05	1.03	1.08	Li *et al.*, 2020[76]
O_3	per 1 ppb	1.04	0.97	1.11	Li *et al.*, 2020[76]
NO_2	Per 10 μg/m^3	1.12	1.03	1.21	Li *et al.*, 2020[76]
SO_2	per 1 ppb	1.10	0.94	1.30	Li *et al.*, 2020[76]
CO	per 1 ppb	1.01	1.00	1.01	Li *et al.*, 2020[76]

MORTALITY

Mortality and population health are closely linked, aiding in describing the overall health of communities. We selected all-cause mortality, all-cause cancer mortality, cardiovascular and stroke mortality, and respiratory mortality as our health variables. Cardiovascular disease mortality, stroke mortality, and respiratory mortality are discussed in other sections of this report.

ALL-CAUSE MORTALITY. All-cause mortality is a term used to describe death from any cause. In Deliverable 2.2 *The ABCs of GES: The State of Health and Environment*, we discussed standardized mortality ratios (SMR), which compares the mortality rate between GES and Denver. We found that the overall mortality rate in GES was higher than the Denver average (SMR: 1.24).[1] For this analysis, we found literature that met our eligibility criteria for the relationships between all-cause mortality and $PM_{2.5}$, O_3, and NO_2 (Table 17).

Table 17. All-cause mortality effect estimates.

Environmental Exposure	Exposure Unit	Effect Estimate	Lower 95% CI	Higher 95% CI	Source
$PM_{2.5}$	Per 10 µg/m^3	1.06	1.04	1.08	Rojas-Rueda *et. al.*, 2021[62]
O_3	Per 10 µg/m^3	0.97	0.93	1.02	Huangfu *et al.*, 2020[10]
NO_2	Per 10 µg/m3	1.02	1.01	1.04	Huangfu *et al.*, 2020[10]

ALL-CAUSE CANCER MORTALITY. We investigated the relationship between environmental exposure and all-cause cancer incidence and mortality. All-cause cancer incidence is defined as the number of new cases of all cancers (e.g., lung, breast, stomach, colon) over a set period of time. All-cause cancer mortality is defined as the total number of all-cause cancer deaths over a set period of time. We were unable to identify exposure-response functions for all-cause cancer incidence that met our eligibility criteria. We identified relationships between all-cause cancer mortality and $PM_{2.5}$, PM_{10}, and NO_2 (Table 18).

Table 18. All-cause cancer mortality effect estimates.

Environmental Exposure	Exposure Unit	Effect Estimate	Lower 95% CI	Higher 95% CI	Source
$PM_{2.5}$	Per 10 µg/m^3	1.17	1.11	1.24	Kim *et al.*, 2018[63]
PM_{10}	Per 10 µg/m^3	1.09	1.04	1.14	Kim *et al.*, 2018[63]
NO_2	Per 10 µg/m^3	1.06	1.02	1.10	Kim *et al.*, 2018[63]

CARDIOVASCULAR DISEASES

Cardiovascular diseases encompass a range of health conditions impacting the heart and blood. Heart disease is also one of the leading causes of death in the United States.[77,78] Exposure to environmental factors such as air pollution, noise, high temperature, light pollution, and the built environment can increase the risk of developing cardiovascular diseases.[79,80] In this analysis, we investigated exposure-response pairs for six criteria air pollutants and cardiovascular disease incidence and mortality, hypertension, and stroke incidence and mortality. Of the 30 possible environmental exposure and cardiovascular disease outcome pairs, we identified 25 exposure-response functions.

CARDIOVASCULAR DISEASE INCIDENCE AND MORTALITY. Cardiovascular disease incidence is defined as the number of new cases of cardiovascular disease over a specific period. We established exposure-response functions between cardiovascular disease incidence and air pollution for O_3, NO_2, SO_2, and CO (Table 19).

Table 19. Cardiovascular disease incidence effect estimates.

Environmental Exposure	Exposure Unit	Effect Estimate	Lower 95% CI	Higher 95% CI	Source
O_3	Per 10 µg/m^3	1.00	0.98	1.02	Chen *et al.*, 2022[66]
NO_2	Per 10 µg/m^3	1.06	0.99	1.13	Chen *et al.*, 2022[66]
SO_2	Per 10 µg/m^3	1.01	1.01	1.02	Chen *et al.*, 2022[66]
CO	per 1 mg/m^3	1.02	1.01	1.04	Chen *et al.*, 2022[66]

In Deliverable 2.2 *The ABCs of GES: The State of Health and Environment*, we discussed evidence suggesting higher cardiovascular disease mortality rates in GES compared to the Denver average.[1] We established exposure-response functions between cardiovascular disease mortality and $PM_{2.5}$, O_3, and NO_2 (Table 20).

Table 20. Cardiovascular disease mortality effect estimates.

Environmental Exposure	Exposure Unit	Effect Estimates	Lower 95% CI	Higher 95% CI	Source
$PM_{2.5}$	Per 10 µg/m^3	1.19	1.09	1.31	Rojas-Rueda *et. al.*, 2021[62]
O_3	per 10 ppb	1.03	1.01	1.06	Lim *et al.*, 2019[64]
NO_2	per 10 ppb	1.11	1.07	1.16	Huang *et al.*, 2021[81]

HYPERTENSION INCIDENCE. Hypertension, also known as high blood pressure, is one of the leading causes of cardiovascular disease mortality.[82–84] This chronic health condition is divided into two categories, primary and secondary. Primary hypertension develops gradually over time and does not have any known specific cause. Secondary hypertension is frequently caused by an underlying condition such as kidney disease. As reported in Deliverable 2.2 *The ABCs of GES: The State of Health and Environment*, evidence suggests that GES has a similar prevalence of hypertension compared to the rest of Denver.[1] We identified exposure-response functions between hypertension incidence and all six air pollutants (Table 21).

Table 21. Hypertension effect estimates.

Environmental Exposure	Exposure Unit	Effect Estimate	Lower 95% CI	Higher 95% CI	Source
$PM_{2.5}$	Per 10 µg/m^3	1.10	1.07	1.14	Qin *et al.*, 2021[67]
PM_{10}	Per 10 µg/m^3	1.04	1.02	1.06	Qin *et al.*, 2021[67]
O_3	Per 10 µg/m^3	0.96	0.85	1.09	Qin *et al.*, 2021[67]
NO_2	Per 10 µg/m^3	1.01	1.00	1.03	Qin *et al.*, 2021[67]
SO_2	Per 10 µg/m^3	1.21	1.08	1.36	Qin *et al.*, 2021[67]
CO	Per 10 µg/m^3	1.13	1.00	1.28	Qin *et al.*, 2021[67]

STROKE INCIDENCE AND MORTALITY. Stroke, also known as a sudden interruption of blood supply to the brain, has been associated with a number of risk factors such as hypertension, diabetes, smoking habits, obesity, and family history.[85] Research suggests that there are relationships between air pollution exposure and stroke incidence and mortality.[68–70,79] Stroke incidence is defined as the number of new cases of stroke over a specified period. We identified exposure-response functions between stroke incidence and all six air pollutants (Table 22). However, it is important to note that the effect estimates between stroke incidence and O_3, NO_2, SO_2, and CO are small compared to $PM_{2.5}$ and PM_{10}.

Table 22. Stroke incidence effect estimates.

Environmental Exposure	Exposure Unit	Effect Estimate	Lower 95% CI	Higher 95% CI	Source
$PM_{2.5}$	Per 5 μg/m^3	1.11	1.05	1.17	Yuan *et al.*, 2019[68]
PM_{10}	Per 10 μg/m^3	1.09	0.96	1.23	Haddad *et al.*, 2023[69]
O_3	Per 10 μg/m^3	0.99	0.99	1.00	Niu *et al.*, 2021[70]
NO_2	Per 10 μg/m^3	1.00	1.00	1.00	Niu *et al.*, 2021[70]
SO_2	Per 10 μg/m^3	1.00	1.00	1.00	Niu *et al.*, 2021[70]
CO	Per 10 μg/m^3	0.99	0.99	1.00	Niu *et al.*, 2021[70]

Stroke mortality is defined as the number of deaths due to stroke over a period of time. In 2022, the stroke mortality rate in the United States was 39.5 per 100,000. This is equivalent to one in six deaths from cardiovascular disease being attributed to stroke.[85,86] In this analysis, we identified exposure-response functions between stroke mortality and six air pollutants (Table 23).

Table 23. Stroke mortality effect estimates.

Environmental Exposure	Exposure Unit	Effect Estimate	Lower 95% CI	Higher 95% CI	Source
$PM_{2.5}$	Per 10 μg/m^3	1.11	1.04	1.18	Chen *et al.*, 2020[65]
PM_{10}	Per 10 μg/m^3	1.01	0.83	1.21	Chen *et al.*, 2020[65]
O_3	Per 10 μg/m^3	1.01	0.99	1.01	Niu *et al.*, 2021[70]
NO_2	Per 10 μg/m^3	1.01	1.00	1.02	Niu *et al.*, 2021[70]
SO_2	Per 10 μg/m^3	1.01	1.01	1.01	Niu *et al.*, 2021[70]
CO	Per 10 μg/m^3	1.05	0.98	1.12	Niu *et al.*, 2021[70]

OBESITY AND DIABETES

Deliverable 2.2 *The ABCs of GES: The State of Health and Environment* reported that evidence suggests that the prevalence of obesity, overweight, and diabetes is greater in GES compared to the rest of Denver.[1] GES Health Study Community Council representatives consistently have expressed that obesity and type two diabetes are concerns for themselves and some of their neighbors. Obesity, characterized by a body mass index (BMI) greater than 30, is a risk factor for type two diabetes, as well as CVD and COPD.[87,88] We identified exposure-response functions between obesity and $PM_{2.5}$, $PM_{10,}$ O_3, NO_2, and SO_2. (Table 24).

Table 24. Obesity effect estimates.

Environmental Exposure	Exposure Unit	Effect Estimate	Lower 95% CI	Higher 95% CI	Source
$PM_{2.5}$	Per 10 µg/m^3	1.21	0.94	1.56	Huang *et al.*, 2020[71]
PM_{10}	Per 10 µg/m^3	1.06	0.98	1.14	Huang *et al.*, 2020[71]
O_3	Per 10 µg/m^3	1.07	1.02	1.13	Huang *et al.*, 2020[71]
NO_2	Per 10 µg/m^3	1.13	1.01	1.26	Huang *et al.*, 2020[71]
SO_2	Per 10 µg/m^3	1.04	1.01	1.06	Huang *et al.*, 2020[71]

Type 2 diabetes, also known as adult-onset diabetes, is a chronic condition impacting how the body regulates blood glucose, also known as blood sugar, and requires lifelong management.[14,89] Type two diabetes can be managed through lifestyle changes, medication, and blood sugar monitoring.[89] We identified exposure-response functions between type two diabetes and $PM_{2.5}$, PM_{10}, and NO_2 (Table 25).

Table 25. Type II diabetes effect estimates.

Environmental Exposure	Exposure Unit	Effect Estimate	Lower 95% CI	Higher 95% CI	Source
$PM_{2.5}$	Per 10 µg/m^3	1.11	1.03	1.19	Rojas-Rueda *et. al.*, 2021[62]
PM_{10}	Per 10 µg/m^3	1.12	1.01	1.23	Rojas-Rueda *et. al.*, 2021[62]
NO_2	Per 10 µg/m^3	1.11	1.07	1.16	Rojas-Rueda *et. al.*, 2021[62]

RESPIRATORY DISEASES

Throughout the GES Community Health Study, community members have raised concerns about respiratory health, particularly asthma. Respiratory disease is a category of health conditions that impact lung function. Risk factors for respiratory diseases include smoking habits, air pollution, and occupational exposures to irritants.[10,90,91] We evaluated the risk of five different respiratory health outcomes and their relationship with the six air pollutants. Of the possible 30 exposure health outcome pairs, we identified 12 exposure-response functions.

ALL-CAUSE RESPIRATORY DISEASE MORTALITY. All-cause respiratory disease mortality is characterized as death from an acute or chronic illness that affects the respiratory system. We identified exposure-response functions between all-cause respiratory disease mortality and $PM_{2.5}$, PM_{10}, O_3, and NO_2 (Table 26).

Table 26. All-cause respiratory disease mortality risk estimates.

Environmental Exposure	Exposure Unit	Effect Estimate	Lower 95% CI	Higher 95% CI	Source
$PM_{2.5}$	Per 10 µg/m^3	1.10	1.03	1.18	Chen *et al.*, 2020.[65]
PM_{10}	Per 10 µg/m^3	1.12	1.06	1.19	Chen *et al.*, 2020.[65]
O_3	Per 10 ppb	1.04	1.00	1.09	Lim *et al.*, 2019[64]
NO_2	Per 10 ppb	1.05	1.02	1.08	Huang *et al.*, 2021[81]

CHRONIC OBSTRUCTIVE PULMONARY DISEASE. Chronic obstructive pulmonary disease (COPD) is a common lung disease characterized by restricted airflow and breathing difficulties. COPD is considered a progressive lung disease that includes emphysema and chronic bronchitis. Scientific studies have shown that COPD has been associated with smoking habits, air pollution genetic factors and a history of asthma.[92] Specifically, studies have demonstrated the relationship between outdoor air pollution and the development of COPD. Extreme heat has also been associated with increased COPD mortality, which presents concerns when focusing on environmental justice communities who are at risk of urban island heat effects.[93,94] The urban heat island effect occurs when paved surfaces like streets, sidewalks, and parking lots that are concentrated in an urban area retain heat over the course of a day, resulting in temperatures that are hotter than those in the surrounding suburban and rural areas.[95,96] As presented in Deliverable 2.2 *The ABCs of GES: The State of Health and Environment*, there is evidence that surface temperatures in GES are hotter than other areas of Denver.[1]

COPD incidence is defined as the number of new cases of COPD over a specific period of time. We did not find eligible scientific literature documenting the quantitative relationship between environmental exposure and COPD incidence. We identified exposure-response relationships between COPD mortality and $PM_{2.5}$, PM_{10}, O_3, and NO_2 (Table 27).

Table 27. Chronic obstructive pulmonary disease (COPD) mortality effect estimates.

Environmental Exposure	Exposure Unit	Effect Estimate	Lower 95% CI	Higher 95% CI	Source
$PM_{2.5}$	Per 10 µg/m^3	1.11	1.05	1.17	Chen *et al.*, 2020[65]
PM_{10}	Per 10 µg/m^3	1.19	0.95	1.49	Chen *et al.*, 2020[65]
O_3	per 10 ppb	1.09	1.03	1.15	Lim *et al.*, 2019[64]
NO_2	Per 10 µg/m^3	1.03	1.01	1.04	Huangfu *et al.*, 2020[10]

ASTHMA INCIDENCE. Asthma incidence was investigated for both adults and children. As discussed in Deliverable 2.2, *The ABCs of GES: The State of Health and Environment*, the association between air pollution and the development and exacerbation of adolescent asthma has been extensively studied.[75,97–100] However, the association between air pollution and adult asthma is less studied. We found this to be a limitation in our own study, resulting in no exposure-response functions being identified for adult asthma incidence and environmental exposures. We identified exposure-response functions reporting the relationship between childhood asthma incidence (ages 1-18 years old) and $PM_{2.5}$, PM_{10}, NO_2, and SO_2 (Table 28).

Table 28. Childhood asthma incidence effect estimates.

Environmental Exposure	Exposure Unit	Effect Size	Lower 95% CI	Higher 95% CI	Source
$PM_{2.5}$	per 1 µg/m^3	1.03	1.01	1.05	Khreis *et al.*, 2017[75]
PM_{10}	Per 2 µg/m^3	1.05	1.02	1.08	Khreis *et al.*, 2017[75]
NO_2	Per 10 µg/m^3	1.13	1.08	1.19	Chen *et al.*, 2022[66]
SO_2	Per 10 µg/m^3	1.11	1.08	1.15	Chen *et al.*, 2022[66]

DISCUSSION

The examination of health impacts from a single substance, whether through toxicological methods or experimental studies in human populations (e.g., chamber studies), has substantially contributed to the understanding of inherent biological effects and the biochemical and physiological mechanisms of action.[101,102] However, most toxicological and epidemiologic studies tend to focus on the detrimental effects of individual environmental pollutants, despite human exposure to environmental factors rarely being limited to an individual chemical.[103–105] Analysis of multipollutant exposures in environmental health research poses two interrelated statistical challenges. The first issue relates to the high levels of correlation in the covariate space for environmentally mediated disease. Given the array of environmental exposures, pollutants, and sociodemographic factors that have been implicated in health outcome incidences, the potential number of explanatory factors can quickly exceed the number of observations.[106–109]

This study is subject to several limitations that affect the interpretation of its findings. Notably, the geographical unit of analysis is confined to neighborhoods, which are defined as combinations of census tracts. Consequently, some environmental exposure and health outcome data may not be accessible at this specific geographical scale, thereby restricting the applicability of our findings. We relied on publicly available data at the census tract, city, or state level. References to smaller geographical scales, such as census blocks, streets, or individual residences, are not feasible within our analysis. By using neighborhood-level data, we operate under the assumption that individuals predominantly spend their time within their residential vicinity. Occupational exposures are excluded from our analysis, which may lead to an underestimation of the overall health impacts experienced by residents. However, as we maintain a consistent approach across neighborhoods, the omission of occupational exposures should have a minimal effect on comparative analyses.

Environmental exposure estimates were derived through inverse distance weighting (IDW) modelling. This type of modelling mirrors methodology is employed in EPA BenMap which uses a grid-cell to calculate metrics for each air monitoring station then calculates an inverse-distance weighted average to obtain an estimated exposure level.[110] The further the air pollution monitor is from the grid-cell, the smaller the weight.[110] The use of IDW requires the analyst to select a power parameter to weight measurements based on distance. In this analysis, we elected to use p = 2, which is the typical values applied to IDW models. We conducted a sensitivity analysis to assess an alternative power parameter of 3. Because we did not observe meaningful differences in the root mean squared error of our estimates, we elected to use the power parameter of 2 to be consistent with other previous work.[17,21,111,112]

Two additional limitations of IDW modelling include locality and edge effects. Locality can significantly influence model results of environmental models, especially when a point measurement is subject to the impacts of larger regional or global processes. One of the main challenges in accurately assessing air quality is the limited number of air pollution monitoring stations available. This scarcity complicates the ability to determine whether exposure levels are consistent across a localized area or whether significant variations exist. For instance, a smaller sample size may fail to capture localized fluctuations, such as pollution hotspots that can emerge near specific sources of emissions, thereby resulting in model estimates that present an overly uniform picture of air quality than what is true in reality. [50,113] Several key factors play a crucial role in influencing air quality within specific locales. These include wind patterns that can disperse pollutants, the topographic features of an area that can trap or channel airflows, and the gradients of pollution concentrations observed in proximity to industrial operations and high-traffic roadways. This context highlights how heterogeneous the air pollution landscape can be, even within a relatively small geographic area.[114,115] By utilizing longer averaging periods (i.e., 5-years) for our exposure assessment, we aimed to minimize the impacts of these localized effects that happen on shorter time scales (e.g., daily or hourly) to capture the long-term trends in exposure. These long-term trends in exposure are consistent with the studies from which we draw our exposure-response functions. Edge effect refers to the idea that points near the edge of a study area have fewer neighboring points to influence interpolation estimates, which can bias estimates, resulting in an overestimation or underestimation of

exposure.[116] To reduce the impact of edge effects on our study results, our IDW model includes air monitoring stations located within a 50-kilometer buffer around the City and County of Denver.

Despite these complexities, our consistent assumption of local homogeneity across all neighborhoods is expected to have a minimal impact on our model results. When we examine this assumption in relation to the specific pollutants of interest, it becomes critical to consider each pollutant on an individual basis to understand its distinctive patterns and sources. For instance, $PM_{2.5}$, which is largely classified as a regional air pollutant, has the largest number of EPA monitoring stations (n = 9). In contrast, when we look at local traffic-related pollutants such as NO_2, the availability of monitoring stations is reduced (n = 6). It is noteworthy that within our study area, there is a dedicated monitoring station in Sunnyside, specifically at La Casa, located at 4545 Navajo St., as well as another in Globeville, situated at 4903 Acoma St (known as I-25 Globeville). These locations provide valuable data points that contribute to our understanding of localized air quality trends and pollutant exposure in these neighborhoods, helping to bridge the gap left by the limited overall network of monitoring stations. Findings from the 2023 Air Quality Data Report from the Colorado Air Pollution Control Division show that annual mean concentrations of $PM_{2.5}$, PM_{10}, and NO_2 measured at the La Casa monitoring site are among the lowest in Denver and generally lower than those measured at other sites of interest, including I-25 Globeville.[117] These monitoring data corroborate our conclusions that the GES neighborhoods generally experience higher exposures than other neighborhoods in Denver and that, for some pollutants, the lowest exposures occur in nearby neighborhoods. Further, $PM_{2.5}$ and NO_2, which are considered to be markers for combustion, have a distinct spatial pattern from secondary pollutants such as O_3, which is not directly emitted from any source but formed from the interaction of NO_2 and volatile organic compounds (VOC) with heat and light. Ozone is a particular problem along the Front Range due to the presence of these chemical precursors combined with the extensive days of sunshine that occur on Colorado's Front Range.[118] Following, O_3 levels are generally downwind of locations with high levels of $PM_{2.5}$ and VOC; our IDW models support these findings, where centralized neighborhoods such as Globeville and Elyria-Swansea will have comparatively lower O_3 models compared to the east side of CCoD.

In this study, we assume that environmental exposures act independently on health outcomes (i.e., toxicologic independence) and that their toxic effects are additive.[119,120] Toxicologic independence follows the idea that if a person is exposed to a quarter of the amount of chemical A necessary to cause harm, and a quarter of the amount of chemical B necessary to cause harm, then the person is only exposed to half (¼ + ¼ = ½) of the amount of chemicals required to cause harm and therefore the person would not experience health effects. However, there are some cases where this may not be true and the combination of chemicals, even at levels lower than what would individually or additively cause harm, would affect the person's health. Historically, EPA guidance has recommended the approach of relying on the evaluation of additive independent impacts when assessing environmental risks.[21,104,121–123] This recommendation arises from the lack of standardized methodologies to adequately address the complexity and variability inherent in environmental exposures, which may differ significantly by nature, source, and mode of exposure.[104,122,124,125] While this assumption simplifies the statistical modelling, it may lead to an underestimation of the risks associated with multiple combined exposures affecting the health of residents.[126,127] When analyzing multiple stressors (e.g., environmental exposures) that may impact the same route of exposure (e.g., inhalation, ingestion, etc.), or operate through similar modes of biological action, we encounter a heightened level of uncertainty. This uncertainty predominately stems from existing gaps in comprehensive scientific evidence that clearly demonstrates how these various stressors may interact with one another and jointly impact human health outcomes. The ambiguity surrounding these potential interactions complicates our ability to develop accurate risk estimates. Without strong scientific evidence, determining whether the risk values generated from our analyses represent an overestimation or an underestimation of the actual health risks posed by these environmental stressors becomes exceedingly challenging. This situation underscores the need for further research and the establishment of standardized methodologies, which are essential for improving our understanding and assessment of cumulative risks associated with diverse environmental exposures.

There also exist significant gaps in the scientific understanding of low-level exposures. Such gaps are often due to the fact that the risks associated with low-level exposure can be so minuscule that they pose challenges for accurate

measurement or verification through controlled experimentation.[128] For low exposure levels, it is generally assumed that risks increase in a linear fashion.[129–131] While this assumption is prevalent in burden assessments, it warrants careful scrutiny and further investigation to ensure that evaluations accurately reflect the potential impacts of low-level exposures on human health and the environment.

Due to the limitations of the current state of science, some factors related to the built environment (e.g., streetlights, sidewalk conditions) do not have a defined measure of association with specific health outcomes. Thus, we focus on the impacts of ambient air pollutants in this study. Deliverable 2.4 *Community Environmental Burden Assessment (CEBA): Planning, Scoping, and Problem Formulation* proposed several environmental exposures that we ultimately did not include in the analysis.[12] This decision was influenced by discrepancies between definitions of exposure-response functions in the literature and the formats of the data available. For example, access to surface temperature data were provided as quartiles while literature supports long-term daily averages. Other environmental exposures that are not included in this analysis are the measure of greenness (measured by calculating satellite imagery's Normalized Difference Vegetation Index; NDVI), and lead through a proxy measurement of percent of housing units built before 1960. Deliverable 2.4 also proposed potential environmental exposures that could be assessed based on statistical models.[12] Environmental exposures from that list (as seen in Deliverable 2.4 Table 3) that are not included in our analysis are black carbon, benzene, and noise. Colorado House Bill (HB) 22-1244, the Public Protection from Toxic Air Contaminants Act, seeks to develop measurement approaches for communities across Colorado, prioritizing the top five air toxics of concern in the state regarding both cancer and non-cancer risks. Benzene often is cited as one of the hazardous air pollutions of concern given its classification as a Group 1 carcinogen (known to cause cancer in humans).[132] If ambient (outdoor) benzene is prioritized for measurement through HB 22-1244, we expect that measurements would be available in the future for additional CEBA analyses or risk assessments.

Importantly, we are excluding social determinants of health (e.g., education or income) from the quantitative portion of the CEBA due to the current limitations in environmental health science that do not support inclusion in this type of analysis.[103,112,133–135] For a more comprehensive understanding of social determinants of health, we provide additional context and information in Deliverable 2.2 *The ABCs of GES: The State of Health and Environment*. Furthermore, we plan to explore these determinants in greater depth in Deliverable 2.6, where we will examine their implications and relevance in a broader context.

As specified in the Study contract, the focus of this analysis is on environmental exposures. Our method to quantitatively assess the health burden from environmental exposures requires that previous studies have reported an exposure-response relationship between the environmental exposure and a specific health outcome. It is crucial to highlight that effective methodologies for integrating historical and cultural values into risk assessments have not been development and will not be explored in this analysis.[127,136] We understand the community's strong desire for a more thorough evaluation of diverse environmental exposures beyond air pollution, and we share these concerns. Quantitative study designs do not account for the valuable insights gained from generations of lived experiences within a neighborhood. As qualitative experiences are central to pursuits of environmental justice, the under representation of this embodied knowledge creates a gap in the data. However, further research and methodological developments are required for this to take place. Lastly, we did not include all possible health outcomes related to environmental exposures in this analysis.

In summary, while our long-term aim is to cover a broad spectrum of environmental exposures, we are unable to include every potential factor in this analysis. Nevertheless, we believe that the air pollution exposures and health outcomes we have included capture a substantial portion of the health burden GES residents face.

NEXT STEPS

The final phase of the CEBA is the burden of health characterization (Figure 3 Box 5) and qualitative review of potential future scenarios. When we created Deliverable 2.4 *CEBA Planning, Scoping, and Problem Formulation*[12] we proposed a risk difference methodology through calculating the population attributable fraction and disability-adjusted life years. However, there are limitations to this methodology, including calculating the variance of attributable fractions, bias within the formulas used to calculate attributable fraction, as well as bias due to the dependence of causal association assumptions.[137,138] Therefore, we are changing our approach in Deliverable 2.6 to adopt EPA BenMap methodology. The EPA BenMap tool was originally developed in 2003 and has been updated periodically to reflect advancements in monitoring technology as well as scientific methods. This approach has been widely adopted to estimate the burden of disease associated with air pollution in the United States.[139,140] The change in mathematical formulas eases the statistical modeling while furthering the use of EPA methods. This change in methodology is anticipated to more accurately estimate the burden of disease by addressing uncertainty and variability across calculations.

The new formula that will be used to calculate the number of cases of disease and mortality that may be due to environmental exposure uses four key parameters, (1) modeled air pollutant concentrations, (2) population data, (3) baseline rates of disease or mortality, and (4) exposure-response effect estimate (often referred to as a beta coefficient which measures the risk of health due to a per unit change in air pollution concentration).[110] Equation 3 follows previously established BenMap applications to determine the estimated risk over a specific period of time.[100,141]

Equation 3. Study period estimated excess cases of disease and mortality in Globeville and Elyria-Swansea.

$$\Delta y = Pop * (\frac{Y_0}{365}) * (1 - exp^{-\beta * \Delta C})$$

Where Δy is the estimated number of excess cases of disease or mortality, pop is the population exposed to air pollution (i.e., Globeville population, Elyria-Swansea population), Y_0 is the annual baseline rate (i.e., incidence) of deaths or illness, and ΔC is the exposure difference calculated in Equation 3. Equation 4 describes how β is defined.

Equation 4. Beta variable.

$$\beta = ln(effect\ estimate)/\Delta X$$

Where effect estimate is the effect estimates and ΔX refers to the per unit change collected through the literature review process.

In addition to the burden of disease and mortality characterization, Deliverable 2.6 will include a qualitative discussion on future scenarios. The analysis of future scenarios will identify how each hypothetical benefits environmental justice neighborhoods to determine the environmental and health equity of each of the prescriptions.

1. **Lower $PM_{2.5}$ standard**. On February 7, 2024, the EPA lowered the primary $PM_{2.5}$ standard from 12 μg/m^3 to 9.0 μg/m^3.[142] We will evaluate the potential impact on GES and other environmental justice neighborhoods by assuming that all neighborhoods above the new 9 μg/m^3 standard will come down to 9 μg/m^3 and all neighborhoods at or below 9 μg/m^3 will stay the same.
2. **Ozone Trend**. In 2022, the EPA classified the area as severe nonattainment for ozone (2008 standard) based on 2018-2020 ozone data. [143] Colorado's ozone state implementation plan was endorsed on October 6, 2023.[144] We will assume that the trend in ozone design values for the last ten years in the Denver region will continue for the next ten years and discuss the implications of this trend at the ten-year mark (2034).
3. **Ozone Attainment**. Ozone nonattainment varies across the Northern Front Range Metropolitan Area (NFRMA), which impacts the region's overall ozone attainment status. While some NFRMA regions may remain in Severe nonattainment, models in Denver's current State Implementation Plan predict that Denver will become in

ozone attainment by 2027.[144] We will discuss possible health implications from ozone attainment within Denver in addition to our discussion of the implications of maintaining the status quo for the next ten years.

4. **Increased Wildfires and Severe Weather:** We will qualitatively discuss the potential impact that an increase in wildfires could have on criteria air pollutants including $PM_{2.5}$, Ozone, and CO, as well as the associated health burdens like respiratory and cardiovascular disease associated with environmental exposures from wildfires. We will also explore potential synergistic relationships between health burdens from wildfires and other social determinants of health, like housing quality.[145–147]
5. **Tree Canopy Coverage.** Using findings from other published studies, we will discuss the implications of increasing tree canopy coverage on health and the environment in GES and other Denver environmental justice neighborhoods.[148–151]
6. **Social Determinants of Health**. We will explore how improvements in social determinants of health may impact environmental justice communities.[152,153]

In conversations with GES residents, community members have expressed concern regarding ownership of data and research findings. As part of our CEBA process, we are committed to returning our data and findings to the community through increased discussions with our Community Council representatives, at our quarterly open Community Meetings, through monthly neighborhood canvassing initiatives by the study team, and through ensuring all final reports, data, and methods are made available on the CDOT website for public access. Garnering feedback from community members and representatives remains of the highest importance to the GES Health Study team, and we encourage community members to participate in reviewing our findings during the public comment period after each Deliverable completion.

APPENDIX A

Table 29. $PM_{2.5}$ EPA AQS Monitoring Data (µg/m3), five-year summary statistics, 2017-2021.

Site ID	Name	Address	Count of 24-hr Average Samples (n)	Minimum	Maximum	Average	Median
2	CAMP	2105 Broadway	32593	0.700	53.404	7.959	6.400
4	Chatfield State Park	11500 N. Roxborough Park Rd.	34857	0.000	62.783	6.721	5.017
5	ACC	6190 S. Santa Fe Dr.	4632	0.700	45.300	6.268	4.800
8*	TCHD	4201 E. 72nd. Ave.	13999	0.600	48.000	9.506	8.300
10**	Birch Street	7275 Birch St	2923	2.300	55.746	9.529	7.900
13***	NJH-E	14TH Ave. & Albion St.	26191	1.200	64.838	8.047	6.100
26	La Casa	4545 Navajo St.	31515	0.500	58.608	7.874	6.183
27	I-25	971 Yuma St.	18240	0.600	51.988	8.465	7.000
28	Globeville	4903 Acoma St.	15785	0.000	56.525	9.701	8.191

*- Site 8, TCHD, data did not included data for 2021

**- Site 10, Birch St. only included 2021 data.

**- Site 13, NJH-E, included 2018-2021 data

Table 30. O_3 EPA AQS Monitoring Data (ppm), five-year summary statistics, 2017-2021.

Site ID	Name	Address	Count of 8-hr run average samples (n)	Minimum 8-hr mean	Maximum 8-hr mean	Average 8-hr mean	Median 8-hr mean	Minimum 8-hr max	Maximum 8-hr max	Average 8-hr max	Median 8-hr max
2	CAMP	2105 Broadway	7238	0.000	0.065	0.029	0.029	0.001	0.095	0.041	0.041
2	Highland Reservoir	8100 S. University Blvd	7269	0.002	0.076	0.039	0.039	0.004	0.108	0.049	0.049
4	Chatfield State Park	11500 N. Roxborough Park Rd.	7223	0.002	0.075	0.038	0.039	0.002	0.106	0.050	0.050
5*	Welch	12400 W. HWY 285	5360	0.000	0.073	0.036	0.037	0.000	0.096	0.047	0.046
6	Rocky Flats-N	16600 W COLO #128	7250	0.005	0.081	0.043	0.044	0.009	0.104	0.052	0.050
6	Aurora East	36001 E. Quincy Ave.	7227	0.007	0.071	0.041	0.041	0.010	0.098	0.050	0.049
11	NREL	2054 Quaker St.	7163	0.002	0.082	0.041	0.042	0.005	0.112	0.051	0.049
13**	Aspen Park	26137 Conifer Road	3925	0.004	0.065	0.041	0.042	0.004	0.098	0.049	0.049
14***	Evergreen	5124 South Hatch Drive	1697	0.005	0.072	0.037	0.038	0.005	0.101	0.048	0.046

Site ID	Name	Address	Count of 8-hr run average samples (n)	Minimum 8-hr mean	Maximum 8-hr mean	Average 8-hr mean	Median 8-hr mean	Minimum 8-hr max	Maximum 8-hr max	Average 8-hr max	Median 8-hr max
26	La Casa	4545 Navajo St.	7045	0.000	0.083	0.029	0.030	0.000	0.102	0.044	0.045
3001	Welby	3174 E. 78th Ave.	7051	0.000	0.064	0.027	0.029	0.000	0.100	0.044	0.044

*- Site 5, Welch included data from 2017-2020

**- Site 13, Aspen Park, included data from 2017-2019

***- Site 14, Evergreen, included data for 2020 and 2021.

Table 31. PM_{10} EPA AQS Monitoring Data (µg/m3), five-year summary statistics, 2017-2021.

Site ID	Name	Address	Count of 24-hr average samples (n)	Minimum	Maximum	Average	Median
2	CAMP	2105 Broadway	603	5.000	149.000	30.060	27.000
8*	TCHD	4201 E. 72nd. Avenue	1367	0.000	158.000	35.556	32.000
10**	Birch Street	7275 Birch St	233	5.000	104.000	36.609	34.000
26	La Casa	4545 Navajo St.	859	1.000	102.000	22.803	20.000
3001	Welby	3174 E. 78th Ave.	3487	1.000	111.571	32.419	28.667

*- Site 8 data consisted of 2017-2020

**- Site 10 only had 2021 data

Table 32. NO_2 EPA AQS Monitoring Data (ppb), five-year summary statistics, 2017-2021.

Site ID	Name	Address	Count of 1-hr samples (n)	Minimum	Maximum	Average	Median
2	CAMP	2105 Broadway	3608	3.565	61.930	17.497	15.369
6*	Rocky Flats-N	16600 W Colo #128	2118	-0.068	23.339	2.865	2.217
26	La Casa	4545 Navajo St.	3470	2.617	56.594	17.339	14.987
27	I-25	971 Yuma Street	3534	3.939	62.935	22.983	21.900
28	Globeville	4903 Acoma St.	3560	2.504	63.474	26.446	25.543
3001	Welby	3174 E. 78th Ave.	3450	-0.184	51.343	15.599	13.759

*- Site 6, Rocky Flats-N, included data from 2019-2021.

Table 33. SO_2 EPA AQS Monitoring Data (ppb), five-year summary statistics, 2017-2021

Site ID	Name	Address	Count of 1-hr samples (n)	Minimum	Maximum	Average	Median
2	CAMP	2105 Broadway	7155	-0.717	6.646	0.633	0.546
26	La Casa	4545 Navajo St.	7135	-0.248	8.244	0.597	0.457
3001	Welby	3174 E. 78th Ave.	7037	-0.317	3.700	0.811	0.722

Table 34. CO EPA AQS Monitoring Data (ppm), five-year summary statistics, 2017-2021.

Site ID	Name	Address	Count of 8-hr run average samples (n)	Minimum	Maximum	Average	Median
2	CAMP	2105 Broadway	3625	0.142	1.999	0.350	0.313
26	La Casa	4545 Navajo St.	3609	0.100	2.019	0.302	0.258
27	I-25	971 Yuma Street	3602	0.173	2.214	0.478	0.426
3001	Welby	3174 E. 78th Ave.	3553	0.100	1.302	0.291	0.246

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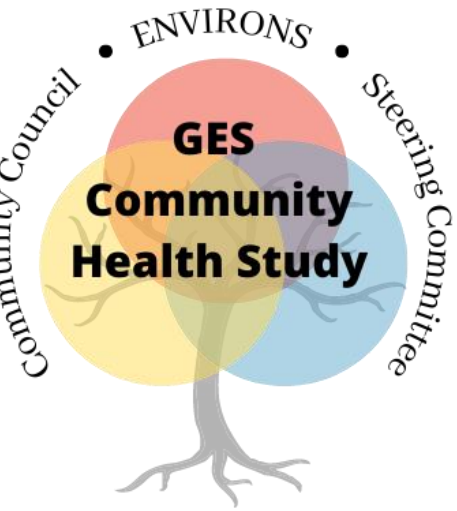

Community Environmental Burden Assessment:

Burden of Disease and Future Scenarios

GES Community Health Study

In response to Deliverable 2.6

February 28, 2025

Updated April 18, 2025

ENVIRONS

Colorado State University

COMMUNITY INSIGHT

Community Insight: From the Community Council.

The GES community faces significant health challenges due to high levels of air pollution from nearby sources such as the I-70 highway, the Purina factory, and emissions from Suncor. This pollution has a direct and severe impact on residents' health, particularly because the community has been historically marginalized and has not received adequate investment in infrastructure or environmental protections. The data in this Deliverable quantifies some of the impacts of air pollution on our health and wellbeing.

This deliverable highlights air pollutants and associated health outcomes, but it does not address other types of pollution in our neighborhood. If we are conducting a health study, it's important that we include everything that impacts the neighborhood—not just air pollution. It's not about showing just one contaminant, it's about many. Right now, we don't have the data we need to do that.

A comprehensive health study is also about showing what has been affecting the neighborhood for many years, throughout our history. While this deliverable captures the most up-to-date data, it does not include all of our historic information. In the future, other studies should collect newer data from additional pollutants and incorporate historical perspectives. This deliverable is a starting point, and it opens the door for new studies that go beyond air pollution and their impacts.

This being said, we also feel that it has been too many years of collecting studies and surveys, more studies and more surveys. It's not just one person that does those studies; there are many groups. In the end, we often don't see the results. The neighborhood is exhausted from studies, surveys, and questions. We have seen many residents leave the neighborhood from air pollution, and from being forced to leave their homes by government actions like building I-70. Residents are tired. We are hopeful that new residents have more energy to participate in studies, and that the results are given back to the community.

The issues are further compounded by the fact that economic and industrial interests are often prioritized over the health and well-being of the community. Large corporations, such as Suncor, have significant influence over local policies, which often favor business growth rather than environmental justice for residents. This has left the community vulnerable to ongoing pollution without sufficient support or intervention.

We hope that studies like this one can help with policy change, which is very important to us as residents. Sometimes as residents we don't know how to speak up to create policy change. Sometimes we only speak to our neighbors because we don't know how to talk to the city, or what data to advocate with. Even when we have meetings with government officials, we don't feel heard because the issues in our neighborhood persist. So, the data in this Deliverable and in future studies is important to bring into future discussions with government officials.

At the heart of this issue is a systemic imbalance where low-income and minority communities, like those in GES, often lack political power. They face barriers to advocacy and are frequently excluded from decision-making processes, which leaves them unable to fully address and resolve the environmental issues that impact their daily lives. This situation underscores the urgent need for stronger community advocacy and policy changes to ensure fair representation and better health outcomes for these residents.

Your GES Health Study Community Council Members

COMMUNITY RELEVANT SUMMARY

Note: This section begins the report written by the ENVIRONS research team.

Purpose: The Community Environmental Burden Assessment (CEBA) for the Globeville, Elyria Swansea (GES) Community Health Study is divided across three study deliverables, Deliverables 2.4, 2.5, and 2.6, to ensure that the analysis is responsive to community needs and interests, and that it is conducted following scientifically valid methodology. The CEBA is a specific type of analysis that quantifies environmental exposures within and around the GES community.

Environmental justice studies have consistently highlighted the concerning link between environmental exposures and adverse health outcomes, particularly in marginalized communities. These findings emphasize the necessity for localized environmental justice analyses. Researchers and government officials have long aimed to address disparities in environmental exposure, often uncovering disproportionate health burdens affecting communities of color and those impacted by historical racism.

Our analyses were limited to focusing on well-defined health outcomes and environmental exposures which have demonstrated robust causal evidence of a relationship between the two. We also required suitable monitoring data for environmental exposures with established scientific standards. As a result, we narrowed the focus of this study to the six criteria air pollutants.

We utilized publicly available data to evaluate health burdens attributable to air pollution exposure experienced by two neighborhoods in Denver, Colorado, between 2017 and 2021. We conducted a quantitative burden assessment using a Monte Carlo approach to estimate deaths and incidence cases of disease attributable to the difference in air pollutant concentrations between GES and the least burdened neighborhood, as well as 95% confidence intervals. We estimated air pollution exposure levels of particulate matter 2.5, particulate matter 10, ozone, nitrogen dioxide, sulfur dioxide, and carbon monoxide using inverse distance weighting interpolation. We estimated that, over a five-year period, that the difference in NO_2 exposure in Globeville compared to the least exposed neighborhood could contribute to the following health conditions:

- Roughly 12 cases of preterm birth (babies born too early), with a possible range between 2 to 22 cases,
- Roughly 7 cases of low birth weight (babies born smaller than 5.5 pounds), with a possible range of 5 to 29 cases,
- Roughly 4 cases of all-cause mortality, with a possible range between 2 and 6 cases,
- Roughly 2 cases of all-cause cancer mortality, with a possible range between 1 and 3 cases,
- Roughly 10 cases of cardiovascular disease (heart disease), with a possible range between 0 and 20 cases,
- Roughly 3 cases of cardiovascular disease mortality (death due to heart disease), with a possible range between 2 and 4 cases,
- Roughly 10 cases of type two diabetes, with a possible range between 7 to 14 cases,
- Roughly 7 cases of childhood asthma, with a possible range of 4 to 11 cases.

Over a five-year period, the difference in NO_2 exposure in Elyria-Swansea compared to the least exposed neighborhood could contribute to the following health conditions:

- Roughly 11 cases of preterm births, with a range between 2 to 20 cases,
- Roughly 15 cases of low birth weight, with a range between 4 to 26 cases,
- Roughly 3 cases of all-cause mortality, with a range between 1 to 5 cases,
- Roughly 8 cases of cardiovascular disease, with a range between 0 to 6 cases,
- Roughly 2 cases of cardiovascular disease mortality, with a range between 1 to 3 cases.

Over a five-year period, the difference in PM_{10} exposure in Elyria-Swansea compared to the least exposed neighborhood could contribute to the following health conditions:

- Roughly 3 cases of all-cause concern mortality, with a range between 1 to 4 cases,
- Roughly 2 cases of stroke, with a range between 0 to 4 cases,
- Roughly 10 cases of type two diabetes, with a range between 1 to 18 cases,
- Roughly 1 case of respiratory disease mortality, with a range between 0 to 4 cases,
- Roughly 29 cases of childhood asthma, with a range between 12 to 51 cases.

Our research shows that people living in the GES area, where air pollution is higher, face serious health problems. Reducing air pollution can greatly improve the health and well-being of the community. Our findings also highlight the importance of helping local residents to speak up for their needs and encouraging decision-makers to create policies based on solid evidence.

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This Deliverable was written by Community Council members and ENVIRONS. It has been reviewed by the Steering Committee.

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LIST OF ACRONYMS, DEFINITIONS, AND DESCRIPTIONS

Table 1. List of acronyms, definitions, and descriptions.

Term	Definition
CC	Community Council is a group of resident collaborators part of the research team that act as community representatives, experts, and liaisons.
CDPHE	Colorado Department of Public Health and Environment. CDPHE is the principal department of Colorado state government responsible for public health and environmental regulations.
CEBA	Community environmental burden assessment. The GES Community Health Study CEBA is comprised of Deliverables 2.4, 2.5, and 2.6.
Census blocks	Small statistical areas bounded by features, such as streets, property lines, and railroad tracts. Census blocks serve as the basis for census tracts and are the lowest geographical area in measuring demographics of a population. [1]
Census tract	Small, relatively permanent subdivision of a city or county with a population between 1,200 and 8,000 people.[1]
CI	Confidence Interval. A confidence interval, or level of significance, is the average value of the estimate plus or minus the variation of that estimate. The confidence interval describes the probability that an estimate will fall between two values centered around the mean.
CCoD	City and County of Denver.
Cumulative risk	The combined risks from aggregate exposures to multiple agents or stressors.
Cumulative risk assessment	An analysis, characterization, and possible quantification of the combined risks to health or the environment from multiple agents or stressors.
CVD	Cardiovascular disease.

Term	Definition
Environmental justice community	Environmental justice is the idea that all people and communities have the right to live and thrive in safe, healthy environments with equal environmental protections and meaningful involvement in these actions.[2] An environmental justice community can also be identified as a disproportionately impacted community. In 2023, Colorado officially defined disproportionately impacted communities as those meeting specific criteria including low income, higher proportions of residents from minoritized race and ethnicity groups, housing cost-burdens, linguistic isolation, historical marginalization, cumulatively impacted, tribal lands, and mobile home communities.[3] This definition places emphasis on historically marginalized and cumulatively impacted communities, highlighting environmental racism and disproportionate environmental burdens.
ENVIRONS	Estudio de Nuestros Vecinos para Investigar los RiesgOs y Nuestra Salud (ENVIRONS) research team is based out of Colorado State University in Fort Collins, CO and is responsible for conducting the GES Community Health Study.
EPA (US EPA)	United States Environmental Protection Agency; the primary agency of the United States government tasked with environmental protection.
Exposure-response/Effect estimate	An exposure-response, often presented as an effect estimate (see measure of association) is a quantitative measurement of an association between an exposure (e.g., air pollution) and health effects. An exposure-response relationship describes the change in risk of a health outcome for a given increase in the exposure. For example, an increase of X ppb of ozone increases the risk of death from heart disease by Y amount.
Exposure pathways or route of exposure	The exposure pathway refers to how a pollutant enters a person's body. The four main routes are inhalation, ingestion, injection, and absorption through the skin.
GES	Globeville, Elyria, Swansea neighborhoods.
Health	Health is a state of physical, mental, and social well-being and not merely the absence of disease.
Heterogeneity	Heterogeneity pertains to the degree of diversity, such as varying study findings. For instance, oil and vinegar can be defined as heterogeneous.
HIA	Health Impact Assessment; Deliverable 2.2 *The ABCs of GES: The State of Health and Environment* of the GES Community Health Study.
Measure of association	A measure of association, presented as an effect estimate refers to a wide variety of statistics that quantify the relationship between environmental exposures and health outcomes, enabling comparison between different groups.
Morbidity	Morbidity describes the effects a disease or a symptom of a disease has on a person's life.
Mortality	Death-producing characteristics of a disease (e.g., cause specific or all-cause mortality).
Neighborhood	The City and County of Denver recognizes 78 official neighborhoods, including Denver International Airport (DIA).[4] These are often made up of a collection of census tracts. For example, GES includes three census tracts.
O_3	Ozone; a type of air pollutant.
PM	Particulate matter; PM contains microscopic solids or liquid droplets that can be inhaled and cause serious health problems. Some particles less than 2.5 micrometers in diameter can get deep into your lungs and some may even get into your bloodstream.
Risk Ratio, Rate Ratio (RR)	Risk ratio is an epidemiological term used to describe the measure of association. A RR compares the risk of a health event (disease or death) among two groups of people.

Term	Definition
SC	The Steering Committee are stewards of the settlement agreement to ensure it is carried out appropriately, including through the approval of work plans, invoices, and deliverables.
Stressors	Chemicals, biological or physical agents that can induce adverse effects on human health.

INTRODUCTION

Globeville, Elyria, and Swansea (GES) represent some of the oldest neighborhoods in Denver, Colorado, each with a rich history and vibrant community (Figure 1). Over the years, GES residents have engaged in dedicated efforts to raise awareness of the environmental challenges they encounter in the community. In response to the Colorado Department of Transportation (CDOT) Central Interstate-70 (I-70) expansion project, a coalition was established. This coalition included the Elyria-Swansea Neighborhood Association, the Colorado Latino Forum, and the Chaffee Park Neighborhood Association, with invaluable support from the Colorado Sierra Club. Together, they took proactive legal action against the expansion, resulting in a lawsuit known as the Central 70 settlement.[5,6] By 2018, the I-70 lawsuit reached a successful settlement, which led to the allocation of funds for a comprehensive health study specifically focusing on the GES community. A key stipulation of this settlement was that the health study must provide decision-makers with relevant information to guide policy choices, without explicitly recommending specific policies. This requirement presents a complex and nuanced challenge, particularly for community members and advocates eager to see tangible, actionable changes that directly affect their environment and health.

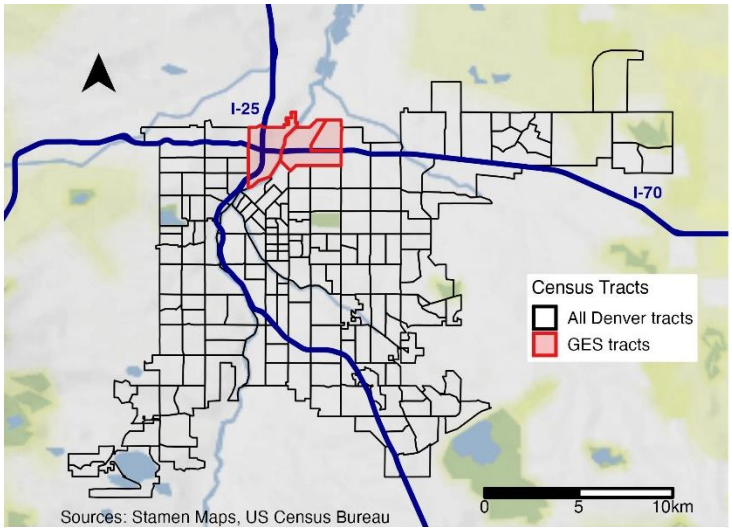

Figure 1. Globeville and Elyria Swansea census tracts in relation to City and County of Denver area.

The Globeville, Elyria, Swansea Community Health Study is committed to gathering an array of previously collected data to glean insights vital for policymakers striving to establish evidence-based initiatives aimed at mitigating the effects of environmental pollutants on community health. A pivotal aspect of the GES Community Health Study is its commitment to accessibility and community engagement. Feedback from GES residents has emphasized the necessity of crafting study deliverables that are not only informative but also easily interpretable by the community. This includes ensuring that the methodologies utilized in the study are clearly articulated to enable community members to understand findings and leverage them for advocacy and actionable change. The GES Community Health Study Community Council plays a vital role in collaboration with the ENVIRONS research team to ensure that study deliverables resonate with the needs, interests, and perspectives of GES residents. Study findings will be shared with the public through a variety of avenues, including community meetings that invite open dialogue, neighborhood canvassing initiatives designed to reach a broad audience, and ongoing discussions with local organizations that are invested in the health and well-being of the community. In alignment with the settlement agreement, all final reports, data, and comprehensive methodologies will be made publicly accessible on the CDOT website, ensuring transparency and community access to information. The GES Community Health Study seeks not only to enrich the existing body of knowledge concerning environmental health but also to illuminate the critical gaps that exist in data availability. Community members and interested parties can find all previous study deliverables on the dedicated GES

Community Health Study website at https://www.geshealthstudy.org/home. Additionally, a detailed table of past study deliverables published to date is provided in Table 2, demonstrating the ongoing commitment to transparency and community engagement in this vital research endeavor.

Table 2. GES Community Health Study Deliverables.

Deliverable	Description
Phase I	Planning and Foundations deliverables
Deliverable 1.1: ENVIRONS Questionaries	After participating in a tour of the GES neighborhoods, each ENVIRONS team member completed a questionnaire prepared by the Community Council. In addition to individual responses, a summary for the team was created.
Deliverable 1.2: Shared Operational Principles	The Community Council, ENVIRONS, and Steering Committee identified roles and defined shared values, motivations, expectations, and limitations for the study.
Deliverable 1.3: Community Engagement Plan	The Community Engagement plan was developed with the Community Council and Steering Committee. It defines how ENVIRONS will communicate with the Community Council and the Steering Committee, and outlines strategies for communicating with residents, soliciting community input, and maintaining transparency.
Deliverable 1.4: Narrative	ENVIRONS identified sources of data, literature, and on-going projects that will be used in Phase II. As part of this, ENVIRONS reviewed the materials provided in the "crowd sourced literature review" folder curated by the Steering Committee prior to ENVIRONS coming onto the study.
Deliverable 1.5: Mapping and Website	The website is available in English and Spanish, and maps are available on the Maps page.
Deliverable 1.6: Course Correction Plan	ENVIRONS worked with the Community Council and Steering Committee to create a course correction plan. This plan ensures that the study is headed in the right direction for Phase II.
Phase II	Analysis
Deliverable 2.1: Data Rubric and Literature Evaluation	ENVIRONS created a rubric to evaluate the quality of literature and data, then applied this rubric to the sources of information identified in the crowd-sourced literature folder or in the Preliminary Data Identification and Narrative.
Deliverable 2.2: The ABCs of GES: The State of Health and Environment	This report characterizes areas of community concern, provides updated data to topics identified in the 2014 Health Impact Assessment report, and evaluates the implementation of recommendations from the 2014 report.
Deliverable 2.3: Exposure Outcome Matrix	The Exposure Outcome matrix demonstrates the connections between environmental exposures in GES, health outcomes, and health disparities based on existing research. The purpose of this matrix is to visualize how environmental exposures (e.g. pollutants) are connected to adverse health outcomes.
Deliverable 2.4: Community Environmental Burden Assessment (CEBA): Planning, Scoping, and Problem Formulation	This document outlines the plan for how ENVIRONS will conduct the Community Environmental Burden Assessment (CEBA), which makes up Deliverables 2.4, 2.5, and 2.6 for the study.
Deliverable 2.5: Community Environmental Burden Assessment (CEBA): The Exposure Response Assessment Phase	This document outlines the methods and preliminary results of the CEBA including modeled air pollution exposures across Denver and literature review of exposure-response relationships.

The Community Environmental Burden Assessment (CEBA), encompassing Deliverables 2.4, 2.5, and 2.6, plays an integral role in the GES Community Health Study, forming a foundation for understanding how environmental factors impact public health (Figure 2).

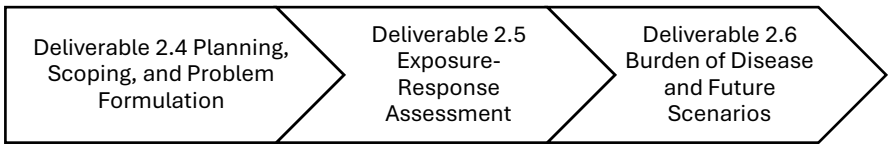

Figure 2. Deliverables 2.4-2.6 Community Environmental Burden Assessment (CEBA) Process Flow.

The Community Environmental Burden Assessment (CEBA) aims to evaluate the cumulative human health impacts stemming from concurrent exposure to environmental pollutants. The overarching purpose of the CEBA is to highlight the urgent need for localized environmental justice analyses, with a concentrated emphasis on the GES community. Environmental justice is the idea that all people and communities have the right to live and thrive in safe, healthy environments with equal environmental protections and meaningful involvement in these actions.[2] Past environmental justice studies have consistently illustrated the alarming connection between harmful environmental exposures and a myriad of adverse health outcomes, particularly within marginalized communities that often bear the brunt of such inequities.[7–9] The CEBA's central hypothesis posits that the GES neighborhoods endure some of the highest cumulative human health burdens in Denver, with environmental exposures playing a substantial role in exacerbating these health challenges. Due to GES's proximity to sources of pollution, such as major interstates, Superfund sites, and extensive industrial operations, GES is likely to experience intensified negative health impacts. The confluence of these factors necessitates a thorough examination of the localized dynamics affecting community health and demands a comprehensive approach to understanding the interplay of these environmental stressors.

Deliverable 2.4, titled "Community Environmental Burden Assessment (CEBA): Planning, Scoping, and Problem Formulation," marked a critical initial phase in the CEBA process. This stage was essential for establishing a structured framework that closely aligns with the specific environmental health needs identified within the community. Deliverable 2.4 emphasized the importance of employing rigorous scientific methodologies to ensure the assessment's validity and reliability. By outlining strategic planning and scoping procedures, this deliverable fostered a collaborative approach that engaged both community members and field experts. This foundational work established a roadmap for subsequent analyses, forming a comprehensive outline for the CEBA initiative (Figure 3). Deliverable 2.4 incorporated well-established analytical techniques rooted in the burden of disease framework,[10–13] thereby providing a basis for quantitative analyses aimed at uncovering the complex relationships between environmental exposures and their detrimental health impacts on the community. In Deliverable 2.4, we presented a selection of candidate health outcomes that are particularly relevant to our analysis. To maintain the robustness of our analysis, we stressed that each proposed health outcome must demonstrate a well-established causal relationship with specific environmental exposures. This connection should be backed by solid, trustworthy evidence that helps explain how these environmental elements affect our health. Our focus on these health outcomes was intentional, aligning with the discussions outlined in Deliverable 2.2, "The ABCs of GES: The State of Health and Environment," and reflecting the interests and concerns expressed by the community members we engage with. By concentrating on these vital community health indicators, we aimed to deepen our understanding of the environmental factors that disproportionately affect environmental justice communities in Denver, Colorado.

Deliverable 2.5, titled "Community Environmental Burden Assessment (CEBA): The Exposure Response Assessment Phase," centered on the critical evaluation of exposure-response relationships. Deliverable 2.5 built upon the groundwork established in Deliverable 2.4 by encompassing the first four steps highlighted in Figure 3. Deliverable 2.5

presented a comprehensive methodology designed to assess exposure levels associated with the six principal air pollutants monitored throughout the City and County of Denver (CCoD) by the US Environmental Protection Agency (EPA). Deliverable 2.5 detailed the data collection processes, allowing for a thorough examination of the spatial (location-based) variations in pollutant exposure across CCoD neighborhoods. Deliverable 2.5 integrated findings from an extensive review of existing scientific literature, encompassing multiple studies and reports, to identify and define relevant health impact measures of association linked to these air pollutants. The exposure response assessment phase enhanced our understanding of the potential public health implications by establishing well-documented connections between varying exposure levels and corresponding health outcomes, such as respiratory issues, cardiovascular diseases, and other chronic health conditions.

Deliverable 2.6, titled "Community Environmental Burden Assessment (CEBA): Burden of Disease and Future Scenarios," serves as the concluding piece in the CEBA process flow (Figure 2). This deliverable provides an in-depth analysis of the disease burden attributable to differences in exposure levels. It offers an examination of how these differences contribute to health disparities, with a particular focus on the GES neighborhoods. By utilizing statistical models and data visualization techniques, Deliverable 2.6 highlights the relationships between environmental exposures and health outcomes, thereby making clear the specific challenges faced by these communities. The insights drawn from this analysis are instrumental in guiding future public health initiatives aimed at reducing environmental health risks and improving overall community wellbeing.

Population-attributable impacts evaluate the contribution of environmental exposures to the overall health outcomes experienced by a population. By analyzing relationships between environmental exposure and health, researchers can estimate the potential reduction in disease burden if these environmental risk factors were reduced or eliminated, offering valuable insights for public health policies and interventions. The application of population-attributable effect estimates occurs most frequently at broader spatial scales, including global, national, and regional levels.[14–16] However, there has been a recent shift toward utilizing these methodologies at more localized levels, such as county, city, and census tract populations.[17–19] For instance, Castilo *et al.* (2021) applied this analytical approach to assess the intra-urban heterogeneity of fine particulate matter ($PM_{2.5}$) and its associated health outcomes, specifically mortality and morbidity, in Washington, DC. The results of their investigation indicated that the health burdens resulting from $PM_{2.5}$ exposure were unevenly distributed and revealed significant inequities across different areas of the city.[19] Similarly, Son *et al.* (2020) explored the intricate relationship between air pollution and mortality rates in North Carolina. Their study took a community-centered approach, incorporating various local factors that could act as potential modifiers in the estimation of population-attributable risk.[20] By considering these community-level determinants, they aimed to provide a more nuanced understanding of how air pollution impacts different populations.

Building on these established methodologies, our approach was designed to apply rigorous analytical techniques typically used in environmental risk assessments[21,22] and environmental burden evaluations.[10,23,24] We aim to estimate the health impacts stemming from disproportionate environmental exposures specifically within the Globeville, Elyria, and Swansea neighborhoods of Denver. This comparison will be made with the least exposed neighborhood in the area, shedding light on the health disparities that may arise due to varying levels of environmental exposure across different communities. Through this analysis, we hope to contribute valuable insights into the public health implications associated with environmental inequities in urban settings.

Our analysis was intentionally designed to concentrate on well-defined health outcomes that accurately reflect the health status of the broader population. We also accounted for health issues that have garnered interest from the community. Throughout the GES health study, community members expressed concerns about childhood asthma, diabetes, cancer mortality, and life expectancy, represented as all-cause mortality. Additionally, we prioritized environmental exposures that current scientific literature has identified as having a causal relationship with specific health outcomes. For instance, Chen et al. (2022) conducted a meta-analysis examining the relationships between air pollution and health, identifying statistically significant associations with childhood asthma, preterm birth, diabetes,

cardiovascular diseases (CVD), and chronic obstructive pulmonary diseases (COPD).[25] Similarly, Niu et al. (2021) determined associations between air pollution and stroke,[26] while Qin et al. (2021) explored the links between air pollution and hypertension.[27]

While this approach is beneficial in many respects, it inherently limits the range of environmental exposures that we can examine quantitatively. We are confined to evaluating exposures backed by robust causal evidence linking them directly to health effects, and we also require that suitable monitoring data for these exposures are readily available. Our analysis must adhere to environmental exposure definitions that are consistent with established scientific standards to ensure reliability and accuracy in our findings.

As a result of these parameters, we narrowed our focus to the six key criteria air pollutants, particulate matter < 2.5µm ($PM_{2.5}$), particulate matter < 10µm (PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO). Notably, some community members express primary concern over environmental exposures that go beyond these six criteria air pollutants. This concern highlights a significant limitation of our study, as it does not encompass the full spectrum of environmental factors that may impact health. It is important to note that airborne lead is classified as a criteria pollutant; however, its levels have significantly declined since the removal of lead from gasoline in the 1970s, leaving no known emissions sources of airborne lead in the community today. As such, we have excluded results related to airborne lead from this analysis. Nonetheless, elevated soil lead levels remain a significant concern in various neighborhoods, as they can pose health risks, particularly to children and other vulnerable populations.

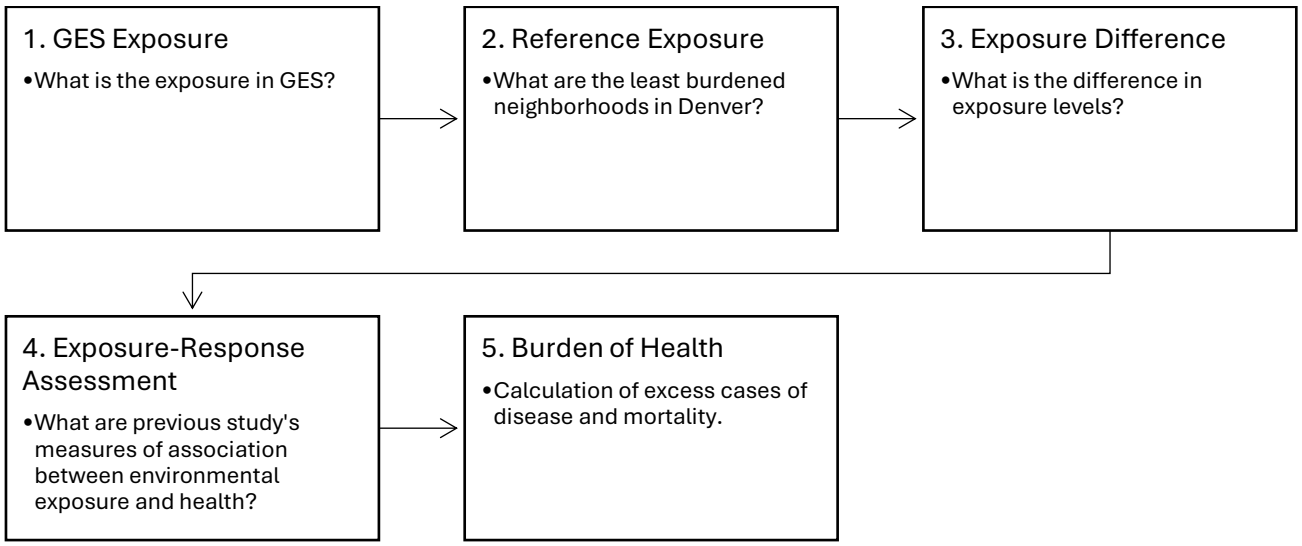

Figure 3. CEBA Aim 1 quantitative analysis process flow diagram.

EPA NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS).

The Clean Air Act mandates that the Environmental Protection Agency (EPA) establish and periodically reassess scientific evidence related to six key air pollutants: particulate matter with diameters of 2.5 micrometers or smaller ($PM_{2.5}$), particulate matter with diameters of 10 micrometers or smaller (PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO). To fulfill this requirement, the EPA undertakes comprehensive scientific evaluations that analyze the latest research findings and health-related evidence. This rigorous review process helps to ascertain whether new air quality standards are necessary to safeguard public health and ensure environmental protection. The EPA's work is vital in identifying potential risks associated with these pollutants and in shaping effective policies to mitigate their impact on air quality and overall community health.

Particulate Matter 2.5 ($PM_{2.5}$) and 10 (PM_{10}). In early 2024, the EPA made significant updates to the NAAQS, specifically revising the standards for $PM_{2.5}$ by lowering the annual standard for $PM_{2.5}$ from 12 $\mu g/m^3$ to 9 $\mu g/m^3$.[28] This change reflects an evolving understanding of the health impacts associated with prolonged exposure to particulate matter, acknowledging that stricter standards may help mitigate adverse health effects on sensitive populations. The previous revision of $PM_{2.5}$ regulations occurred in 2012, indicating a substantial gap of over a decade before the latest adjustments were made.[29] $PM_{2.5}$ air quality standards are established based on the annual arithmetic mean concentration measured over a three-year period. This approach allows for a detailed assessment of air quality trends and variations. In conjunction with the $PM_{2.5}$ changes, the EPA chose to maintain the existing standard for PM_{10}, which is set at a 24-hour concentration limit of 150 $\mu g/m^3$. This PM_{10} standard is designed to ensure that this level of particulate matter is not exceeded more than once per year, based on an average calculated over a three-year period.

Ozone (O_3). In December 2020, the EPA conducted a review of scientific evidence concerning exposure risks associated with the current NAAQS for ozone.[30] The existing standard, established in 2015, is set at 0.070 parts per million (ppm), or 70 parts per billion (ppb), which represents the fourth highest maximum daily 8-hour ozone concentration each year, averaging over three years.

Nitrogen Dioxide (NO_2). Nitrogen dioxide (NO_2) is a significant air pollutant that presents various health and environmental challenges. It is primarily produced from the combustion of fossil fuels, especially in vehicles, power generation facilities, and various industrial processes. NO_2 is a reddish-brown gas characterized by a sharp, unpleasant odor and is a major contributor to the formation of smog and acid rain. The EPA has established NAAQS for NO_2, designating a 98th percentile of 1-hour daily maximum concentrations, averaging over 3 years of 100 ppb and an annual mean concentration limit of 53 ppb.[31]

Sulfur Dioxide (SO_2). Sulfur dioxide (SO_2) is a colorless gas with a pungent odor, primarily generated through the combustion of fossil fuels such as coal and oil, as well as from various industrial processes, including metal smelting and oil refining. The EPA last conducted a comprehensive review of the NAAQS for SO_2 in 2019.[32] This review aimed to assess the levels of SO_2 in the atmosphere and evaluate the effectiveness of existing regulations. Ultimately, the EPA decided to maintain the current one-hour standard of 75 ppb, which is designated as the 99th percentile of daily maximum concentrations observed over a three-year monitoring period.

Carbon Monoxide (CO). Carbon monoxide (CO) is a colorless, odorless gas that is predominantly produced by the exhaust emissions of motor vehicles and various industrial processes. The EPA has established NAAQS to monitor and manage CO levels in the atmosphere consisting of two key thresholds: an 8-hour standard and a 1-hour standard.[33] The 8-hour standard is set at a maximum concentration of 9 ppm (equivalent to 9000 ppb), while the 1-hour standard permits a higher concentration of 35 ppm. Notably, both standards allow for exceedances only once per calendar year.

METHODS

SPATIAL UNIT OF ANALYSIS. For this study, we drew upon the definitions of statistical neighborhoods as established by the City and County of Denver (CCoD), intentionally omitting the area of Denver International Airport (DIA) from our analysis.[4] This approach allowed us to concentrate on a total of 77 neighborhoods of interest (Figure 4). The concept of statistical neighborhoods typically combines multiple census tracts, reflecting the diverse social and demographic characteristics within those areas. In our neighborhood dataset, the Globeville, Elyria, Swansea area is divided into two designated neighborhoods: Globeville and Elyria-Swansea. However, we recognize that many residents view GES as three individual neighborhoods. For the purposes of this study, we report the findings for GES as two separate spatial units, Globeville and Elyria-Swansea, aligning our methodology with the CCoD's definitions of statistical neighborhoods. This decision ensures consistency in our analysis while also acknowledging the unique identities that residents associate with this region.

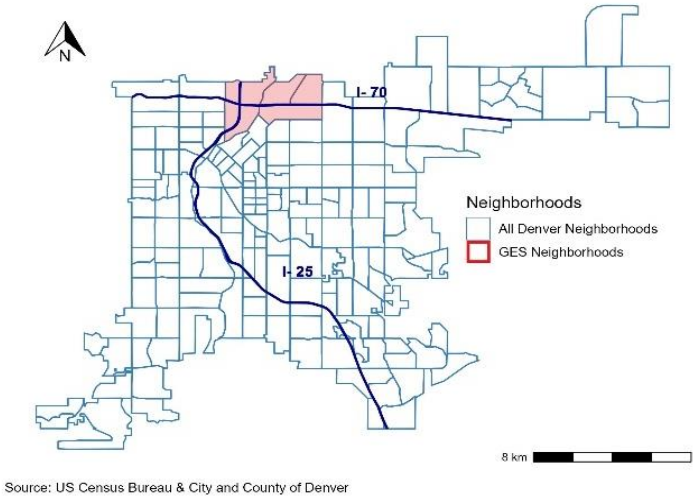

Figure 4. Denver neighborhoods.

ESTIMATING EXPOSURE. Here we provide a brief description of our modeling estimates, for a full description of this methodology, please refer to Deliverable 2.5. In this study, we gathered Colorado air monitoring data spanning from 2017 to 2021. Data included measurements for $PM_{2.5}$ expressed as a 24-hour mean based on the 2012 annual standard in micrograms per cubic meter ($\mu g/m^3$), O_3 measured as an 8-hour daily mean and 8-hour daily maximum in parts per million (ppm), PM_{10} recorded as a 24-hour mean in $\mu g/m^3$, NO_2 presented as a 1-hour mean based on the NO_2 2010 standard in parts per billion (ppb), SO_2 measured as a 1-hour mean adhering to the SO_2 2010 standard in ppb, and CO quantified as an 8-hour mean according to the CO 1971 standard in ppm. These data were sourced through the EPA Air Quality System (AQS) application programming interface (API), utilizing the RAQSAPI package in R for data retrieval and analysis.[34] $PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, and CO observations from EPA surface monitors were interpolated using inverse distance weighting (IDW). The five-year average concentrations of these six air pollutants were estimated at the neighborhood centroids across Denver. The resulting estimated concentration exposures were used to calculate the difference in exposure between Globeville, Elyria-Swansea, and the neighborhood least exposed to air pollutants (Deliverable 2.5 Equations 1 and 2).

HEALTH OUTCOMES. This study initially identified the health outcomes outlined in Deliverable 2.2. We then refined this selection to concentrate on health outcomes that GES community members have shown interest in, those with suitable exposure-response relationships, and those supported by sufficient available secondary data (Table 3).

Health at birth data, including preterm birth and low birth weight, were obtained from restricted birth records supplied by the Center for Health and Environment. Other health outcome data were sourced from the University of Washington's Institute for Health Metrics and Evaluation (IHME) Global Burden of Disease (GBD) health data platform for the years 2017 to 2021 (Table 3).[35] These health outcomes included mortality data for all-cause mortality, cancer, respiratory diseases, cardiovascular disease (CVD), chronic obstructive pulmonary disease (COPD), and stroke. Health outcomes also included incidence data for childhood asthma, hypertension, stroke, and type two diabetes. The GBD uses a variety of data sources, including hospital records, clinical trials, surveys (e.g., the American Community Survey), disease registries, and epidemiological surveillance records. State-level data from the GBD were necessary because small-area estimates for Denver or GES could not be utilized either due to a lack of data for the analyzed period (2017-2021) or because available health outcome data did not meet our specific requirements (e.g., only prevalence data were available when we required incidence data).

Table 3. Summary of health outcomes, descriptions, and sources.

HEALTH OUTCOME	DESCRIPTION	SOURCE
Mortality		
All-cause mortality	Death from any cause	GBD
All-cancer mortality	Cancer is a disease in which abnormal cells divide uncontrollably and destroy body tissue. All-cancer mortality is deaths from any type of cancer.	GBD
Respiratory disease mortality	Death from an acute (short-term) or chronic (long-term) illness affecting the respiratory system and the body's ability to breathe.	GBD
Cardiovascular disease (CVD) mortality	Cardiovascular disease (CVD) is a group of health conditions that impact the heart and blood vessels. CVD mortality is death from any cardiovascular disease.	GBD
Chronic obstructive pulmonary disease (COPD)	COPD is a common lung disease that restricts airflow.	GBD
Stroke mortality	Deaths from stroke.	
Incidence		
Childhood asthma	Asthma is a respiratory condition in which a person's airways become inflamed, narrow, and swollen, making breathing difficult.	GBD
Hypertension	Incidence of high blood pressure (140/90 mmHg or higher)	GBD
Low birthweight	Incidence of infants born weighing 5.5 pounds (2500 grams) or less	2017-2021 Birth Records
Preterm birth	Incidence of infants born alive before 37 weeks of pregnancy are completed	2017-2021 Birth Records
Stroke	Incidence of stroke, a type of medical emergency where the blood supply to the brain is disrupted.	GBD
Type II diabetes (T2DM)	T2DM, also referred to as adult-onset diabetes, is a medical condition that impacts how the body regulates blood glucose, also known as blood sugar.	GBD

Health at birth information was provided as count data, which we aggregated to the state level to match the geographic scale of GBD. Data included the total number of live births (n = 313,108), low birth weight (n = 29,339), and preterm births (n = 29,190) from the years 2017 to 2021 (Table 4). We applied Equation 1 to calculate the five-year average incidence rates for low birth weight and preterm births expressed per 1,000 live births. 95% confidence intervals were calculated using a 1.96 z-score and a standard error of the proportion of low birth weight and preterm births to total live births.[36]

Table 4. Annual birth statistics in Colorado (2017-2021): Counts of low birthweight, preterm birth, and total live births.

Year	Low birthweight [A]	Preterm birth [B]	Total live births
2017	5,860	5,641	64,109
2018	5,917	5,794	62,572
2019	5,927	6,007	62,580
2020	5,679	5,617	61,219
2021	5,956	6,131	62,628
Total	29,339	29,190	313,108

[A] Low birth weight is defined as infants born weighing 5.5 pounds (approximately 2,500 grams) or less
[B] Preterm birth refers to deliveries occurring before the completion of the 37th week of gestation.

Equation 1. Estimation of incidence rate per 1,000 live births.

$$I = \frac{C}{X} * 1{,}000$$

Where *C* is the number of low birth weight or preterm birth cases and *X* is the total number of live births.

To synthesize the GBD annual mortality for all-cause mortality, all-cause cancer, respiratory diseases, CVD, COPD, and stroke, and annual incidence for hypertension, stroke, and type 2 diabetes, we calculated the five-year average incidence and mortality rates for each health outcome. We calculated 95% confidence intervals (CIs) as the mean CI estimates provided in the datasets by health outcome.

GBD childhood asthma incidence and 95% confidence intervals are categorized by age group, including under 20 years, 0-14, 10-14, and 10-19 years. We assumed an equal age distribution and estimated the five-year average incidence rate and 95% CIs for childhood asthma among children aged 1 to 18.

In contrast to the information detailed in Deliverables 2.4 and 2.5 concerning obesity, we face significant challenges in quantifying the cases of obesity in this analysis due to existing data limitations. The health impact function, which is crucial for gauging the environmental burden, relies on having reliable incidence or mortality rates. Regrettably, these rates cannot be calculated with the data currently available to us. The Centers for Disease Control and Prevention's Behavioral Risk Factor Surveillance System (CDC BRFSS) offers valuable data regarding the demographics of adult males and females aged 18 years and older who were classified as obese or overweight in Colorado from the years 2017 to 2021.[37,38] This dataset includes the percentage of individuals classified as obese or overweight, as well as the sample size gathered from a telephone survey conducted during this period. While this information allows for the calculation of the annual prevalence of obesity and overweight in the population, it falls short of providing insight into the number of new cases emerging each year versus the number of individuals who are continuing to experience obesity from previous years. Epidemiological methodologies can potentially yield rough estimates of incidence using applicable equations, a substantial limitation arises from our constrained understanding of the duration that individuals remain classified as obese or overweight. Without this critical information, our ability to extrapolate and apply these estimates effectively is significantly restricted. This limitation emphasizes the need for more

comprehensive data collection efforts and further research to enhance our understanding of obesity trends and dynamics in the population.

POPULATION. Globeville and Elyria-Swansea population data were obtained at the census tract level from the five-year American Community Survey (ACS) estimates for 2017-2021, provided by the U.S. Census Bureau. These data were retrieved using the U.S. Census Bureau API through the tidycensus package in R.[39,40] 95% CIs for population estimates were calculated following the US Census Bureau guidelines.[41,42]

Based on the exposure-response functions described in Deliverable 2.5, the measures of association for all mortality outcomes, as well as the incidences of diabetes, hypertension, and stroke, relate specifically to the adult population. However, not all studies clearly specified the age groups included in their definitions of "adults." GBD health outcome data for the adult population were categorized as individuals aged 20 years and older. Therefore, we assumed the adult population as the 5-year ACS population estimates for those aged 20 and older. For childhood asthma, we assumed an equal distribution across all age categories to calculate 5-year ACS population estimates for children aged 1-18 years.[39]

Deliverable 2.5 exposure-response functions identified pregnant individuals as the at-risk population for low birth weight and preterm birth, though they infrequently specified the age range encompassed within this group. For this analysis, we assumed a baseline population as women aged 15-44, representing a general reproductive age range. We estimated the proportion of women in this age group who were pregnant each year in Colorado from 2017 to 2021 by dividing the average number of live births each year (n = 62, 612.6) during this five-year period by the five-year ACS estimated total female population within the 15-44 age range (n = 174,747), resulting in an overall proportion of approximately 36%. We then applied this proportion to the ACS five-year population estimates for women aged 15-44 in the Globeville and Elyria-Swansea census tracts to determine the number of at-risk pregnant women aged 15-44 who had live births during that time frame.

Table 5. Population characteristics of Globeville and Elyria-Swansea (2017-2021).

Population	Globeville	Globeville	Elyria-Swansea	Elyria-Swansea
	Count (n)	95% CI	Count (n)	95% CI
Total Population	4005.0	(3969.92, 4040.08)	6712.00	(6667.42, 6756.58)
Under 18	708.50	(680.25, 736.75)	2218.00	(2173.86, 2262.14)
Adults aged 18 and older	3258.50	(3198.18, 3318.82)	4440.00	(4371.11, 4508.89)
Adults aged 20 and older	3107.00	(3088.24, 3125.76)	4349.00	(4334.41, 4363.59)
Females aged 15 to 44	949.00	(918.00, 980.00)	1491.00	(1452.78, 1529.22)
At-risk pregnant individuals aged 15-44	341.64	(330.48, 352.80)	536.76	(523.00, 550.52)

EXPOSURE-RESPONSE. An exposure-response relationship describes how the risk of a health outcome varies with a specific increase in exposure. For instance, an increase of *X* parts per million (ppm) of ozone may elevate the risk of mortality from heart disease by a certain amount (*Y*). In the exposure-response assessment phase (Figure 3 Box 4), we conducted a literature review of previous scientific studies that documented the environmental exposure-response relationships to health outcomes of interest. Deliverable 2.5 outlines the literature review methodology and the creation of the exposure-response function dataset, utilizing parameters presented in Deliverable 2.5 Table 5.

We were successful in identifying many environmental exposure health outcome pairs (e.g., air pollution and stroke mortality). Out of 102 potential exposure-response pairs, we identified 63 exposure-response functions, as detailed in Deliverable 2.5 Table 14. The specific values for these exposure-response assessments are further elaborated in Deliverable 2.5 and have not been repeated here to avoid redundancy.

ESTIMATING ENVIRONMENTAL BURDEN. We concentrated on the health impacts of air pollution exposure related to the health outcomes previously addressed in Deliverable 2.2. While we acknowledge that not all health outcomes from Deliverable 2.2 are included in this analysis, our approach was to focus on the health outcomes that GES residents have shown interest, those with suitable exposure-response relationships, and for which we possess relevant data. We estimated the cases of health outcomes attributable to air pollution exposure using a Monte Carlo sampling approach, based on the health impact function (Equation 2). Monte Carlo simulations samples (n = 10,000) are drawn repeatedly from the distribution of baseline incidence and mortality by health outcome, population, and effect estimates. We present the mean of these simulated values, with the 95% confidence intervals represented by the 2.5th and 97.5th percentiles of the distribution. We assumed our health impact function follows the same functional form as presented in the EPA's BenMap.[43,44]

Equation 2. Cases of disease and mortality attributable to air pollutant exposures.

$$\Delta Y = Population \cdot Y_0 \cdot \left(1 - \exp^{-\beta \cdot \Delta C}\right)$$

In Equation 2, Y_0 represents the 5-year average incidence or mortality rate, and ΔC signifies the difference in the 5-year average air pollution concentration between Globeville or Elyria-Swansea and the least exposed neighborhood in Denver. The β coefficient serves as the effect estimate per unit change, derived from the literature, as illustrated in Equation 3.

Equation 3. Deriving beta from effect estimates and per unit change (Delta X).

$$\beta = \frac{\ln(Effect\ Estimte)}{\Delta X}$$

In this context, ΔX denotes the specific exposure unit being considered. Prior to this calculation, we ensured that the exposure units, typically expressed in micrograms per cubic meter (μg/m^3), were accurately converted to align with the reporting units utilized by the EPA.[45] Detailed mathematical equations for these unit conversions can be found in Appendix A.

RESULTS

Deliverable 2.5's analysis involved comparing environmental exposures to determine the variance in exposure levels between Globeville, Elyria-Swansea, and the neighborhood with the lowest environmental exposure burden. Details of this in-depth analysis can be found in Deliverable 2.5 and are highlighted here for reference.

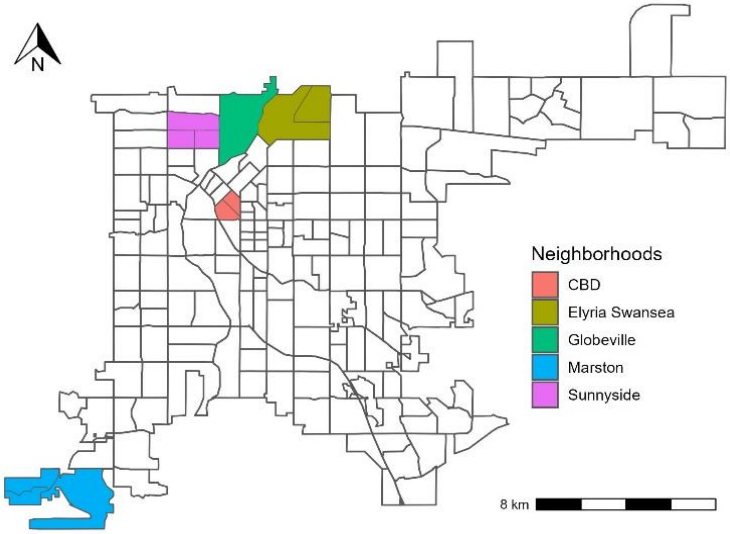

Figure 5. Neighborhoods with the lowest five-year average air pollution concentration exposure levels across the six criteria air pollutants in reference to GES, 2017-2021.

The three neighborhoods with the lowest exposure levels across the six air pollutants are Marston, Central Business District (CBD), and Sunnyside, with Globeville and Elyria-Swansea also highlighted for reference (Figure 5; Table 6). Sunnyside is directly west of Globeville while CBD and Marston are south, southwest of Globeville and Elyria-Swansea.

Table 6. Five-year average air pollution concentration differences between Globeville and Elyria-Swansea, and the least burdened neighborhood, 2017-2021.

Air Pollutant	Least Burdened Neighborhood	Minimum Exposure	Globeville Exposure	Elyria-Swansea Exposure	Globeville Exposure Difference	Elyria-Swansea Exposure Difference
$PM_{2.5}$ ($\mu g/m^3$)	Marston	7.43	9.15	8.54	1.72	1.12
O_3 (ppb)	CBD	30.03	30.31	30.65	0.28	0.62
PM_{10} ($\mu g/m^3$)	Sunnyside	23.33	25.81	30.74	2.48	7.41
NO_2 (ppb)	Sunnyside	18.12	24.87	21.79	6.75	3.67
SO_2 (ppb)	Sunnyside	0.60	0.61	0.65	0.01	0.05
CO (ppb)	Sunnyside	307.17	319.66	337.10	12.49	29.93

HEALTH OUTCOMES

In Deliverable 2.2 *The ABCs of GES: The State of Health and Environment* we discussed how the largest environmental impacts on health often present as chronic health conditions.[46] Exposure to physical, social, and built environmental factors have cumulative impacts on human health. One aim of Deliverable 2.5 was to identify exposure-response relationships between environmental exposures and health outcomes. In line with best methodological practices, we assumed all measures of association are indicative of risk, meaning we interpret all effect estimates, regardless if it is an odds ratio, hazard ratio, or risk ratio, as the increased risk of health due to environmental exposure. Deliverable 2.5 presents the results of the literature review and exposure-response functions (Deliverable 2.5 Tables 15-28).

HEALTH AT BIRTH

PRETERM BIRTH INCIDENCE. Preterm birth cases attributable to the difference in air pollution vary depending on the specific pollutant involved, ranging from 12.11 to 0.08 cases. Notably, there are differences in the cases of preterm birth attributable to exposure to air pollutants beyond those experienced in the least burdened community between Globeville and Elyria-Swansea. In both neighborhoods, the largest estimated cases of preterm birth were attributed to NO_2 exposure. This is likely due to the difference in NO_2 concentrations between GES and the least exposed neighborhood, with ΔC values of 6.75 ppb in Globeville and 3.67 ppb in Elyria-Swansea (Table 7). Over a 5-year period, we estimated approximately 12.11 cases of preterm births (95% CI: 1.68, 22.20) in Globeville and 10.69 cases of preterm births (95% CI: 1.51, 19.64) in Elyria-Swansea were attributable to NO_2 exposure, beyond those experienced in the least burdened community. In Globeville, the second-largest caseload was attributed to O_3 exposure, which accounted for an estimated 2.01 cases of preterm birth (95% CI: 0.30, 3.72), followed by PM_{10} exposure, attributable for 1.70 cases of preterm birth (95% CI: 0.82, 2.61). Conversely, in Elyria-Swansea, the order of attribution changed; PM_{10} was attributable for 7.96 cases of preterm birth (95% CI: 3.87, 12.04), with O_3 exposure accounting for 2.81 cases (95% CI: 0.41, 5.19).

Table 7. Estimated cases of preterm birth among pregnant individuals aged 15-44 who had a live birth attributable to air pollution differences in Globeville and Elyria-Swansea compared to the least burdened Denver neighborhoods (2017-2021).

Air Pollutant	Globeville	Elyria-Swansea
$PM_{2.5}$	0.56 (0.00, 2.95)	0.55 (0.00, 3.01)
O_3	2.01 (0.30, 3.72)	2.81 (0.41, 5.19)
PM_{10}	1.70 (0.82, 2.61)	7.96 (3.87, 12.04)
NO_2	**12.11 (1.68, 22.20)**	**10.69 (1.51, 19.64)**
SO_2	0.08 (0.00, 0.18)	0.52 (0.00, 1.15)
CO	0.33 (0.01, 0.65)	1.24 (0.03, 2.43)

LOW BIRTHWEIGHT INCIDENCE. The three main air pollutants linked to low birthweight cases were NO_2, $PM_{2.5}$, and PM_{10}. In both Globeville and Elyria-Swansea, the highest estimated cases of low birthweight were attributable to NO_2 exposure over five years, beyond those experienced in the least affected neighborhood (Table 8). In Globeville,

there were an estimated 17.15 cases (95% CI: 4.87, 28.79) attributable to NO_2, while in Elyria-Swansea, the estimate was approximately 15.16 cases (95% CI: 4.25, 25.65). In Globeville, 2.12 cases of low birth weight were associated with $PM_{2.5}$ exposure (95% CI: 1.20, 3.05), and 2.02 cases were attributable to PM_{10} exposure (95% CI: 1.21, 2.86). Conversely, in Elyria-Swansea, there were 9.35 cases of low birth weight attributable to PM_{10} (95% CI: 5.63, 13.14), along with 2.17 cases attributable to $PM_{2.5}$ exposure (95% CI: 1.23, 3.12).

Table 8. Estimated cases of low birthweight among pregnant individuals aged 15-44 who had a live birth attributable to air pollution differences in Globeville and Elyria-Swansea compared to least burdened Denver neighborhoods (2017-2021).

Air Pollutant	Globeville	Elyria-Swansea
$PM_{2.5}$	2.12 (1.20, 3.05)	2.17 (1.23, 3.12)
O_3	<0.01	<0.01
PM_{10}	2.02 (1.21, 2.86)	9.35 (5.63, 13.14)
NO_2	**17.15 (4.87, 28.79)**	**15.16 (4.25, 25.65)**
SO_2	0.19 (0.00, 0.50)	1.27 (1.24, 1.30)
CO	<0.01	<0.01

MORTALITY

ALL-CAUSE MORTALITY. We utilized GBD data to analyze annual all-cause mortality among adults aged 20 and older from 2017 to 2021. Our findings indicated an annual average mortality rate of 971.13 per 100,000 individuals in Colorado during these five years (95% CI: 929.56, 1013.30) (Appendix B). In Deliverable 2.2, we reported on all-cause mortality using the standardized mortality ratio (SMR) to compare the GES area with the average for Denver. Deliverable 2.2's analysis demonstrated that the SMR for GES was 1.24 (95% CI: 1.10, 1.37), exceeding the Denver average SMR of 1.00 (95% CI: 0.98 - 1.01).[46] Deliverable 2.5 presented three effect estimates of the relationship between all-cause mortality and $PM_{2.5}$, O_3, and PM_{10} exposure. Our study estimated that cases of all-cause mortality attributable to air pollution exposure ranged from 3.85 to less than 0.01 beyond those in the least burdened community (Table 9). The largest estimated all-cause mortality cases in GES were attributable to NO_2 exposure, with approximately 3.85 cases (95% CI: 1.68, 6.01) in Globeville and 2.95 cases (95% CI: 1.29, 4.62) in Elyria-Swansea. The second largest impact was associated with $PM_{2.5}$ exposure, which accounted for an estimated 1.50 attributable cases (95% CI: 1.04, 1.98) in Globeville and 1.36 attributable cases (95% CI: 0.94, 1.80) in Elyria-Swansea.

Table 9. Estimated cases of all-cause mortality among adults aged 20 years and older attributable to air pollution differences in GES compared to least burdened Denver neighborhoods (2017-2021).

Air Pollutant	Globeville	Elyria-Swansea
$PM_{2.5}$	1.50 (1.04, 1.98)	1.36 (0.94, 1.80)
O_3	0.00 (0.00, 0.88)	0.00 (0.00, 1.10)
NO_2	**3.85 (1.68, 6.01)**	**2.95 (1.29, 4.62)**

ALL-CAUSE CANCER MORTALITY. The GBD project defines cancer mortality as the total number of deaths attributed to all forms of cancer.[47,48] Our analysis of annual cancer mortality rates from 2017 to 2021 shows that the average annual cancer mortality rate in Colorado was approximately 211 deaths per 100,000 individuals (95% CI: 188.02, 229.53) (Appendix B). This study identified variations in air pollutants associated with estimated cases of all-cause cancer mortality in Globeville and Elyria-Swansea, beyond those expected in the least burdened neighborhood (Table 10). In Globeville, the highest estimated number of all-cause cancer mortality cases attributable to NO_2 exposure was 1.89 (95% CI: 0.73, 3.13), followed by an estimated 0.88 cases (95% CI: 0.58, 1.21) attributable to $PM_{2.5}$. PM_{10} was associated with an estimated 0.68 attributable cases of all-cause cancer mortality (95% CI: 0.33, 1.05) in Globeville. In contrast, Elyria-Swansea's highest estimated cases of all-cause cancer mortality were attributable to PM_{10}, with 2.77 cases (95% CI: 1.37, 4.27). NO_2 exposure was associated with 1.46 attributable all-cause cancer mortality cases (95% CI: 0.55, 2.43), followed by $PM_{2.5}$ exposure, which was attributed with estimated 0.80 cases of all-cause cancer mortality (95% CI: 0.52, 1.10).

Table 10. Estimated cases of all-cause cancer mortality among adults aged 20 years and older attributable to air pollution differences in GES compared to least burdened Denver neighborhoods (2017-2021).

Air Pollutant	Globeville	Elyria-Swansea
$PM_{2.5}$	0.88 (0.58, 1.21)	0.80 (0.52, 1.10)
PM_{10}	0.68 (0.33, 1.05)	**2.77 (1.37, 4.27)**
NO_2	**1.89 (0.73, 3.13)**	1.46 (0.55, 2.43)

CARDIOVASCULAR DISEASES

CARDIOVASCULAR DISEASE INCIDENCE AND MORTALITY. Cardiovascular disease incidence and mortality encompass a variety of cardiovascular conditions. Based on GBD annual incidence and mortality data, we found that the average cardiovascular disease incidence rate among adults aged 20 years and older was 1,085.45 per 100,000 (95% CI: 1,034.21, 1,142.31), and the average cardiovascular disease mortality rate was 250.02 per 100,000 (95% CI: 210.71, 275.07) in Colorado between 2017 and 2021 (Appendix B). In Deliverable 2.5, we identified four effect estimates highlighting the relationship between cardiovascular disease incidence and exposure to O_3, NO_2, SO_2, and CO, and three effect estimates demonstrating the relationship between cardiovascular disease mortality and $PM_{2.5}$, O_3, and NO_2. In GES, incident cardiovascular disease cases among adults aged 20 years and older attributable to air pollution beyond those expected in the least burdened neighborhood, ranging from 9.69 to 0.01 cases (Table 11). In Globeville, 9.69 incident cases of cardiovascular disease (95% CI: 0.00. 20.09) were attributable to NO_2, and 0.13 incident cases were attributable to O_3 exposure (95% CI: 0.00, 1.16). In Elyria-Swansea, 7.62 incident cases of cardiovascular disease (95% CI: 0.00, 15.74) were attributable to NO_2 exposure. The second largest estimated incident cases of cardiovascular disease in Elyria-Swansea were 0.16 cases attributable to O_3 exposure (95% CI: 0.00, 1.46) and 0.16 cases attributable to CO exposure (95% CI: 0.08, 0.25). For cardiovascular disease mortality among adults aged 20 years and older, cases attributable to air pollution ranged between 2.65 and less than 0.01 cases. Globeville had an estimated 2.65 cases (95% CI: 1.66, 3.77), and Elyria-Swansea had 2.05 cases (95% CI: 1.27, 2.94) attributable to NO_2 exposure. $PM_{2.5}$ exposure accounted for the second-largest number of attributable cardiovascular disease mortality cases, with estimates of 1.14 cases (95% CI: 0.98, 1.27) in Globeville and 1.06 cases (95% CI: 0.89, 1.16) in Elyria-Swansea.

Table 11. Estimated cases of incident cardiovascular disease and cardiovascular disease mortality among adults aged 20 years and older attributable to air pollution differences in GES compared to least burdened Denver neighborhoods (2017-2021).

Air Pollutant	Globeville	Elyria-Swansea
Cardiovascular disease incidence		
O_3	0.13 (0.00, 1.16)	0.16 (0.00, 1.46)
NO_2	**9.69 (0.00, 20.09)**	**7.62 (0.00, 15.74)**
SO_2	0.01 (0.00, 0.01)	0.03 (0.02, 0.05)
CO	0.05 (0.20, 0.07)	0.16 (0.08, 0.25)
Cardiovascular disease mortality		
$PM_{2.5}$	1.14 (0.57, 1.77)	1.03 (0.52, 1.62)
O_3	<0.01	<0.01
NO_2	**2.65 (1.66, 3.77)**	**2.05 (1.27, 2.94)**

HYPERTENSION INCIDENCE. Hypertension, commonly referred to as high blood pressure, is a leading cause of mortality due to cardiovascular disease.[49,50] The 5-year average annual incidence rate of hypertension among adults aged 20 years and older was estimated to be 0.46 per 100,000 (95% CI: 0.36, 0.59) in Colorado between 2017 and 2021(Appendix B). As reported in Deliverable 2.2, evidence indicates that the GES exhibits a hypertension prevalence comparable to that of the wider Denver area.[46] Deliverable 2.5 identified six effect estimates regarding the relationship between hypertension and air pollution. However, our analysis determined that hypertension cases attributable to the difference in air pollution exposure were notably low, ranging from 0.03 to less than 0.01 (Table 12). Carbon monoxide was found to be attributable to the largest number of hypertension cases, with an estimated 0.01 cases (95% CI: 0.00, 0.02) in Globeville and 0.03 cases (95% CI: 0.00, 0.06) in Elyria-Swansea.

Table 12. Estimated cases of incident hypertension among adults aged 20 years and older attributable to air pollution differences in GES compared to least burdened Denver neighborhoods (2017-2021).

Air Pollutant	Globeville	Elyria-Swansea
$PM_{2.5}$	<0.01	<0.01
O_3	<0.01	<0.01
PM_{10}	<0.01	<0.01
NO_2	<0.01	<0.01
SO_2	<0.01	<0.01
CO	**0.01 (0.00, 0.02)**	**0.03 (0.00, 0.06)**

STROKE INCIDENCE AND MORTALITY. Previous studies have established a relationship between stroke incidence, stroke mortality, and air pollution exposure. A national population-based cohort study by Ma et al. (2022) found that consistent exposure to $PM_{2.5}$ and NO_2 significantly elevates the risk of stroke, with NO_2 exhibiting the strongest association.[51] Deliverable 2.5 identified effect estimates documenting the relationship between $PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, and CO and stroke incidence and mortality. This study found that the 5-year estimated annual stroke incidence was 124.87 per 100,000 (95% CI: 109.77, 141.35), and the annual stroke mortality was 59.87 per 100,000 (95% CI: 49.30, 66.71) in Colorado between 2017 and 2021 (Appendix B).

The air pollutants attributable to incident stroke cases varied by neighborhood, with estimates ranging from 1.59 to less than 0.01, with the most prominent pollutants being $PM_{2.5}$, PM_{10}, and NO_2 (Table 13). In Globeville, $PM_{2.5}$ exposure was attributable to the largest number of cases of incident stroke cases, totaling 0.68 (95% CI: 0.34, 1.05), while in Elyria-Swansea, the largest number of estimated cases of incident stroke, at 1.59 (95% CI: 0.00, 3.91), were attributable to PM_{10} exposure. The associations reversed for the second-largest estimated cases of incident stroke. In Globeville, PM_{10} exposure accounted for the second largest estimated cases of incident stroke, at 0.39 (95% CI: 0.00, 0.98), whereas in Elyria-Swansea, the second largest estimated cases of incident stroke were attributed to $PM_{2.5}$ exposure, at 0.62 (95% CI: 0.30, 0.97). NO_2 exposure accounted for the third largest estimated attributable cases of incident stroke, with 0.03 (95% CI: 0.00, 0.06) in Globeville and 0.02 (95% CI: 0.00, 0.05) in Elyria-Swansea.

Air pollution exposure associated with stroke mortality cases ranged from 1.43 to less than 0.01 in Elyria-Swansea and between 0.45 and less than 0.01 in Globeville (Table 13). The difference in CO exposure was attributable to 0.45 cases of stroke mortality (95% CI: 0.00, 1.10) in Globeville and 1.43 cases of stroke mortality (95% CI: 0.00, 3.42) in Elyria-Swansea. $PM_{2.5}$ exposure was attributable to 0.16 cases (95% CI: 0.06, 0.26) in Globeville and 0.14 cases (95% CI: 0.06, 0.24) in Elyria-Swansea. The third largest caseload, 0.09 (95% CI: 0.03, 0.15) in Globeville and 0.07 (95% CI: 0.02, 0.12

Table 13. Estimated cases of incident stroke and stroke mortality among adults aged 20 years and older attributable to air pollution differences in GES compared to least burdened Denver neighborhoods (2017-2021).

Air Pollutant	Globeville	Elyria-Swansea
Incident Stroke		
$PM_{2.5}$	**0.68 (0.34, 1.05)**	0.62 (0.30, 0.97)
O_3	<0.01	<0.01
PM_{10}	0.39 (0.00, 0.98)	**1.59 (0.00,3.91)**
NO_2	0.03 (0.00, 0.06)	0.02 (0.00, 0.05)
SO_2	<0.01	<0.01
CO	<0.01	<0.01
Stroke Mortality		
$PM_{2.5}$	0.16 (0.06, 0.26)	0.14 (0.06, 0.24)
O_3	0.01 (0.00, 0.03)	0.02 (0.00, 0.04)
PM_{10}	0.00 (0.00, 0.41)	0.00 (0.00, 1.61)
NO_2	0.09 (0.03, 0.15)	0.07 (0.02, 0.12)
SO_2	<0.01	<0.01
CO	**0.45 (0.00, 1.10)**	**1.43 (0.00, 3.42)**

TYPE 2 DIABETES

The CDC has reported that 90-95% of individuals with diabetes are diagnosed with type 2 diabetes.[52] Previous environmental health studies have highlighted the relationships between air pollution exposure and the risk of type 2 diabetes (T2DM). However, various factors often influence these risks, including sociodemographics, lifestyle choices, and genetics.[53–55] Our study determined that the five-year annual average incidence rate of T2DM in Colorado was 603.27 cases per 100,000 from 2017 to 2021 (95% CI: 559.23, 646.68) (Appendix B). Deliverable 2.5 presented three effect estimates on the relationship between $PM_{2.5}$, PM_{10}, and NO_2 and the risk of T2DM. This study found that the number of cases of incident T2DM attributable to the difference in air pollution exposure compared to the least

burdened neighborhood ranged between 10.04 and 1.49 cases (Table 14). In Globeville, 10.02 cases (95% CI: 6.54, 13.71) were attributable to NO_2 exposure, 2.48 cases (95% CI: 0.35, 4.65) were attributable to PM_{10}, and 1.62 cases (95% CI: 0.53, 2.75) were attributable to $PM_{2.5}$ exposure. In Elyria-Swansea, PM_{10} was found to be attributable to the largest estimated cases of incident type 2 diabetes, at 10.04 cases (95% CI: 1.42, 18.48). NO_2 exposure was attributable to 7.85 cases (95% CI: 5.08, 10.85), and $PM_{2.5}$ exposure was attributable to 1.49 cases (95% CI: 0.49, 2.50).

Table 14. Estimated cases of incident type two diabetes among adults aged 20 years and older attributable to air pollution differences in GES compared to least burdened Denver neighborhoods (2017-2021).

Air Pollutant	Globeville	Elyria-Swansea
$PM_{2.5}$	1.62 (0.53, 2.75)	1.49 (0.49, 2.50)
PM_{10}	2.48 (0.35, 4.65)	**10.04 (1.42, 18.48)**
NO_2	**10.02 (6.54, 13.71)**	7.85 (5.08, 10.85)

RESPIRATORY DISEASES

Respiratory diseases, particularly childhood asthma, continue to be a pressing concern of community members throughout the GES Community Health study. In Deliverable 2.2, we presented evidence indicating that the GES area experiences elevated rates of chronic respiratory illnesses. Deliverable 2.2 data indicated that there was evidence that GES experienced higher rates of adult chronic obstructive pulmonary disease (COPD) and asthma hospitalizations.

RESPIRATORY MORTALITY. In Deliverable 2.5, we established exposure-response relationships between respiratory disease mortality and $PM_{2.5}$, PM_{10}, O_3, and NO_2. Respiratory mortality is defined as death from acute (short-term) and chronic (long-term) illnesses that impact breathing. Our analysis revealed that the five-year average annual incidence rate of all-cause respiratory mortality among adults aged 20 years and older in Colorado was 76.52 per 100,000 people (95% CI: 64.38, 89.12) from 2017 to 2021 (Appendix B). Our findings highlighted that the estimated number of respiratory disease mortality cases attributable to the difference in air pollution compared to the least burdened neighborhood varies, with estimates ranging from 1.37 cases to less than 0.01 cases (Table 15). Among the pollutants studied, NO_2 and PM_{10} were identified as two major contributors to increased cases of all-cause respiratory mortality. In Globeville, 0.38 cases (95% CI: 0.16, 0.63) were attributable to NO_2 exposure, 0.34 cases (95% CI: 0.17, 0.53) were attributable to PM_{10} exposure, and 0.20 cases (95% CI: 0.07, 0.35) were attributable to $PM_{2.5}$ exposure. In Elyria-Swansea, these same pollutants were applied, but the order of largest to smallest estimated cases switched the order. 1.37 cases (95% CI: 0.71, 2.13) were attributable to PM_{10} exposure, followed by 0.29 cases (95% CI: 0.13, 0.48) attributable to NO_2 exposure, and 0.18 cases (95% CI: 0.06, 0.32) attributable to $PM_{2.5}$ exposure.

Table 15. Estimated cases of respiratory mortality among adults aged 20 years and older attributable to air pollution differences in GES compared to least burdened Denver neighborhoods (2017-2021).

Air Pollutant	Globeville	Elyria-Swansea
$PM_{2.5}$	0.20 (0.07, 0.35)	0.18 (0.06, 0.32)
O_3	<0.01	<0.01
PM_{10}	0.34 (0.17, 0.53)	**1.37 (0.71, 2.13)**
NO_2	**0.38 (0.16, 0.63)**	0.29 (0.13, 0.48)

CHRONIC OBSTRUCTIVE PULMONARY DISEASE MORTALITY. Chronic obstructive pulmonary disease (COPD) mortality is characterized as the result of a progressive lung condition that includes both emphysema and chronic bronchitis.[56] Deliverable 2.5 explored the impact of $PM_{2.5}$, PM_{10}, O_3, and NO_2 on COPD mortality rates. Leveraging GBD data, our study estimated the five-year annual average COPD mortality rate among adults aged 20 years and older in Colorado from 2017 to 2021 to be 72.51 deaths per 100,000 individuals (95% CI: 62.27, 80.14) (Appendix B). This study revealed that PM_{10} exposure accounted for the largest estimated number of attributable COPD mortality cases (Table 16). In Globeville, 0.46 cases (95% CI: 0.00, 1.05), and in Elyria-Swansea, 1.81 cases (95% CI: 0.00, 4.01) were attributable to PM_{10} exposure. Following PM_{10}, NO_2 exposure was identified as the second leading contributor to COPD mortality. There were 0.28 cases (95% CI: 0.12, 0.46) in Globeville and 0.22 cases (95% CI: 0.09, 0.35) in Elyria-Swansea attributable to NO_2 exposure.

Table 16. Estimated cases of chronic obstructive pulmonary disease mortality among adults aged 20 years and older attributable to air pollution differences in GES compared to least burdened Denver neighborhoods (2017-2021).

Air Pollutant	Globeville	Elyria-Swansea
$PM_{2.5}$	0.19 (0.09, 0.30)	0.18 (0.09, 0.28)
O_3	<0.01	<0.01
PM_{10}	**0.46 (0.00, 1.05)**	**1.81 (0.00, 4.01)**
NO_2	0.28 (0.12, 0.46)	0.22 (0.09, 0.35)

CHILDHOOD ASTHMA. Between 2017 and 2021, Colorado's estimated 5-year average annual incidence rate of asthma among children aged 1 to 18 was 1,570.08 cases per 100,000 individuals (95% CI: 1,148.58, 2,104.95) (Appendix B). This study identified exposure to NO_2 and PM_{10} as the leading contributors to childhood asthma (Table 17). In Globeville, 7.12 cases (95% CI: 4.02, 11.01) were attributable to NO_2 exposure, 3.34 cases (95% CI: 1.34, 5.94) were attributable to PM_{10} exposure, and 2.83 cases (95% CI: 0.99, 5.21) were attributable to $PM_{2.5}$ exposure. In Elyria-Swansea, PM_{10} emerged as the main pollutant impacting childhood asthma, accounting for 29.41 attributable cases (95% CI: 12.20, 51.15). Following PM_{10}, NO_2 was attributable to 12.49 cases (95% CI: 6.99, 19.36), and $PM_{2.5}$ was attributable to 5.81 cases (95% CI: 2.04, 10.80).

Table 17. Estimated cases of incident childhood asthma among children aged 1-18 attributable to air pollution differences in GES compared to least burdened Denver neighborhoods (2017-2021).

Air Pollutant	Globeville	Elyria-Swansea
$PM_{2.5}$	2.83 (0.99, 5.21)	5.81 (2.04, 10.80)
PM_{10}	3.34 (1.34, 5.94)	**29.41 (12.20, 51.15)**
NO_2	**7.12 (4.02, 11.01)**	12.49 (6.99, 19.36)
SO_2	0.02 (0.01, 0.03)	0.21 (0.13, 0.32)

DISCUSSION

This comprehensive study examined the health impacts attributable to air pollution exposure in two of Denver's oldest neighborhoods, Globeville and Elyria-Swansea, over five years from 2017 to 2021. The research navigated the intricate challenges of spatial modeling associated with surface air monitoring data and the limitations posed by the availability of secondary data. Despite these complexities, the findings revealed that nitrogen dioxide (NO_2), particulate matter with a diameter of less than 2.5 micrometers ($PM_{2.5}$), and particulate matter with a diameter of less than 10 micrometers (PM_{10}) were the most substantial pollutants contributing to adverse health outcomes in these communities.

Our study found that NO_2 and PM_{10} were the two pollutants associated with the largest estimated number of attributable health burdens in Globeville and Elyria-Swansea compared to the least exposed neighborhoods. As presented in Table 6, the difference in exposure in NO_2, compared to Sunnyside was 6.75 ppb in Globeville and 3.67 in Elyria-Swansea. The exposure difference in PM_{10}, compared to Sunnyside was 2.48 ug/m3 in Globeville and 7.48 ug/m3 in Elyria-Swansea.

Table 18 highlights a selection of the attributable health burdens due to NO_2 exposure and PM_{10} exposure in Globeville and Elyria-Swansea compared to exposure in the least burdened neighborhood. The estimated health burdens could be lowered if NO_2 and PM_{10} exposure in Globeville and Elyria-Swansea were equal to the exposure levels in the least exposed neighborhood.

Table 18. Estimated health burdens attributable to air pollution differences in GES compared to the least burdened Denver neighborhoods (2017-2021).

	Globeville		Elyria-Swansea	
Health Outcome	**NO_2**	**PM_{10}**	**NO_2**	**PM_{10}**
Preterm Birth	12.11 (1.68, 22.20)	1.70 (0.82, 2.61)	10.69 (1.51, 19.64)	7.96 (3.87, 12.04)
Low Birthweight	17.15 (4.87, 28.79)	2.02 (1.21, 2.86)	15.16 (4.25, 25.65)	9.35 (5.63, 13.14)
All-cause mortality	3.85 (1.68, 6.01)		2.95 (1.29, 4.62)	
All-cause cancer mortality	1.89 (0.73, 3.13)	0.68 (0.33, 1.05)	1.46 (0.55, 2.43)	2.77 (1.37, 4.27)
CVD Incidence	9.69 (0.00, 20.09)		7.62 (0.00, 15.74)	
CVD Mortality	2.65 (1.66, 3.77)		2.05 (1.27, 2.94)	
T2DM	10.02 (6.54, 13.71)	2.48 (0.35, 4.65)	7.85 (5.08, 10.85)	10.04 (1.42, 18.48)
Respiratory mortality	0.38 (0.16, 0.63)	0.34 (0.17, 0.53)	0.29 (0.13, 0.48)	1.37 (0.71, 2.13)
COPD mortality	0.28 (0.12, 0.46)	0.46 (0.00, 1.05)	0.22 (0.09, 0.35)	1.81 (0.00, 4.01)
Childhood Asthma incidence	7.12 (4.02, 11.01)	3.34 (1.34, 5.94)	12.49 (6.99, 19.36)	29.41 (12.20, 51.15)

Key factors influencing the attributable health estimates presented in this study include the magnitude of effect estimates and the variations in air pollution exposure among Globeville, Elyria-Swansea, and the least exposed neighborhoods in Denver. In this study, we assume that environmental exposures act independently on health outcomes (i.e., toxicologic independence) and that their toxic effects are additive.[57,58] Toxicologic independence follows the idea that if a person is exposed to a quarter of the amount of chemical A necessary to cause harm, and a quarter of the amount of chemical B necessary to cause harm, then the person is only exposed to half (¼ + ¼ = ½) of

the amount of chemicals required to cause harm and therefore the person would not experience health effects. However, there are some cases where this may not be true and the combination of chemicals, even at levels lower than what would individually or additively cause harm, would affect the person's health. Historically, EPA guidance has recommended the approach of relying on the evaluation of additive independent impacts when assessing environmental risks.[22,59–62] This recommendation arises from the lack of standardized methodologies to adequately address the complexity and variability inherent in environmental exposures, which may differ significantly by nature, source, and mode of exposure.[63,64] While this assumption simplifies the statistical modelling, it may lead to an underestimation of the risks associated with multiple combined exposures affecting the health of residents.[11,65] When analyzing multiple stressors (e.g., environmental exposures) that may impact the same route of exposure (e.g., inhalation, ingestion, etc.), or operate through similar modes of biological action, we encounter a heightened level of uncertainty. This uncertainty predominately stems from existing gaps in comprehensive scientific evidence that clearly demonstrates how these various stressors may interact with one another and jointly impact human health outcomes. The ambiguity surrounding these potential interactions complicates our ability to develop accurate risk estimates. Without strong scientific evidence, determining whether the risk values generated from our analyses represent an overestimation or an underestimation of the actual health risks posed by these environmental stressors becomes exceedingly challenging. This situation underscores the need for further research and the establishment of standardized methodologies, which are essential for improving our understanding and assessment of cumulative risks associated with diverse environmental exposures.

There also exist significant gaps in the scientific understanding of low-level exposures. Such gaps are often due to the fact that the risks associated with low-level exposure can be so minuscule that they pose challenges for accurate measurement or verification through controlled experimentation.[66] For low exposure levels, it is generally assumed that risks increase in a linear fashion.[67–69] While this assumption is prevalent in burden assessments, it warrants careful scrutiny and further investigation to ensure that evaluations accurately reflect the potential impacts of low-level exposures on human health and the environment.

Further research is necessary to obtain additional measures of the association between air pollution and health and enhance these findings. Our literature review identified 63 exposure-response pairs involving $PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, CO, and various health outcomes (Deliverable 2.5 Table 14). The absence of specific exposure-response pairs may stem from several reasons: 1) a lack of relevant scientific literature, indicating that our search did not yield articles meeting the inclusion criteria; 2) the available literature may have contained data in improper formats or lacked essential information needed for inclusion; or 3) there may be insufficient evidence to establish a quantitative relationship between environmental exposure and health outcomes confidently. Additionally, this study assumes that all measures of association indicate risk, interpreting all effect estimates—whether expressed as odds ratios, hazard ratios, or risk ratios—as indicative of heightened health risks resulting from environmental exposure. While this assumption aligns with best methodological practices, it may lead to underestimating or overestimating attributable health impacts due to environmental exposure.[10,21,23,24]

This study aggregated secondary data from 2017 to 2021 at the state level to estimate the five-year average incidence and mortality rates for various health outcomes. The Global Burden of Disease project, which began in 1991, aims to systematically quantify the extent of diseases across different populations and health outcomes.[70] GBD is an international collaboration project that estimates disease burdens granularly and facilitates comparability of measurements by reporting health outcomes in consistent units of measure, including rates, percentages, and absolute numbers.[71,72] Additionally, GBD data undergoes rigorous validation processes before publication, enhancing confidence in the reliability of the information obtained.[72] The GBD defines adults as individuals aged 20 years and older; as such, to estimate our baseline ACS adult populations, we used the same population of adults aged 20 years and older. Unlike the decennial census, which counts every individual, the ACS surveys a small percentage of the population annually. The 5-year estimates produced from the ACS survey data enable the calculation of small area estimates, such as those for census tracts.[73] Furthermore, the ACS incorporates a necessary weighting procedure to

adjust for individuals who do not respond to the survey.[74] However, non-response rates in the 2020 census were higher compared to previous years.[75] Therefore, the ACS 5-year estimates, which address non-response bias, offer the most reliable population estimates for the Denver metropolitan area.

Due to the limitations of using meta-analyses effect estimates on the relationships between air pollution exposure and health outcomes, we were not able to stratify by sociodemographic factors. This is because many of the effect estimates used are presented for an overall population and rarely specify demographic characteristics such as specific age categories past adult population and child population aged 1 to 18 years, or race and ethnicity. Therefore, this study's assumption of a uniformly heterogeneous population across Colorado overlooked significant variations introduced by critical sociodemographic factors, including racial and ethnic diversity, income levels, and age distribution. For instance, Colorado is home to various demographic groups, each with distinct cultural backgrounds and economic opportunities, which can influence health outcomes, access to resources, and overall well-being.[3,46] By not accounting for these differences, the study may fail to accurately reflect the multifaceted nature of the state's population, ultimately limiting the applicability of its findings to specific communities or groups within Colorado.

One limitation of this study is the estimation of attributable birth outcome cases. Due to data constraints, we were unable to stratify birth outcomes by maternal age. Therefore, we assumed a general reproductive age range of 15-44 years to approximate the at-risk pregnant population who had a live birth in GES. However, a report by Maddow-Zimet and Kost (2021) analyzing pregnancy and birth trends between 1973 and 2017 found that pregnancy rates have been decreasing among women aged 24 and younger while increasing among women aged 30 and older.[76] By assuming a fixed reproductive age range, we introduce selection bias, potentially misrepresenting the true at-risk population. This may lead to an underestimation of the number of preterm births and low birth weight cases attributable to air pollution exposure. Additionally, we cannot assume that low birthweight and preterm birth were mutually exclusive, as some births may meet both criteria. This introduces differential misclassification bias, which may lead to an underestimation of the true number of cases attributable to the differences in air pollution between GES and the least burdened neighborhood

When examining the factors contributing to childhood asthma, the GBD provides incidence statistics categorized primarily into two age groups: 0 to 14 years and 10 to 19 years, along with specific 5-year increments within these ranges. For our analysis, we assumed an equal age distribution across these two categories. However, we recognize that this assumption may not align with the actual demographic distribution of the pediatric age group, which can vary significantly based on geographical and socioeconomic contexts. For instance, urban areas may exhibit different prevalence rates than rural settings due to varying environmental exposures and access to healthcare services.[77,78] Existing research emphasizes the complexities associated with accurately diagnosing childhood asthma, primarily due to the lack of a definitive gold standard test.[79] Commonly used lung function tests, such as spirometry and peak expiratory flow rate assessments, play a critical role in aiding the determination of asthma status. However, these tests can prove impractical and challenging to administer to children under the age of 5, particularly in typical clinical environments where cooperation from the child may be insufficient.[79,80] The Mayo Clinic highlights that these diagnostic tests are often not deemed reliable or effective for younger children, as their limited ability to follow instructions can compromise test results.[80] In line with this, the Global Initiative for Asthma recommends that children aged 6 years and older undergo testing using lung function assessments, as these tools can yield valuable insights into respiratory function and help establish a more accurate diagnosis while diagnosis for children under 6 may rely more upon symptoms.[81]

In our analysis, we utilized a range of measures of association that reported on the incidence of childhood asthma, irrespective of the specific age ranges examined in various studies. For instance, Khreis *et al.* (2017) concentrated on a population with ages spanning from 1 to 18 years old,[82] while Chen *et al.* (2022) presented effect estimates that included all age groups without restriction.[25] By synthesizing these varied effect estimates, we tailored our findings to focus specifically on childhood asthma among children aged 1 to 18. This methodological approach enabled us to

account for variations across age brackets. Nevertheless, it is vital to acknowledge the diagnostic challenges present within this age group, which can complicate both the identification and reporting of asthma cases. These complexities can result in underdiagnosis or misdiagnosis, particularly in younger children, further complicating the landscape of childhood asthma research.[79–81] This generalization could introduce potential bias, particularly considering demographic differences in GES compared to the broader Denver area. In GES, approximately 25% of the population is under the age of 18 and 4.7% under the age of 5, which contrasts with only 19% of Denver's overall population falling under the age of 18 and 5.4% under the age of 5.[46] This notable difference in demographic composition underscores the importance of cautious interpretation of our findings, as the higher prevalence of younger children in GES may skew the reported incidence of childhood asthma in this locality in comparison to more age-diverse neighborhoods throughout Denver.

FUTURE SCENARIOS FOR RESEARCH

This study emphasizes the pressing need for continuous monitoring and the implementation of targeted intervention strategies to mitigate the health risks linked to air pollution, particularly in historically marginalized communities. These communities frequently confront a complex web of socioeconomic challenges, such as limited access to healthcare, lower educational attainment, and inadequate housing conditions, which amplify the detrimental health effects associated with poor air quality. Consequently, it is essential to adopt proactive measures, including community outreach programs, policy advocacy, and improved air quality regulations, to ensure the protection of vulnerable populations who are especially susceptible to the adverse effects of environmental pollutants. By addressing these disparities, we can work towards fostering healthier living conditions and improving overall public health outcomes in these communities.

NAAQS REGULATIONS. Air pollutant regulations established by the EPA necessitate ongoing research and refinement due to the continuously evolving scientific understanding of safe exposure levels to various pollutants.[83] In June 2021, the EPA announced its reconsideration of the $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS). After extensive review and public input, the agency concluded that the existing primary annual standard of 12 $\mu g/m^3$ failed to provide an adequate margin of safety to protect public health, particularly for sensitive populations such as children, the elderly, and individuals with preexisting health conditions. In February 2024, the agency finalized this critical revision, lowering the annual standard to 9 $\mu g/m^3$, reflecting the latest scientific evidence regarding the health risks associated with long-term exposure to $PM_{2.5}$.[28,84]

Our spatial interpolation approach for assessing ambient concentrations at the neighborhood level, which utilized all available EPA monitoring data, indicated that $PM_{2.5}$ levels in Denver are relatively low compared to other urban areas.[85–87] However, model estimates revealed variability across neighborhoods. The highest concentration is estimated in the Globeville area, where $PM_{2.5}$ 5-year average concentration level was estimated 9.15 $\mu g/m^3$, slightly above the newly established standard. Conversely, the Marston neighborhood shows the lowest concentrations, measuring at 7.43 $\mu g/m^3$ (Table 5). It is important to note that directly comparing our model estimates and NAAQS can be misleading, as the NAAQS are set as the annual mean, averaged over 3 years and our estimates are a 5-year average.

Prior scientific studies have established a concerning link between a small (e.g., 1 $\mu g/m^3$) increase in annual $PM_{2.5}$ exposure and adverse health outcomes, including heightened rates of all-cause mortality, cardiovascular disease mortality, and incidents of stroke.[88] It is particularly alarming that communities of color, often situated near industrial zones or high-traffic areas, are disproportionately exposed to elevated levels of $PM_{2.5}$ in metropolitan regions, exacerbating existing health disparities.[89] One limitation of our methodology is that data collected from fixed regional monitors may not adequately reflect the day-to-day variability in individual personal exposure to $PM_{2.5}$. Despite this shortcoming, our approach allows us to derive estimates of $PM_{2.5}$ related health impacts on a neighborhood scale, which can inform targeted interventions aimed at reducing exposure and promoting health equity in affected communities.

Another air pollutant regulation of significant concern involves ozone. In 2018, the Denver metropolitan area and the northern front range regions were designated as marginal nonattainment areas based on the 2015 8-hour O_3 NAAQS.[90,91] Subsequently, in 2022, the EPA reclassified the Northern Front Range Metropolitan Area (NFRMA) as severe nonattainment due to its failure to meet the 2008 standard of 75 parts per billion (ppb) and the 2015 standard of 70 ppb, based on O_3 data collected from 2018 to 2020.[92,93] Accordingly, Colorado was mandated to develop a State Implementation Plan (SIP) that outlines the specific measures necessary to achieve compliance with these federal standards. The Regional Air Quality Council approved the O_3 SIP in 2022, and it received formal endorsement from Colorado's state government on October 6, 2023.[92] Although some regions within the NFRMA may remain classified as severe nonattainment, projections based on models included in the SIP suggest that Denver could achieve ozone attainment by 2027 if the proposed measures are effectively implemented.

Research conducted in 2017 identified mobile sources, such as vehicles, and oil and gas operations as the two most significant contributors to O_3 pollution. Notably, oil and gas operations appear to exert a more pronounced influence in the northern sections of the NFRMA.[94] Further investigations carried out in 2020 examined modeled air pollution concentrations, particularly focusing on nitrogen oxides (NO_x) and volatile organic compounds (VOCs), both of which are precursors to ozone formation. Flocke *et al.* (2020) revealed a significant underestimation of these pollutants' concentrations across the NFRMA.[95] However, in a 2023 study, Reddy found that concentrations of ozone correlated with oil and gas-related VOC emissions witnessed a reduction from 2012 to 2019.[96] This trend was corroborated by the 2020 RAQC O_3 SIP update, which noted that while ozone-forming pollutants had substantially decreased since the NFRMA's initial nonattainment classification, these decreases were inadequate to achieve compliance with the NAAQS.[91] An in-depth analysis of the SIP conducted by deSouza *et al.* (2024) identified two critical shortcomings: first, inaccuracies in the emission inventories and O_3 level modeling led to erroneous conclusions that the NAAQS could be met within the proposed timeframe; second, deficiencies in the SIP's structural organization resulted in a lack of strong political leadership to drive the plan forward.[97] These critiques stem in part from the fact that while the RAQC, in collaboration with the Air Pollution Control Division of CDPHE, is responsible for outlining compliance strategies for the state, the RAQC lacks the authority to implement specific control measures.[90] To achieve compliance with the NAAQS, further actions will be necessary. These actions should include revisions to oil and gas emission standards, a comprehensive approach to addressing greenhouse gas emissions, and enhanced energy management practices for manufacturers.[90,98]

CLIMATE CHANGE, EXTREME WEATHER EVENTS, AND BUILT ENVIRONMENT. Another area for future research focuses on climate change and the built environment, particularly within the environmental justice communities. The increasing frequency of wildfires, severe weather events, and the lack of tree canopy coverage in urban areas pose significant threats to public health and safety. These interconnected issues disproportionately affect vulnerable communities, intensifying existing social and economic inequalities. Wildfires have become more frequent and intense due to rising temperatures and prolonged droughts, leading to hazardous air quality and increased health risks for urban populations.[99] Severe weather events, such as hurricanes and heavy rainfall, can result in flooding and property damage, affecting low-income neighborhoods more severely due to inadequate infrastructure. The minimal tree canopy coverage in cities further exacerbates these issues; trees play a critical role in urban environments by providing shade, improving air quality, and mitigating heat.[100–102] A lack of adequate green spaces can lead to higher temperatures and diminished resilience against climate impacts, contributing to a disadvantage cycle for already marginalized communities. Addressing these interrelated issues is crucial for promoting equity and resilience in the face of climate change.

The frequency and magnitude of wildfires, particularly in the western United States, have been increasing over the past decade and are predicted to continue increasing in frequency and volume.[103–105] While human activity has been partially attributed to the increase in wildfires, climate change is considered the primary contributor.[106] In 2012, researchers conducted a long-term historical review of wildfires. They found that the combined effects of human influence, ecological drivers, and climate change are the three most significant attributable factors impacting wildfires.[103]

Research has increasingly focused on the public health implications of wildfires. In a burden assessment study conducted in 2019, researchers identified a concerning correlation between increased ozone levels from wildfire smoke and pediatric asthma emergency department visits. The findings indicated an estimated median of 2,403 pediatric asthma-related visits (95% CI: 235, 5382) could be attributed to enhanced ozone exposure associated with wildfire smoke between 2005 and 2014 across the continental United States.[107] During active fire periods, exposure to particulate matter ($PM_{2.5}$) was significantly associated with exacerbations of asthma and COPD, with these adverse health effects persisting even after controlling for O_3 levels.[108] A comprehensive global study conducted by Chen *et al.* (2021) found that wildfire-related $PM_{2.5}$ exposure contributes to overall mortality rates, attributing approximately 0.62% (95% CI: 0.48, 0.75) of all-cause deaths annually to acute impacts of this exposure.[109] These studies underscore the urgent need for multi-faceted strategies to address the environmental and health challenges posed by increasing wildfire incidences and their associated impacts on vulnerable populations.

Other extreme weather and climate events, such as hurricanes, floods, heat waves, and wildfires, pose significant risks to the health and well-being of communities across the globe. These risks stem from various physical hazards, including high winds, heavy rainfall, rising temperatures, and shifting precipitation patterns that can disrupt local ecosystems. The extent of exposure to these hazards varies widely and is influenced by geographic location, community infrastructure, and preparedness measures in place. According to the Centre for Research on the Epidemiology of Disasters (CRED), the emergency events database recorded an alarming 399 global disasters in a year, resulting in over 85,000 fatalities and affecting more than 90 million individuals worldwide.[110,111]

Hurricanes and flooding threaten communities in flood-prone areas and along coastal regions. These coastal areas face an increased risk due to their susceptibility to the destructive forces of nature.[112] For instance, researchers estimated that following Hurricane Maria, there were 1,139 excess deaths (95% CI: 1,006, 1,272) attributed to the hurricane-related mortality burden by December 2017.[113] The intense winds and heavy rainfall associated with hurricanes can result in widespread devastation, with health impacts extending well beyond the immediate vicinity of the storm's center.[110] Hurricane aftermath often includes secondary events, such as tornadoes and extensive flooding, which can further exacerbate existing dangers and complicate recovery efforts.[114] In 2021, scientists conducted a scoping review to assess the current state of hurricane-health research. They found that many adverse health impacts (e.g., unintentional injuries, respiratory illness, overall morbidity) occur within six months following a hurricane, while chronic diseases (e.g., cardiovascular issues, mental health challenges) can persist for years.[115]

On a global scale, the number of hot days and nights has increased since the 1950s.[110] In 2023, the Southern and Midwest regions of the United States experienced a significant drought coupled with a heat wave, equating to 14.5 billion dollars in damages.[111] Rising temperatures are strongly associated with human health risks, particularly heat-related illnesses such as heat exhaustion, heat syncope (fainting due to heat), and heat stroke.[114,116,117] These conditions occur when the body overheats and struggles to regulate its temperature. The likelihood of experiencing these health issues varies significantly based on several factors, including an individual's duration of exposure to high temperatures, the local climate where they reside (for example, urban areas may be hotter due to the heat island effect), and their personal health characteristics, such as age, pre-existing health conditions, and hydration levels. Understanding these connections is crucial for taking preventive measures, especially during heat waves and in areas vulnerable to extreme temperatures.

Heat waves contribute to urban heat island effects, which occur when paved surfaces (e.g., streets, sidewalks, and parking lots) are concentrated in one urban area, resulting in hotter temperatures than the surrounding rural areas. Prior research has demonstrated the relationship between the urban heat island effect and several adverse health outcomes related to heat exposure, including exacerbation of cardiovascular disease, heat stroke, and mortality.[101,116,118,119] Across the United States, Black and Brown communities are more likely than White communities to experience higher temperatures due to the urban heat island effect.[101,119] These same communities are also less

likely to have access to resources (e.g., air conditioning, infrastructure, cooling centers) needed to mitigate the urban heat island effect.[120,121]

One effective strategy to combat heat and other environmental challenges is the establishment of tree canopies and green spaces. Urban tree canopies significantly enhance the environment by cooling the atmosphere, reducing energy consumption, and absorbing pollution.[122,123] Research conducted by Wang *et al.* (2018) utilizing forecasting urban modeling revealed that, on average, near-surface air temperatures in urban areas decreased by 3 degrees Celsius due to the shading effects of tree canopies.[124] However, other studies indicate that communities of color and low-income neighborhoods often suffer from lower tree coverage compared to their high-income counterparts.[123,125,126] A 2021 study found that, on average, low-income areas have 15.2% less tree cover and are 1.5 degrees Celsius hotter than high-income areas. These trends were similarly observed when comparing Hispanic/Latino communities to non-Hispanic white communities.[127] In a recent study focused on Denver, Colorado, and Phoenix, Arizona, Dean *et al.* (2024) determined that uniformly increasing the urban tree canopy by 20% in Denver and 25% in Phoenix could prevent approximately 32.9 per 100,000 at-risk individuals (95% CI: 99.6, 306) and 33.3 per 100,000 at-risk individuals (95% CI: 16.4, 50.4), respectively, from experiencing annual premature deaths among adults aged 18 and older.[128]

SOCIAL DETERMINANTS OF HEALTH

Social determinants of health represent a critical area for further exploration within environmental health research. According to Healthy People 2030, social determinants of health (SDOH) are defined as the "conditions in the environments where people are born, live, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks."[129] SDOH encompasses a network of interconnected factors that shape individual and population health and wellbeing. Healthy People 2030 identified five key domains of SDOH: (1) healthcare access and quality; (2) neighborhood and built environment; (3) social and community context; (4) economic stability; and (5) education access and quality.[129] Current research suggests that genetic and biological factors account for approximately 30% of an individual's health status, while the remaining 70% is attributable to SDOH.[129] This highlights the importance of addressing social and environmental conditions to improve community health and well-being.

This section explores how improvements in SDOH in GES may impact health and well-being. Through discussions with the GES Community Health Study Community Council, the following two scenarios were selected: (1) Improving educational access and quality in GES and (2) improving access to health insurance and healthcare.

EDUCATIONAL ACCESS AND QUALITY. Health-related literature demonstrates a strong connection between health outcomes and educational achievement. Higher educational achievement has been linked to better health outcomes, longer lifespan, lower health care costs, and employment status.[130,131] In this way, education is a critical component influencing both short-term and long-term health.[132] This section will briefly revisit the findings of the GES Health Study's Deliverable 2.2 Health Impact Assessment (HIA) in relation to health outcomes and concludes with a discussion on the impacts environmental health has on education.

Deliverable 2.2 Health Impact Assessment (HIA) revealed several key areas of concern related to early childhood, adolescent, and adult education. The first five years of a child's life are critical for reaching developmental milestones that will have a life-long influence on educational achievement.[133] The 2024 Denver Human Services Index highlights concern regarding the lack of preschool participation among children ages three and four in the Globeville and Elyria-Swansea neighborhoods.[134] Denver Great Kids Head Start and the Office of Children's Affairs 2019 Community Assessment Report indicated that while childcare demand in Globeville was being met, Elyria-Swansea was in need of more childcare options.[133] Positive early childhood experiences, such as the enrollment in high-quality early childhood education, play a role in fostering healthy development. Conversely, research has shown that adverse early childhood experiences can impact long-term health. Specifically, adverse experiences are linked to an increased risk of coronary artery disease, COPD, and cancer.[135–137]

There is an increasing emphasis on reading comprehension for third-grade students, who are expected to read to learn rather than merely learn to read. According to the 2024 Denver Human Services Index, 68% of Globeville and 61% of Elyria-Swansea third-grade students are not reading at grade level.[134] Research shows a relationship between parents reading with their kids in early childhood, and children's later reading comprehension skills and motivation to read for enjoyment.[138] Consequently, studies have shown that the educational achievements of adults in a community impact the educational outcomes of children.[139,140] Specifically, researchers have found a strong correlation between higher levels of parental education and academic success among children.[141] Less discussed in the literature, however, is the relationship between these trends and intersectional social factors, such as socioeconomic status, employment status, and ongoing environmental injustice concerns.

Deliverable 2.2 highlighted disparities in educational attainment between the GES community and the broader Denver area. While high school graduation rates in GES are comparable to those in Denver, 39.4% of GES residents aged 25 and older lack a high school diploma, in contrast to just 10% in Denver.[46] This educational gap is particularly concerning, as research has consistently shown that obtaining a high school diploma is associated with several positive outcomes, including improved health metrics, increased life expectancy, and a lower probability of experiencing poverty.[142] Additionally, studies have shown that individuals who do not have a high school diploma are at a heightened risk for a range of chronic health conditions, such as asthma, diabetes, cardiovascular disease, hypertension, stroke, and stomach ulcers.[142]

Findings from Deliverable 2.2 and the recent 2024 Human Services Index suggest an opportunity to improve adult educational opportunities and pathways within the GES neighborhood. The Denver Public Schools (DPS) Community Hubs bridges educational gaps by providing family support and educational services at no cost to Denver community members.[145] Within GES, a DPS Community Hub located at Swansea Elementary, offers diverse services designed to empower community members, including General Educational Development (GED) test preparation, citizenship preparation courses, computer and technology assistance, financial literacy workshops, parenting classes, and workforce development programs. By addressing the educational needs of adults in the community, such initiatives aim to foster greater economic stability and improved health outcomes for GES residents.

It is important to note that the relationship between health and education is bidirectional. This means that in addition to educational attainment affecting health outcomes, environmental health conditions also impact educational performance.[130] Chronic health concerns may hinder a student's performance at school. Additionally, exposure to allergens, pollutants, chemicals, and classroom conditions might negatively affect students' health, attendance, and academic performance.[146] Human bodies continue to develop throughout childhood, and exposures to environmental contaminants can cause adverse health impacts well into adulthood.[146] Indoor air quality of classrooms has impacts on the concentration performance of students.[146,147] Similarly, in a study conducted by Magzamen *et al*. (2015) highlighted the relationship between student test performance and lead exposure, with lower scores linked to greater effects from lead exposure.[148] The environmental health of schools is a vital component to protecting children's short-term and long-term health and educational achievement.

Data are necessary for analysis before any claims can be made about indoor air quality in GES public schools. One potential resource partner is the Environmental Services team at Denver Public Schools, which is committed to providing a safe and healthy environment for both staff and students.[149] This team oversees various responsibilities, including indoor air quality management, lead-based paint management, water quality, and asbestos management in DPS schools. Additionally, the LoveMyAir program could serve as another valuable partner for data collection, as it currently operates an outdoor monitoring station at Swansea Elementary.

Moreover, research underscores the link between literacy and health comprehension, indicating that strong reading skills are crucial for effectively understanding and navigating the complexities of the healthcare system, as well as for managing chronic health conditions such as diabetes and cancer.[143,144] Lincoln et al. (2015) discovered that limited

literacy skills were associated with obstacles in accessing health information.[150] Additionally, Katz et al. (2007) found that patients with low literacy are less likely to ask questions about their medical care, which may hinder their ability to learn about their conditions and treatment options.[151] In addition to examining the relationship between health insurance coverage and health outcomes, the following section will further consider how English language proficiency affects health care access.

HEALTH INSURANCE AND HEALTH CARE ACCESS. Health insurance and access to healthcare are interconnected. The availability of health insurance coverage influences how individuals obtain various healthcare services, including preventative care, emergency interventions, pediatric services, pharmaceutical access, and mental health support. In this way, health insurance improves disease management, treatment, screening, and early detection.[152] Health insurance coverage is influenced by a myriad of factors, including health literacy, English language proficiency, migration and citizenship status, and employment status. While the extent of this issue is beyond the scope of Deliverable 2.6, our aim is to revisit the findings from Deliverable 2.2, the Health Impact Assessment (HIA). This assessment highlights disparities in health insurance coverage and healthcare access in GES compared to the rest of Denver. We also aim to demonstrate how improving health insurance access could improve health outcomes of GES residents.

Recent data suggest that GES residents have lower rates of health insurance compared to the Denver average. Specifically, fewer adults (aged 18-64) in GES have health insurance compared with the rest of Colorado and Denver. Between 2014 and 2017, the estimated percentage of adults with health insurance in Denver was 84.8% (CI: 83.4-86.2). In comparison, health insurance coverage was lower in GES, with 76.1% of adults in Globeville (CI: 75.6-76.6) and 71.5% of adults in Elyria-Swansea (CI: 70.8-72.1) estimated to have had health insurance.[153,154] More recent prevalence estimates demonstrate that health insurance coverage has not improved since 2017. In 2023, adults aged 18-64 in GES were more likely to be uninsured compared to Denver. In Denver, an estimated 12.4% of adults were uninsured (CI: 9.5-15.5). In Globeville, an estimated 28.3% of adults were uninsured (CI: 23.0-33.7) and in Elyria-Swansea the estimate was 33.6% (CI: 26.8-40.4).[155]

Barriers to accessing healthcare and obtaining health insurance may prevent individuals from seeking necessary care. In terms of health insurance, possible barriers include a lack of affordable coverage options, eligibility status for coverage, and the enrollment process itself.[156] These barriers have contributed to a relationship between health insurance status and demographic factors, such as race, ethnicity, and citizenship status.[157] In Deliverable 2.2 (HIA), we highlighted that GES is a Medically Underserved Area (MUA) - a geography with a shortage of primary care services available. One of the only facilities for primary care in GES is the Tepeyac Health Clinic, and many who utilize this facility are uninsured. In 2021, the Tepeyac Health Clinic in GES reported that 64% of their patients were uninsured, demonstrating that individuals without insurance continued to seek care despite these barriers.[158] In 2017, the predicted prevalence of adults who sought an annual check-up was 57.3% (CI: 56.6-57.9) in Globeville, 59.2% (CI: 58.5-59.9) in Elyria-Swansea, and 63% (CI: 59.1-63) in Denver as a whole.[153]

The intersection of identity and barriers to accessing health insurance may result in disproportionate adverse health outcomes. For example, those with chronic illness, lower socioeconomic status, and individuals in certain racial and ethnic groups experience disproportionate negative impacts from being uninsured.[159] Other health related factors including unemployment, unstable housing, need for maternal health services, immigration status, and chronic disease can also interact to compound the burden of being uninsured. Conversely, these populations can benefit from improved coverage, because coverage of these groups is associated with reducing disparities in healthcare utilization and improving the receipt of care, including appropriate care and screenings, continuity of care, and higher quality of care.[152]

Health insurance status, and the barriers to obtaining it, is related to health outcomes. While it is difficult to quantify the impacts of insurance status due to the co-existing environmental (e.g., air pollution) and social factors (e.g., social

economic status, housing, and educational attainment) that simultaneously impact health outcomes, a growing body of literature indicates that uninsured adults experience worse health outcomes than insured adults.[160–163] There is evidence that uninsured adults are less likely to obtain preventative screening services, and are more likely to delay these services.[152,164–167] For example, uninsured adults experience earlier mortality from cancers compared to insured adults, largely due to delayed diagnosis.[168,169] Further, studies show that uninsured adults with chronic diseases, such as diabetes, CVD, human immunodeficiency virus (HIV), mental illness, and renal disease are less likely to receive appropriate care.[170–172] Adults managing diabetes should receive regular blood glucose monitoring and undergo dilated eye and foot examinations. Individuals with diabetes who lack health insurance are less likely to receive essential care, which can worsen both diabetes outcomes and increase the risk of associated conditions such as cardiovascular disease, stroke, kidney disease.[152,173] Finally, uninsured adults are more likely to receive lower quality care when hospitalized, and have an increased likelihood of death when hospitalized.[174] This is tied to delayed pursuit of medical attention, which negatively impacts health outcomes.

Beyond immediate health outcomes, there are numerous additional benefits to having consistent health insurance. Reduced financial risk and improved economic security, as well as higher quality care and patient satisfaction, all can promote individual well-being and in turn influence other social determinants of health. Social determinants of health like economic security are the "causes of the causes" of many poor health outcomes.[175] Without the financial risk of large medical expenses or medical debt, an individual or a family can focus on other health-promoting aspects of life, like education, housing, or food access.

Social determinants of health are complex and mutually reinforcing. It is difficult to isolate these interconnected determinants to understand how changing any single variable – like health insurance – will extend life-years or improve quality of life. Despite this, there is strong evidence in the literature that insurance, access, and appropriate utilization of healthcare will improve individual health outcomes. Other related benefits of health insurance, like improved economic security, are also relevant to wholistic wellbeing in GES. As Deliverable 2.6 demonstrates, the GES community experiences disproportionate environmental health burdens. Accessibility to health insurance is vital for mitigating immediate and long-term negative health outcomes. As a future scenario, this section highlights the importance of removing barriers to health insurance access for GES residents.

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APPENDIX A UNIT CONVERSIONS

The formulas needed to convert between micrograms per cubic meter (µg/m^3), parts per million (ppm), and parts per billion (ppb) are illustrated using Equations 4 and 5.

Equation 4. Conversion calculation between air pollutant concentrations in micrograms per cubic meter (µg/m^3) and parts per billion (ppb).

$$Concentration\ \left(\frac{\mu g}{m^3}\right) = Concentration\ (ppb) * \frac{Molecular\ Weight}{Molecular\ Volume}$$

$$Concentration\ (ppb) = Concentration\ \left(\frac{\mu g}{m^3}\right) * \frac{Molecular\ Volume}{Molecular\ Weight}$$

Where the molecular volume (in liters) is calculated using the Equation 5.

Equation 5. Molecular volume estimation using temperature and atmospheric pressure.

$$Molecular\ Volume\ (L) = 22.41 * \frac{T}{273} * \frac{1013}{P}$$

In this formula, T represents the absolute temperature in Kelvin, which can be calculated by adding 273 to the temperature in Celsius (°C) and P denotes the atmospheric pressure in hectopascals (hPa). For our calculations, we assumed a constant temperature of 25°C (298 K) and an atmospheric pressure of 840 hPa, resulting in a molecular volume of 29.50 L.

The molecular weight is determined by the molecular structure, as referenced in Table 20.

Table 19. Molecular weights (g/mol) of air pollutants.

Air Pollutant	Molecular Weight (g/mol)
O_3	48.00
NO_2	46.01
SO_2	64.07
CO	28.01

Table 20. Annual preterm and low birthweight incidence rates per 1,000 live births in Colorado (2017–2021).

Year	Low birthweight rate [A, B]	Preterm birth rate [A, C]
2017	91.41 (89.18, 93.64)	87.99 (85.80, 90.18)
2018	94.56 (92.27, 96.86)	92.60 (90.33, 94.87)
2019	94.71 (92.42, 97.00)	95.99 (93.68, 98.30)
2020	92.77 (90.47, 95.06)	91.75 (89.47, 94.04)
2021	95.10 (92.80, 97.40)	97.90 (95.57, 100.22)
Overall	**93.71 (91.43, 95.99)**	**93.25 (90.97, 95.52)**

Parenthesis show 95% CI

[A] Rate per 1,000 live births

B Births <2,500 g (5.5 lbs.)

[C] Births before 37 weeks gestation

Table 21. Annual all-cause mortality and all-cause cancer mortality rates per 100,000 among adults 20 years and older in Colorado (2017–2021).

Year	All-cause mortality	All-cause cancer mortality
2017	901.34 (886.24, 917.42)	210.76 (191.59, 222.93)
2018	896.04 (878.86, 911.08)	206.84 (186.51, 219.75)
2019	907.73 (891.67, 923,90)	208.60 (188.51, 220.82)
2020	1054.12 (1034.62, 1071.88)	210.60 (190.71, 228.26)
2021	1096.43 (956.49, 1242.18)	219.98 (182.77, 255.89)
Overall	**971.13 (929.58, 1013.29)**	**211.36 (188.02, 229.53)**

Parenthesis show 95% CI

Table 22. Annual CVD incidence, CVD mortality, and hypertension incidence rates per 100,000 among adults 20 years and older in Colorado (2017–2021).

Year	CVD Incidence	CVD Mortality	Hypertension
2017	1032.54 (993.07, 1078.93)	247.24 (212.04, 265.68)	0.46 (0.36, 0.58)
2018	1058.89 (1013.87, 1106.88)	245.31 (209.22, 264.98)	0.46 (0.36, 0.59)
2019	1081.55 (1032.61, 1136.43)	248.31 (212.64, 267.69)	0.46 (0.36, 0.59)
2020	1093.97 (1041.05, 1153.06)	249.96 (211.50, 273.44)	0.46 (0.37, 0.59)
2021	1160.33 (1090.47, 1236.25)	259.30 (208.07, 303.55)	0.47 (0.36, 0.59)
Overall	**1085.45 (1034.21, 1142.31)**	**250.02 (210.71, 275.07)**	**0.46 (0.36, 0.59)**

Parenthesis show 95% CI

Table 23. Annual stroke incidence, stroke mortality, and type 2 diabetes incidence rates per 100,000 among adults 20 years and older in Colorado (2017–2021).

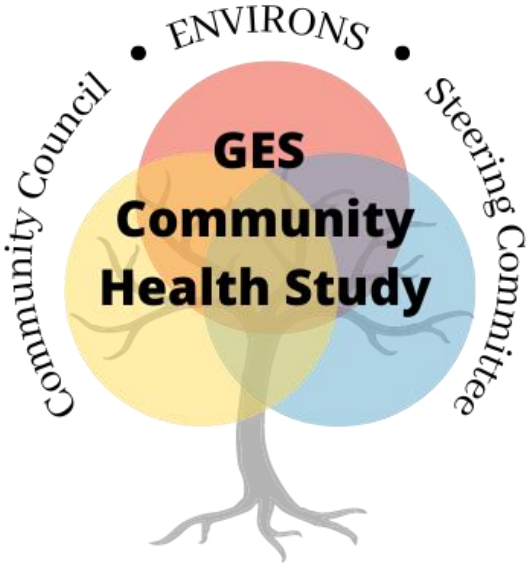
Year	Stroke incidence	Stroke mortality	T2DM incidence
2017	117.81 (105.11, 132.13)	60.26 (50.52, 65.82)	576.14 (535.48, 616.30)
2018	122.17 (108.30, 137.51)	58.95 (49.19, 64.81)	588.70 (546.77, 634.71)
2019	125.50 (110.74, 142.16)	59.00 (49.29, 64.80)	601.40 (557.37, 650.42)
2020	128.80 (111.39, 146.75)	59.38 (49.34, 66.06)	616.23 (572.45, 662.88)
2021	130.05 (113.30, 148.23)	61.79 (48.14, 72.05)	633.89 (584.09, 684.07)
Overall	**124.87 (109.77, 141.35)**	**59.88 (49.30, 66.71)**	**603.27 (559.23, 649.68)**

Parenthesis show 95% CI

Table 24. Annual respiratory disease mortality and COPD mortality rates per 100,000 among adults 20 years and older in Colorado (2017–2021).

Year	Chronic Respiratory Disease Mortality	Respiratory Infections Mortality	COPD Mortality
2017	84.49 (74.04, 91.08)	18.70 (15.59, 20.48)	73.15 (64.23, 79.13)
2018	83.90 (73.07, 91.30)	18.04 (15.11, 19.86)	72.19 (62.72, 78.66)
2019	82.58 (72.13, 89.15)	16.53 (13.80, 18.15)	70.69 (61.72, 76.56)
2020	83.71 (72.88, 91.80)	140.29 (96.39, 187.64)	71.65 (62.21, 78.73)
2021	87.12 (70.19, 102.45)	149.85 (140.63, 179.27)	74.86 (60.48, 87.60)
Overall	**76.52 (64.38, 89.12)**	**72.51 (62.27, 80.14)**	**72.51 (62.27, 80.14)**

Parenthesis show 95% CI



Updated Data and Literature Evaluations and Gap Analysis

GES Community Health Study

In response to deliverable 2.7

March 14, 2025

ENVIRONS

Colorado State University

COMMUNITY INSIGHT

Note: This section was written by the Community Council as a preface to the report.

Dear Neighbors,

This deliverable references a lot of data and literature. Some of it is old, and some is more recent. Studies have come and gone. They have researched many neighbors who were displaced from the area, and other neighbors who have stayed only to see that no improvements have been made to our health and wellness.

We have been studied excessively without finding answers. This community has been promised that studies will lead to improvements. However, many individuals and/or groups only began their studies within this neighborhood to complete a thesis, class, or analysis of a local construction or development project. Researchers and organizations get paid millions of dollars to conduct research and projects, but residents get nothing and often don't even see the data. Where is the accountability? As members of the community, we would have liked to see the results. Further, when they finish their research, they leave the neighborhood and fail to complete the second half of the work: the improvements.

As you review the sources in this deliverable, ask yourselves: Who called for these studies? Who benefited from them? What impacts have they had on our neighbors? Who is accountable?

This is a call to action.

Involve us in the entire process. This deliverable came out of a settlement. Originally, we were not going to be included in this Study—the outcome of the Settlement we fought. We had to advocate for our roles as Community Council members. Now, we are involved in the process; we are learning about research, data and how to engage with it meaningfully to advocate for our needs.

This Deliverable demonstrates that there have been many more studies and reports within the neighborhood than we knew. Many of them are unfamiliar to us because researchers did not do enough community outreach to notify us and disseminate the results of the studies. We request that if new studies are done to the community, we must be consulted, and the studies must be returned to, and readable by, the public. The community should no longer be "instrument of experiment". We should know what is taking place before, during, and after the studies. This is our neighborhood—our home.

Unless researchers return data to the community, and unless the government responds to community experiences and inequities, one more study won't make a difference. We have been surveyed over and over and over and we have almost never received the results, plus no reaction or response from the city or state.

Return data in meaningful ways. Publishing data on a website—the bare minimum effort to share data—is not enough. Many of our neighbors do not have access to the internet due to lack of resources and factors like age, language barriers, or free time to invest in reading the studies. Many reports are very long and residents are not paid to read them like the government employees and researchers are. Reports meant to educate and engage community members should be five pages or less, and they should use clear language. The studies use a lot of technical language that makes them difficult to understand and residents get exhausted from trying to read everything. We are not familiar with names of specific toxins and their impacts. In Spanish we are not used to using acronyms, so these studies are inaccessible to a large part of our population. In our own review we needed to put in more than a page of

acronyms to explain terms. As a team, we went through the outcomes of the GES Health Study together, and broke down technical topics so that we are all on the same page.

The data reveal injustices: act on them. The data and literature we included this deliverable, and all of the deliverables from the GES Health Study, show that our neighborhoods have higher levels of pollution and worse health outcomes compared to other neighborhoods in Denver. We know this from our personal experiences as neighbors, and this study confirms it. Despite this, we see no investment by the city, and if there is any investment, it comes from private developments, advanced by other interests outside the community. Years have passed, studies have come and gone, data are collected, government plans have been made, development has occurred, and we still do not have access to healthy food, clean lead-free water, clean odor-free air, and updated infrastructure like sidewalks or street lighting. What we do still have is the smell of Purina, the toxins from Suncor, the smell of marijuana from the new dispensaries, the smells of rotting meat from slaughterhouses, processing plants, and agriculture, among others.

Every day, we fulfill our civic duties and pay taxes like any other person, citizen or community - will researchers, government and developers listen to us?

Your GES Health Study Community Council

COMMUNITY RELEVANT SUMMARY

Note: This section begins the report written by the ENVIRONS research team.

The goal of this deliverable is to support community members by providing access to the data and literature that informed the Globeville, Elyria, Swansea (GES) Community Health Study. This deliverable contains an extensive list of literature and data sources we used to describe, model, and report on environmental health in GES throughout our Study. Each source is paired with a descriptive summary of the available data, the reason we included it in the Study, and any limitations we discovered. It is important to us that the neighbors can access this information, provide insights, and make their own conclusions. We hope that community members, local organizations, and supporters see the list of datasets and articles in Tables 8 and 9 as this study sharing data with the community in one place altogether.

For Deliverable 2.7, we assessed 597 sources identified in Deliverable 2.1 (*Data and Literature Evaluation)* and subsequent deliverables to determine whether these sources specifically describe the GES community health and environment. Of these sources, 49 data and 42 literature sources were previously evaluated and discussed in Deliverable 2.1 and therefore omitted here. An additional 427 sources were omitted from this report because they do not specifically discuss GES. This resulted in a total of 76 sources evaluated in this report.

In the process of developing Deliverable 2.7, we summarized a variety of sources including environmental information, health outcome information, and information on social determinants of health. We also observed critical gaps in the data and literature that may prevent scientists, policymakers, and community members from drawing conclusions GES community health.

The GES Community Council members often remind us that the true community benefit comes when studies both engage residents in the process and share their data and findings with local residents. We recognize that many of the documents and datasets listed here are highly technical and may not feel useful or accessible to community members. We hope that our Community Relevant Summaries at the beginning of each Deliverable of the GES Community Health Study are more approachable for community members to understand. At the end of the day, we recognize that a limitation of our study is the heavy reliance on technical documents and production of data that may not always be inclusive and equitable for community members to engage with. Nevertheless, we believe that the data belong to the community, and we hope that these findings are useful for achieving the environmental health goals, actions, and desires of GES residents.

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This Deliverable was written by ENVIRONS and reviewed by the Steering Committee.

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LIST OF ACRONYMS, DEFINITIONS, AND DESCRIPTIONS

Table 1. List of acronyms, definitions, and descriptions.

TERM	DEFINITION
Accessibility, Obtainable, Access Security	Data are easily accessible, usable, and retrievable, data are available for download or from another research team. Data accessibility also refers to access security, interpretability and understandability, concise and consistent presentation, timeliness, and amount of data.
Accuracy	Often used synonymously for validity, lack of systematic error, completeness, and reliability. Data are accurate when the data measure what they are intended to measure. Accuracy measures whether data were recorded correctly and reflects realistic values. Data are correct, objective, reliable, certified, and validated.
ATSDR	Agency for Toxic Substance and Disease Registry; ATSDR is a federal public health agency within the US Department of Health and Human Services. The agency focuses on minimizing human health risks associated with exposure to hazardous substances.
CC	Community Council is a group of resident collaborators part of the research team that act as community representatives, experts, and liaisons.
CCoD	City and County of Denver.
CDC	Centers for Disease Control; the Centers for Disease Control and Prevention is the national public health agency of the United States.
CDOT	Colorado Department of Transportation; the principal department of the Colorado state government responsible for maintaining interstates and highways in Colorado.
CDPHE	Colorado Department of Public Health and Environment; CDPHE is the principal department of Colorado state government responsible for public health and environmental regulations.
CEBA	Community environmental burden assessment. The GES Community Health Study CEBA is comprised of Deliverables 2.4, 2.5, and 2.6.

TERM	DEFINITION
Census blocks	Small statistical areas bounded by features, such as streets, property lines, and railroad tracts. Census blocks serve as the basis for census tracts and are the lowest geographical area in measuring demographics of a population.
Census Tracts	Small, relatively permanent subdivision of a city or county with a population between 1,200 and 8,000 people.
Completeness	Data are appropriately inclusive and there is minimal missingness of data entries. All necessary data that could have been reported have been. Data are sufficient in breadth, depth, and scope.
Comparability	Comparability refers to the capacity to make meaningful comparisons across datasets.
Crowd-sourced Literature Folder	The Crowd-sourced Literature Folder was created by the GES Community Health Study Steering Committee as a way for GES residents and other concerned individuals to add documents they had or found to what would be used in the health study. The Crowd-sourced Literature Folder was created before ENVIRONS started on the study. It can be accessed as part of the *GES Master Folder* on Google Drive and is available in the Crowd Sourced Lit Review folder.
DDPHE/DEH	Denver Department of Public Health and Environment (DDPHE), formally called Denver Environmental Health (DEH); the city department responsible for public health and environmental regulations, serves a similar function as CDPHE, but at a local level.
DOTI	Denver Department of Transportation and Infrastructure.
DRCOG	Denver Regional Council of Governments; serves as the metropolitan planning organization for the region.
Environmental justice community	Environmental justice is the idea that all people and communities have the right to live and thrive in safe, healthy environments with equal environmental protections and meaningful involvement in these actions. An environmental justice community can also be identified as a disproportionately impacted community. In 2023, Colorado officially defined disproportionately impacted communities as those meeting specific criteria including low income, higher proportions of residents from minoritized race and ethnicity groups, housing cost-burdens, linguistic isolation, historical marginalization, cumulatively impacted, tribal lands, and mobile home communities.
ENVIRONS	Estudio de Nuestros Vecinos para Investigar los RiesgOs y Nuestra Salud (ENVIRONS) research team is based out of Colorado State University in Fort Collins, CO and is responsible for conducting the GES Community Health Study.

TERM	DEFINITION
EPA (US EPA)	United States Environmental Protection Agency; the primary agency of the United States government tasked with environmental protection.
FHWA	Federal Highway Administration; the division of the United States Department of Transportation that specializes in highway transportation.
GES	Globeville, Elyria, and Swansea neighborhoods.
Health	Health is a state of physical, mental, and social well-being and not merely the absence of disease.
HIA	Health Impact Assessment; Deliverable 2.2 *The ABCs of GES: The State of Health and Environment* of the GES Community Health Study.
Incidence	Incidence is the number of new cases of disease or illness in a population over a specified time.
Interpretability & Ease of Understanding	Past study findings and data presented to the community should be conveyed so that a person without scientific training can easily understand what the data means. Metrics and data definitions should have the right amount of information to be interpretable. Data is presented in a way that is easy to comprehend.
NAAQS	National Ambient Air Quality Standards; The Clean Air Act requires EPA to set NAAQS for carbon monoxide (CO), lead (Pb), ground-level ozone (O_3), nitrogen dioxide (NO_2), particulate matter (PM), and sulfur dioxide (SO_2).
Neighborhood	The City and County of Denver recognizes 78 official neighborhoods, including Denver International Airport (DIA). These are often made up of a collection of census tracts. For example, GES includes three census tracts.
NWC	National Western Center.
Objectivity	Data are unbiased and impartial.
PM	Particulate matter; PM contains microscopic solids or liquid droplets that can be inhaled and cause serious health problems. Some particles less than 10 micrometers in diameter can get deep into your lungs and some may even get into your bloodstream.
Precision	Precision refers to a lack of random error or variation in a study's estimates. Precision can also mean consistency in study results. Data should have a sufficient level of detail to permit decision making (e.g., the margin of error is less than anticipated change).

TERM	DEFINITION
Prevalence	Prevalence, sometimes referred to as prevalence rate, is the proportion of persons in a population who have a particular disease or illness. This includes both new and preexisting cases.
Relevancy	Data are applicable or pertinent to the task of data user.
Reliability	Data collected are based on protocols and standards that do not change. Data are reliable because of how they are measured and collected. Data should reflect stable and consistent data collection processes and analysis methods over time. Reliability also refers to accuracy, integrity, consistency, completeness.
RTD	Regional Transportation District; the public transit system that operates buses and trains in the Denver metro area.
SC	Steering Committee; The steering committee are stewards of the Central 70 settlement agreement to ensure it is carried out appropriately.
Spatial Scale & Scalability	Data has a scale of which measurements were collected (e.g., population level, community level). Scalability refers to the ability to downscale data to different spatial levels. Spatial scale can also include geographical correlation and granularity. Spatial scale can be referenced as neighborhood level, census blocks, census tracts, county level, etc.
Timeliness, Currency, and Time Period	Timeliness measures whether data are up to date and the extent to which the age of the data is appropriate. Time period of when data was collected needs to be accurately reported.
VB/I-70	Vasquez Boulevard and Interstate 70 Superfund site; this superfund site was created to remediate soil contamination primarily from historic smelting activities. The site includes two commercial/industrial areas as well as residential properties in all or part of the following neighborhoods: Cole, Clayton, Swansea/Elyria, southwest Globeville and northern Curtis Park.
VOCs	Volatile organic compounds; VOCs are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects.

INTRODUCTION

At the start of the Globeville, Elyria, Swansea (GES) Community Health Study, community members, settlement petitioners, and representatives from the Steering Committee (SC) and Community Council (CC) provided ENVIRONS with a set of crowd-sourced documents. This collection included research papers, data, maps, and news articles relevant to the GES neighborhoods. The Steering Committee organized these materials into a *Crowd-sourced Literature Folder*, which is located in the GES Community Health Study Google Drive managed by the Steering Committee (SC). In Deliverable 2.1, titled "Data and Literature Evaluation," ENVIRONS conducted an evaluation of the materials in this folder, and enhanced the repository by performing preliminary additional literature and data searches. We assessed the information using a detailed rubric to determine which sources would be included or excluded from the subsequent study deliverables. Deliverable 2.1 summarized each information source, outlined ENVIRONS' rationale for the inclusion or exclusion of each source, and explained the reasoning behind those decisions.

This report builds upon the foundational framework established in Deliverable 2.1 by thoroughly evaluating the extensive data and literature compiled in Deliverables 2.2 through 2.6. While it maintains continuity with the insights and methodologies outlined in Deliverable 2.1, Deliverable 2.7 also introduces necessary adaptations to the evaluation process.

SUMMARY OF ACTIVITIES IN 2.1. In Deliverable 2.1, ENVIRONS developed two rubrics to evaluate data and literature provided by community members, petitioners, and other invested organizations and groups. These sources were evaluated based on criteria like timeliness, objectivity, accuracy, and relevance. Full definitions of these terms are in Deliverable 2.1 Table 8. After assessing datasets and literature based on these criteria, they were “included” or “excluded” in the GES Community Health Study. In other words, this process allowed ENVIRONS to filter out data and literature that was not determined to be high quality enough to provide a basis for future research. For a complete description of the process, readers can refer to Deliverable 2.1, where they will find a detailed description as well as the rubrics themselves in the appendices.

ENVIRONS evaluated 95 items as part of Deliverable 2.1. Of these, 42 were articles and reports in the peer-reviewed and gray (i.e., non-peer-reviewed) literature, 49 were datasets, and 4 were ongoing studies. Tables 2 and 3 highlight the final determination for the literature documents and data evaluated based on their type. Importantly, Deliverable 2.1 was limited to data and literature listed in Deliverable 1.4 *Narrative* and the Crowd-Sourced Literature folder. The purpose of Deliverable 2.1 was to organize and assess literature provided to ENVIRONS, prior to Phase II of the Study where ENVIRONS would begin identifying additional data and literature available and relevant to GES to be incorporated in the ongoing Study.

Table 2. Deliverable 2.1 reviewed literature sources by type.

Literature Type	Included	Excluded	Total
Peer-reviewed Journal Articles	6	4	10
Technical Reports	15	3	18
Public Reports	3	0	3
News Media	1	2	3
Other	2	6	8
Total	27	15	42

Table 3. Deliverable 2.1 reviewed data sources by type.

Dataset Source	Included	Excluded	Total
CDPHE Open Data	18	6	24
Denver Open Data Catalog	9	9	18
Other	3	4	7
Total	30	19	49

The GES Community Health Study is dedicated to collecting and sharing previously gathered data. Our first goal of Deliverable 2.7 is to empower community members to effectively advocate for improvements in community health and well-being. The second goal is to provide insights for policymakers in their efforts to implement evidence-based initiatives that specifically address environmental pollutants' impact on community health. A key feature of the Study is its commitment to accessibility and active community engagement. By providing clear insights derived from these data, the GES Community Health Study aims to enhance the existing body of knowledge regarding environmental health, highlight significant data availability gaps, foster informed decision-making, and drive meaningful change to enhance community health outcomes. Community members and interested stakeholders can access all previous study deliverables on the dedicated website for the GES Community Health Study at https://www.geshealthstudy.org/home. Additionally, Table 4 presents a comprehensive list of study

deliverables published to date, showcasing the ongoing commitment to transparency and community involvement in this essential research initiative.

Table 4. GES Community Health Study Deliverables.

Deliverable	Description
Phase I	Planning and foundations deliverables
Deliverable 1.1: ENVIRONS Questionnaires	After participating in a tour of the GES neighborhoods, each ENVIRONS team member completed a questionnaire prepared by the Community Council. In addition to individual responses, a summary for the team was created.
Deliverable 1.2: Shared Operational Principles	The Community Council, ENVIRONS, and Steering Committee identified roles and defined shared values, motivations, expectations, and limitations for the study.
Deliverable 1.3: Community Engagement Plan	The Community Engagement plan was developed with the Community Council and Steering Committee. It defines how ENVIRONS will communicate with the Community Council and the Steering Committee, and outlines strategies for communicating with residents, soliciting community input, and maintaining transparency.
Deliverable 1.4: Narrative	ENVIRONS identified sources of data, literature, and on-going projects that will be used in Phase II. As part of this, ENVIRONS reviewed the materials provided in the "crowd sourced literature review" folder curated by the Steering Committee prior to ENVIRONS coming onto the study.
Deliverable 1.5: Mapping and Website	The website is available in English and Spanish, and maps are available on the Maps page.
Deliverable 1.6: Course Correction Plan	ENVIRONS worked with the Community Council and Steering Committee to create a course correction plan. This plan ensures that the study is headed in the right direction for Phase II.
Phase II	Analysis
Deliverable 2.1: Data Rubric and Literature Evaluation	ENVIRONS created a rubric to evaluate the quality of literature and data, then applied this rubric to the sources of information identified in the crowd-sourced literature folder or in the Preliminary Data Identification and Narrative.

Deliverable 2.2: The ABCs of GES: The State of Health and Environment	This report characterizes areas of community concern, provides updated data to topics identified in the 2014 Health Impact Assessment report, and evaluates the implementation of recommendations from the 2014 report.
Deliverable 2.3: Exposure Outcome Matrix	The Exposure Outcome matrix demonstrates the connections between environmental exposures in GES, health outcomes, and health disparities based on existing research. This matrix visualizes how environmental exposures (e.g., pollutants) are connected to adverse health outcomes.
Deliverable 2.4: Community Environmental Burden Assessment (CEBA): Planning, Scoping, and Problem Formulation	This document outlines the plan for how ENVIRONS will conduct the Community Environmental Burden Assessment (CEBA), which makes up Deliverables 2.4, 2.5, and 2.6 for the study.
Deliverable 2.5: Community Environmental Burden Assessment (CEBA): The Exposure Response Assessment Phase	This document outlines the methods and preliminary results of the CEBA including modeled air pollution exposures across Denver and literature review of exposure-response relationships.
Deliverable 2.6: Community Environmental Burden Assessment (CEBA): Burden of Disease and Future Scenarios	As the final installment of the CEBA, this deliverable highlights the extent to which health outcomes are attributable to air pollution in GES.
Deliverable 2.8: Root Cause Analysis	This document investigates a root cause analysis of the environmental causes of concerns and health outcomes in GES. Informed by community members and previous deliverables (2.2-2.7).
Deliverable 2.9: Static Maps	This document contains the static maps created in Deliverables 2.2-2.8.
Deliverable 2.10: Dynamic Maps	This document details the process for creating the study's web-based, interactive mapping tool that investigates environmental health concerns.

METHODS

To meet the requirements of Deliverable 2.7, and to avoid burdening readers with analyses of over 500 sources included in Deliverables 2.2 through 2.6, ENVIRONS refined the original process for assessing articles and datasets. We updated our previous methods to provide the community of neighbors, advocates, scientists, and policymakers interested in the GES Community Health Study with a clear and targeted analysis of data, literature, and gaps pertaining to environmental health in GES. For all literature and data referenced in Deliverables 2.2 through 2.6, we assessed whether the materials should be "incorporated" or "omitted" from Deliverable 2.7, based on its relevance and applicability. The literature referenced in Phase II of the GES Community Health Study is much broader than referenced materials in Phase I, now comprising hundreds of citations pertinent to GES, environmental health topics, and our various analytical methodologies. The added step of "incorporate" or "omit" allows for a more direct assessment of the information sources.

It is important to note that, upon scrutiny, many of the sources we used throughout the Study did not satisfy the central evaluation criteria of this deliverable: direct relevance to the GES context. **Consequently, we excluded any literature or data sources from this deliverable that failed to address GES directly, such as methodological papers outlining statistical analysis techniques, since they did not contribute to the targeted objectives of Deliverable 2.7.** All excluded literature and data have been cataloged in our study deliverables as cited in the references. This refined focus ensures that the findings and recommendations presented in Deliverable 2.7 are pertinent and actionable.

INCORPORATED DATA AND LITERATURE. To be "incorporated," data and literature must be cited in Deliverables 2.2-2.6, and must not duplicate the literature and data already included in Deliverable 2.1. Next, "incorporated" data and literature must be specific and relevant to GES, meaning that it must present or describe conditions in GES. To meet this criterion, "incorporated" data and literature had to include the area within the boundaries of Globeville, Elyria and Swansea neighborhoods at the most granular, usable level. In other words, the data had to be the most specific and useful spatial resolution possible for describing environmental health in GES, which in some cases is neighborhood level and at other times is state level. For our purposes, data available at census block and census tract level are preferred, but data available at the county or state level may be most relevant if these are the only data that can be used to describe or calculate conditions in GES as compared to other parts of Denver. This decision is described in the limitations section of this deliverable.

For literature to meet the criteria of being GES-specific, the source must specifically mention Globeville, Elyria, or Swansea, places within these neighborhoods, or legislation or policy that directly impacts the neighborhood's environmental health. For example, activities related to Vasquez Boulevard/Interstate 70 superfund site may be specific to GES, even if it includes areas outside of the neighborhood boundaries. Importantly, historic, and older datasets and literature are included in this deliverable to provide context and background information to readers. Some data and literature sources are 20 or more years old, which can allow for a longitudinal assessment of the environmental health conditions in GES but should not automatically be interpreted as representative of current neighborhood conditions. Older data and literature are noted in the "Limitations" column in the Tables 8 and 9.

OMITTED DATA AND LITERATURE. Data and literature that were utilized in Deliverables 2.2-2.6 but did not present or describe conditions specific to GES were "omitted" from Deliverable 2.7. "Omitted" sources include those used to support scientific claims, such as health etiology, causal relationships between environmental exposures and health, and scientific knowledge of health and environmental exposures more broadly. The application of our criteria resulted in the omission of hundreds of studies that were primarily used to inform the methodology the ENVIRONS team used in our analyses but which do not pertain specifically to GES. Omission does not imply that the data and literature are not of high quality or valid; omission was primarily based on the lack of specificity to GES. All sources cited in the GES Community Health Study can be trusted as a useable, high quality, vetted and valid sources, regardless of whether they were "omitted" from this deliverable.

PROCESS. We adopted a thorough, streamlined process for evaluating the literature and data sources for this deliverable. First, the ENVIRONS team coalesced all cited literature and data from Deliverables 2.2-2.6 of the GES Community Health Study. Each source was independently reviewed by two ENVIRONS team members (the "Primary Reviewer" and "Secondary Reviewer") to determine (a) whether it was previously analyzed in Deliverable 2.1, and (b) whether the source was specific to GES (described earlier in this section). For included sources, each reviewer drafted a brief summary, explained the inclusion reasoning, and identified potential limitations (Figure 1). The evaluation process and resulting products were then reviewed and discussed together with the GES Community Council and the ENVIRONS team.

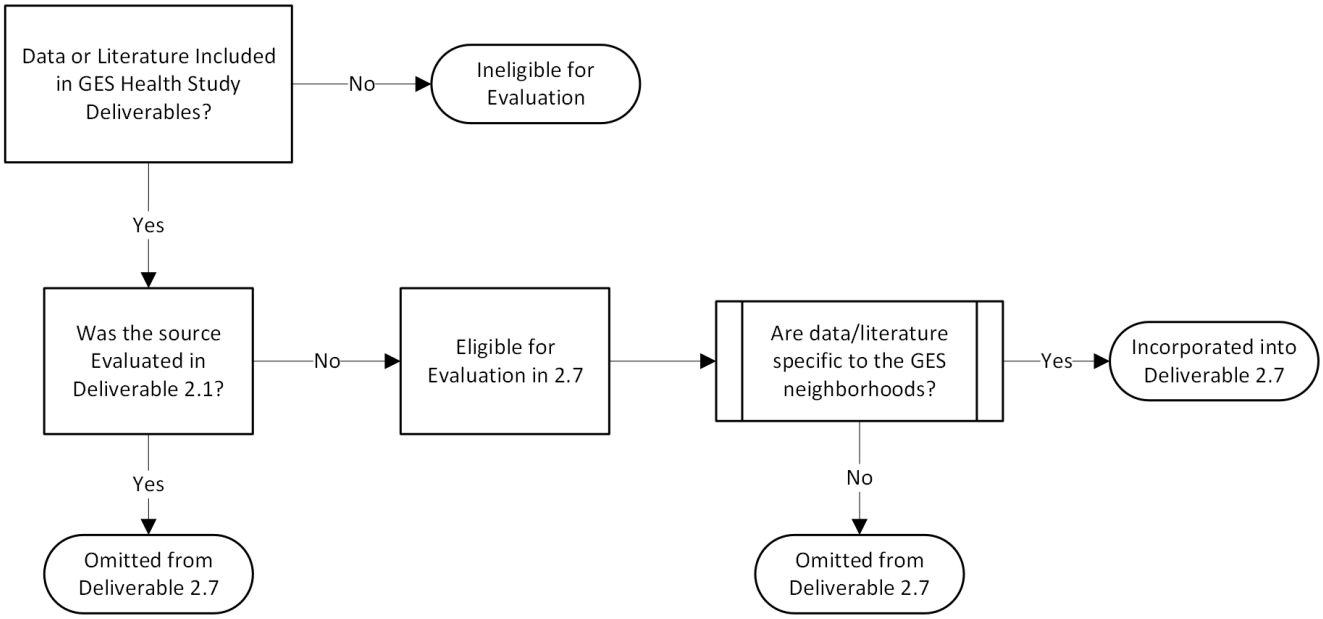

Figure 1. Deliverable 2.7 Evaluation Process.

RESULTS

ENVIRONS evaluated 597 documents and datasets for Deliverable 2.7. These items covered a variety of topics including environmental information (e.g., air quality, transit, infrastructure, odor, soil, water, etc.) health outcome information (e.g., cardiovascular diseases, respiratory diseases, chronic diseases, etc.) and social determinants of health (e.g., sociodemographic, housing, income, education, etc.). Of these 597 documents and datasets, we evaluated 103 datasets from governmental repositories like the American Community Survey (ACS), Behavioral Risk Factor Surveillance System (BRFSS), CDPHE Open Data and Vital Statistics, and other data from public-led initiatives, such as American Forests. Of these 103 data sources, we incorporated 35 and omitted 68. We evaluated 494 literature sources including scientific and statistical methods, government reports, neighborhood plans and news media. We incorporated 41 of these literature sources and omitted 453. This resulted in the final evaluation and inclusion of 76 (13%) sources into Deliverable 2.7. We did not include any omitted literature or data in this deliverable; each of these omitted items is cited in Deliverables 2.2-2.6 if researchers or other invested parties are interested in accessing them. Table 5 outlines the number of literature documents and datasets that each previous deliverable contained, and our final determination of inclusion or omission. It is important to note that in some cases, a source was used in more than one deliverable, and therefore the key takeaway rows are All Sources, Omitted, and Total Evaluations Completed.

Table 5. Summary of cited data and literature in GES Community Health Study Deliverables.

	Data	Literature	Total
All Sources	103	494	597
Deliverable 2.1	52	42	94
Deliverable 2.2	31	209	240
Deliverable 2.4	13	58	71
Deliverable 2.5	7	144	151
Deliverable 2.6	10	165	175
Omitted	68	453	521
Total Evaluations Completed	35	41	76

Table 6 highlights the final determination for the literature documents evaluated based on their classification as a peer-reviewed journal article, technical report, public report, news media, or other (e.g., factsheets, books, websites, etc.). Appendix A Table 8 groups the incorporated literature based on their topic and provides a summary, reason for inclusion, and any limitations we found.

Table 6. Deliverable 2.7 reviewed literature by type.

Literature Type	Included	Omitted	Total
Peer-reviewed Journal Articles	0	294	294
Technical Reports	8	46	54
Public Reports	7	36	43
News Media (e.g., online news articles, press releases, etc.)	6	7	13
Other (e.g., books, websites, presentations, factsheets, etc.)	20	70	90
Total	41	453	494

Table 7 highlights the final determination of datasets evaluated based on author, such as CDPHE, City and County of Denver (CCOD), other governmental agencies (e.g., Centers for Disease Control and Prevention (CDC), US Census Bureau, EPA, etc.), or other. Appendix B Table 9 groups these data by topic (e.g., air quality, social determinants of health, human health outcomes, etc.) and provides a summary, reason for inclusion, and potential limitations.

Table 7. Deliverable 2.7 reviewed data by type.

Dataset Source	Included	Omitted	Total
CCOD	11	25	36
CDPHE	9	25	34
Other government agencies (e.g., CDC, EPA)	9	15	24
Other	6	3	9
Total	35	68	103

DISCUSSION

Throughout the course of the GES Community Health study, some residents have expressed their frustration over being the subjects of numerous research studies without receiving any feedback or information regarding the outcomes of these inquiries. During the initial phases of our research, we uncovered a concerning reality: only a limited number of peer-reviewed scientific studies focus specifically on the health and environmental conditions within the GES community. Instead, our preliminary data screening efforts primarily identified government technical reports, court documents, publications by non-governmental organizations (NGOs), information from various websites, and news articles, all of which can be inaccessible or difficult to interpret for residents.

The aim of Deliverable 2.7 is to provide a comprehensive and high-quality compilation of GES-specific data and literature to community members, organizations, and stakeholders who are actively working to enhance health outcomes, environmental conditions, and the social determinants of health within GES. However, several factors present challenges in our endeavor to equitably and comprehensively compile literature and data sources for the community. Community members have also underscored the critical need for transparency and accessibility. They have pointed out that accessing and interpreting information from previous studies can be prohibitively challenging, especially when dealing with dense government technical reports, many of which often exceed one hundred pages in length and are filled with jargon that is not easily understood by the general public.

As highlighted in Tables 8 and 9, there are a diverse array of data and literature sources relevant to the GES community. The organizations responsible for producing and maintaining these data operate at various levels including national (e.g., EPA and CDC), state (e.g., CDPHE), and local city levels (e.g., City and County of Denver (CCOD)). The data utilized for this Study encompasses a wide range of topics and levels of specificity, addressing environmental factors such as air quality, the built environment, and health data that includes metrics on mortality rates, health conditions at birth, cardiovascular diseases, respiratory illnesses, and chronic diseases. Social determinants of health (SDOH) data cover essential factors such as demographics, education, employment, income levels, housing conditions, and health-related behaviors.

LITERATURE GAPS

A troubling trend observed over the past three years is the apparent scarcity of published data pertaining to the GES community in academic research journals, despite the widespread sentiment among residents that they are being overstudied. This disconnect raises significant issues regarding the perceived responsiveness and transparency of the research processes that involve the community. The literature presented in Table 8 varies across scales spanning state, city, and local levels. For instance, several technical reports on air quality focus on the Northern Front Range Denver Metropolitan Area (NFRDMA), while reports from CCOD Denver Public Schools (DPS) reflect educational outcomes at the city level, often referencing specific census tracts. Additionally, some research studies, technical reports, and news articles delve into issues at the neighborhood level, providing an intricate tapestry of information that can be both valuable and

overwhelming for community members seeking to navigate these resources. Regardless of the scales, a reoccurring limitation of literature is the lack of community member involvement and input in environmental health projects, research, and state and city initiatives.

As highlighted in the Community Insight section of this report, residents are frustrated over the unclear research processes, not being involved in either study design, nor made aware of study results. This leads to the current scenario, where residents are not aware of who is accountable for data and literature maintenance. This lack of involvement leads to a lack of trust in the information presented in journal articles, and mistrust in regulations and governmental representatives. Residents have expressed that they would feel more confident regarding the literature if they were involved in the planning, execution, and presentation of results. In other words, the residents do not feel heard or represented. Deliverable 2.8 further delves into these impacts.

DATA RELEVANCY AND APPLICABILITY

As with all scientific literature and data, the relevance of the information pertaining to individuals or locations can diminish over time as these sources become outdated. In certain cases, significant changes within the GES neighborhoods, such as urban development, changes in local governance, or demographic shifts, have rendered older data less relevant for current or future use, complicating efforts to fully understand the present conditions. For instance, air pollution monitoring was conducted near Interstate 70 (I-70) prior to the I-70 East expansion project, which involved construction and infrastructure changes in the area. The air quality metrics tracked before this expansion may not reflect the current state, as emissions and traffic patterns have likely changed since construction activities commenced. Additionally, some data are subject to intrinsic delays caused by their collection and processing methods, which can further impede timely assessments.

One considerable barrier to data applicability is the variation in spatial scales, which complicates the assessment of various health and environmental characteristics. For the majority of our study deliverables, we utilized neighborhood and census tract level data. This approach allows both us and the community to access the most relevant GES-specific information available. For instance, in Deliverable 2.2, we drew on census tract-level sociodemographic data from the American Community Survey (ACS), health statistics from the CDPHE and the CDC, as well as environmental data obtained from Denver Open Data. In contrast, for the statistical methods employed in Deliverables 2.4 through 2.6, we relied on state-level data sources, such as the EPA and Global Burden of Disease (GBD) data. This was necessary due to the unavailability of small-area estimates for Denver or GES during the analyzed period (2017-2021) or because the available data did not satisfy our specific needs (for example, CDC PLACES data is provided as prevalence estimates, whereas we required incidence data). This demonstrates one of the major data gaps we encountered during the course of the Study.

DATA ACCESSIBILITY

Publicly available data often presents challenges in terms of accessibility and usability, as it is frequently limited in scope and formatted in ways that complicate public engagement. Several datasets are accessible solely through downloadable files, which can be cumbersome for those unfamiliar with data processing. These datasets may be substantial not only in terms of the sheer volume of information they contain but also concerning their file sizes, which can reach several gigabytes. This can require familiarity with filtering or data cleaning, a skill that is typically not possessed by individuals who do not regularly work with large datasets. Also, when data are presented in formats that require visualization software, like ArcGIS or R, the barriers to accessibility increase. These software tools often require training to use effectively, thereby limiting access for the average user who may not have the technical skills. Some tools and trainings also require financial resources.

In addition to accessibility challenges related to formats and tools, some crucial datasets like vital statistics registries are not openly available to the public. Interested parties must go through a formal request process to obtain such data. While theoretically open to anyone, this process can be burdensome or confusing, deterring many individuals from pursuing access to this valuable information. Datasets related to community concerns, such as odor complaints or street temperature readings, were also acquired through specific data requests, which further restricts their availability to GES community members.

Accessibility also encompasses language equity. While many state and government resources are available in English, not all literature and data utilized in the Study and relevant to GES community members are available in Spanish. Given that many residents of the GES community are Spanish speakers, this language barrier can hinder equitable engagement and interaction with the information we have provided in our Study. This limitation highlights the necessity for organizations to provide materials in multiple languages to ensure that all community members can fully participate in discussions and decision-making processes relevant to their community's health and environment.

BARRIERS TO FUTURE DATA & LITERATURE ACCESS

During the production of Deliverable 2.7, we encountered several limitations, primarily regarding the accessibility and availability of data and literature sources necessary for effective community-based research. Firstly, while reviewing cited materials from Deliverable 2.2 Health Impact Assessment, we discovered that many of the cited URLs had changed since the publication of this document in the fall of 2023. This situation posed a challenge, as we found it essential to locate and verify updated sources to ensure the accuracy and reliability of our information. Despite our efforts to identify most of the new URLs and update the links accordingly, there remains a risk that similar issues may recur following the publication of Deliverable 2.7. This unpredictability underscores the need for continued vigilance in tracking the changes in online resources. Additionally, the ongoing shifts in political administration priorities at various levels (i.e. local, state, and federal) may fundamentally impact the accessibility of the data utilized in this study. Such changes can also influence federal funding opportunities or grants aimed at maintaining data availability. As

political priorities evolve, so too can the focus on data-related initiatives, leading to potential reductions in funding for public health research and data collection endeavors. Consequently, the production and dissemination of crucial information may become more inconsistent, posing challenges for ongoing studies and community engagement efforts. To mitigate these challenges, we strongly encourage government agencies to implement redirects whenever a URL changes. This proactive approach would help ensure the continued accessibility of essential data for GES residents and facilitate ongoing research efforts within the community.

CONCLUSION

These data and literature considerations and limitations are systemic and have a pronounced impact on GES residents, some of whom have expressed feelings of being heavily researched while receiving little to no data in return for their communities. Additionally, the continual feedback we receive from some community members suggests that existing data and literature often fail to match their lived experiences. The Community Council and ENVIRONS have discussed these gaps extensively throughout this study. The qualitative data (i.e., lived and experiential) from community members are as important to understanding the health and environment in GES as the numbers and literature presented in the Study deliverables. All of our study Deliverables from 2.2-2.11 aim to usefully return data to the community, and we recommend individuals explore Deliverables 2.9 and 2.10 to access the data visualizations we produced for the study.

We encourage anyone engaging with the GES Community Health Study to read our community summaries, which reflect the perspectives of our Community Council, who are community members themselves. This will enhance your understanding of the neighborhood's circumstances and complement the scientific literature and data presented in the tables of this report. We also encourage researchers, agencies, and organizations to respond to the community's calls for more up-to-date, neighborhood-specific data for the environmental health areas they care most about. Our Community Council members and local collaborators have clarity and insight into the data gaps within the community, and future GES-specific data should be produced under the guidance of community members and include a plan to return data to the community.

Ultimately, data sovereignty is vital to environmental justice. Returning data to the community allows residents greater ownership in a world where decisions are often made without local input or consent. Data ownership enables residents to enhance how they share their experiences, employ tools to leverage policy change, and make informed choices about their environmental health scenarios.

APPENDIX A. LITERATURE

The following table outlines literature specific to GES that were Incorporated in the GES Community Health Study Deliverables 2.2-2.6. The table highlights a summary of the document, reasoning for inclusion, as well as limitations.

Table 8. Summary of literature documents, inclusion reasoning, and potential limitations.

TITLE (PUBLICATION; DATE)	SUMMARY	INCLUSION REASONING	LIMITATIONS
Air Quality and Odor			
2023 Colorado Air Quality Data Report (CDPHE, 2024)	The Air Quality Data Report addresses historical trends in air quality and includes a detailed examination of the monitoring data collected by CDPHE in 2023. The Report to the Public discusses the policies and programs designed to improve and protect Colorado's air quality.	These CDPHE air quality data were utilized in both the HIA and CEBA. They are regularly updated and reliable. Cited data were from 2023. Community members, researchers and other stakeholders can rely on these data for future analyses and comparisons.	These data may be inaccessible for those without familiarity using large data files, performing statistical analysis, or navigating other complex language inherent to large datasets. Further, to our knowledge, this report is only available in English.
Air Monitoring in GES 2017 (Ogletree, 2017)	This 2017 presentation provides an overview of air monitoring efforts in and around GES. It includes static maps that illustrate the locations of air monitoring stations operated by CDPHE, as well as details on the Globeville Landing Outfall Air Monitoring Initiative conducted from 2016 to 2018 and the tentative air monitoring sites associated with the National Jewish Health STAR Grant as of 2017. Additionally, information is presented regarding the Swansea air monitoring station, which collected air quality data from 2017 to 2023.	This presentation is relevant to ongoing community concerns regarding air quality in GES. In addition to providing an overview of the air quality monitoring stations around GES, this presentation also provides transparency regarding goals, collaborators, and funding sources allocated for each project.	This presentation is over 5-years old and can serve as background information, but more recent data are necessary for any analysis.

TITLE (PUBLICATION; DATE)	SUMMARY	INCLUSION REASONING	LIMITATIONS
Air quality monitoring ends after 2 years in Commerce City (Yuen, 2023)	This news story highlights that after two years of air quality monitoring in Commerce City, Cultivando has decided to end data collection and to pivot attention to action. As a community non-profit, Cultivando serves Commerce City, Globeville, and Elyria-Swansea residents. For this air monitoring study, Cultivando hired BoulderAIR to gather air quality data.	Air quality has been a major concern for GES residents. While this news report focuses primarily on Commerce City, this story is important because it highlights environmental health actions taken by a community-based organization that works in Commerce City, Globeville, and Elyria-Swansea.	While this story provides relevant context on community-driven action, the monitoring phase has been completed. More information would be needed to better understand next steps and how these data are being utilized.
Community Scale Air Dispersion Modeling in Denver: Airing on the Side of Caution (Thomas et al., 2008)	This study monitored air toxics at four locations across City and County of Denver for a one-year period between 2006-2007. This report highlights the results.	Air quality concerns and childhood asthma both have been expressed as topics of community concerns. Air toxics data were collected at Swansea Elementary School, and this report outlines these data in depth.	The data are from 2006-2007, and the report was published in 2008. This limits the usability of the report to background information. Another limitation is the highly technical nature of the report, which makes it less community facing.
Denver's Updated Odor Ordinance Factsheet (CCOD, 2016)	This factsheet provides an overview of the 2016 odor ordinance requirements for businesses. It also advertises workshops that were offered in 2017.	Odor is often described as a major issue in GES. This document presents relevant information regarding Denver's Updated Odor Ordinance in a manner that is more approachable and accessible than reading the entire ordinance. It also affirms residents' concerns that business and industry (like meat, cannabis, and pet food) are responsible for regulating their own odors.	This is a dated factsheet, and we were unable to find a more recent document on odor ordinances for GES residents.
EPA report finds Suncor refinery having more air pollution incidents compared to other refineries (Piantanida, 2023)	This 2023 press release highlights an analysis conducted by the EPA regarding the operational standards at the Suncor refinery. The analysis revealed concerns about the refinery's air quality management, indicating	While Suncor is located in neighboring Commerce City, residents of GES have voiced concerns about the refinery, citing issues with odors and air quality. The press release reports the reactions of EPA and CDPHE	The press release reports that the EPA's Suncor Report Analysis will inform CDPHE inspections, investigations, permit updates, and enforcement actions. Subsequent information is required to understand the

TITLE (PUBLICATION; DATE)	SUMMARY	INCLUSION REASONING	LIMITATIONS
	that Suncor may face an increased frequency of air quality incidents. These potential incidents arise from deficiencies in the facility's preventive maintenance protocols and the thoroughness of machinery inspections. The press release provides a high-level summary of the EPA's analysis, along with URL links to the full technical reports.	representatives. This report also provides links to the Suncor Report Analysis and to Suncor's Settlement Agreement.	extent to which the Suncor Report Analysis has impacted the facility's air pollution.
Going One Step Beyond in North Denver A Neighborhood Scale Air Pollution Modeling Assessment Part I (Ogletree, 2016)	This presentation compares 2011 emissions to a projected 2035 emissions if I-70 East were to be partially covered ("Partial Cover Lowered" or "PCL").	While the data are too outdated to base future analysis from, this document provides a contextual understanding of air quality and I70, concerns many residents have to this day.	This presentation is dated (over 5-years old) and can serve as background information, but more recent data are necessary for any analysis.
Going One Step Beyond in North Denver A Neighborhood Scale Air Pollution Modeling Assessment Part II (Ogletree, 2016)	The presentation titled "Going One Step Beyond in North Denver, Part II," created in 2016, offers insights into the Good Neighbor Project. The slides outline the modeling methods used and present projections for nitrogen dioxide, benzene, particulate matter 10 (PM_{10}), and particulate matter 2.5 ($PM_{2.5}$) for the year 2035. Additionally, the presentation discusses the next steps for the project.	While the data are too outdated to base future analysis, this document provides a contextual understanding of air quality and I-70. Additionally, the concluding disclaimer of this presentation details that Denver Environmental Health conducted this research in response to citizen and stakeholder concerns regarding near highway gradients and hot-spots. Throughout the GES Community Health Study, many GES residents have expressed ongoing concerns related to air quality and I-70.	This presentation is dated (over 5-years old) and can serve as background information, but more recent data are necessary for any analysis. This presentation uses a lot of technical language, which may be inaccessible to those outside of the scientific community.
Governing Nuisance Odors (CCOD, 2017)	This rule is aimed to mitigate and control nuisance odors in Denver. This document establishes the required components of an Odor Control Plan (OCP) and details the plan's approval process. Facilities that must submit	This document provides relevant contextual information regarding the rules and regulations of odors in Denver. It also highlights facilities that are subject to OCP regulations.	As a regulatory document, this document does not outline to what extent these regulations are followed or violated. Nor does it outline to what

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	an OCP to CCOD are outlined in this document.	Throughout the study, GES residents have expressed concerns regarding nuisance odors.	extent processes and procedures are effective in meeting community concerns.
Built Environment			
44th Avenue & Broadway Pedestrian Accessibility Improvements (CCOD DOTI, n.d.)	This website details the 44th Avenue and Broadway pedestrian accessibility improvement projects; it highlights the pedestrian ramp, reconfigured intersection, and the new sidewalks and railings.	Residents have voiced concerns about neighborhood connectivity, especially due to the presence of highways cutting through the neighborhood.	While this website reports that this pedestrian-focused project was completed in 2024, the website does not report community insights regarding the extent to which this infrastructure project has addressed their connectivity concerns.
Brighton Boulevard | RiNo Art District (CCOD, 2018)	This website is a press release by RiNo Art District about the Brighton Blvd. project of new sidewalks, traffic signals, pedestrian crossings, and streetlights.	The infrastructure listed in this press release connect to social determinants of health by focusing on neighborhood connectivity. They also connect to residents' concerns about the development of RiNo and potential for similar gentrification that could displace GES residents.	This website does not provide community insights regarding community experiences with this infrastructure project. It also does not address the issue of gentrification.
Denver Connector Microtransit Program (CCOD, n.d.)	This website provides information about the Denver Connector Microtransit Program. The Connector is a free ride-share that offers rides between 6:00am-8:00pm throughout GES.	Mobility and accessibility have been voiced as concerns of GES residents. The Connector is a service that is frequently utilized by community members involved in the GES Health Study, demonstrating the ongoing need for transit in GES.	Most of the information on the website refers to the Montbello neighborhood, with few references to GES. Further, residents report long wait times and limitations from the Connector service terminating at 8:00pm.
Denver Moves: Transit Plan (CCOD, 2019)	CCOD's Denver Moves: Transit Plan provides a long-term planning document for transit in Denver. For GES, this provides relevant	This document provides relevant contextual information regarding transit planning in Denver, as well as details regarding Denver's goals for the Brighton/48th station. Transit, development of major corridors, and	Since this document was published in 2019, it stands to reason that plans may have changed or been modified due to external factors, such as the COVID-19 pandemic.

TITLE (PUBLICATION; DATE)	SUMMARY	INCLUSION REASONING	LIMITATIONS
	information on Denver's goals for transit corridors, such as Brighton/48th station.	connectivity are ongoing concerns among residents of GES.	
DGI Completed Project Portfolio Brighton Boulevard (CCOD DOTI, 2023),	This collection of literature sources discusses various infrastructure projects that have been completed or are planned in and around GES. Some of these projects are led by the North Denver Cornerstone Collaborative, which selected six initiatives to enhance connectivity, mobility, and infrastructure in the GES neighborhood. While some projects, such as the Brighton Boulevard initiative, have been completed, others are still ongoing. The goal of these projects is to improve accessibility to the area with a strong emphasis on safety.	The Brighton Boulevard project is focused on increasing neighborhood connectivity and stormwater management. The streetside stormwater planters aid in improving water quality by treating the stormwater runoff that would have drained directly into the South Platte River. The goals of the project also connect to community concerns about connectivity.	This website does not provide community insights regarding community experiences with this infrastructure project. Further, residents voice concerns about gentrification and the prioritization of developer interest over residents' needs. This page does not address either of those concerns.
Elyria Swansea is getting a grocery store for the first time in at least a half-century (Beaty, 2022)	The Denverite news article from 2022 discusses the Noir Market in Elyria-Swansea. The Noir Market was set up as a biweekly Saturday pop-up food market,3 however there have been no updates on the status of the market since 2022.	Food access has been a concern voiced by residents throughout the GES Community Health Study. Specifically, a lack of grocery stores within a safe walking distance is often expressed.	There is limited information available since this article was posted. For example, the Noir Market social media pages have not posted any updates since 2022.
Elyria-Swansea is one step closer to a bridge over troubled walkers (Sachs, 2019)	This news article from Denverite is about the pedestrian bridge project that goes over the York Street train tracks.	Residents have previously expressed frustration over the lack of walkable areas in GES.	This news article highlights the construction efforts of the pedestrian bridge project, but does not include community members insight on the usability of the bridge itself.
Energize Denver Renewable Heating and Cooling Plan Resilient Existing Buildings and Homes. (Keleher, 2021)	This document provides a plan for Denver's transition to renewable heating and cooling in buildings (including residential buildings). This aims to improve indoor air quality, access to	This plan highlights the importance of cost effective and equitable approaches to heating and cooling for homes in lower-income communities. Resources may be helpful as the	This Plan only briefly mentions Globeville, Elyria and Swansea neighborhoods. Depending on how the Plan is implemented,

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	cooling, enhance job opportunities, and increase Denver's resiliency to climate change. The document specifically notes how renewable heating and cooling improves racial equity and quality of life, especially in long-term planning for climate change. Globeville and Elyria Swansea are identified (on a list of 18) as Denver's priority neighborhoods for equity-focused support. The plan includes "playbooks" that outline options for partial and full-electrification. Additionally, the plan features an implementation strategy that includes communication, policy, programs, and incentives.	burden of climate change alters heating and cooling trends and residents' associated needs in GES.	neighbors may not be particularly impacted by it.
Food Sovereignty group prepares to open grocery store in Elyria-Swansea (Smith, 2023)	This Denver 7 News article from 2023 discusses the East Denver Food Sovereignty Initiative (EDFSI) which would operate in the RiNo Art District. EDFSI aimed at introducing a community-owned grocery store and commissary kitchen into the area. However, there has not been any additional news regarding the project.	Food access has been a concern voiced by residents throughout the GES Community Health Study. Residents have continually called for a walkable, affordable grocery store.	Upon further investigation, EDSI currently operates a food share program out of Harvey Park, community gardens at 5 locations in Harvey Park and 1 location in Athmar Park. We could not find information regarding any planned EDFSI activities in GES.
Healthy Corner Stores. City and County of Denver (DDPHE, n.d.)	This CCOD website provides information about the Denver Healthy Corner Store Initiative (HCSI). On the website there is a map displaying participating locations, some of which occur in or around GES.	Food access has been a concern voiced by residents throughout the GES Community Health Study.	This source has not been updated recently. The map was created in August 2016, and the website is not clear on the current status of the HCSI project.

TITLE (PUBLICATION; DATE)	SUMMARY	INCLUSION REASONING	LIMITATIONS
Huerta Urbana Farmers Market (Focus Points, n.d.)	The Huerta Urbana Farmers Market, located at Focus Points, offers a pay-what-you-can food market aimed at increasing food access in GES. However, the website does not indicate the current status of this initiative (e.g., embedded news articles are from 2022).	Food access has been a concern voiced by residents throughout the GES Community Health Study. A walkable, affordable grocery store is a high priority for GES residents.	Huerta Urbana addresses a need within the GES community. However, the Huerta Urbana Farmers Market operations are confined to certain dates and times. This may be a barrier to accessing this important service.
Marijuana Facility Location Guide (CCOD, 2024)	The Marijuana Facility Location Guide (2024) is a technical report aimed at helping marijuana businesses understand CCOD laws regarding marijuana zoning, permits, and how to navigate between medical and retail marijuana stores, product manufacturing, and cultivation facilities.	GES residents have voiced concerns over the marijuana odors in the neighborhood and surrounding area. Residents have also expressed that the development of marijuana stores in lieu of grocery stores represent developer priorities and government permissions that ignore residents' expressed needs and interests.	This report does not mention Globeville specifically, and only mentions Elyria Swansea one time in regards to being a cultivation restricted area in terms of the number of businesses allowed to operate in the neighborhood.
National Western Center Master Plan (NWC, 2015)	This document provides a master implementation plan for the National Western Center Campus. This document discusses the following considerations for the site: NWC planning partners, connectivity and transit, environmental issues and remediation, park and public spaces, and stakeholder involvement. Components of the master plan include considerations for facilities (such as arenas and stockyards), programmatic opportunities, architectural design, and the character of the broader neighborhood.	This Plan is a historical document that describes an important development project in GES. The NWC is a significant site in the GES neighborhoods, and this plan demonstrates how it has developed over time, and what stakeholder involvement has looked like. The NWC may be tied to environmental health factors including connectivity, mobility, transit, air pollution, greenspace and more. Residents have voiced a spectrum of feelings about the NWC, and resident involvement in decisions regarding the NWC, as well as leveraging the NWC as a resource for their benefit, is important.	This Plan was drafted in 2015, and should be used to understand historic context and community involvement in development. It does not provide information on future expansion or plans, current impacts or community concerns and experiences of the NWC.

TITLE (PUBLICATION; DATE)	SUMMARY	INCLUSION REASONING	LIMITATIONS
North Denver Cornerstone Collaborative (CCOD, 2015)	This presentation provides an overview of the North Denver Cornerstone Collaborative (NDCC) by establishing an overarching vision for six separate development projects aimed to "reconstruct 3,000 acres" in GES. The six projects include I-70 redevelopment, three transit lines (4 stations), GES neighborhood plans, River North/South Platte development, Brighton Blvd planning, and National Western Center campus planning and development.	The presentation outlines major construction projects within GES, including development of I-70, the Western Center, CSU Spur, and other controversial projects that have been named as concerns for GES community members.	The presentation outlines goals to retain history, inspire health and wellness, and uphold community integration. Despite stating an objective of NDCC is to establish a community engagement effort, the document does not provide information regarding the existing conditions of GES residents or how these projects will impact health and environmental conditions in GES. This source is also a decade old at the time of publication, making it more useful for historical context.
North Denver Cornerstone Collaborative Heron Pond/Heller/Northside Park Master Plan (CCOD, 2018)	This document provides existing conditions of the Heron Pond/ Heller/ Northside Park as an early stage for the master planning process.	This document provides relevant information about park master planning in GES. The pond is directly adjacent to the NWC, located in the heart of the neighborhoods.	As this document was drafted in 2018, it would be helpful to know what progress has been made toward the document's goals, how GES residents have been engaged, and how progress is communicated to residents.
System Map and Stations (CCOD, n.d.)	This website provides a static map of the transit service stations around Denver. The main point of interest in GES is the National Western Center.	Mobility and accessibility have been voiced as concerns of GES residents. Despite the development of a station in GES, it is listed as an “Entertainment” stop, and residents frequently voice that the station is difficult to get to because of street and railroad crossings.	The links for National Western Center contained within the website include the 2015 Elyria-Swansea neighborhood plan, the 2015 National Western Center master plan, which are dated, and may not accurately reflect present-day community viewpoints or the most recent environmental health conditions.
Swansea Indoor Pool Project (CCOD, n.d.)	This website details the Swansea Indoor Pool Project and outlines the project scope and timeline. The project is estimated to be completed in 2026.	Access to community resources and gathering places is of importance to GES community members. Further, opportunities for health and exercise are relevant to community concerns surrounding obesity and diabetes.	The website does not include information on future community engagement events.

TITLE (PUBLICATION; DATE)	SUMMARY	INCLUSION REASONING	LIMITATIONS
What's Environmental Justice Mean? Look at North Denver. Earth Justice. (Rushing, 2022)	This 2022 article from Earth Justice details activities around community action regarding the I-70 expansion project, with mentions of Suncor permit violations.	This article can serve as background knowledge about the community-driven actions opposing the I-70 expansion project. These actions resulted in the Central-70 Settlement.	While this article provides contextual information regarding the community-driven actions opposing the Central I-70 project, more information is needed to further understand community perspectives.
Social Determinants of Health (Population Data)			
2019 Denver Great Kids Head Start Community Assessment (Denver Office of Children's Affairs, 2019)	This 2019 report, prepared by Denver Great Kids Head Start and the Office of Children's Affairs, provides statistics and information about sociodemographic factors, education services, and some health conditions that could impact early childhood education attainment in GES.	This report highlights that in 2019, while childcare demand in Globeville was being met, Elyria-Swansea was in need of more childcare options. Childcare and childhood health are an often-sited priority for GES residents.	The report only mentions Globeville in text, with regards to third grade students not meeting expectations on English language arts assessment. The report does not mention Elyria or Swansea in text. However, all three neighborhoods are highlighted in the static maps throughout the report as having disparities in early childhood education.
Community Hubs (Denver Public Schools, n.d.)	Denver Public Schools operates community hubs which provide services such as GED classes, citizenship preparation, financial planning, and multilingual education support. One of the community hubs is located at Swansea Elementary School. This website provides contact information for each hub location.	There is a community hub located at Swansea Elementary, which could provide a useful resource for neighbors.	Services vary by Hub location. It is unclear from the website which services are offered at Swansea Elementary.
Tepeyac Community Health Center 2021 Annual Report (Tepeyac, 2021)	The Tepeyac Community Health Center is one of the only healthcare centers in GES. This report provides information about the Tepeyac Community Health Center, including	This report can be utilized to highlight who Tepeyac serves, and to understand more about health insurance status and access among GES residents.	This report only describes health service information for one center, and cannot be generalized to form conclusions about healthcare in GES.

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	information on number of patients served as well as their insurance status.		
Settlement			
I-70 East ROD 1: Phase 1 (Central 70 Project). (Horn, 2017)	This technical report is the January 2017 record of decision update on the Central 70 Project for I-70 East. The report provides the federal highway administration's decisions regarding the project, based on the previously conducted environmental impact statements and evaluations.	This document provides contextual information regarding the Central I-70 Project. The Central-70 settlement funds the GES Community Health Study. Throughout this Study, residents have expressed concerns regarding potential environmental health and construction impacts to everyday life as a result of this highway project.	The main limitation of this report is that it has a lot of jargon that is not common knowledge, making it difficult to read.
Lewis M. RE: Sierra Club *et. al* v. Elaine Chao *et. al* [No. 1:17-Cv-01661-WJM-MEH] Confidential Communication in Possible Settlement: Subject to Federal Rule of Evidence 408. (Lewis, 2018)	This report outlines the official settlement agreement arising from the litigation case Sierra Club et al v. Elaine Chao et al. It provides a comprehensive overview of the terms of the settlement, offering insights into the conditions agreed upon by both parties. Additionally, the report summarizes the broader context of the case, highlighting the key issues at stake. However, one notable limitation of this document is its nature as a legal text, which can render it challenging to read and fully grasp without a background in legal language and principles.	This document is part of the settlement background and was provided by CDPHE.	The settlement documents are not readily available to the public. For access, please contact the GES Community Health Study Steering Committee.
Report to the Club on the Settlement of Sierra Club et al. v. Chao, et al. (D. Colo. No. 17-1679) (Burton, 2019)	This report details the Sierra Club's role in the settlement of the case Sierra Club et al. v. Chao et al. It summarizes the actions taken by the Sierra Club and related community	The GES Community Health Study is funded under the Central-70 settlement.	The report provides background on the Central-70 project, outlines the initial steps taken, and describes the litigation process that followed.

TITLE (PUBLICATION; DATE)	SUMMARY	INCLUSION REASONING	LIMITATIONS
	organizations concerning the Central-70 project settlement. Additionally, it summarizes the settlement agreement and concludes with insights on implementation and lessons learned throughout the process.		
Water, Soil & Superfunds			
VB/I-70 Group: Your Questions Answered: Globeville Landing Park Redesign (CCOD, 2017)	This factsheet, published in 2016 by the North Denver Cornerstone Collaborative, addresses frequently asked questions (FAQs) regarding the redesign of Globeville Landing Park. The park is situated within the Vasquez Boulevard Interstate 70 Superfund site, and the construction aspect of the project was categorized as a removal action by the Environmental Protection Agency (EPA). The project's objective was to develop an area that functions both as a park and as a stormwater outfall for the South Platte River. The construction was completed in 2020.	This document answers key questions and concerns community members and interested parties may have regarding Denver's Globeville Landing Park Redesign. Healthy parks, greenspaces, and water systems aid in positive community health outcomes.	FAQs cannot provide a comprehensive list of questions or address every concern a community may have. While there is a range of topics covered in this FAQ, it is unclear how these questions were gathered.
2016 Water Quality Update (CCOD, 2016)	This report presents an overview of water quality in the City's streams during 2016 and describes ongoing efforts by Denver and its stakeholders to improve water quality. The report also contains information on actions citizens can take to prevent pollution from reaching Denver's streams and lakes. Includes the stormwater project plan in Elyria-Swansea	This document includes an outline to build the Globeville Landing Park to improve local storm water quality, ecosystems, and wildlife corridors.	This document is a plan from 2016, and the project has since been executed and can be viewed at this link: https://www.aslacolorado.org/award/globeville-landing-park This report also does not address drinking water quality. It may not be highly relevant to

TITLE (PUBLICATION; DATE)	SUMMARY	INCLUSION REASONING	LIMITATIONS
	from 2016, but no update on completion or improvement of water quality.		neighbors, but it is included for historic reference.
Denver Water. Lead Service Line Replacement Program (CCOD, 2021)	Denver Water's lead reduction program, which was approved in 2019, aims to replace all lead service lines in its service area. This project is expected to be completed by 2035. A service line is the pipe that carries water from the main water line, which typically runs parallel to the street, to the plumbing inside a property.	GES residents have expressed concerns regarding lead and its impacts on health. They also express lack of clarity/communication regarding the lead removal process. Some residents report that lead pipes have been addressed on their streets, while others have not seen those changes. Neighbors express concern about led in connection with broader concerns about older homes and related environmental health risks.	It is important to note that this initiative does not cover updates to the plumbing within the premises. Therefore, any necessary plumbing updates inside the home will be the homeowner's responsibility and expense.
Final Remedial Action Report. Vasquez Boulevard/Interstate 70 Operable Unit 1 - Residential Soils, Denver, Colorado (Romalia et. al., 2017)	The Final Remedial Action Report provides an overview of residential soil testing and remediation at the Vasquez Boulevard/ Interstate 70 (VB-I70) Operable Unit 1 (OU1) superfund site in Denver, Colorado. The site is located within GES. In addition to detailing the soil sampling, community health biomonitoring, and soil remediation processes, this document also provides a chronology of events and provides tables of property soil statuses within VB/I-70 OU1. Residents can find the date their residential soil was sampled and (if necessary) the date contaminated soil was removed.	This technical report provides soil sample information directly related to concerns GES residents have expressed throughout this Study.	Property Status tables appear to have incomplete information. For example, despite soil removal being conducted at a couple homes, the waste soil disposal location is not identified.

TITLE (PUBLICATION; DATE)	SUMMARY	INCLUSION REASONING	LIMITATIONS
Third Five-Year Review Report for Vasquez Boulevard and I-70 Superfund Site. (Smidinger, 2019)	The EPA prepared this document to explain the progress they have made in remediating this site since the last 5-year review. This review includes Community involvement and site interviews, as well as site inspections. The review identified an issue that some property owner names were not found during property record research in Denver, the report provided a recommendation to address this by the next 5-year plan.	This document is relevant to concerns raised by GES residents regarding soil quality impacts of the superfund site.	The next review was due 9/30/2021, information in this document would provide more up-to-date information regarding the site remediation.
VB/I-70 Group: Vasquez Boulevard/Interstate 70 Superfund Site (CDPHE, n.d.)	This CDPHE webpage contains information about the Vasquez Blvd. Interstate 70 Superfund site. Readers can use this webpage as a starting point to learn more about the superfund site.	This CDPHE webpage includes history, current activities and technical documents that provide thorough background information on the Vasquez Blvd. Interstate 70 (VB I70) Superfund site. The page also provides resources that may be of interest to community members, including tips for safe gardening. Users can also find other relevant pages using this link, like the EPA's 2024 update to Lead guidance.	Some GES community members have voiced high concerns about soil quality, cleanups, and ongoing issues related to the VB I70 Superfund site. These pages can empower community members to dig into current and historical information, as well as contact the EPA with questions.

APPENDIX B. DATASETS

The following table outlines datasets specific to GES that were Incorporated in the GES Community Health Study Deliverables 2.2-2.6. The table highlights a summary of the document, reasoning for inclusion, as well as limitations.

Table 9. Summary of datasets, inclusion reasoning, and potential limitations.

Title (Source; Date)	Summary	Inclusion Reasoning	Limitations
Air Quality and Odors			
CAMML Air Monitoring Stations (CDPHE, 2023)	CDPHE web platform contains downloadable data (e.g., Colorado Air Monitoring Mobile Lab). Air Toxics and Ozone Precursor Data Repository and data regarding the CAMML at Eagle Point (2021) and Lorraine Granado (2023) can be located under the Oil and Gas Activity Monitoring Data & Reports section.	These data (CAMML Eagle Pointe and CAMML Lorraine Granado Park) were used in the HIA, and describe conditions within GES.	These data are not easily accessible, and require data cleaning for interpretation. Further, the webpage houses a variety of data files and reports, which can be confusing to navigate. During the development of this deliverable, many of the data download URLs are no longer working, limiting the future availability of these data.
Love My Air Dashboard (CCOD-DDPHE, 2024)	The Love My Air data dashboard, maintained by Denver Department of Public Health and Environment (DDPHE) is an interactive mapping platform that enables users to locate active air monitoring sites in Denver. Within the GES area, there are three designated monitoring locations: Tepeyac Community Health Center, Swansea Elementary School, and Lorraine Granado Community Park. At both Tepeyac and Lorraine Granado Park, the air pollutants monitored include particulate matter 2.5 ($PM_{2.5}$), carbon monoxide, nitrogen	Air quality has been a central concern throughout the GES Community Health study, and this data dashboard provides a user-friendly platform that delivers visible, accessible, and actionable information on air quality. Residents can zoom in to understand what air quality monitors in their neighborhoods are capturing. They can also compare this numbers to monitors in nearby neighborhoods.	This online mapping tool contains information about the current status of air quality around Denver, however longer time trend data are not readily available from this platform.

Title (Source; Date)	Summary	Inclusion Reasoning	Limitations
	dioxide, ozone, and particulate matter 10 (PM_{10}). Swansea Elementary School focuses specifically on monitoring particulate matter 2.5 ($PM_{2.5}$).		
Odor Complaints (CCOD-DDPHE, 2023)	Denver Department of Public Health and Environment provided data on odor complaints for 2022 and January and February of 2023.	Odor is frequently cited as a concern by GES residents. These data provide information on odor complaints related to the GES area.	One main limitation of this dataset is that it is not publicly accessible, requiring a formal data request to obtain it. Additionally, the complaint data encompasses all 311 service requests, which include, but are not limited to, issues such as loose animals, abandoned vehicles, litter, snow removal complaints, and odor complaints. We filtered this dataset to focus specifically on odor complaints related to the GES area.
Social Determinants of Health (Population Data)			
American Community Survey 5-Year Estimates, 2013-2017 and 2017-2021 (U.S. Census Bureau, 2022)	The US Census Bureau's American Community Survey (ACS) is an ongoing survey that provides demographic data. The ACS 5-year refers to the demographic data collected over a five-year period. Demographic information includes age, sex, race and ethnicity, employment status, educational attainment, living arrangements, and income status. Data can be examined at various scales, including state, county, census tract, and block group levels. These data are vital to understanding the existing conditions	The ACS data provide important population data at more regular intervals than the decennial census, and includes data as granular as the census block level, making it useful for GES residents. We used both ACS 5-year estimates from 2013 to 2017 and 2017 to 2021 for various deliverables throughout the GES Community Health Study.	The ACS data may not reflect the full community experience, and may generate fear among residents who are foreign born or are not citizens. These data, unlike the decennial census, are a weighted sample that include some but not all households.

Title (Source; Date)	Summary	Inclusion Reasoning	Limitations
	that serve as a backdrop to environmental health considerations.		
CDC/ATSDR Social Vulnerability Index (SVI) (Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry/ Geospatial Research, Analysis, and Services Program, 2024)	The Social Vulnerability Index provides community-level data on the following topics: Socioeconomic status; Household characteristics; Racial & ethnic minority status; and Housing type and transportation. The themes are then combined into a single measure of overall social vulnerability. The SVI Index provides data at county, zip code, and census tract levels. The SVI provides neighborhood level information on social socioeconomic status, household characteristics, race and ethnicity, housing, and transportation. These factors are combined to inform a Social Vulnerability score, which attempts to characterize social conditions that could impact community's capacity to withstand disasters.	SVI includes social and environmental determinants of health. It is calculated at neighborhood level, allowing for neighbors to explore data specific to GES.	The SVI framework is deficit-based, characterizing communities by their vulnerabilities rather than their strengths.
Colorado EnviroScreen (CDPHE, 2023)	Colorado EnviroScreen is a mapping tool that uses data for population and environmental factors. Factors are aggregated into a composite "score." The higher the score of a geographic area, the more likely that area is affected by environmental health injustice. As a dynamic "drill down" map, EnviroScreen provides data at county, census tract, and block group level.	Data are available at the census tract level for GES, and are useful for understanding health outcomes included in this Study such as asthma, diabetes, tobacco use, and more. Additionally, data are comparable to other Denver neighborhoods and relevant to the concerns GES residents have shared during Study meetings.	While this tool is useful for visualization and is very user friendly, the tool may contribute to a deficit-based framing of communities facing EJ challenges if users only view the "composite score" that could detract from nuanced understandings. Users can find more specific data on pollutants, climate impacts, and so on by exploring the tool. Users should recognize that many of the data were collected at

Title (Source; Date)	Summary	Inclusion Reasoning	Limitations
			different times, because not all indicators have updated data available at the same intervals.
Human Services Index (2023, 2024) (Denver Human Services, 2024)	This data library displays data on social determinants of health in all Denver neighborhoods to show areas where there are societal and systemic challenges that may be limiting communities. The platform also shows resourced and under-resourced neighborhoods across Denver to hopefully have these data better collaborate with community partners to improve conditions for Denver residents.	Denver Human Services Index compiles 16 essential indicators by neighborhood into a summary map. Decision-makers and community partners can use this map to inform programs, practices, services, and investments throughout the Denver community.	The key limitation of the HSI is that the 2023 data are no longer accessible, as the site platform is updated with 2024 information, with no option to review previous years. This makes it difficult to look at larger historical trends.
Human Health Outcomes			
Blood Lead Levels in Children. Rate of Elevated Blood Lead Levels in Globeville and Elyria-Swansea (CDPHE, 2021)	The percentage of elevated test in children under 6 from 2017-2021 was provided by the Childhood Lead Prevention Program at CDPHE. Elevated tests are those greater than or equal to 3.5 µg/dL.	Lead is a stated concern of residents. Lack of communication and trust in lead removal/soil remediation processes in GES has been an ongoing point of frustration and conversation.	These data were obtained by data request, limiting data accessibility. Also, these data are from 2017-2021, which may not reflect the current status of children's blood lead levels.
CHORDS Maps and Data Visualization Hub. Colorado Health Observation Regional Data Service (CHORDS, 2020)	The CHORDS Maps and Data Visualization Hub uses electronic health records data from partnering healthcare providers to understand population health at the census tract-level in several Colorado counties, including Denver. Indicators include asthma, depression, anxiety, diabetes, obesity and overweight, tobacco use, and hypertension. While CHORDS no longer updates the data (2019-2020 data visualized), these maps provide a	The Colorado Health Observation Regional Data Service (CHORDS) compiles health care, public health, and behavior health electronic health record data to identify and visualize health trends. These data, used in Deliverable 2.2, included asthma, depression, anxiety, diabetes, obesity and overweight, tobacco use, and hypertension. Additional CHORDS information can be found at	CHORDS was an initiative by healthcare providers and public health organizations in metro Denver, Larimer, and Weld Counties to track health measures through electronic health records. Electronic health records were shared by participating healthcare providers to a central database that then calculated rates for health measures based on the total number of people who sought care at a participating provider. This initiative recently stopped

Title (Source; Date)	Summary	Inclusion Reasoning	Limitations
	helpful context for existing health conditions in GES among adults who received care from a participating health provider.	https://www.coloradohealthinstitute.org/research/CHORDS	operating, and the most recent data available through a web map is from 2019-2020. Requests by our team to access the datafiles underlying the web map were denied, so where included, CHORDS data were manually recorded from the web map. These data have significant limitations based on who received care from the participating healthcare providers. Without greater level of detail that is no longer provided, it is difficult to assess exactly how the reported data (manually recorded) differ from the true rates.
COVID-19 Data (CDPHE, 2024)	This CDPHE webpage contains information on viral respiratory diseases. There are three primary viral disease conditions reported, including SARS-CoV-2, Influenza, and RSV. There is also a link which takes users to the CDPHE Open Data platform, where COVID-19 data are located. The Colorado COVID-19 Data Summary contains data on cases, hospitalizations, and deaths since the start of the COVID-19 pandemic to the end of 2024.	As reported in Deliverable 2.2, the 2020 morbidity and mortality weekly report found that between March and-October 2020, the majority of adults COVID-19 cases in Denver were among residents who identify as Hispanic or Latino. We used these data in Deliverable 2.2.	These data are at the state-level and statistical analyses were required to estimate the standardized mortality ratio of COVID-19 in GES.
Global Burden of Disease Study Data (Global Burden of Disease Collaborative Network, 2021)	The Institute for Health Metrics and Evaluation at the University of Washington led the Global Burden of Diseases, Injuries and Risk Factors Study (GBD). GBD uses data from different sources, such as hospital records, clinical trials, surveys (e.g., American Community	GBD data were used in Deliverables 2.4-2.6 for all-cause mortality, all-cancer mortality, respiratory disease mortality, cardiovascular disease incidence and mortality, chronic obstructive pulmonary disease mortality, stroke incidence and mortality, childhood	State-level data from the GBD were necessary because small-area estimates for Denver or GES could not be utilized either due to a lack of data for the analyzed period (2017-2021) or because available health outcome data did not meet our specific requirements (e.g., only prevalence data were available when we

Title (Source; Date)	Summary	Inclusion Reasoning	Limitations
	Survey), disease registries, and epidemiological surveillance records.	asthma incidence, hypertension incidence, and type two diabetes incidence.	required incidence data). This may not fully capture neighborhood level health outcomes.
PLACES: Local Data for Better Health, Census Tract Data (CDC, 2023)	CDC's PLACES interactive map and data portal provides health-related information, such as health outcomes, social determinants of health, prevention, risk behaviors, and dis/ability. These data are presented at county, place, census tract, and ZIP code level. CDC PLACES data consists of small-area estimates that combine Behavioral Risk Factor Surveillance System (BRFSS) survey data with American Community Survey (ACS) sociodemographic characteristics.	Data are available at the census tract level for GES, and are useful for understanding health outcomes included in this Study.	These estimates have limitations because they are derived from a statistical model rather than direct survey results. As a result, there is a higher likelihood that these values may differ from the actual figures in the community.
Registries and Vital Statistics. Birth and Mortality Rates (2017-2021) (CDPHE, 2023)	CDPHE Center for Health and Environmental Data provides county level data on vital statistics (e.g., births and deaths). Specific health at birth and mortality data at a geographical scale smaller than county level were used in the GES study. These data were obtained through an official vital record request to CDPHE Center for Health and Environmental Data. Vital records data include births and deaths available at the County level. To submit a request, contact cdphe.healthstatistics@state.co.us.	These data provide more detailed information about births and deaths in GES than is available online, which helps inform our understanding of different birth and mortality trends in GES compared to other neighborhoods.	These data are limited because they are not open access, and a data request must be completed. However, this is done to protect sensitive information such as low counts of birth or mortality outcomes at small enough geospatial scales that the individuals impacted could potentially be identified. Additionally, vital statistics, while considered high quality and complete, these data are also limited in certain regards. Birth records collect information at the time of birth, so health outcomes that are not apparent at birth are not collected well. Death records record the main cause of death and may not include contributing factors. For example, extreme heat increases the risk of heart attacks, but the

Title (Source; Date)	Summary	Inclusion Reasoning	Limitations
			cause of death will likely be recorded as a heart attack, not the heat stress that contributed. Additionally, death records do not represent conditions that do not often cause death, such as asthma. Both birth and death records are also limited for rare outcomes in that too few cases make it difficult to compare the rate between two locations. To minimize the limitations, we combined vital statistics for a five-year period (2017-2021).
Environmental Data			
Denver Open Data (CCOD, n.d.)	This is the main landing page for Denver Open Data Catalog, where users can search for data at the county level and smaller. Users can find data on zoning, statistical neighborhoods, and other infrastructure.	These data can be used to understand infrastructure at the neighborhood level in GES, as well as the rest of Denver. They present relevant aspects of built environment in GES.	While this data catalog provides valuable contextual and reference information for GES, it does not capture qualitative data regarding lived experiences and everyday life for GES residents.
Denver Open Data – Recreation Centers (CCOD, 2023)	This dataset provides the locations of recreation centers in Denver. This includes Recreation centers in GES (such as 5090 Broadway, Globeville Recreation Center, Johnson Recreation Center, and Swansea Recreation Center). The table includes information regarding the addresses of each recreation center, the amenities, programs, and website links.	This dataset is relevant to the GES Health Study because it provides information related social determinants of health. Recreation centers provide safe places for residents and youth to actively engage in their community.	While the dataset provides programmatic information, it does not provide information regarding how many GES residents utilize the recreation centers, nor how the recreation centers may compare to other neighborhood facilities.

Title (Source; Date)	Summary	Inclusion Reasoning	Limitations
Denver Open Data - Statistical neighborhoods (CCOD, 2023)	This dataset provides geographic information on Denver's statistical neighborhoods. These geographical data provide context to the GES neighborhood, and could serve as a reference map for layering relevant environmental health data.	This dataset provides contextual information regarding how CCoD defines the Globeville and Elyria-Swansea neighborhoods.	While this dataset provides valuable contextual information regarding neighborhood boundaries, it is important to recognize that definitions of "community" may vary. During the GES Community Health Study, some residents have expressed viewing GES as three individual neighborhoods.
Denver Open Data - Street Centerlines (CCOD, 2023)	This dataset contains geographic information on CCoD's streets and alleyways. As Denver has grown, the streets have been digitized from various sets of aerial photography, and as new subdivisions are constructed those streets are also added to this dataset.	This dataset provides contextual information regarding the built environment of GES and Denver.	While this dataset provides contextual information regarding the streets and alleys of Denver, it does not provide information regarding the current conditions of the road or upcoming infrastructure plans.
Denver Open Data - Zoning (CCOD, 2023)	These data contain information on the zoning boundaries of CCoD. The zoning boundaries data are governed by ordinance and only change accordingly.	These data can be used to understand infrastructure at the neighborhood level in GES, as well as the rest of Denver. They present relevant aspects of built environment in GES.	While zoning data are incredibly valuable to understand neighborhood-level planning, this information may not include the actual activities occurring on the land.
Denver Regional Bicycle Map (Denver Regional Council of Governments, 2024)	These data maps show where there are bicycle facilities in Denver including both on-and-off-street travelways that are not exclusively recreational. These data can serve as a visual representation of bicycle lane infrastructure in Denver, including GES. The paths serve both recreational and other functions and are a component of neighborhood connectivity and mobility.	These data can enhance neighbors' understanding of connectivity and mobility in GES compared to the rest of Denver.	This source highlights very few designated bike paths within the boundaries of the GES neighborhood, which may make this resource less useful.

Title (Source; Date)	Summary	Inclusion Reasoning	Limitations
Department of Revenue – Liquor License Lists (CDOR, n.d.)	The dataset provides information for all liquor licensed facilities throughout Colorado. Some examples of the types of liquor licenses include categories such as taverns, hotels and restaurants, entertainment facilities, wholesale, manufacturer, and retail liquor stores. Information in datasets includes license and business names, license numbers, license type, and street addresses.	Licenses for alcohol retailers were used in the HIA but were limited to off premises license types, including the following types: fermented malt beverage and wine off-premises, liquor licensed drug store, and retail liquor stores.	While this dataset provides helpful information regarding the physical location of businesses with liquor license, registries cannot provide key experiential information of what it means to live near an abundance of alcohol retailers. Additionally, this dataset does not provide information regarding if employees are GES residents or the extent to which businesses support the GES economy.
Department of Revenue – Medical Marijuana Licensed Facilities (CDOR, n.d.)	This dataset provides location information for Medical Marijuana Licensed Facilities throughout Colorado. This includes all marijuana business licenses. Categories include cultivation, delivery, hospitality, operators, product manufacturers, research and development cultivators, stores, testing facilities, and transporters. Information in datasets includes business names, license numbers, facility type, and street addresses.	Three subsets were used in calculating spatial access in the HIA: marijuana cultivations, marijuana stores, and off-premises alcohol.	While this dataset provides helpful information regarding the physical location of businesses with medical marijuana licenses, registries cannot provide key experiential information of what it means to live near an abundance of MED licensed facilities. Additionally, this dataset does not provide information regarding if employees are GES residents or the extent to which businesses support the GES economy.
Food Access Research Atlas (Economic Research Service (ERS), U.S. Department of Agriculture (USDA), 2021)	The 2019 USDA food access atlas is a geospatial dataset that presents an overview of food access indicators at the census tract level using different measures of supermarket accessibility.	During the Study, GES residents have expressed concerns regarding food access.	These data are compiled in an Excel spreadsheet using census tract polygons from the 2010 census. Accessing these data requires GIS software, which can limit its availability. Additionally, the atlas is based on 2010 census tracts, which may not account for changes in census boundaries or how communities perceive their neighborhood boundaries.

Title (Source; Date)	Summary	Inclusion Reasoning	Limitations
Interactive Greater Denver Transit Map (Denver Greater Transit, 2022)	This map provides a visual representation of Denver's local transit routes as of 2023. This map includes local and regional RTD bus and rail routes, AMTRAK routes, and more. They demonstrate strengths and gaps in neighborhood connectivity.	These routes may be useful for neighbors who are seeking public transit to enhance neighborhood connectivity.	These routes were updated in 2023, so they may not be useful to GES residents who are seeking the most up to date information.
Mapping Inequality: Redlining in New Deal America (Nelson, 2023)	The Mapping Inequality project is an online mapping tool where users can see historical redlining maps as they overlap with current day city layouts. The website hosts both literature about redlining, a racially discriminatory practice implemented under the Home Owner's Loan Act of 1933. Residential Security Maps were used to rank (e.g., A, B, C, D) and color-code neighborhoods on a spectrum of most desirable (A; green), still desirable (B; blue), declining (C; yellow), and hazardous (D; red). To use the mapping tool, users can select the "Explore Maps" tab, or under download the data, search for a city of interest.	The history of redlining in Denver and GES informs current environmental health and justice conditions that are relevant to neighbors.	These are historical data and should be used to inform long-term understanding. It does not reflect or visualize current conditions or laws.
Micromobility Dashboard (Ride Report, 2023)	The Ride Report provides micromobility data at the street level. The heat map provides e-bike and scooter rides, as well as dashboard data regarding average trip distance, number of trips, and average trip speed.	Mobility and accessibility have been voiced as concerns of GES residents.	These data only consider micromobility options from businesses (such as Bird and Lime). This dashboard does not factor in personally owned transportation options. Cost may be a barrier for people to utilize Bird and Lime micromobility options.

Title (Source; Date)	Summary	Inclusion Reasoning	Limitations
National Transportation Noise Map Documentation and Data (Bureau of Transportation Statistics, 2022)	This dataset tracks trends in transportation-related noise. The accompanying map visualizes noise linked to aviation, rail, and road use. The interactive National Transportation Noise Map is available for the general public to view online. Additionally, raster and geodatabase files are available for download.	Residents have expressed concerns regarding noise from transportation activities in GES.	This dataset is from 2020. More up-to-date data would be helpful to assess the extent to which noise in GES has been affected by the Central I-70 project.
National Walkability Index (EPA, 2023)	The EPA Walkability dataset provides geographical information that ranks census block groups according to their relative walkability. The dataset was developed using factors such as land use types and proximity to transit. This source can be used to visualize, assess or compare neighborhoods, as well as inform policy or investment decisions. The Interactive Map Tool prioritizes visualizing how workplace location may impact commute.	Connectivity and mobility are often cited as important issues for neighbors in GES. The Walkability Index is one tool for visualizing or describing neighborhood connectivity and developing priority areas for development.	The tool centers workplace locations and commutes, meaning the information may not be relevant to community members who are interested in neighborhood connectivity to access locations such as supermarkets, healthcare facilities, parks, and more. Further, if data from this tool are utilized without input from neighbors, the information could lead to development that does not respond to community member's goals, concerns, or needs.
Street Temperatures (2009 - 2019) (DOTI, n.d.)	Data on surface temperatures averaged at the street segment level were made available to the ENVIRONS team by Chauncie Bigler of the Denver Department of Transportation and Infrastructure (DOTI), Division of Green Infrastructure. These data were originally published in their Denver Green Continuum Streets Guidelines in October, 2021.	This dataset may be particularly helpful as the climate change continues to impact heat trends across Denver and in GES.	These data are limited because they are not open access, and a data request must be completed. The obtained data were provided as land surface temperature by street segment and then percentile ranked. This limited our ability to conduct a quantitative analysis, and in the HIA we mapped street temperature percentiles by quartile and made qualitative comparisons between GES and other parts of Denver.

Title (Source; Date)	Summary	Inclusion Reasoning	Limitations
Tree Equity Score (American Forests, 2023)	This dataset provides a tree equity score based on tree canopy, demographics, health, and historical data (such as redlining). The composite score provides a priority level (low, moderate, highest) and a priority index at the Census Block Group level.	These data connect tree canopy concerns with socioeconomic factors. In this way, these data are relevant to the Study and connects to concerns expressed by GES residents.	This site is updated as new census and tree canopy data are released. This means that updates are dependent on when resources are available.
Soil, Water & Superfunds			
Colorado Segmentation 2024 (CDPHE, 2024)	Colorado Segmentation is a mapping data platform about streams, lakes, and water basins in the state. This map platform visualizes streams, lakes, wetlands and basins across the state.	Water access and quality are relevant to environmental health and community wellbeing. This map shows water resources in GES, and across the entire state.	This information may not be highly relevant to GES community members and was not an important source of data for the overall GES Health Study.

Root Cause Analysis

GES Community Health Study

In response to Deliverable 2.8

March 14, 2025

ENVIRONS

Colorado State University

COMMUNITY RELEVANT SUMMARY

Note: This section was written by the Community Council as a preface to the report.

The GES Health Study community council held an activity called the "5 Why's" to get to the "Root Causes" of just a few of the issues that we face in our community. Through this activity, we noted that while there are various root causes to these issues, we were able to get clear about where these issues come from. You can also identify the root cause of an issue in our community. Here was our approach.

The topics we chose to address for this activity and their resulting "whys" are as follows:

- **High rates of Asthma are a concern in our community**
    - Dust
        - Dust is an irritant for people with Asthma
            - Local dust is contaminated due to historic industrial pollution
                - The EPA didn't do a good Job of cleaning the soil
                    - We need to ask the EPA to clean the soil again
    - General Pollution
        - I 70 Pollution
            - Large Trucks and heavy traffic on I70
                - Pollution and contamination are irritants for asthma
                    - Pollution from large projects in the area are a result of poor government planning and not taking into consideration the risks to residents
    - Historic Respiratory illnesses
        - People worked at the iron smelter and the toxic industries
            - People had no idea of the long-term effects of these industries on their bodies and communities
                - Maybe the local industries predated the expansion of residences and had no idea how much the area would expand
                    - It feels like because of the longevity of these issues that the city does not pay close attention to our issues like our high Asthma rates
    - Constant Construction
        - Little control of dust and pollution from construction sites
            - No one at the city takes responsibility for the duration and contamination
                - The residents feel unheard
                    - We are told that this is our fault for living near I70
                        - People have nowhere else to go as housing is still somewhat affordable here
                            - I70 cut through the neighborhoods after the people were already here

- Frequent visits to the hospital
    - Asthma can be severe and can require additional medical attention
        - Asthma is caused by inflammation around the airways
            - Asthma can worsen over time

- **Strong Odors are a constant problem for our neighborhoods**
    - Smells
        - Various sources of odors including Slaughterhouses and Purina
            - Ongoing poor smells are an irritant for asthma as well
                - We need real action from the city to address this concern
                    - Protecting Purina to preserve their taxes is in the cities benefit but is not good for locals
                        - It feels like the city wouldn't allow this for other communities
                            - The city should care for us just like they do other neighborhoods
    - Odors can be noticed immediately
        - When we call 311 it takes them a while to come check the issue and they require many calls for anyone to even come out to check in the first place
            - They are never fast enough to smell it when it's at its worst
                - There are not enough regulations against the odor producers
                    - The few regulations there are don't feel enforced
                        - We don't feel heard by the city
                            - The city should be held accountable
    - Odors have negative impacts on our mental health and emotions
        - Bad odor in your neighborhood is embarrassing and affects your self esteem
            - The bad odor outside also isolates us from our neighbors because we often have to stay indoors
                - We don't go out for walks
                    - Our physical and mental health is affected by Purina and other strong odors

- **Being a community of immigrants comes with severe challenges**
    - Neighbors are experiencing higher levels of stress and fear
        - Stress of losing home or having to leave family means you may fear going to work
            - This can cause mental and physical health problems
                - Causing a lack of self-esteem and confidence
                    - Causing isolation from organizing collectively
                        - Causing generational PTSD
    - Migrants often experience a lack of access to resources in Spanish or that can support despite their status
        - Can't apply for financial aid

- Can’t receive tax incentives or refunds
    - Systematic Injustice
        - Environmental and institutional racism are prolific
            - Even more today
                - Fear of speaking with politicians to advocate for migrant communities

- **Food Insecurity is a major issue in our community**
    - Very little food access in the GES neighborhoods
        - Even less availability of fresh health food
            - You need a vehicle to get to a store because they are so far away
                - Stores are not brought to the neighborhood that are culturally relevant
                    - City doesn't seem to advocate for fresh healthy or culturally relevant food in our area
                        - City continues to approve dispensaries in the area
                            - They approve these kinds of businesses because they don’t want them in nice neighborhoods
                                - They give the “nicer” neighborhoods food access
    - The soil is contaminated
        - Growing vegetables in contaminated soil may not be healthy
            - The city never cleaned our soil enough for us to safely grow our own food

All of the topics that we addressed during the 5 whys activity are really important in the community. Some topics may be more important from person to person but there wasn’t any one topic that outweighed the others. We did dive into a deep conversation about air contamination since it was related to so many of the topics, including asthma rates and odors in our community. Another theme that we noted was that in many examples that the city was a responsible party to many of these issues that wouldn’t be tolerated in other Denver neighborhoods.

By following the 5 Why’s activity, we were able to get closer to the root causes of these 4 topics, but we recognize there are other challenges in our community. Together, we can continue to use this critical thinking tool to address other issues and to better identify what institution is responsible and needs to be held accountable.

We know that facing these issues is exhausting to the community, however, neighbors should feel inspired by this activity to see more clearly the root cause - a truth- of our lived experiences with these ongoing issues. With this information, neighbors can get involved in collective efforts to continue to research who is responsible for each of these issues that affect our community. Our Asthma, the Odors, the food insecurity, and additional challenges faced by our immigrant neighbors are not our fault. Let’s get educated and call on

those that are responsible to address these issues. This may mean joining the efforts of local organizations or groups, or taking individual actions like calling federal, state, and local representatives. This burden is for the responsible institutions to address, not ours - not anymore.

ACKNOWLEDGEMENTS

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LIST OF ACRONYMS, DEFINITIONS, AND DESCRIPTIONS

Table 1. List of acronyms, definitions, and descriptions

TERM	DEFINITION
CC	Community Council is a group of resident collaborators part of the research team that act as community representatives, experts, and liaisons.
CCoD	City and County of Denver
CDC	Centers for Disease Control; the Centers for Disease Control and Prevention is the national public health agency of the United States.
CDOT	Colorado Department of Transportation; the principal department of the Colorado state government responsible for maintaining interstates and highways in Colorado.
CDPHE	Colorado Department of Public Health and Environment; CDPHE is the principal department of Colorado state government responsible for public health and environmental regulations.
CEBA	Community environmental burden assessment. The GES Community Health Study CEBA is comprised of Deliverables 2.4, 2.5, and 2.6.
DDPHE/DEH	Denver Department of Public Health and Environment (DDPHE), formally called Denver Environmental Health (DEH); the city department responsible for public health and environmental regulations, serves a similar function as CDPHE, but at a local level.
DOTI	Denver Department of Transportation and Infrastructure
DRCOG	Denver Regional Council of Governments; serves as the metropolitan planning organization for the region
Environmental justice (EJ)	Environmental justice is the idea that all people and communities have the right to live and thrive in safe, healthy environments with equal environmental protections and meaningful involvement in these actions.
Environmental justice community	An environmental justice community can also be identified as a disproportionately impacted community. In 2023, Colorado officially defined disproportionately impacted communities as those meeting specific criteria including low income, higher proportions of residents from minoritized race and ethnicity groups, housing cost-burdens, linguistic isolation, historical marginalization, cumulatively impacted, tribal lands, and mobile home communities.

ENVIRONS	Estudio de Nuestros Vecinos para Investigar los RiesgOs y Nuestra Salud (ENVIRONS) research team is based out of Colorado State University in Fort Collins, CO and is responsible for conducting the GES Community Health Study.
EPA (US EPA)	United States Environmental Protection Agency; the primary agency of the United States government tasked with environmental protection.
GES	Globeville, Elyria, and Swansea neighborhoods
Health	Health is a state of physical, mental, and social well-being and not merely the absence of disease.
HIA	Health Impact Assessment; Deliverable 2.2 *The ABCs of GES: The State of Health and Environment* of the GES Community Health Study.
Neighborhood	The City and County of Denver recognizes 78 official neighborhoods, including Denver International Airport (DIA). These are often made up of a collection of census tracts. For example, GES includes three census tracts.
NWC	National Western Center
SC	Steering Committee; The steering committee are stewards of the Central 70 settlement agreement to ensure it is carried out appropriately.

INTRODUCTION

The residents of the Globeville, Elyria, and Swansea (GES) neighborhoods enjoy a rich and vibrant history as being some of the oldest neighborhoods in Denver, Colorado (Figure 1). However, throughout this history, GES residents have had to actively contend and engage with environmental health concerns. In 2017, GES residents opposed the Colorado Department of Transportation's (CDOT) expansion of Central Interstate-70 (I-70) through the GES neighborhoods. As a collaborative effort between the Sierra Club, the Elyria-Swansea Neighborhood Association, the Colorado Latino Forum, and the Chaffee Park Neighborhood Organization, community members brought legal action against CDOT.[1,2] This collective action was guided by the shared concern that the Central I-70 project would contribute to disproportionate environmental health burdens in GES. The resulting Sierra Club *et al.* V. Chao *et al.* Settlement agreement allocated funds for a comprehensive health study that focused on environmental health in GES.[2]

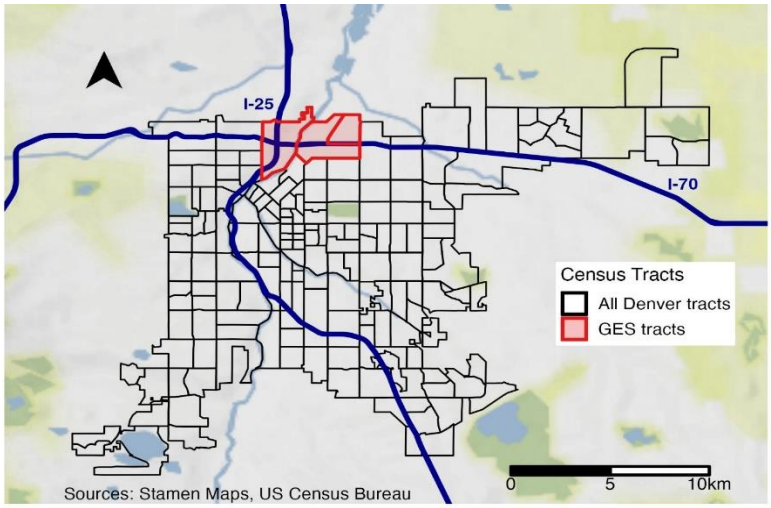

Figure 1. Globeville, Elyria, and Swansea neighborhoods in relation to the Denver area.

The GES Community Health Study evaluates the impact of environmental exposures on the health and well-being of GES residents. Understanding the historical and systemic contexts for environmental exposures in GES is a critical component to this study. Deliverable 2.8 Root Cause Analysis (RCA) provides a systems-thinking approach to analyzing the environmental causes of concern and health outcomes in GES.

RCA is a process for determining underlying reasons for a problem or outcome. Root cause analyses help participants move beyond *what* and *how*, to understanding *why* a problem might exist.[3] The point of the RCA process is not to assign blame, but rather to focus on systemic issues and potential opportunities for preventing the problem in the future.[4] However, this does not mean that various agencies and entities do not share a responsibility for improving conditions. As a problem-solving tool, the RCA's casual relationships and root causes alike become sites for recommendations and interventions.[3] RCA breaks down complex topics into small components to help interested parties identify pathways for intervention and action. This deliverable drew on public health literature that provided a community-led RCA framework that interrogated

structural factors in the analysis.[5–8] This deliverable is informed by health literature, previous deliverables, and community insights.

The success of the GES Community Health Study is dependent on the insights and input from community members. The Study's Community Council (CC) is comprised of GES residents who work closely with the ENVIRONS research team to ensure that Study deliverables address the needs, interests, and experiences of the GES community. The CC was pivotal in defining the scope and direction of Deliverable 2.8. It is impossible for any deliverable to address every health concern and uncover every root cause. Instead, Deliverable 2.8 focuses on four areas of concern, as identified by the CC, in order to begin investigating and identifying the structural and social root causes. As this Study was formed from the collective transformation of shared concerns into collaborative action, this community-engaged RCA process has the potential to mobilize everyday environmental experiences into sites of intervention across local, state, and federal scales.

In addition to conducting a comprehensive assessment, an underlying goal of the GES Community Health Study is to provide the evidence needed for community members and policymakers to advocate for environmental initiatives and changes. This deliverable is part of an assemblage of publicly accessible products being developed for the study, as outlined by the settlement agreement. Interested community members can find previous Study deliverables on the Study website, https://www.geshealthstudy.org/home. Table 2 provides a comprehensive list of previous Study deliverables.

Table 2. Description of GES Community Health Study deliverables.

Deliverable	Description
Phase I	Planning and Foundations deliverables included
Deliverable 1.1: ENVIRONS Questionaries	After participating in a tour of the GES neighborhoods, each ENVIRONS team member completed a questionnaire prepared by the Community Council. In addition to individual responses, a summary for the team was created.
Deliverable 1.2: Shared Operational Principles	The Community Council, ENVIRONS, and Steering Committee identified roles and defined shared values, motivations, expectations, and limitations for the study.
Deliverable 1.3: Community Engagement Plan	The Community Engagement plan was developed with the Community Council and Steering Committee. It defines how ENVIRONS will communicate with the Community Council and the Steering Committee, and outlines strategies for communicating with residents, soliciting community input, and maintaining transparency.
Deliverable 1.4: Narrative	ENVIRONS identified sources of data, literature, and on-going projects that will be used in Phase II. As part of this, ENVIRONS reviewed the materials provided in the "crowd sourced literature review" folder curated by the Steering Committee prior to ENVIRONS coming onto the study.
Deliverable 1.5: Mapping and Website	The website is available in English and Spanish, and maps are available on the Maps page.

Deliverable 1.6: Course Correction Plan	ENVIRONS worked with the Community Council and Steering Committee to create a course correction plan. This plan ensures that the study is headed in the right direction for Phase II.
Phase II	Analysis
Deliverable 2.1: Data Rubric and Literature Evaluation	ENVIRONS created a rubric to evaluate the quality of literature and data, then applied this rubric to the sources of information identified in the crowd-sourced literature folder or in the Preliminary Data Identification and Narrative.
Deliverable 2.2: The ABCs of GES: The State of Health and Environment	This report characterizes areas of community concern, provides updated data to topics identified in the 2014 Health Impact Assessment report, and evaluates the implementation of recommendations from the 2014 report.
Deliverable 2.3: Exposure Outcome Matrix	The Exposure Outcome matrix demonstrates the connections between environmental exposures in GES, health outcomes, and health disparities based on existing research. The purpose of this matrix is to visualize how environmental exposures (e.g. pollutants) are connected to adverse health outcomes.
Deliverable 2.4: Community Environmental Burden Assessment (CEBA): Planning, Scoping, and Problem Formulation	This document outlines the plan for how ENVIRONS will conduct the Community Environmental Burden Assessment (CEBA), which makes up Deliverables 2.4, 2.5, and 2.6 for the study.
Deliverable 2.5: Community Environmental Burden Assessment (CEBA): The Exposure Response Assessment Phase	This document outlines the methods and preliminary results of the CEBA including modeled air pollution exposures across Denver and literature review of exposure-response relationships.
Deliverable 2.6: Community Environmental Burden Assessment (CEBA): Burden of Disease and Future Scenarios	As the final installment of the CEBA, this deliverable highlights the extent to which health outcomes are attributable to air pollution in GES.
Deliverable 2.7: Updated Data Evaluations and Data Gap Analysis	As a continuation of Deliverable 2.1, this document evaluates data sources and literature used in Deliverables 2.2-2.6. It includes a data gap analysis that analyzes the availability of data on environmental stressors, health outcomes, and health disparities in GES.
Deliverable 2.10: Dynamic Maps	This document details the process for creating the study's web-based, interactive mapping tool that investigates environmental health concerns.

COMMUNITY-ENGAGED APPROACH

Underlying this deliverable is a place-based approach to conducting an RCA. Place-based means that this RCA is specific to the geographic area of GES and its residents, ensuring that the analysis bridges historical contexts with current conditions while centering the GES community. This necessitates a community-engaged process.[9] Expanding on the GES Community Health Study's continued community engagement, this place-based approach prioritizes the interests, needs, and insights of GES community members. The study team hosted two community meetings and dedicated two CC meetings to the RCA process. Additionally, the CC discussed and drafted Deliverable 2.8's Community Relevant Summary during an office hours meeting. At the following CC Meeting, the CC approved their Community Relevant Summary draft. While community meetings are open to the public, CC meetings are restricted to study team members in the CC, ENVIRONS research team, and the Steering Committee (SC). Figure 2 summarizes the timeline of the community engaged RCA process for Deliverable 2.8. Discussions from the community meetings provided both initial guidance and qualitative evidence for this deliverable. The CC members provided direction by selecting the RCA model utilized and the four health topics analyzed in this deliverable. This section provides a methodological narrative of how the GES Community Health Study designed, planned, and conducted the RCA process.

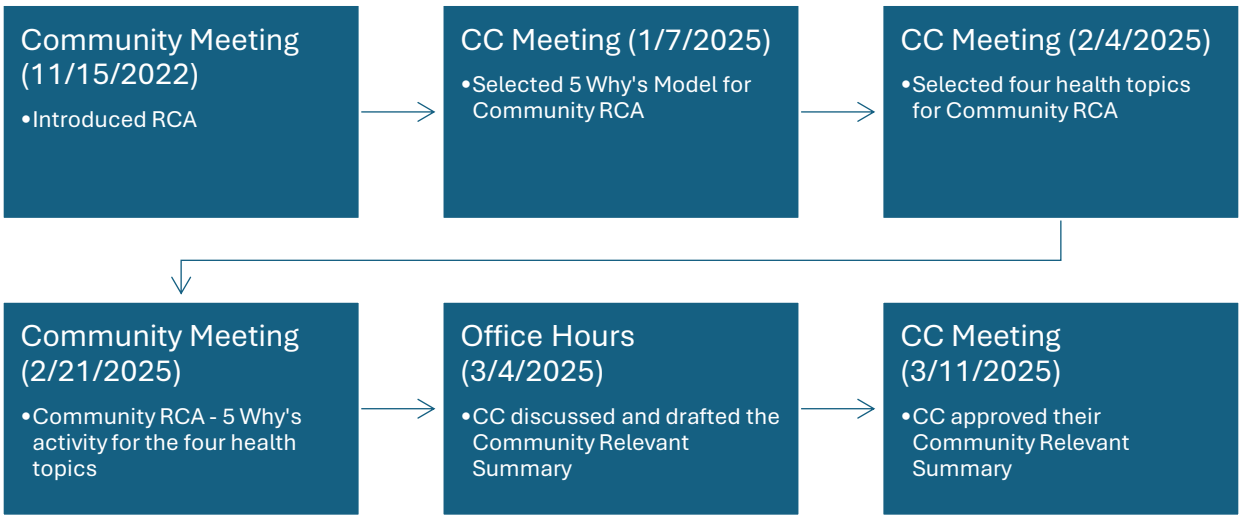

Figure 2. Timeline of Community Meetings, CC Meetings, and their outcomes for the RCA process.

ADDRESSING STRUCTURAL FACTORS

The initial RCA community meeting was held during Phase 1 of the GES Community Health Study on November 15, 2022. During this community meeting, the ENVIRONS research team introduced the concept of a root cause analysis and conducted a brief RCA activity using Jamboard.[10] The key problems identified were (1) people experiencing homelessness, (2) crime, and (3) the highway system in GES. This early meeting helped the research team understand community concerns regarding how systemic factors such as structural racism, socioeconomic status, and decision-making power impact health outcomes. The discussion from this meeting highlighted the importance of designing a RCA process that was specific and relevant to the concerns and experiences of GES community members, while also addressing larger systemic concerns. To address the former concern, the research team leaned into the GES Community Heath Study's preexisting community-engaged processes and relationships. For latter concern, the research team turned to health literature that addressed structural factors as root causes.

ADDRESSING STRUCTURAL FACTORS. Designing an RCA process for the GES Community Health Study requires the research team to be attentive to how structural factors play a role in impacting health outcomes. The GES Community Health Study's Deliverable 2.2 Health Impact Assessment (HIA) placed social variables into conversation with available health data, highlighting the extent GES contends with more environmental health concerns compared to Denver's average.[11] Deliverables 2.4-2.6 Community Environmental Burden Assessment (CEBA) demonstrated that GES experiences disproportionate health impacts when compared to the least environmentally burdened neighborhoods in Denver.[12–14] These deliverables highlight that the Globeville, Elyria, and Swansea neighborhoods experience a unique environmental health story that requires an RCA approach attuned to the specific historical contexts, current conditions, and community interests of GES.

The GES Community Health Study has previously utilized the Social Determinants of Health (SDoH) framework to examine existing health conditions in GES. Healthy People 2030 defined SDoH as the conditions of interconnected factors that impact health and wellbeing.[15] These factors are largely grouped into the following five categories: educational access and quality; health care access and quality; neighborhood and built environment; social and community context; and economic stability. While genetics only accounts for 30% of one's health status, the remaining 70% can be attributed to SDoH. But what determines a community's SDoH?

Yearby (2020) revised the SDoH framework to include root causes of health inequities.[5] Figure 3 demonstrates that root causes (such as structural discrimination) leverage tools (such as laws, policies, and decision-making processes) in order to affect the systems (seen here as SDoH) that influence health and wellbeing.[5] This revised SDoH framework pushes practitioners to dive deeper into structures and systems of root causes by considering how tools are mobilized to uphold goals, mindsets, and drivers. Additionally, the bidirectionality of Yearby's SDoH framework suggests that intervention can also be bidirectional. For example, this means that interventions with tools have the potential of influencing root causes *and* downstream systems.

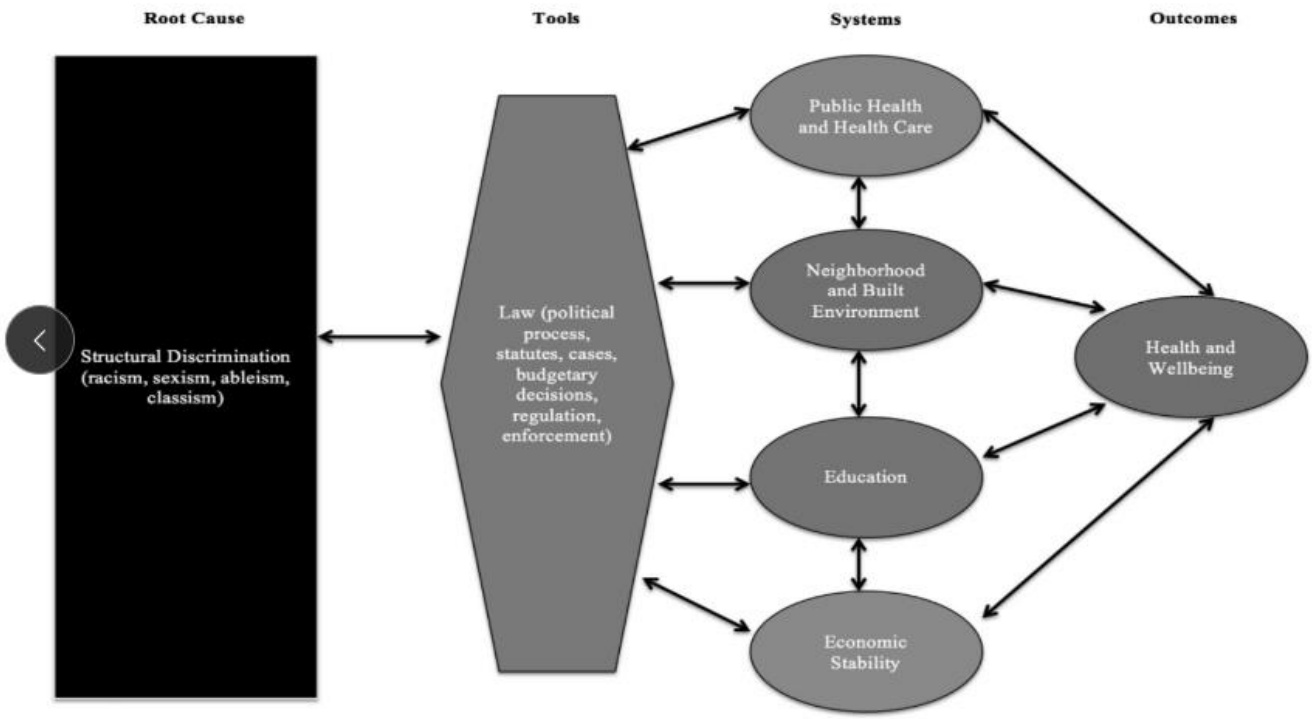

Figure 3. Yearby's (2020) revised Social Determinants of Health model to include root causes.[5]

Malawa *et al.* (2021) further interrogates the role of structural racism as a root cause of health inequities in the Racism as a Root Cause (RRC) approach.[6] The RRC framework is comprised of four core components that empower practitioners to address the large, multidimensional problem that is structural racism. These components include (1) prioritizing a specific racialized community in the analysis and interventions, (2) focusing on changing systems, what Yearby (2020) would define as "Tools," rather than changing individuals, (3) designing interventions that are long-term and sustainable, and (4) repairing historical injustices by shifting access to resources, power, and opportunities to include marginalized groups.[6] The RRC's emphasis on structural and systemic concerns is shared by the Structural Justice (SJ) approach to analyzing root causes. Burnett *et al.* (2018) defines structural justice as the acknowledgement and restoration of the oppressive nature of social structures, by centering those who have been marginalized while attending to equity, power, and human dignity.[8] Similar to the RRC framework, the SJ approach calls for centering the diverse experiences of a specific community and the collective intervention to changing and improving systems.

Emerging from community psychology, Collins and Watson's (2021) anti-racist systems praxis examines root causes as systemic. Similar to the previous approaches, this systems-thinking approach follows a cyclical process of (1) (re)defining patterns of white privilege and black, indigenous, and people of color (BIPOC) oppression within a community, (2) designing interventions to disrupt these patterns, and then (3) implementing interventions to reinforce social justice.[7] The anti-racist system praxis interrogates the patterns of how benefits and burdens are distributed within a community, patterns of access to resources,

and patterns of representation in decision-making processes. This systems-thinking approach provides pathways for challenging mindsets, goals, resources, networks, and feedback loops.[7]

Put together, the revised SDOH framework, RRC framework, SJ approach, and the anti-racist systems praxis helps researchers understand that health outcomes are not inevitable, instead they are an entanglement of decisions and actions, spanning from history to today. This means that health outcomes can be changed by decisions and actions, spanning from today to the future.

This literature has contributed to Deliverable 2.8's approach to RCA. The RCA approach is intentionally designed to accommodate the complexities of heterogeneity and intersectionality, acknowledging that each individual's experiences related to environmental issues are unique and shaped by various factors, including social identities. By embracing these differences, the RCA approach aims to foster understanding while still pursuing the overarching objective of systematically interrogating and questions root causes of environmental disparities. The RCA process used here encourages participants to explore patterns of disproportionate environmental burdens and patterns of access to resources and decision-making processes. This RCA approach facilitates conversations that connect historical contexts with present-day conditions by connecting community insights with relevant historical and planning documents. While the settlement agreement specifies the extent to which the research team can provide recommendations, it is our hope that the public accessibility of this document and its findings will enable community organizations, policymakers, and advocacy groups to design long-term and sustainable interventions.

5 WHY'S MODEL AND FOUR TOPICS OF ANALYSIS

5 WHY'S MODEL. During the CC Meeting on January 7, 2025, the CC members determined which model would be most appropriate for a community RCA activity. At this meeting, the ENVIRONS team revisited the RCA process with the CC, discussed the purpose and goals of RCA, and showcased a variety of RCA models.

There are a number of different RCA models used in health literature, such as the 5 Why's Model, Event Sequencing, and the Fishbone Diagram.[16] RCA models help practitioners explain problems, from small everyday mistakes to larger structural concerns. Generally, RCA models take practitioners through the following steps: (1) data collection, (2) charting causal relationships, (3) identifying root cause(s), and (4) generating and implementing solutions.[3] While this process may sound clear-cut, causal relationships are rarely singular, one-dimensional, or one-directional. Instead, there could be many different causes underlying a problem, uneven feedback loops, and many different participants involved, even across temporal and geographical considerations. It is important to note that the analysis of any RCA model will always be subjective to an extent, as findings are born out of the participants' experiences, insights, and relationships in a certain time and place.[4]

CC members elected to use the 5 Why's model for this deliverable's RCA. As the name suggests, this model has participants create a chain of causal relationships by asking "why" five times.[4] As seen in Figure 4, the 5 Why's model has participants start with the problem and work backwards toward uncovering the root cause. The 5 Why's Model provides flexibility for participants to explore the breadth and depth of each topic. As RCA

is a problem-solving process, action and interventions can be designed for any level of the 5 Why's chain of causal relationships.

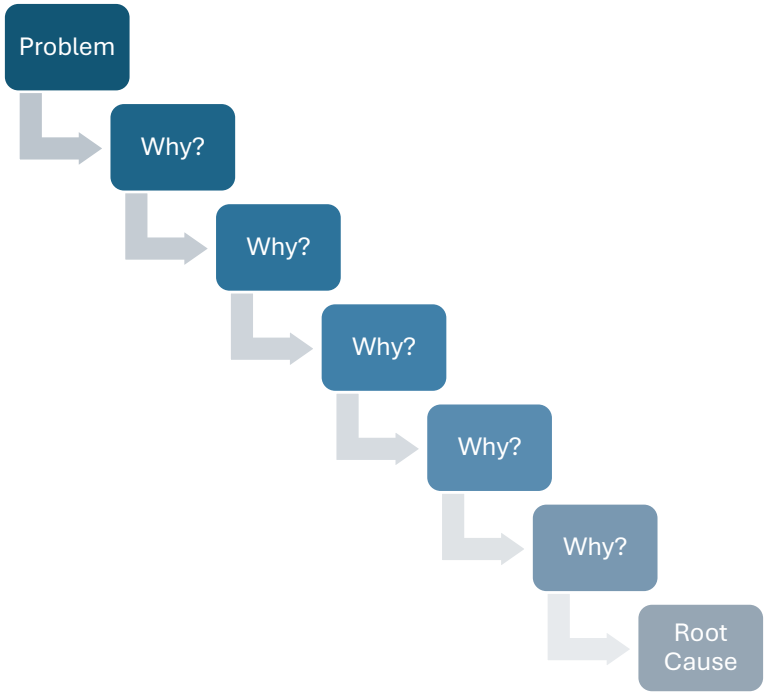

Figure 4. The 5 Why's Model for RCA.

FOUR HEALTH TOPICS FOR ANALYSIS. At the following CC meeting on February 4, 2025, the study members continued to plan for the upcoming community RCA activity. CC members identified four health-related topics to be analyzed at the community RCA activity and in this deliverable. Those four topics included asthma, odor, citizenship status, and food access in GES.

Asthma is a Health Concern in GES. Throughout the GES Community Health Study, community members have raised concerns about respiratory health and asthma. Deliverable 2.2 Health Impact Assessment (HIA) found that while there is limited evidence to suggest adult and childhood asthma prevalence is higher in GES compared to the Denver average, asthma hospitalization rates are notably higher in GES than compared to Denver. However, the HIA noted that more data are needed to further validate these findings.[11] The HIA discussed the relationship between asthma and air pollution, highlighting that there is strong evidence that connects air pollution exposure and adolescent asthma prevalence. Evidence also connects poorer air quality with higher asthma hospitalization rates.[11]

The relationship between air pollution and asthma in GES was further explored in the GES Community Health Study's Community Environmental Burden Assessment (CEBA). Deliverable 2.5 CEBA: The Exposure Response Assessment Phase focused on air pollution concentration levels across Denver and estimated the difference in air pollution levels between GES and the least burdened neighborhood in Denver.[13]

Deliverable 2.6 CEBA: Burden of Disease and Future Scenarios highlighted the extent to which childhood asthma cases in GES can be attributed to air pollution.[14] By comparing air pollution levels in GES to those in the least burdened neighborhoods, the CEBA identified that the increased exposure to nitrogen dioxide (NO_2) and particulate matter with diameters of 10 micrometers or smaller (PM_{10}) was a leading contributor to childhood asthma.[14] GES residents have expressed concerns about the known, and the still unknown, impacts air quality has on their health.

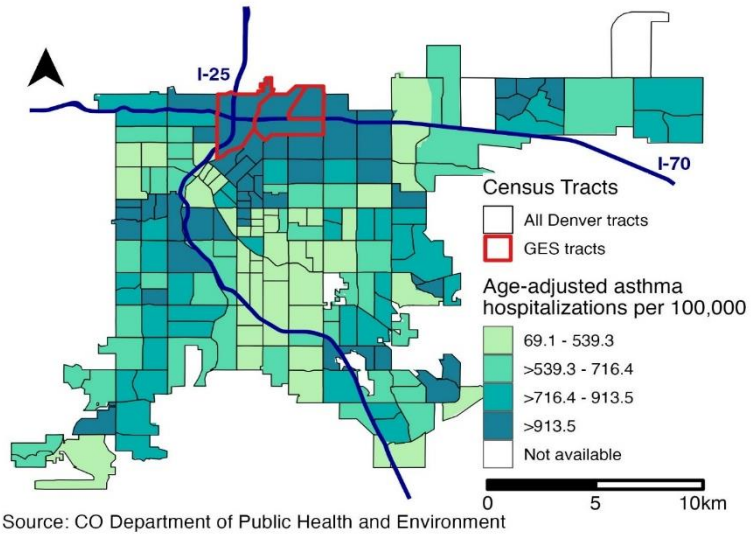

Figure 5. Age-adjusted asthma hospitalizations in Denver, Colorado, 2015-2019.

Odor is a Health Concern in GES. Air quality and odor are intertwined. Throughout the study, residents have expressed concerns regarding unpleasant odors in GES. Deliverable 2.2 emphasized that while odors do not have long-term direct health effects, they are a nuisance that can interfere with the quality of life, cause distress, hinder outdoor activities, and may lead to short-term health impacts such as headaches, eye irritation, and throat irritation. Deliverable 2.2 also found the majority of odor complaints in GES reported to Denver Department of Public Health and Environment (DDPHE) stem from odors associated with industrial processes, such as Purina and marijuana cultivation centers.[11] While Denver's local odor ordinance has been revised to include regulating nuisance odors, concerns regarding odor enforcement remain. For example, Deliverable 2.2 reported that in 2022, there were 74 odor complaints with 22 of which originated in GES, however, a resident expressed that they themselves called 15 times.

Food Access is a Health Concern in GES. In addition to nuisance odors, another characteristic of GES's high concentration of industrial land use is the lack of grocery stores. Limited access to health food has been a common concern voiced by GES residents. Deliverable 2.2 called attention to GES's limited access to healthy foods, and reemphasized that this issue was highlighted 10 years prior in the community's 2014 Health Impact Assessment.[11] Furthermore, while food access in GES is lower than the Denver average, marijuana access and alcohol access in GES are both higher than the Denver average. For every grocery store in Globeville, there are 3.5 marijuana stores, and in Elyria-Swansea there are 1.75 marijuana stores for

every grocery store.[11] This ratio creates a burden for GES residents who have to travel further than the average Denver resident to access healthy foods. 2021 data suggest that roughly 10.5% of Globeville residents and 0% of Elyria-Swansea residents were reported to live within a 10-minute walk of a full grocery store, compared to Denver's population-weighted average of 42.1%.[17]

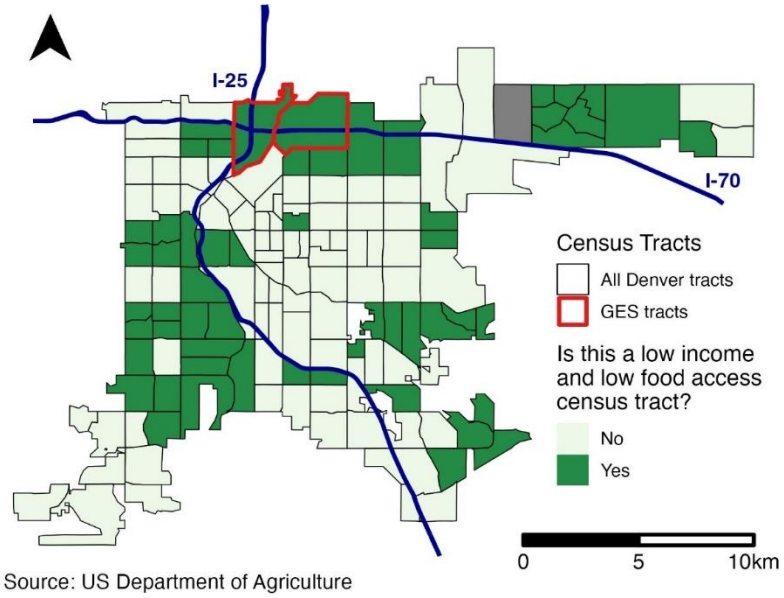

Figure 6. Low income and low food access in Denver, Colorado.

Living a walkable distance to a full grocery store is especially important for individuals who do not have access to a personal vehicle or who rely on public transportation or micro transit. Mobility, connectivity, and transportation concerns can further complicate access to distant grocery stores.

Citizenship Status is a Health Concern in GES. The fourth health-related topic that the CC selected for analysis was citizenship status. As detailed in the HIA, GES enjoys a long history with Denver's immigrant communities. As some of the oldest neighborhoods in Denver, GES was originally settled by European immigrants in the late 1800s. Today, GES is home to a rich and vibrant community with European, Latino, and Hispanic roots.[11] Throughout the study, residents have expressed pride in the many community leaders who actively strive to make GES a healthy environment for all those who live, work, play, and learn, regardless of citizenship status.

In the United States, citizenship status and immigration status are inextricably linked to every SDoH. For example, citizenship status may impact employment options, economic and housing stability, familial and community support systems, ability to engage with research or decision-making processes, and literacy and language competence. Through using SDOH as a framework, Deliverable 2.2 illustrates how immigration and citizenship status are connected to health outcomes by specifically looking at two SDOH, education and healthcare access. The connections between educational achievement and health outcomes are well documented. Deliverable 2.2 highlights that structural factors related to immigration status may present barriers for individuals to pursue educational attainment or access childcare options.[11] This is a concern in GES, where early childhood education options are already inadequately and inequitably distributed.

The HIA also highlighted that structural factors linked to immigration status may result in additional barriers to accessing healthcare, such as the lack of linguistically and culturally appropriate healthcare resources and messaging, socioeconomic stressors, or barriers to accessing health insurance.[11] Deliverable 2.6 CEBA: Burden of Disease and Future Scenarios further elaborated on the connection between citizenship status and accessing health care or obtaining health insurance by stating possible barriers could include the lack of affordable coverage options, attaining eligibility status, as well as navigating the enrollment process itself.[14] Beyond GES, local, state, and federal policies and sentiments regarding citizenship status can further complicate the connections between citizenship/immigration status and health outcomes.

CONDUCTING THE COMMUNITY RCA ACTIVITY

Under the CC's leadership, we conducted the Community RCA Activity during the study's quarterly community meeting on February 21, 2025 from 5:30-7:30 PM at CSU Spur. This event was advertised with a flyer via the GES Health Study's Facebook account and email listserv in English and in Spanish. Additionally, the Community Council leveraged their personal networks and social media accounts to recruit attendees.

Six GES residents attended this meeting, including four members of the Community Council. Participants represented Globeville, Elyria, and Swansea. Interpretation was provided in English and Spanish for the entirety of the meeting. Dinner was provided for all participants.

After providing an overview of the GES Community Health Study and Deliverable 2.8 Root Cause Analysis, participants were invited to engage with the RCA stations around the room. Each of the four stations was comprised of a 5 Why's model dedicated to one of the health topics identified by the CC. Participants were given pens, markers, and sticky notes to complete their own 5 Why's of all four topics. Appendix A provides a typed list of the 5 Why's conducted at that meeting, and Appendix B contains the images of the 5 Why's activity.

ENVIRONS created a discussion guide to help facilitate conversations at each RCA station. Questions were pulled from Collins & Watson (2021) and Malawa et al. (2021) to help participants assess the underlying ideologies, decision-making processes, resources, feedback loops, and pathways for intervention for each health topic. While a handful of discussion guides were placed at each station, participants were not required to use the guide.

After the activity, participants gathered for a large group discussion. During this discussion, participants identified underlying root causes and key takeaways from each health topic. The following section dives deeper into the findings from this activity.

KEY FINDINGS FROM THE COMMUNITY RCA ACTIVITY

This section summarizes insights from the Community RCA activity on February 21, 2025. The findings are reflective of the GES residents who participated in the Community RCA and accompanying discussion. These insights were then interpreted by ENVIRONS research team and presented as follows. This section concludes with a brief exploration of the four health topics, root causes, and impacts by identifying overarching key themes.

ASTHMA IS A HEALTH CONCERN IN GES

"…They thought about their own benefit, not how it would affect people like children, the elderly, and in general."

During the Community RCA activity and large-group discussion, participants referenced historical and current land-use in GES as connected to asthma prevalence in GES. Historically, GES was the site of industrial land-use, such as heavy metal smelters. Participants noted that smelters have resulted in ongoing concerns regarding environmental contamination and remediation efforts. Participants stated that the prevalence of industrial land-use has continued into the present-day context of GES. Participants attributed asthma concerns with the proximity to sites like I-70, Purina, meat processing, nearby refineries, and constant construction projects within the neighborhoods. During the discussion, participants reflected on the community's development history resulting in relatively inexpensive land for industrial and transportation projects. Throughout the meeting, participants evaluated the extent to which health consequences are considered in decision-making processes related to these industrial and transportation activities.

Participants reported that related decision-making processes lacked accountability and attention to the people living in GES. Participants expressed concern that business and governmental decisions regarding zoning, land use, and neighborhood planning prioritize profit over the wellbeing of residents. Participants observed that the lack of attention to health impacts and the lack of their involvement in decision-making processes has resulted in the additional burden of self-sufficiency. Participants reported that due to this ongoing history of environmental pollution, GES residents with asthma-related health concerns, including children, must take on the additional burden of monitoring air quality daily. Asthma is a serious chronic disease and when it's exacerbated, individuals may require additional medical attention, including hospital visits. Participants reported that because decision-making process and systems inadequately include the concerns of GES residents, community members must continually advocate for their wellbeing. These burdens are placed on a historically immigrant community that faces additional interrelated socioeconomic and health concerns.

ODOR IS A HEALTH CONCERN IN GES

"We notice odors instantly. Something is wrong here."

Participants examined how odors are a health concern that impact mental health and the community context of GES. Participants observed that odors are a quick indicator that something is wrong, resulting in negative impacts to mental and emotional health. Participants expressed feelings of being overwhelmed by the myriads of odor sources in GES, shame that their neighborhood smells, embarrassment to have company over, and nervousness regarding pollution and potential health impacts. Additionally, participants reflected that odor causes them to stay indoors and expressed feelings of being trapped and isolated within their homes.

Being trapped in one's home negatively affects a sense of community. Participants reported that odor impedes their ability to enjoy their neighborhood, such as going outside for a walk. Participants have had to leave the GES community in order to access outdoor amenities, such as parks, due to odor. Barriers to outdoor amenities impacts one's ability to engage in physical activity. In turn, these barriers continue to exacerbate physical and mental health. Participants expressed the desire to enjoy their own community, go on walks, and enjoy local parks, but odor has prevented them from being able to do so.

Participants expressed dissatisfaction with processes, such as Denver 311 City Services, that inadequately address the issue. Participants reported that their dissatisfaction stems from concerns that odor complaint and follow-up processes are not timely enough to address issues, that thresholds for DDPHE action are too high, that complaint and enforcement processes are not transparent enough, and that regulations are not strict enough or are inadequately enforced. When participants compared odors in GES with other Denver neighborhoods, participants had not heard of odor being as prominent of a concern in other neighborhoods as it is for GES. Identifying odor as a disproportionate burden in GES led participants to express concerns that interconnected structural factors, such as socioeconomic status, may be connected to residents' experiences with inadequate processes. These concerns have resulted in participants feeling unheard, unsupported, and forgotten.

FOOD ACCESS IS A HEALTH CONCERN IN GES

"All residents from GES, we deserve to have a grocery store in GES"

During the Community RCA activity, participants evaluated root causes that impact food access in GES. Participants reported a lack of grocery stores in GES, and having to leave GES in order to access grocery stores that provided affordable, healthy, and culturally relevant foods. This requires residents to have a vehicle or other reliable means of transportation.

To explain why GES lacks grocery stores, participants turned to the neighborhood's history and land-use planning. Residents identified industrial zoning both as a barrier and as an opportunity to siting grocery stores in GES. History also helped participants explain the barriers to gardening as a potential pathway to food access. The history of heavy metal smelting and other industrial uses in GES has contributed to

participants' concerns regarding soil quality. Participants reported that remediation efforts have been unsatisfactory to address their concerns.

Participants also noted that while there is a lack of grocery stores in GES, there is an abundance of cannabis dispensaries. This caused participants to examine the reasons why dispensaries would be approved for GES, but not the stores that addressed prevalent community needs. Discussions regarding marijuana dispensaries and cultivation facilities demonstrated the interconnectedness of residents' concerns, as marijuana facilities are also a source of unpleasant odors. Participants reflected on the fact that GES residents pay taxes, just like any other neighborhood in Denver. This includes wealthier neighborhoods and neighborhoods whose food access needs are met by nearby grocery stores. Drawing this comparison led to the concerns that profit was being prioritized over the wellbeing of Denver residents and that interconnected structural factors, such as socioeconomic status and race/ethnicity, may be connected to residents' experiences with inadequate food access.

CITIZENSHIP STATUS IS A HEALTH CONCERN IN GES

"We pay taxes, but we don't get the benefits."

Participants examined how citizenship status is a health concern that has intergenerational mental health and community impacts in GES. Participants identified that citizenship status is connected to access to health care, financial assistance, and other resources. This includes the ability to access medical assistance, receive tax incentives or refunds, navigate bureaucratic processes, access environmental remediation projects and actions, and access linguistically and culturally relevant resources. Potential stressors due to an individual's citizenship status could include housing instability, separation from family, and the inability to attend work or school. All these stressors accumulate into mental health concerns. Participants reported residents without citizenship may feel fear, isolation, post-traumatic stress disorder, and negative impacts to self-esteem and confidence. Participants noted that these mental health impacts can exacerbate existing physical health concerns.

Participants highlighted that health impacts connected to citizenship status are intergenerational. Children and youth feel the same fear, isolation, stress, and esteem impacts as the adults in their community. Participants stated that youth and adults share concerns regarding safety and security in an uncertain and shifting political landscape.

Fear and nervousness extend beyond the individual and to the entire community. Participants highlighted that as the federal gaze shifts to focus on citizenship status, the situation becomes difficult for all residents, regardless of personal immigration history. Participants expressed that fear is mobilized to silence populations. Participants discussed that community members are having to refocus energy away from organizing for environmental health and towards addressing overarching safety concerns. In this way, in addition to tackling environmental health burdens, GES residents are pushed into taking on additional advocacy and community support roles. Participants stated that it should not be the responsibility of only community members to address environmental health issues.

As mentioned previously, participants reported that decision-making processes and systems inadequately included GES residents and/or addressed the concerns of GES residents. This concern is exacerbated by citizenship status. Participants reflected on the fact that already inadequate decision-making processes for GES residents are even more so insufficient and inequitable for residents without secure citizenship statuses. These burdens are placed on a historically immigrant community that faces additional interrelated socioeconomic and health concerns, resulting in participants feeling silenced and overburdened, and yet, called to action.

KEY THEMES

> *"…To take action in this neighborhood will be hard with everything that is being done. But we have to continue with the work we are doing. It is so important to keep thinking about how we can make improvements… We need to focus. We now have data and information, so what can we do with it?"*

Asthma, odor, food access, and citizenship status are all environmental health concerns in GES. While each topic carries unique considerations, they are united by several overarching key themes, related to both root causes and impacts. This section synthesizes insights from the Community RCA on February 21, 2025, previous GES Community Health Study deliverables, and relevant historical and current documents. Weaving together multiple lines of evidence generates overarching key themes.

As action can be taken all along the 5 Why's chain of causal relationships, this section provides key themes as potential pathways for community partners, practitioners, researchers, and other stakeholders to intervene. As the settlement agreement specifies the extent to which the ENVIRONS research team can provide recommendations, this section provides questions to accompany root cause themes. We hope these questions are generative for designing long-term and sustainable interventions. These questions are for any reader who finds them productive for enacting change, including readers from the GES community, government agencies, private sector entities, and academic institutions.

ROOT CAUSES

As participants explored the root causes of each health topic during the Community RCA, the following key themes arose: (1) History is ongoing and present in the community; (2) Priority is often placed on profit over health and wellbeing; and (3) Current processes and procedures are often insufficient to address the concerns of GES residents.

HISTORY IS PRESENT. As seen throughout the Community RCA and discussion, the history of GES is ongoing and embedded in the present-day landscape. This history is detailed in the study's Deliverable 1.4 Narrative. The Globeville, Elyria, and Swansea neighborhoods were originally settled in the late 1800's by European immigrants.[18] These early GES residents sustained the workforce for north Denver's growing industrial footprint.[19,20] Following WWII, an increasing number of Hispanic and Latino immigrants began

calling GES home. It was around this time that Interstate 25 (I-25) and Interstate 70 (I-70) were built, transecting the neighborhoods.[19,20]

The Globeville, Elyria, and Swansea neighborhoods were established as three separate neighborhoods. To many residents today, GES remains three distinct neighborhoods. While each neighborhood is distinct, their environmental health histories are entangled. The Community RCA highlighted that industrial land use has resulted in air quality and soil quality concerns that impact health outcomes. Air pollutants trigger asthma, nuisance odors impact quality of life, and a legacy of contaminated soil has raised concerns on whether residential gardening can increase access to healthy foods.

The history of industrial activities in GES has always been accompanied by residential life. History shows that GES has been the site of homes, schools, churches, and businesses since Denver's early days as a settler establishment.[19,20] As development and industrial activities continue to encroach on the daily life of GES residents, it becomes increasingly impossible to ignore how environmental health concerns disproportionately impact an immigrant community, as well as how race/ethnicity and socioeconomic status are intertwined with this burden. The historical context of GES is important to this deliverable because it reveals an ongoing legacy of environmental health burdens institutionalized through priorities and processes.

A historical approach to understanding and addressing root causes may benefit from asking the following questions:

- What historical and environmental injustices exist within the environmental health context of GES? To what extent do local, state, and federal institutions acknowledge the injustices shaping the environmental health landscape of GES?
- How can interventions (across local, state, federal scales) repair historical environmental injustices? What resources, power, and opportunities need to shift to repair historical injustices?[6] How can community voices, interests, and experiences drive these interventions?
- What issues and topics have GES residents identified that need to be explored and addressed in order to disrupt existing patterns of environmental health burdens in GES?[7]
- What role can community organizations, governments, businesses, and academic institutions play in addressing these ongoing histories? What entities are already doing this work? How do they track their progress? To what extent is this work driven by the interests of GES residents?
- How does "history is present" affect the following themes related to Impacts?

PRIORITIZING PROFIT OVER HEALTH. Participants of the Community RCA expressed concerns that business and governmental decisions regarding development and land use in GES have prioritized profit over the health and wellbeing of residents. During the discussions on odors and asthma, concerns regarding these decisions were linked to the siting of locally unwanted land uses (LULUs) that generate nuisance odors and air pollutants. As seen in the discussion regarding food access, these decisions were also connected to the location of grocery stores and cannabis dispensaries. Participants linked the proximity of LULUs to GES's lower land prices that may provide an incentive for businesses to develop in the community.

During the Community RCA, participants interrogated why GES contended with a disproportionate burden of environmental health concerns. Participants emphasized that GES residents pay taxes, regardless of immigration status, just like any other Denver resident. However, they do not experience the same environmental health benefits. This inequity has been illustrated in past deliverables (Table 2), as well as by the City and County of Denver's exploration of how history impacts social equity today.[21] Interrogating the priorities underlying decision-making is necessary to address the processes and procedures themselves.

Designing interventions that interrogate underlying priorities may benefit from asking the following questions:

- What underlying beliefs, values, and priorities are influencing environmental decision-making in GES? In what ways? And to what extent does this differ from other Denver neighborhoods?[7]
- How can interventions (across local, state, federal scales) focus on changing policies, systems, or environments. To what extent do interventions work towards long-term health and environmental impacts? How could interventions be institutionalized for longevity?[6] How can community voices, interests, and experiences drive these interventions?
- What role can community organizations, governments, businesses, and academic institutions play in prioritizing community health and wellbeing? What entities are already doing this work? How do they track their progress? To what extent is this work driven by the interests of GES residents?
- How do underlying priorities affect the following themes related to Impacts?

PROCESSES AND PROCEDURES. Echoing Yearby (2020), processes and procedures are defined largely here as the tools leveraged by underlying goals, mindsets, and drivers.[5] This could include policies, regulations, enforcement, neighborhood planning practices, and even budgetary decisions. A historical interrogation of processes and procedures reveals that GES residents have a long and involved history of challenging insufficient systems and institutions. In the late 1980's, Elyria-Swansea residents successfully challenged the siting of a "medical waste incinerator and a radium-tainted earth weigh station" in their neighborhood.[19] When a hydrochloric acid leak from a railroad tank car released a cloud of toxic fumes into GES in 1995, resident Lorraine Granado led community members to file a lawsuit against the Vulcan Materials Company. This resulted in a settlement and the establishment of Lorraine Granado Community Park next to the Swansea Community Center.[19] In the fall of 1996, the Valdez-Perry Branch of the Denver Public Library opened in GES as part of the deal neighbors negotiated that allowed for the National Western Stock Show's Events Center to be built.[19] And over a decade later, GES neighbors advocated for their

environmental health while opposing the Central I-70 project, resulting in the settlement that funds this study. Throughout GES's history, community leaders and activists have confronted institutional processes and procedures in order to advocate for the wellbeing of community members.[20] In addition to highlighting the strength of the GES community, the Community RCA also revealed the gaps in the institutional processes and procedures that have led to GES's existing environmental health conditions.

Participants of the Community RCA reported that GES residents experienced a lack of meaningful involvement in decisions related to environmental health. This resulted in processes and procedures that dedicate insufficient attention to how environmental health impacts everyday life. For example, participants stated that reporting processes for nuisance odors are not timely, sensitive, or strict enough to address residents' concerns. During the discussions regarding asthma and food access, participants reported a lack of inclusion in land use decisions, as well as a lack in processes to hold institutions accountable for environmental health outcomes. Participants also discussed how the lack of meaningful involvement is exacerbated when it comes to citizenship status. This is an environmental justice concern.

In their definitions of environmental justice (EJ), both the United States Environmental Protection Agency (EPA) and the Colorado Environmental Justice Act include the participation of all people in the decisions that affect their environment.[22,23] Additionally, both the EPA and CDPHE are attentive to the distribution of environmental benefits and burdens. Community RCA participants expressed inadequate opportunities to meaningfully participate in decision-making processes. Aligned with EPA and Colorado's EJ definitions, participants expressed a desire for more opportunities to participate in decision-making processes and procedures aimed at equitably distributing environmental benefits.

Interventions for addressing processes and procedures may benefit from the following questions:

- What does meaningful involvement mean, or look like, to GES residents? To what extent do community organizations, governments, businesses, and academic institutions achieve meaningful involvement? Where are the areas of community involvement could be improved and how?
- How are current policies, practices, procedures, regulations influencing environmental benefits and impacting health burdens?[7]
- To what extent do processes and procedures amplify environmental health disparities? How do processes and procedures reduce patterns of environmental health disparities?[7]
- How can interventions for processes and procedures (across local, state, federal scales) impact underlying mindsets and priorities? How can interventions for processes and procedures influence downstream social determinants of health? How can community voices, interests, and experiences drive these interventions?
- How do processes and procedures affect the following themes related to Impacts?

IMPACTS

When exploring how each health topic impacts GES residents during the Community RCA, the following key themes arose: (1) mental and emotional wellbeing, (2) sense of community, and (3) intergenerational impacts. These themes highlight that disproportionate environmental health burden is more than a community's exposure to environmental pollutants, it also relates to the mental, emotional, communal, and intergenerational impacts individuals carry throughout their daily lives.

MENTAL AND EMOTIONAL HEALTH. As seen throughout the Community RCA, mental and emotional wellbeing is inextricably linked with each of the four health topics analyzed. Deliverable 2.2 highlights that GES residents experience higher frequent mental health distress compared to Denver's average. Deliverable 2.2 also discussed that residents have expressed concern regarding mental health impacts linked to strong odors, safety concerns, and concerns regarding environmental pollution.[11] This is similar to the concerns participants expressed during the Community RCA.

In the Community RCA, mental and emotional considerations ranged from being overwhelmed from the myriads of pollution sources in GES, to feeling nervous about the ways in which pollution may impact an individual's health outcomes, to feeling burdened by the extra steps residents must engage to advocate for and protect their community wellbeing. Participants of the Community RCA discussed how they have felt shame and embarrassment by industrial activities that prohibit residents from enjoying their community, such as by producing nuisance odors. Participants discussed feeling trapped and isolated, forced to take refuge in their own homes from both physical and social causes, such as industrial activities and the political landscape. When discussing citizenship status, participants reported feelings of fear and pressure to be silenced, despite an active history of advocating to be heard and included. Participants discussed how each of the four health concerns negatively impact self-esteem and confidence. These mental and emotional health considerations affect the sense of community for GES residents and have lasting impacts that span across generations.

SENSE OF COMMUNITY. Participants examined how each of the four health topics analyzed disrupt a sense of community in GES. To meet their health needs, residents are confined to their homes or pushed out of their community. Regarding asthma and odor, participants reflected seeking refuge from poor air quality by remaining inside and at home. When discussing citizenship status, participants reported that fear also pressures residents to remain home. Unable to enjoy their neighborhood, a walk outside, or hosting friends, participants reported feeling isolated and trapped.

In addition to isolating people indoors, the health topics analyzed further disrupt a sense of community in GES by pushing people outside of the neighborhood in order to access resources. Participants reported having to leave the community in order to access grocery stores with affordable, healthy, and culturally relevant foods. In addition to being pushed out of the neighborhoods due to a lack of resources, health concerns push residents out even when amenities are present in GES.

To avoid bad air quality and odors, participants reported leaving GES with their children to access outdoor amenities, such as parks. Similarly, Deliverable 2.2 noted that while the number of parks and greenspaces in GES has increased over the years, residents' concerns regarding the usability of outdoor parks have

remained.[11] Placing the HIA into conversation with the Community RCA reveals that environmental health concerns, such as air quality or nuisance odors, are barriers to accessing environmental amenities within the neighborhoods.

INTERGENERATIONAL IMPACTS. As seen in the Community RCA, the entanglement of mental wellbeing and community belonging has intergenerational impacts. In the past this study has examined physical intergenerational impacts of environmental exposures, such as rates of low birth weight.[11,13,14] What is less explored in GES's environmental health literature is the social intergenerational impacts of environmental burdens.

A major intergenerational impact discussed in the Community RCA was the increased responsibilities that young people adopt for their health and wellbeing. Participants reported that their children with asthma-related health concerns have had to learn how to check air quality reports and modify daily activities based on pollutant levels. Participants also discussed the increased burden that young people face regarding citizenship status, as they experience the same mental and emotional impacts as the adults in their community. And, as discussed previously, families navigate environmental health concerns by leaving GES to access parks and greenspaces. The Community RCA suggests that disproportionate environmental health burden is more than a community's exposure to pollutants; it is also the physical, mental, emotional, and communal impacts on young people as they navigate their daily lives.

DISCUSSION AND NEXT STEPS

PARTICIPATION. The design of the Community RCA meeting provided both benefits and barriers to participation. The study team was attentive to how language, food, and comfort could provide pathways for meaningful participation of attendees. Meeting materials were provided in both English and Spanish, this included the presentation, activity, and discussion guide. Interpretation was provided for in-person and online attendees in both Spanish and English. Dinner was also provided for in-person participants. The meeting start was delayed slightly, due to technical difficulties for the online attendees and due to in-person attendees getting settled into the space. As the meeting was designed to discuss potentially sensitive issues, the study team felt it was important to spend time on making sure participants were comfortable and were able to make a plate for dinner. Lastly the Community RCA meeting was rescheduled from Tuesday, February 11 to Friday, February 21 due to safety concerns regarding winter weather.

REPRESENTATION. As discussed previously, the findings from any RCA model will be subjective to an extent, as the analysis is born out of the participants' experiences, insights, and relationships.[4] This deliverable is representative of the six GES residents who participated in the Community RCA and the subsequent interpretation by the ENVIRONS research team. Aligned with RCA approaches that address structural factors, this deliverable embraces the diversity of experiences, insights, and relationships each participant brought to the Community RCA. Future RCAs of environmental health concerns, even those that differ from this report, are of value to better understand how structural and systemic factors affect everyday life in GES, as well as to better understand potential sites for intervention and change.

PUBLIC COMMENT. Community insight for this deliverable does not end with the Community RCA. In addition to the CC's Community Relevant Summary at the beginning of this document, another important opportunity for community insight is through the public comment period that all study deliverables undergo. If you are a GES resident or community partner reviewing this deliverable, we invite you to provide feedback and input on the extent to which the findings of this deliverable reflect your experiences and insight. The findings in this document are reflective of community meeting discussions and are interpreted by researchers from outside of the community. Public comments, especially those that differ from the findings of this deliverable, are valuable. The final deliverable and public comments will be made publicly accessible on the study website. It is our hope that community engagement might also include future advocates reviewing this document as they explore potential opportunities for interventions, initiatives, and action.

DELIVERABLE 2.11 COMMUNITY HEALTH STUDY. This deliverable, alongside Deliverables 2.1-2.9, will culminate into the Deliverable 2.11 Community Health Study. This comprehensive study will address the requirements from section 1.A.3 of the Sierra Club *et al.* V. Chao *et al.* Settlement agreement. This includes an assessment of the potential causes of the disparate health outcomes in GES, identification of data sources, and consideration of possible significant causes of disparate health outcomes. The aim of this study is to provide information to the public and policymakers that can help inform future policy discussions.

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APPENDIX A. COMMUNITY RCA RESULTS – TYPED

11/15/2022 - Community Meeting

- https://drive.google.com/drive/folders/1p24kRGlqdAZl_flCMqRdMLAfTiPqguKh
- Presentation: https://drive.google.com/file/d/1s0Vi3fQw5354GMNQcWy2uuWC0orz158h/view
- PDF: https://drive.google.com/file/d/1Kca74lEHEIuWkNIXVfIAZurU3sghP_12/view

ASTHMA IS A HEALTH CONCERN IN GES

1. **Why?**
    a. Because of smelters (historical)
    b. Because of dust
    c. Pollution and contaminators are triggers for asthma
    d. Lack of attention from the city
    e. I-70 pollution
        2. **Why?**
            a. Workers would work in smelters
            b. Makes you cough
            c. Because there are iron melter, Purina, we live near 70, the gas refinery, and these are a time bomb for children and adults with asthma and respiratory problems
            d. Authorizing projects without accountability
            e. Trucks and many vehicles drive on I-70
                3. **Why?**
                    a. When smelters were buried, the air gets contaminated
                    b. Can't think when coughing

c. First of all, because they needed a lot of money for this smelting plant and they thought about their own benefit, not how it would affect people like children, the elderly, and in general.

d. Not listening to the residents

e. Because we are very close to I-70

4. Why?

a. Ever since we have air pollution problems, EPA didn't do a good job of cleaning all the soil, we need EPA or the city to clean the soil again

b. You can go to hospital

c. Because at that time they were not aware of how it affected the residents, but for them the important thing was the money, not the health

d. Real attention is what is needed

e. People have nowhere to go; this is the cheapest place to live, so we live near I-70, poor government city planning and not thinking of the residents and the risks for residents' health

5. Why?

a. When I-70 project happened more people got sick because of the soil, which causes asthma; a more profound study on the causes of asthma

b. Because society or the city cares about the health of affected residents

c. Lack of health for residents

d. Maybe they didn't think the city would grow as much as it did, they were only thinking about providing travel, they didn't know and didn't care; Who is in the government? The city is only doing it for their benefit, not for the benefit of the people; city reps are not paying attention to air issues like asthma

ODOR IS A HEALTH CONCERN IN GES

1. **Why?**
    a. Because we feel left out as community
    b. Odor negatively impacts mental health
    c. The smell also affects you emotionally
    d. Notice quickly when it's bad
        2. **Why?**
            a. Bad odor affects self esteem
            b. Because when we bring it to 311 or the city, no one listens
            c. It affects your confidence
                3. **Why?**
                    a. Feels like city and local businesses don't care, isolated from our community
                    b. Because they tell us to call, but we need five people so they can do something
                    c. We felt forgotten by the city
                    d. Regulations not strict enough
                        4. **Why?**
                            a. Technology cannot capture human nose
                            b. Odors come from different sources and it's overwhelming
                            c. We are repressed, we don't go out for a walk
                                5. **Why?**
                                    a. And we stay home and that causes us to get weight or get other sicknesses
                                    b. It lowers your self-esteem

FOOD ACCESS IS A HEALTH CONCERN IN GES

1. **Why?**
    a. We don’t have access
    b. Contamination in the vegetables that one grows at home
    c. Lack of stores in our community
    d. It's hard to get to the store without a car
    e. No affordable stores in GES
        2. **Why?**
            a. The shops are far away
            b. Because of the land
            c. Because there’s no space, they need zoning
            d. Because there are not any stores close to us
            e. Current options don’t reflect needs of community (ex. MJR alcohol)
                3. **Why?**
                    a. But we have marijuana stores, not necessities
                    b. Because of the factories
                    c. Zoning needs to be updated
                    d. Because the city doesn’t care
                    e. Area is industrial zoned
                        4. **Why?**
                            a. They don't pay attention to GES in the city
                            b. Because they didn’t think about the community

c. So we can have a store in our community

d. Because we are poor neighborhoods. Why didn't they put it further away from the urban area?

e. Historical land use

5. Why?

a. The land is too contaminated for planting

b. My health has been going downhill since I came to live here

c. We have to go out of our community for food access

d. Because the city doesn't care

6. Root Cause(s)

a. The factories

b. The throughline between all of those was that the superfund site is tied to all factors: soil, health, food, etc.

c. All residents from GES, we deserve to have a grocery store in GES

CITIZENSHIP STATUS IS A HEALTH CONCERN IN GES

1. **Why?**
    a. Limited access to health care due to the legal status
    b. Lack of access to resources for undocumented people
    c. More health problems like mental and physical health problems
    d. A lot of stress
        2. **Why?**
            a. Financial $, part is status and financial
            b. Poor distribution of resources in Spanish for undocumented people
            c. Because of stress of losing our home and not been able to go to work
            d. Lack of confidence
                3. **Why?**
                    a. If you can't apply for financial aid
                    b. Environmental and general institutionalized racism
                    c. Because it affects our ability to work or get medical assistance
                    d. Plus the times
                        4. **Why?**
                            a. U.S. forms is difficult for a foreigner
                            b. Community of migrant history with local issues never addressed
                            c. And fear can make us also have PTSD and that affects all our body and mind
                            d. Housing problems
                                5. **Why?**

a. Time and have to have a direct connection with a family member or government

b. We pay taxes but don't get the benefits

c. It isolates us from everything and everyone that affects our mental health, to the extent that a child is not protected

d. Family problems

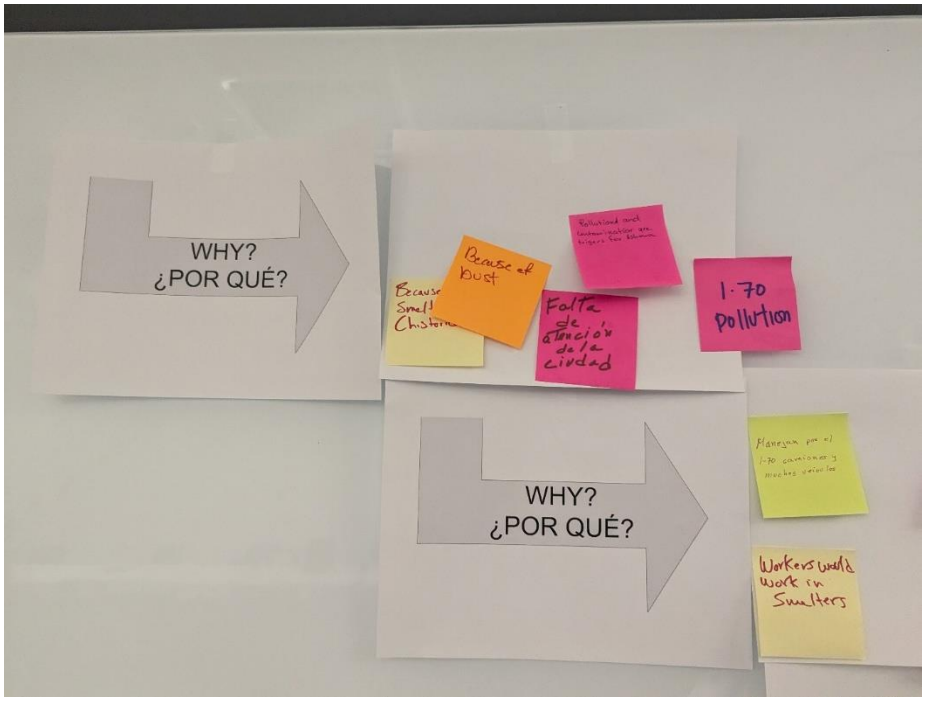
6. Root Cause(s)

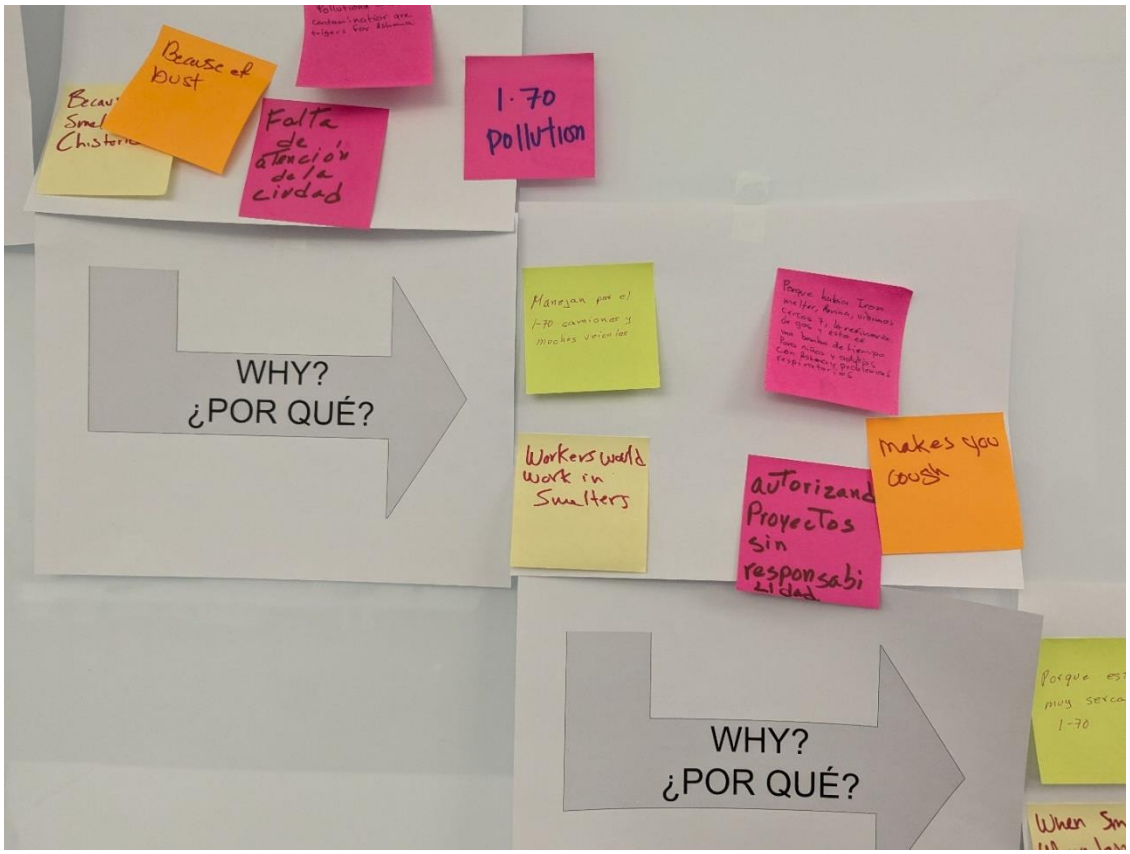
a. If you are illegal your access to health care is limited because you can't get financial aid and if you get it is limited, due to the inflation is harder to afford health care. But if we have opportunity to fix your status we will make the difference more

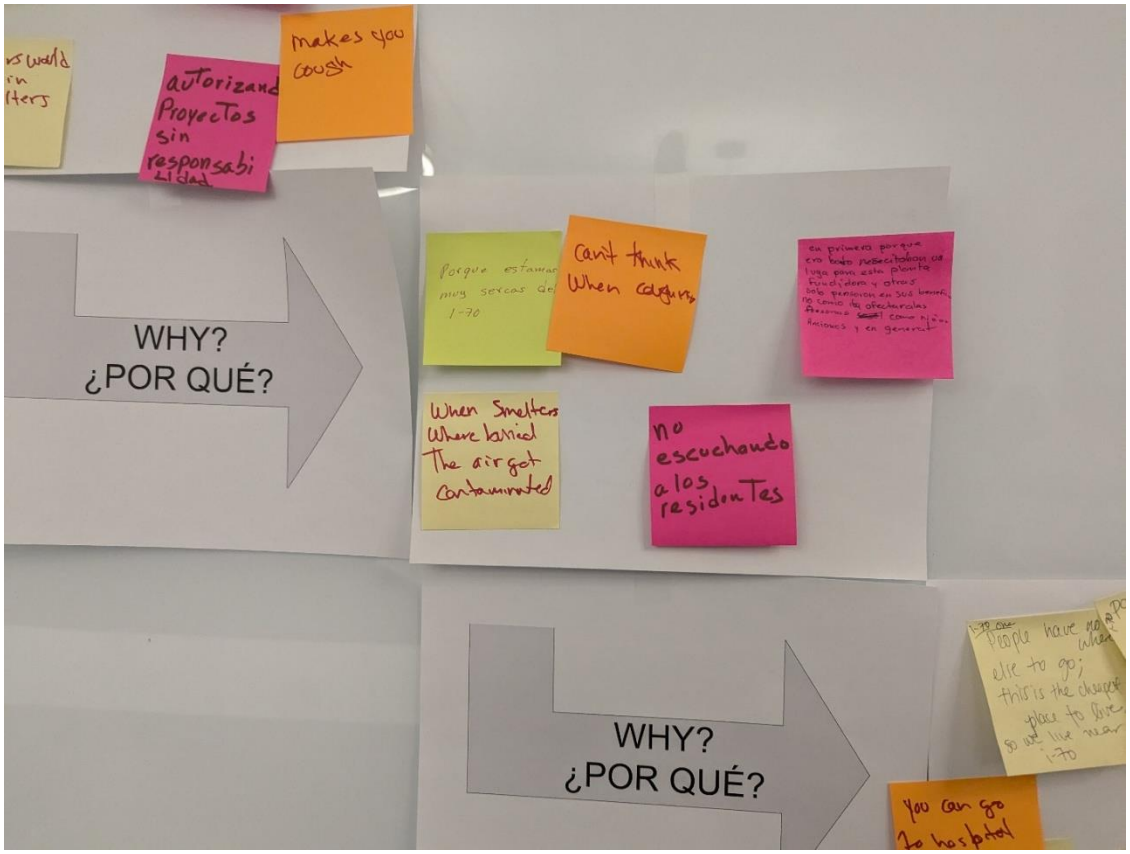
b. Employers and government wants cheap labor but won't defend our rights

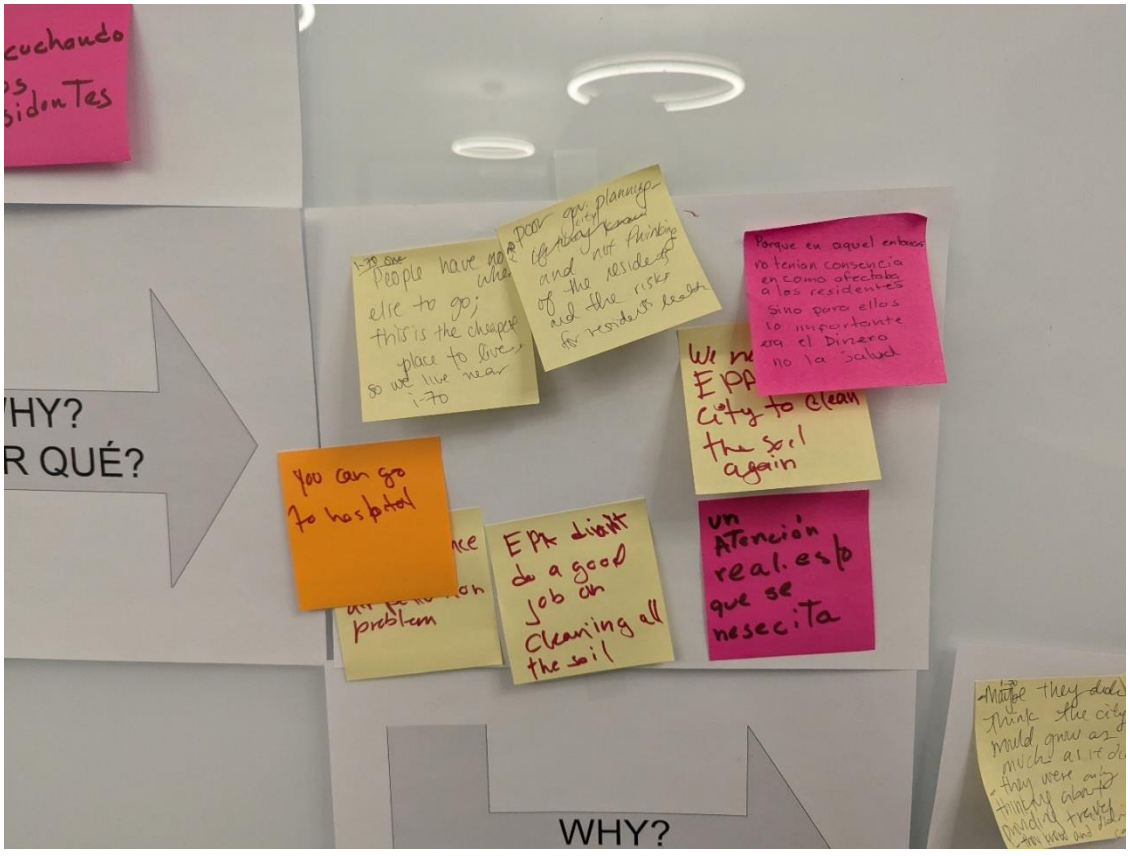
APPENDIX B. COMMUNITY RCA RESULTS – IMAGES

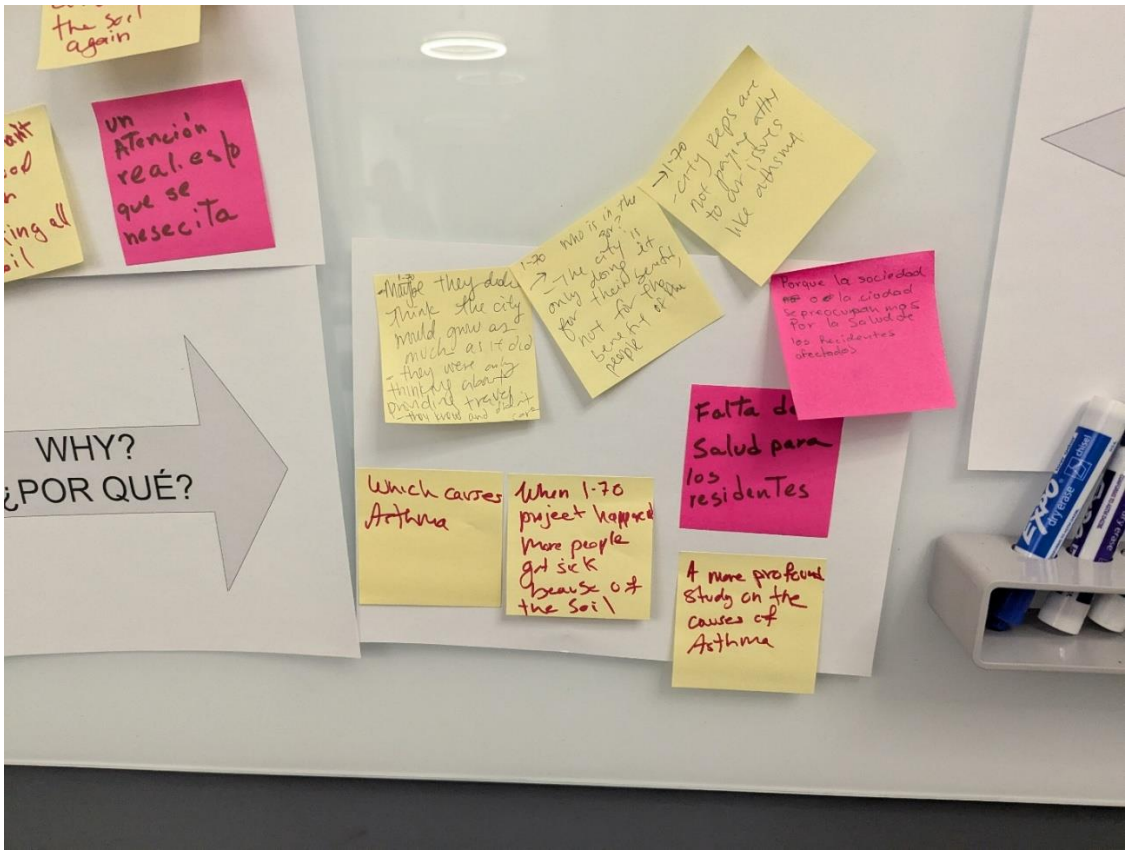
ASTHMA IS A HEALTH CONCERN IN GES


WHY?
¿POR QUÉ?
Because of Dust
Falta de atención de la ciudad
1-70 Pollution
WHY?
¿POR QUÉ?
Workers work in Smelters

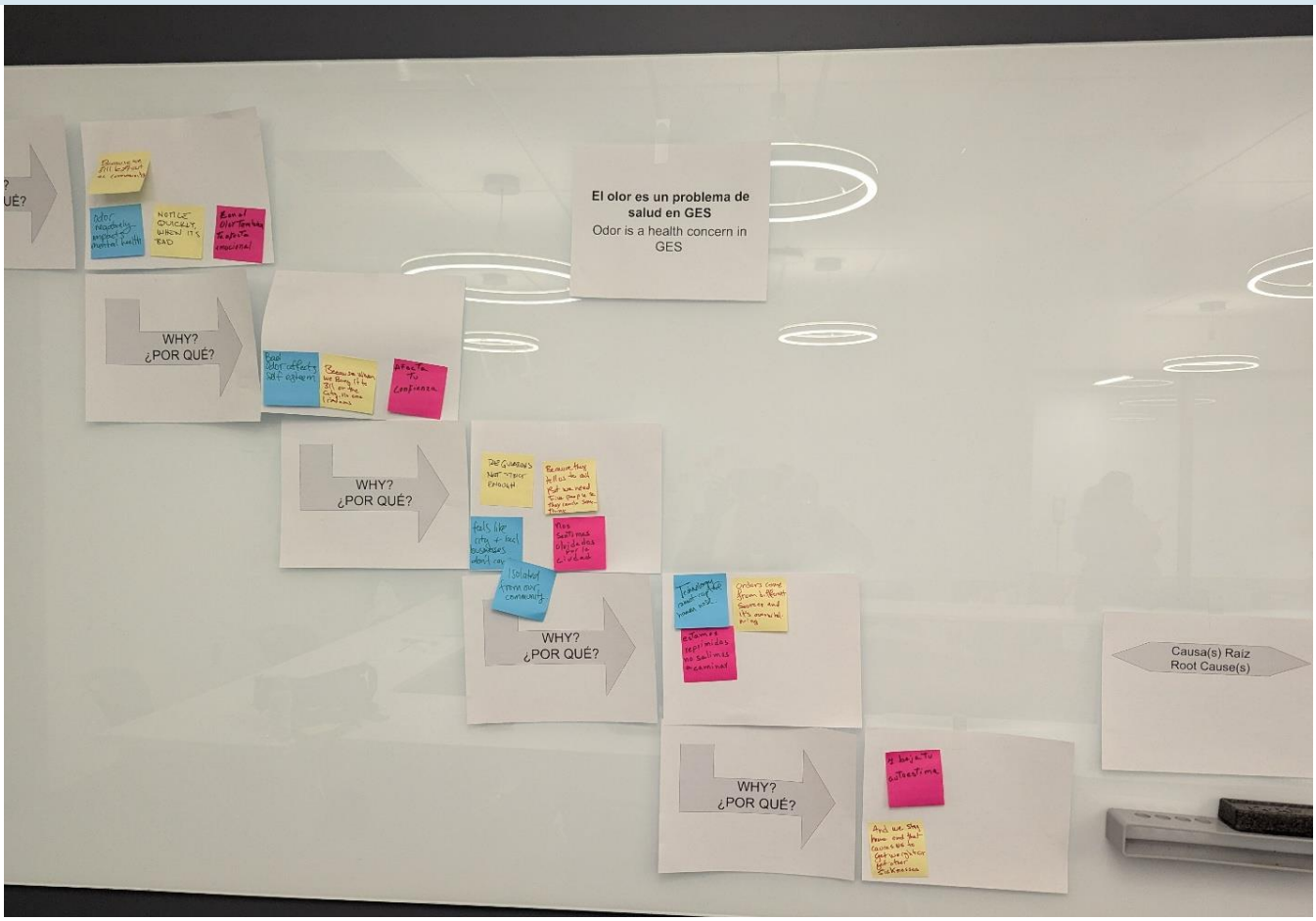

Because of Dust
Falta de atención de la ciudad
1-70 Pollution
WHY?
¿POR QUÉ?
Workers work in Smelters
Makes you cough
WHY?
¿POR QUÉ?

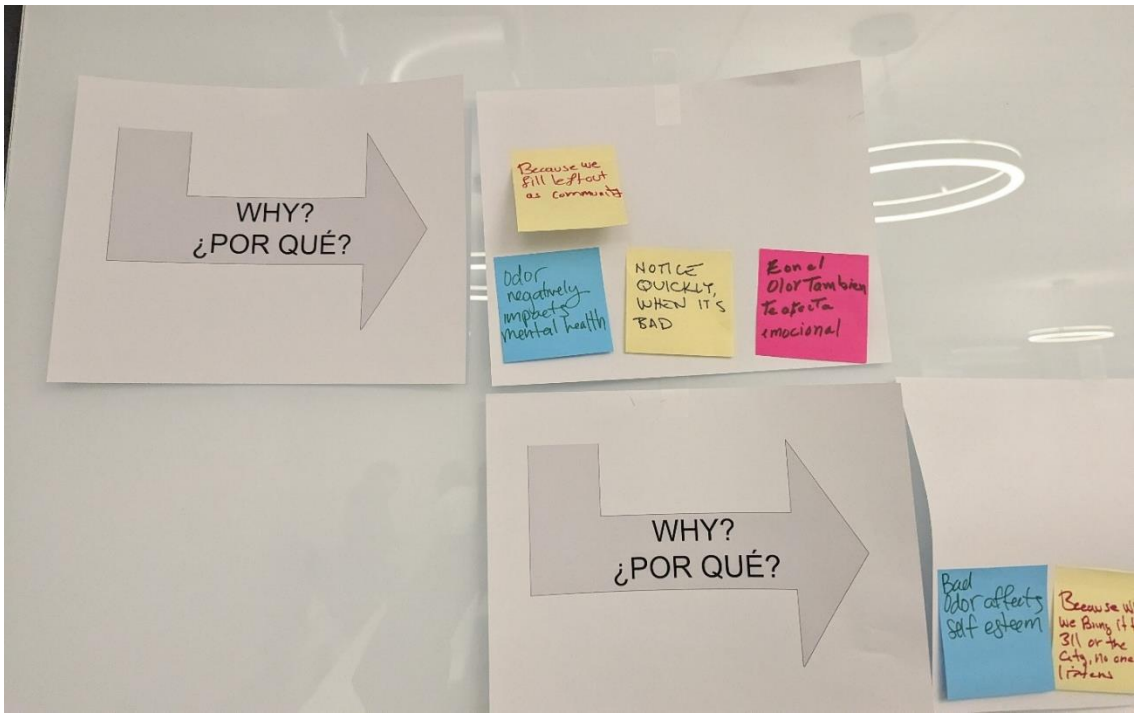

makes you cough
WHY?
¿POR QUÉ?
When Smelters Where buried The air got Contaminated
no escuchando a los residentes
WHY?
¿POR QUÉ?
You can go to hospital

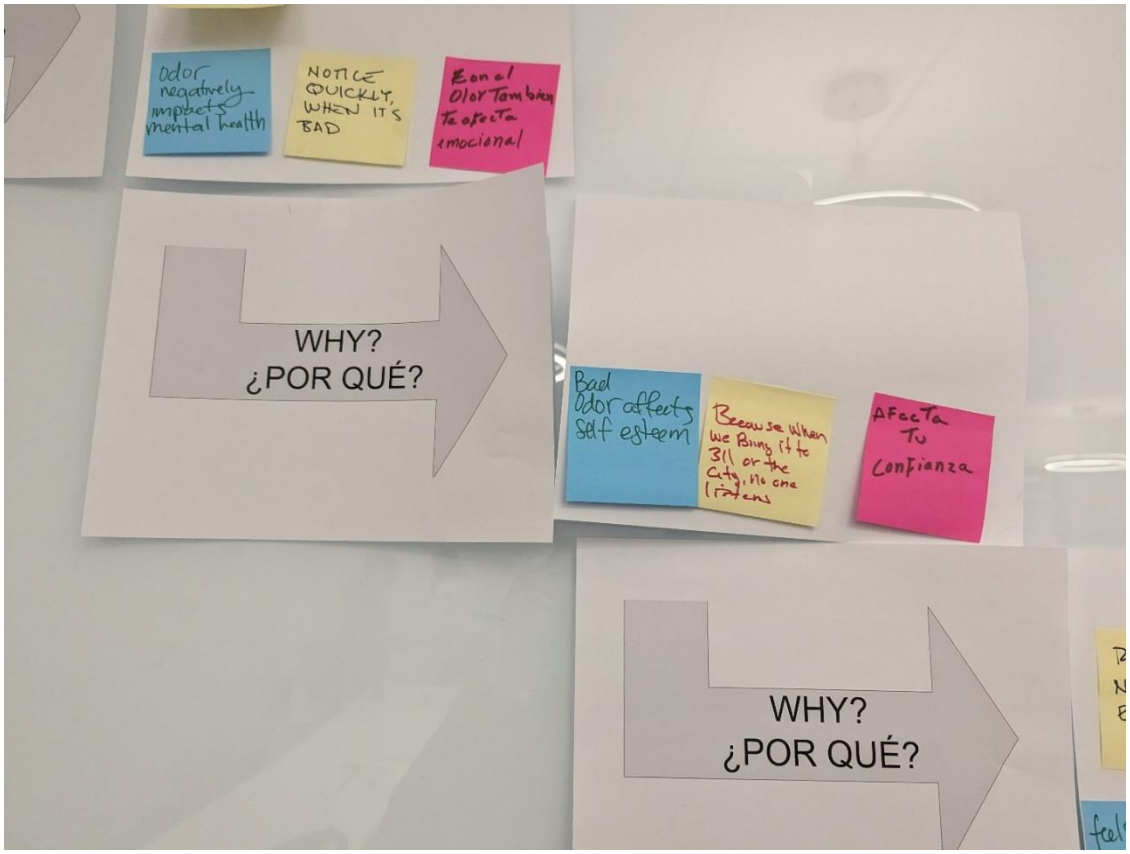

You can go to hospital
EPA doesn't do a good job on Cleaning all the soil
un Atencion real. esp que se nesecita
Porque en aquel entonces no tenian consencia en como afectaba a los residentes sino para ellos lo importante era el Dinero no la salud
WHY?

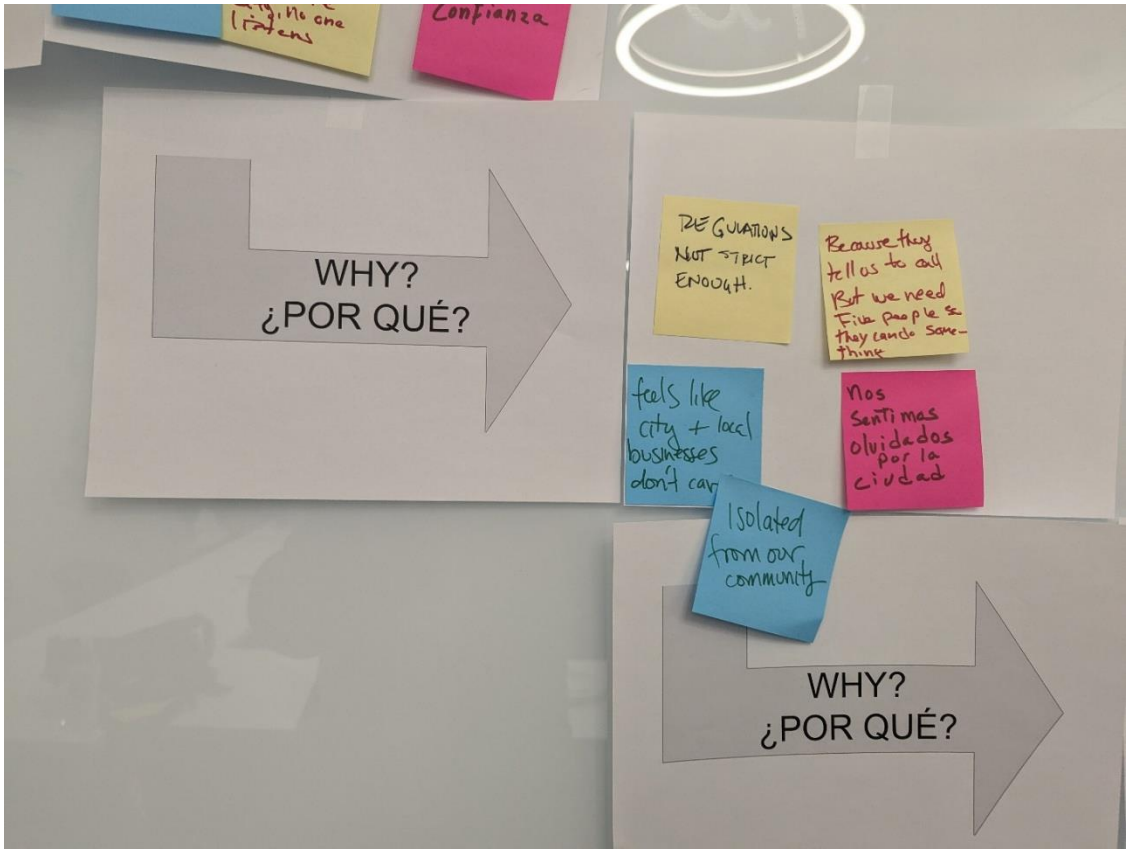

the soil again
Un Atención real. es/p que se nesecita
WHY?
¿POR QUÉ?
Which causes Asthma
When I-70 project happened more people got sick beause of the soil
A more profound study on the causes of Asthma
Porque la sociedad se preocupan mas Por la Salud de los residentes afectados
Falta de Salud para los residenTes

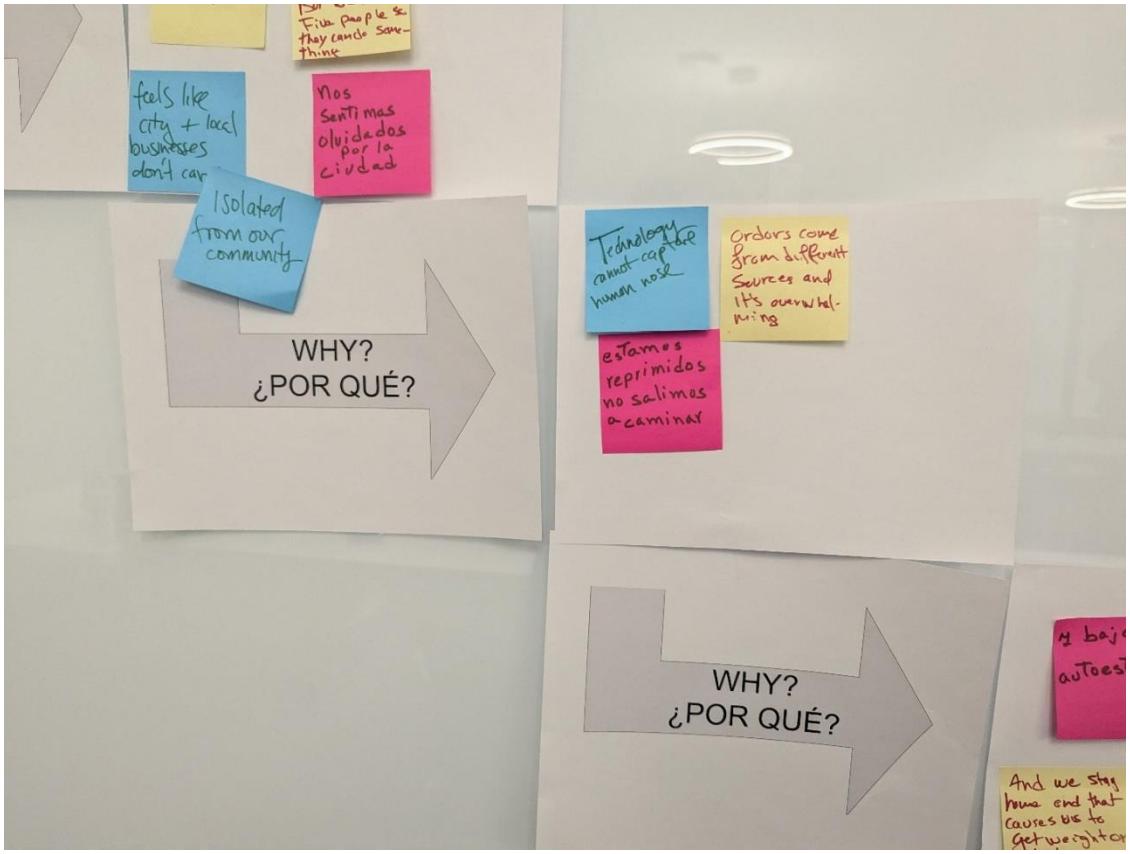
ODOR IS A HEALTH CONCERN IN GES

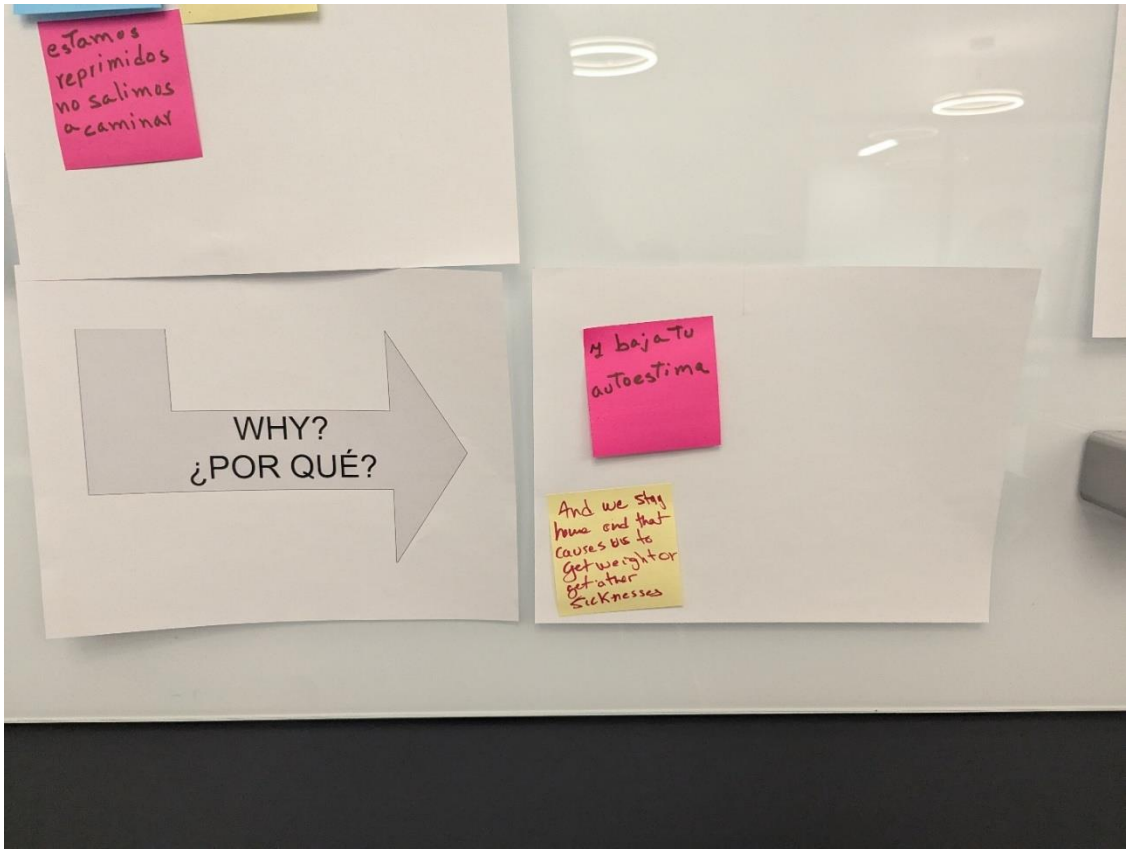




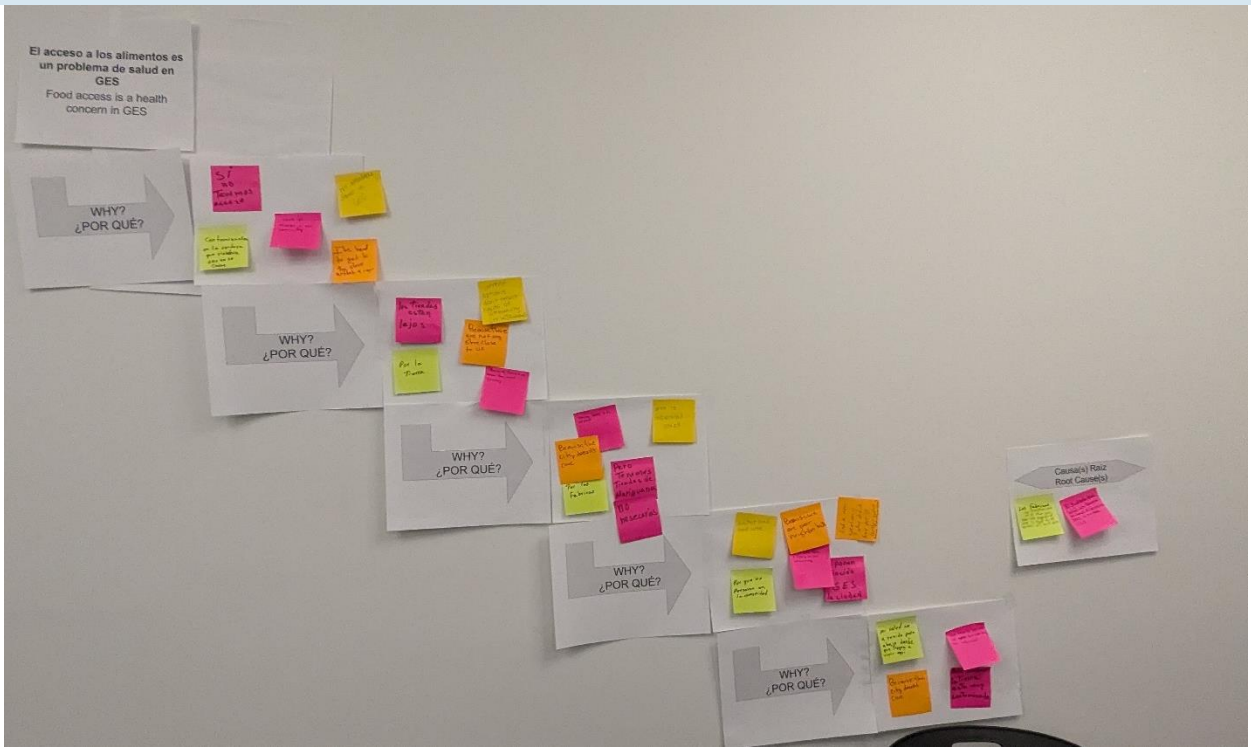

Odor negatively impacts mental health
NOTICE QUICKLY, WHEN IT'S BAD
Bad Odor affects Self esteem
Because when we Bring it to 311 or the City, No one listens
AFecta Tu Confianza
WHY?
¿POR QUÉ?
WHY?
¿POR QUÉ?

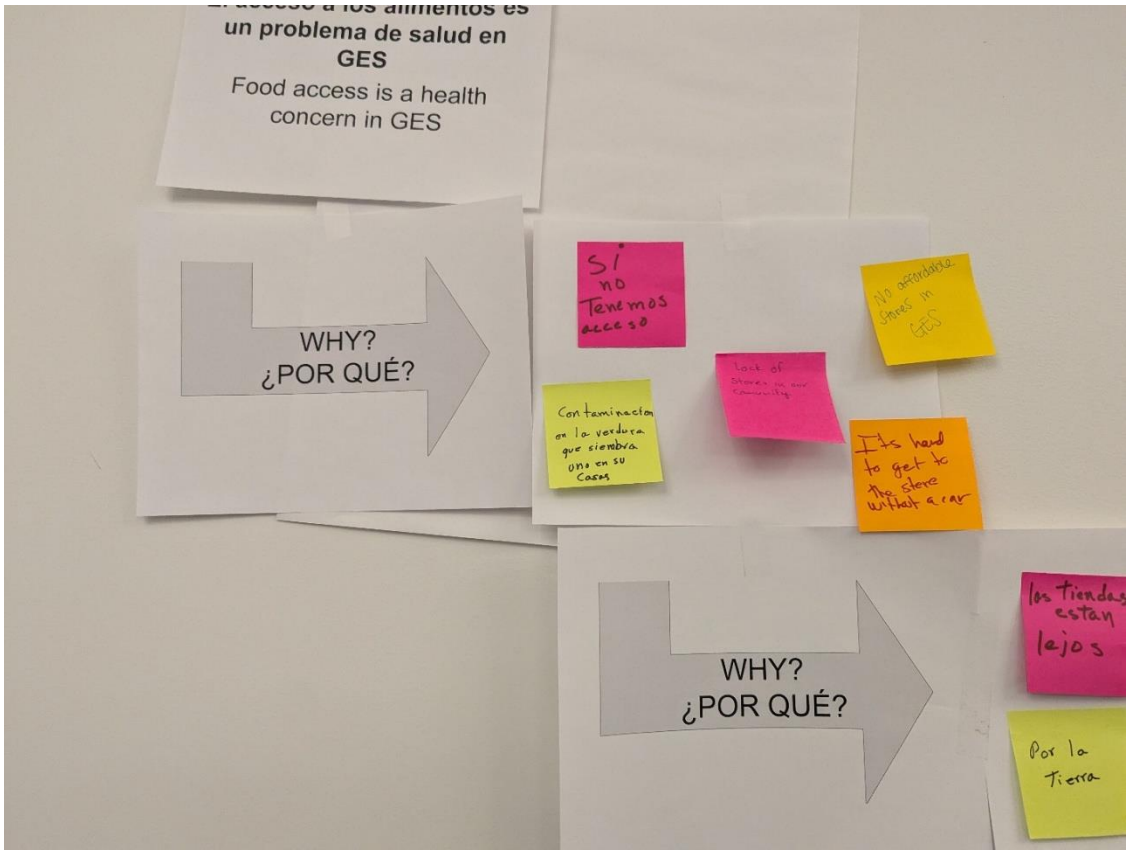

Confianza
WHY?
¿POR QUÉ?
REGULATIONS NOT STRICT ENOUGH.
Because they tell us to call But we need Fine People so they can do Some-thing
feels like city + local businesses don't car
Nos Sentimos olvidados por la ciudad
Isolated from our community
WHY?
¿POR QUÉ?

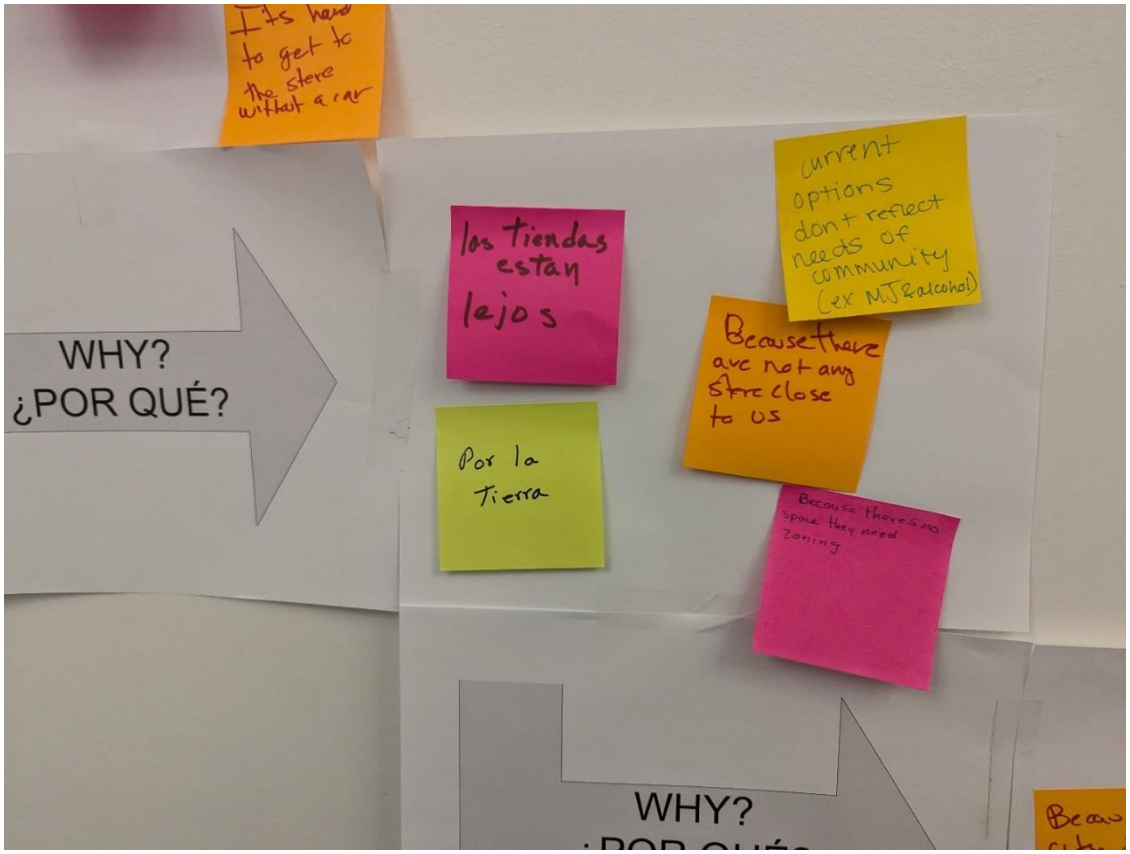

feels like city + local businesses don't car
Nos Santimos olvidados por la ciudad
Isolated from our community
WHY?
¿POR QUÉ?
Tecnology cannot capture human nose
Orders come from different Sources and it's overwhelming
estamos reprimidos no salimos a caminar
WHY?
¿POR QUÉ?
And we stay home and that causes us to

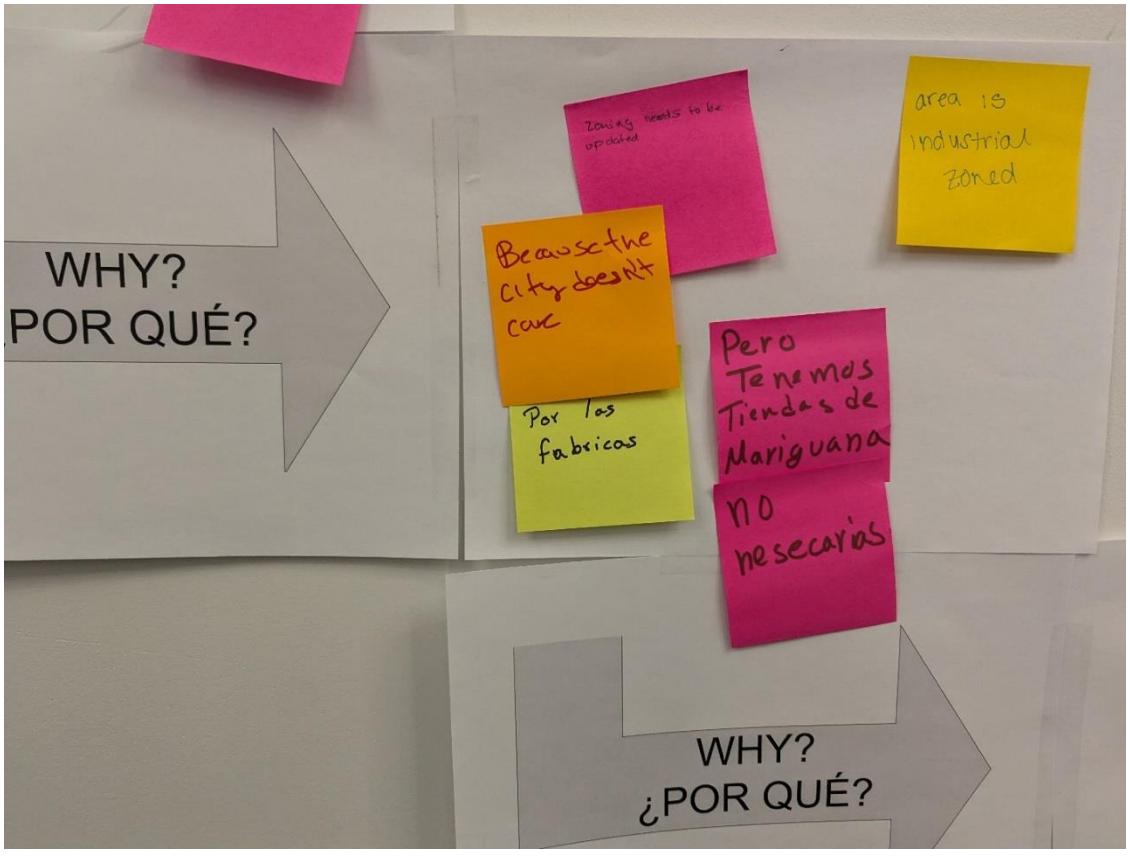

estamos reprimidos no salimos a caminar
WHY?
¿POR QUÉ?
y baja Tu autoestima
And we stay home and that causes us to Get weight or get other Sicknesses

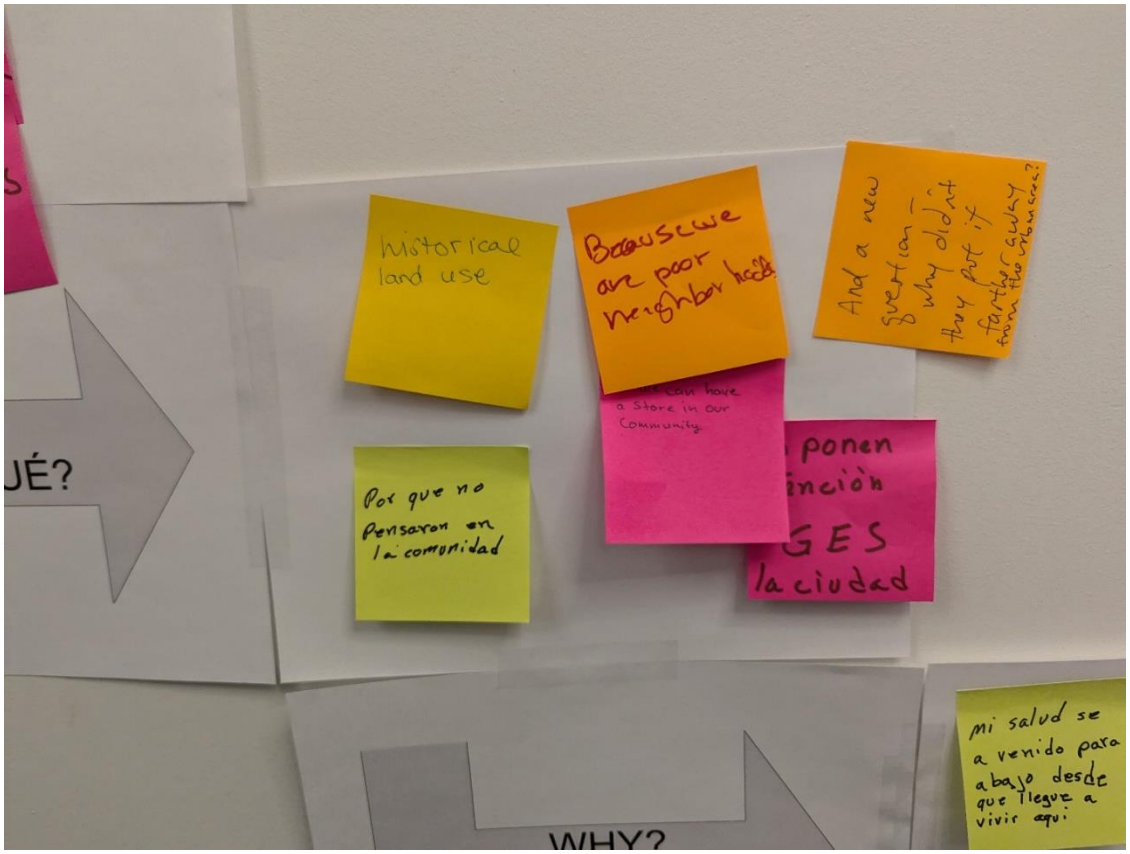
FOOD ACCESS IS A HEALTH CONCERN IN GES

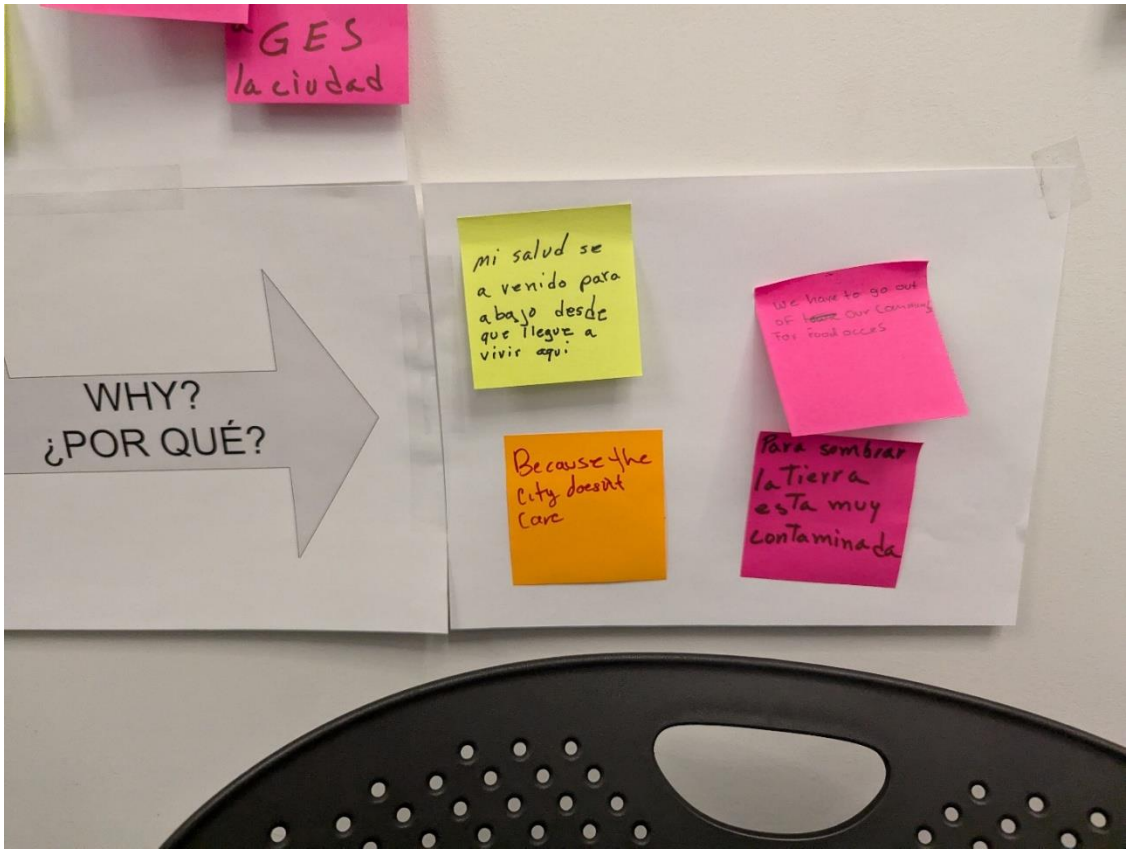


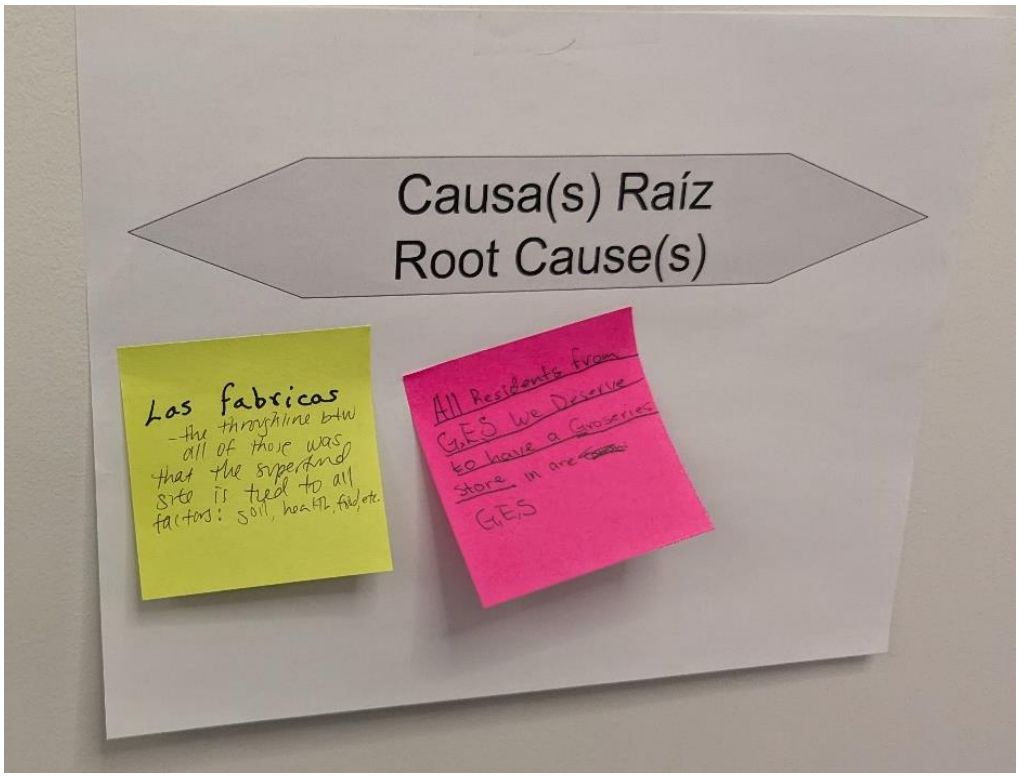



It's hard to get to the store without a car
WHY?
¿POR QUÉ?
los tiendas estan lejos
current options don't reflect needs of community (ex MJ&alcohol)
Because there are not any store close to us
Por la Tierra
Because there's no space they need Zoning
WHY?

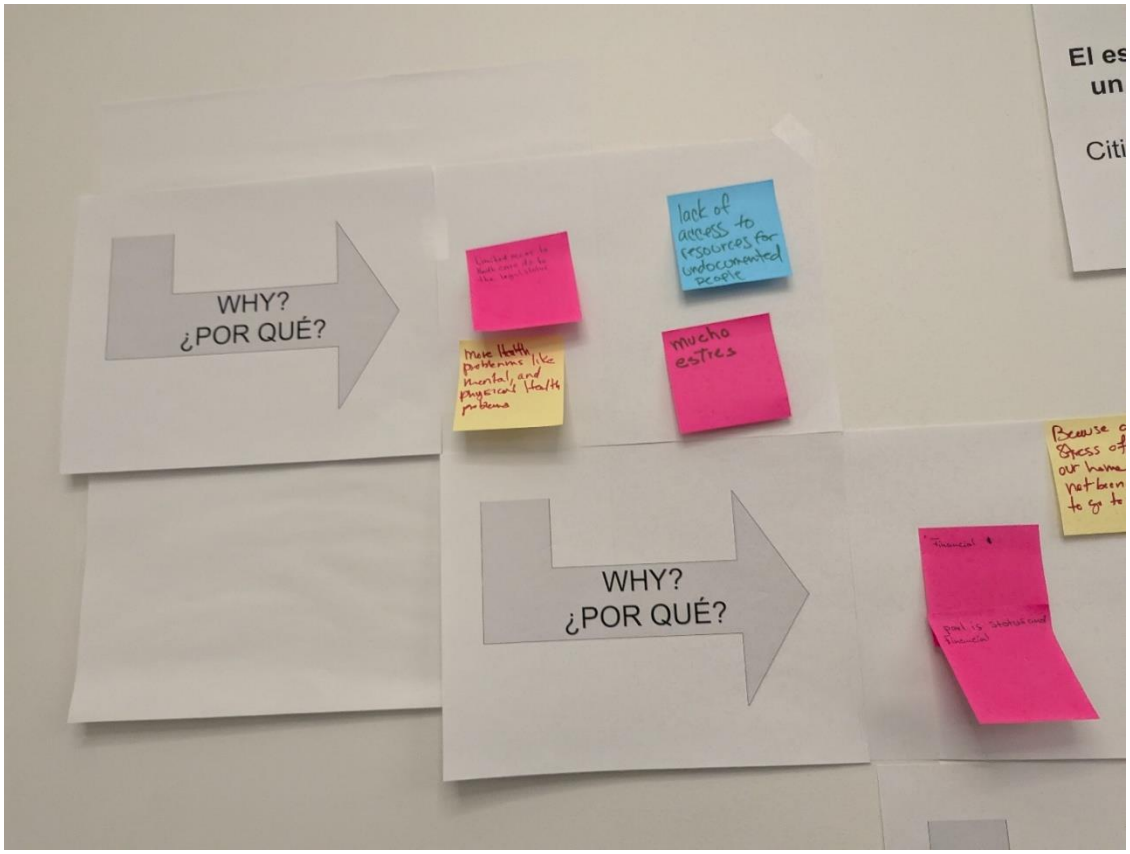

WHY?
POR QUÉ?
Zoning needs to be updated
area is industrial zoned
Because the city doesn't care
Pero Tenemos Tiendas de Mariguana
Por las fabricas
NO nesecarias
WHY?
¿POR QUÉ?

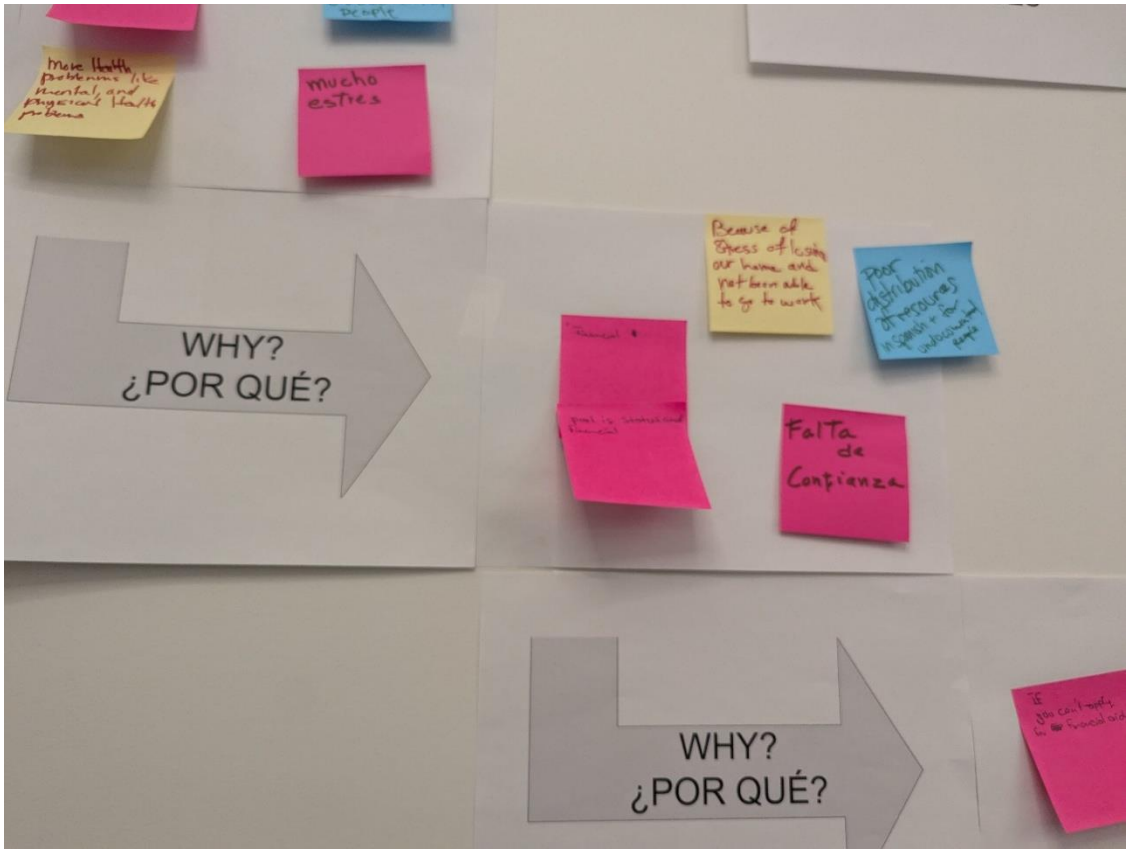

historical land use
Por que no Pensaron en la comunidad
ponen
GES
la ciudad
mi salud se a venido para abajo desde que llegue a vivir aqui
WHY?

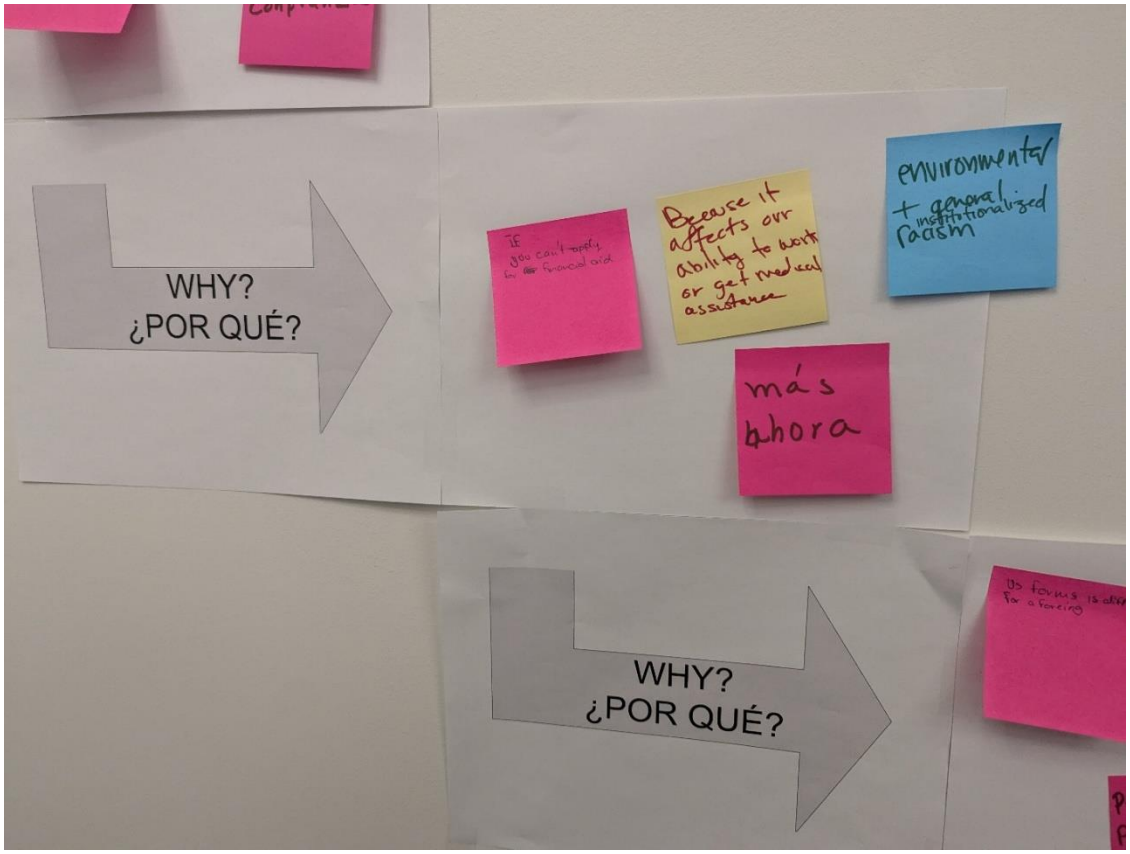

GES
la ciudad
WHY?
¿POR QUÉ?
mi salud se a venido para abajo desde que llegue a vivir aqui
Because the City doesn't Care
Para sombrar la tierra esta muy contaminada

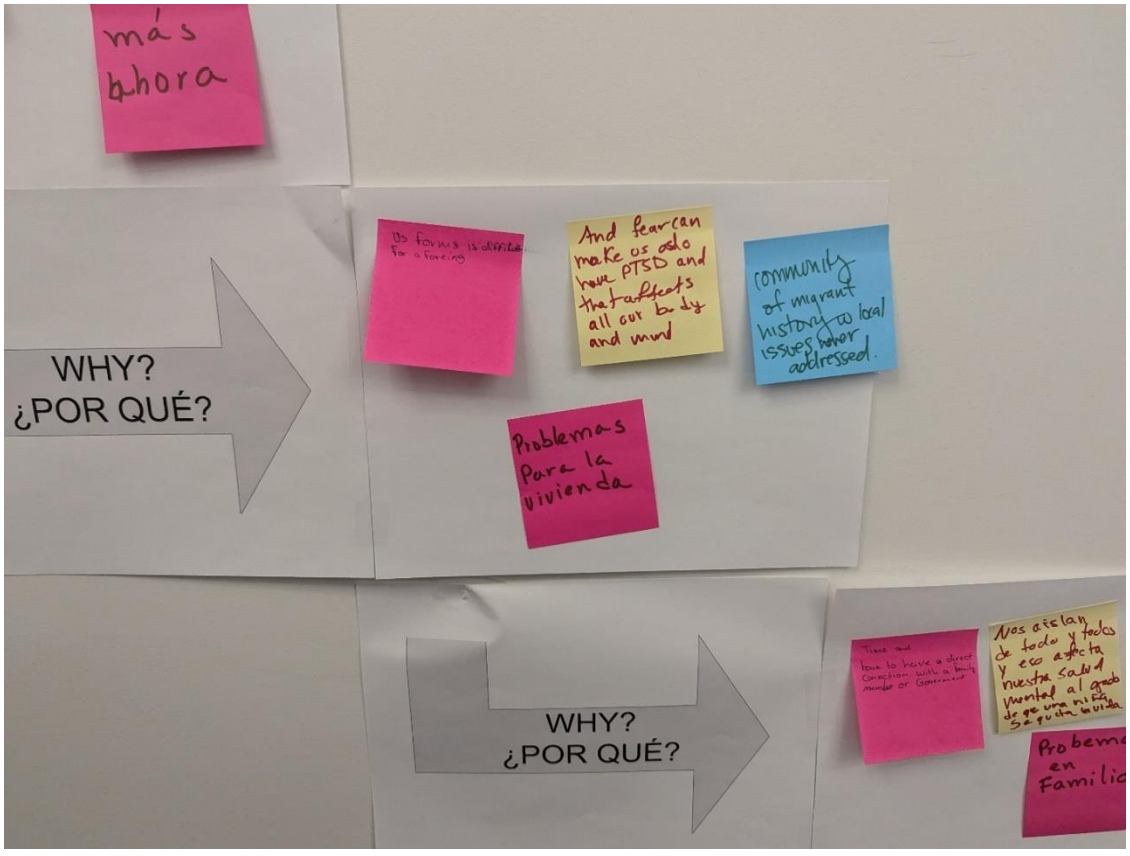


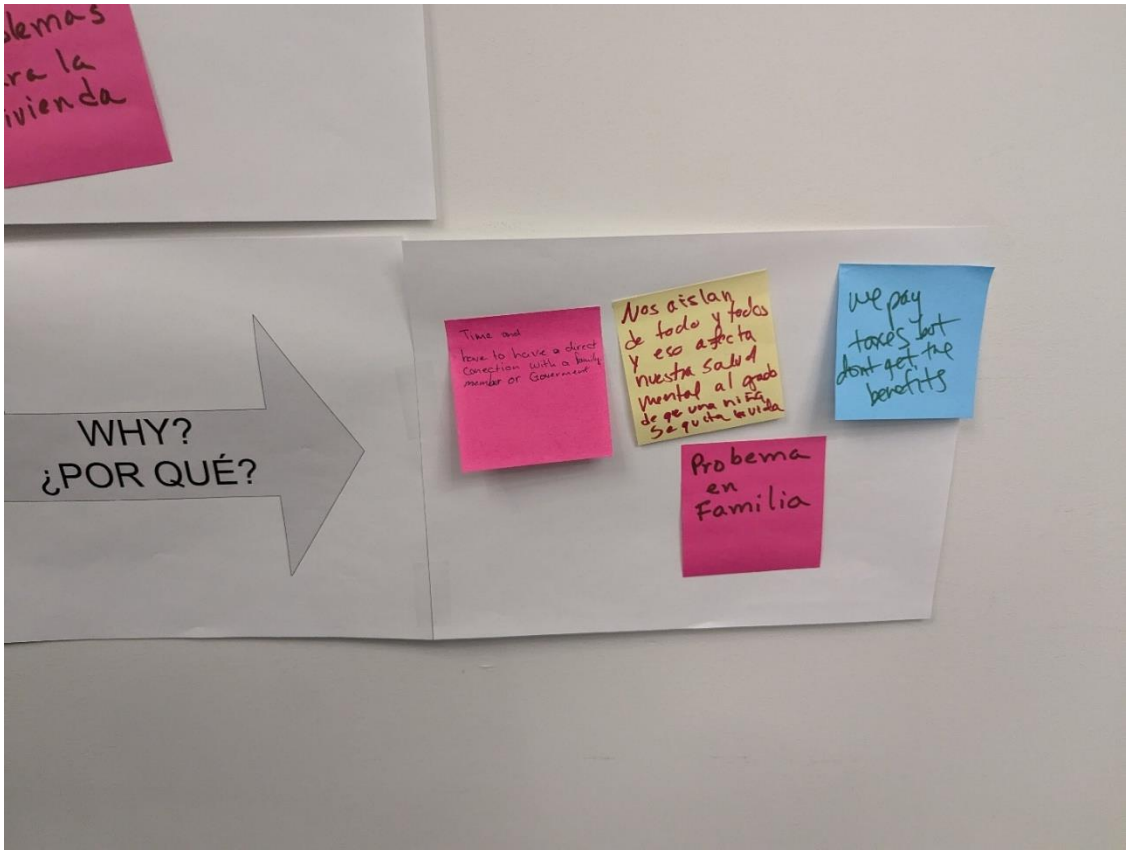
CITIZENSHIP STATUS IS A HEALTH CONCERN IN GES

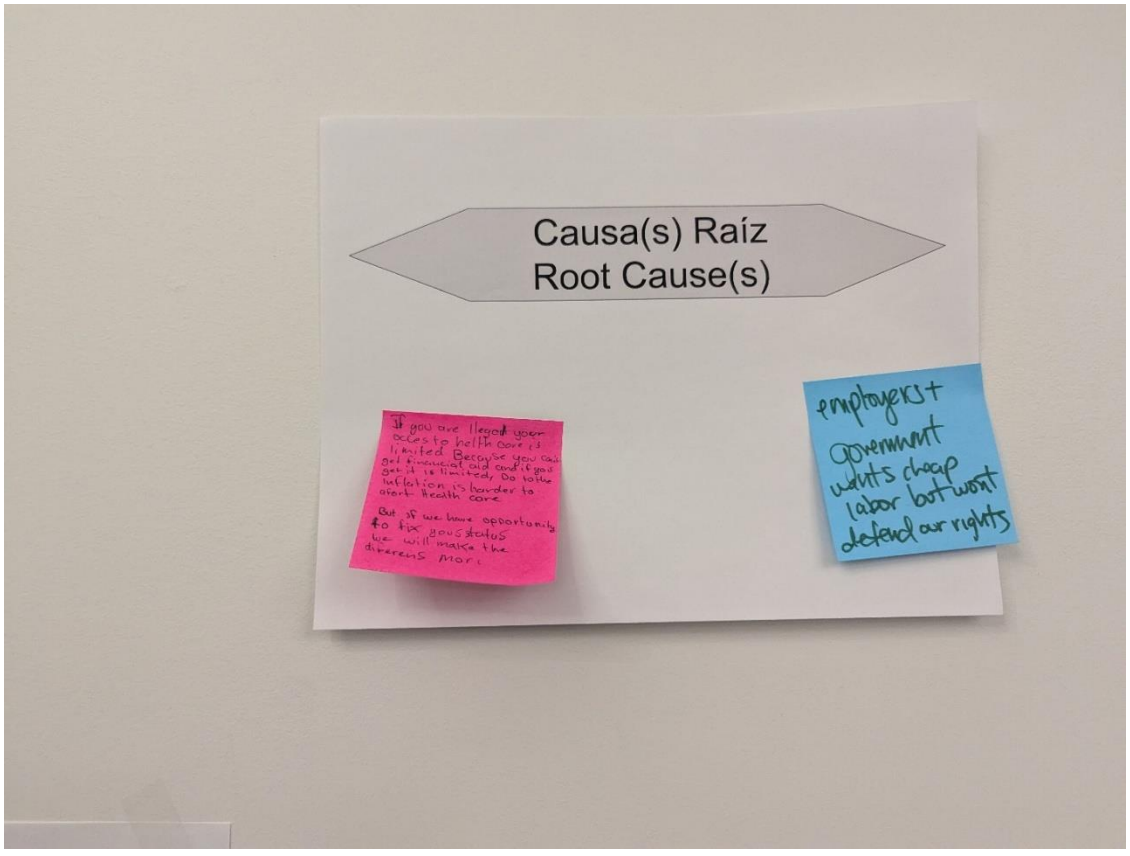

WHY?
¿POR QUÉ?
lack of access to resources for undocumented people
mucho estres
WHY?
¿POR QUÉ?

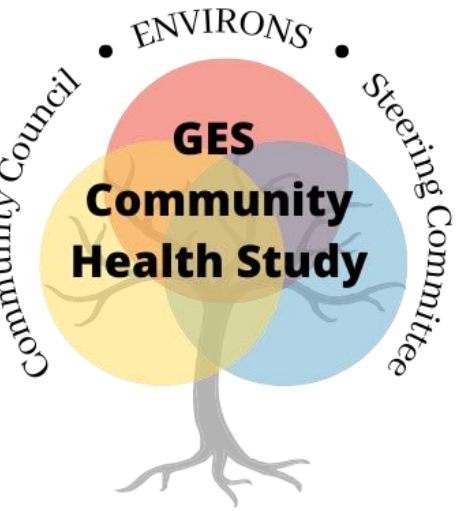

mucho estres
Because of Stress of losing our home and not been able to go to work
Poor distribution of resources
Falta de Confianza
WHY?
¿POR QUÉ?
WHY?
¿POR QUÉ?


WHY?
¿POR QUÉ?
Because it affects our ability to work or get medical assistance
environmental + general institutionalized racism
más ahora
WHY?
¿POR QUÉ?


más ahora
WHY?
¿POR QUÉ?
And fear can make us sick have PTSD and that affects all our body and mind
community of migrant history so local issues better addressed.
Problemas Para la vivienda
WHY?
¿POR QUÉ?


WHY?
¿POR QUÉ?
Time and
have to have a direct
connection with a family
member or Government
Nos aislan
de todo y todos
y eso afecta
y nuestra salud
mental al grado
de que una niña
se quita su vida
Probema
en
Familia
we pay
taxes but
dont get the
benefits


Causa(s) Raíz
Root Cause(s)
If you are illegal your
acces to health care is
limited Because you can
get financial aid and if you
get it is limited. Do to the
inflation is harder to
afort health care
But if we have opportunity
to fix your status
we will make the
diferens Mars
employers +
government
wants cheap
labor but wont
defend our rights



Static Maps

GES Community Health Study

In response to Deliverable 2.9

March 14, 2025

ENVIRONS

Colorado State University

COMMUNITY RELEVANT SUMMARY

If you live in a community outside of the GES neighborhoods, our summary and excitement about these maps might be hard to understand. We can imagine that in other neighborhoods, maps showing data about levels of pollution or short life expectancies, that indicate visually the “numbers” of the problems, may be unnecessary. Stay tuned, however, because other communities have a role to play in this new development. In the GES neighborhoods, we are continuously looking for new ways to communicate our lived experiences more clearly with those who are willing to learn and listen. These maps may be the next step towards that.

Maps help present data clearly and visually, making it easier to highlight problems. For example, these maps can show the density of marijuana dispensaries compared to food stores and the health impacts of pollution and proximity to I-70. Maps provide residents with concrete data to advocate for change, communicate concerns to representatives, and take collective action without relying solely on individual experiences. What's particularly interesting about these maps, is that we can compare our data to the data of other communities. What are the asthma or cancer rates in your community compared to ours? Take a look yourself. You can use these maps to look into what matters most to you and your family.

As a community, we’ve spent countless hours without feeling heard when we describe what it's like to live in communities adjacent to highways and heavy industry. Clear data is essential to having our lived experiences believed by advocates, legislators, and policymakers who, up until now, have not been held accountable for their promises. As a working-class community, having a tool that shows the stark differences between our struggles and those of other Denver communities may help legislators and allies understand that the GES neighborhoods are not being heard.

Finally, these maps are validating. As a working-class community, it is energy-consuming and demoralizing to go through pages and pages of hard-to-understand numbers and data and then extremely time-consuming to call city hotlines to report every problem- we’d be on the phone as a full-time job. When we have called, we feel that corrections are minimal and any response at all is days delayed. These visual maps are easier to understand than elaborate spreadsheets. We can describe the odors we smell or tell stories of how many friends we have lost due to our proximity to deep polluters, but it isn't until we can see our stories that we are able to feel that our struggles are real and more easily communicated.

- Your GES Health Study Community Council

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LIST OF ACRONYMS AND DEFINITIONS

Table 1. List of Acronyms and Definitions

Acronym or Term	Definition
BC	Black carbon
CDC	Centers for Disease Control and Prevention
CO	Carbon monoxide
dBA L_{eq}	A-weighted decibels, equivalent level (a measure of noise)
EPA	United States Environmental Protection Agency
GES	Globeville, Elyria, and Swansea
HOLC	Home Owners Loan Corporation
IDW	Inverse-distance weighted
km	kilometer
MUA	Medically underserved area
NO_2	Nitrogen dioxide
O_3	Ozone
OU	Operable Unit
PM_{10}	Particulate matter with an aerodynamic diameter of less than 10 microns
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of less than 2.5 microns
ppb	parts per billion (a unit for gas pollutants)
SO_2	Sulfur dioxide
µg/m^3	micrograms per cubic meter (a unit for particulate matter)

INTRODUCTION

Deliverable 2.9 Static Maps serves as a permanent record for all of the maps created for GES Community Health Study Deliverables 2.2 through 2.8. All of the maps available in this document are also available in these original deliverables. They are presented here for the convenience of community members and others who may wish to explore the data used in the GES Community Health Study.

The goal of this deliverable is to archive the work of the GES Community Health Study to date.

Readers should consult the original deliverables for specific information about the maps presented in this document. For each of the maps in this deliverable, we include in the caption the figure number so that readers can reference these maps in their primary deliverable. These original deliverable documents also include important information on references, authorship, and recommended citations. All previous study deliverables are available on the GES Community Health Study website, located at https://www.geshealthstudy.org/home. We have included a list of study deliverables published to date below (Table 2).

Table 2. Description of GES Health Study deliverables

Deliverable	Description
Phase I	Planning and Foundations deliverables included
Deliverable 1.1: ENVIRONS Questionaries	After participating in a tour of the GES neighborhoods, each ENVIRONS team member completed a questionnaire prepared by the Community Council. In addition to individual responses, a summary for the team was created.
Deliverable 1.2: Shared Operational Principles	The Community Council, ENVIRONS, and Steering Committee identified roles and defined shared values, motivations, expectations, and limitations for the study.
Deliverable 1.3: Community Engagement Plan	The Community Engagement plan was developed with the Community Council and Steering Committee. It defines how ENVIRONS will communicate with the Community Council and the Steering Committee, and outlines strategies for communicating with residents, soliciting community input, and maintaining transparency.
Deliverable 1.4: Narrative	ENVIRONS identified sources of data, literature, and on-going projects that will be used in Phase II. As part of this, ENVIRONS reviewed the materials provided in the "crowd sourced literature review" folder curated by the Steering Committee prior to ENVIRONS coming onto the study.
Deliverable 1.5: Mapping and Website	The website is available in English and Spanish, and maps are available on the Maps page.
Deliverable 1.6: Course Correction Plan	ENVIRONS worked with the Community Council and Steering Committee to create a course correction plan. This plan ensures that the study is headed in the right direction for Phase II.
Phase II	Analysis
Deliverable 2.1: Data Rubric and Literature Evaluation	ENVIRONS created a rubric to evaluate the quality of literature and data, then applied this rubric to the sources of information identified in the crowd-sourced literature folder or in the Preliminary Data Identification and Narrative.
Deliverable 2.2: The ABCs of GES: The State of Health and Environment	This report characterizes areas of community concern, provides updated data to topics identified in the 2014 Health Impact Assessment report, and evaluates the implementation of recommendations from the 2014 report.

Deliverable 2.3: Exposure Outcome Matrix	The Exposure Outcome matrix demonstrates the connections between environmental exposures in GES, health outcomes, and health disparities based on existing research. The purpose of this matrix is to visualize how environmental exposures (e.g. pollutants) are connected to adverse health outcomes.
Deliverable 2.4: Community Environmental Burden Assessment (CEBA): Planning, Scoping, and Problem Formulation	This document outlines the plan for how ENVIRONS will conduct the Community Environmental Burden Assessment (CEBA), which makes up Deliverables 2.4, 2.5, and 2.6 for the study.
Deliverable 2.5: Community Environmental Burden Assessment (CEBA): The Exposure Response Assessment Phase	This document outlines the methods and preliminary results of the CEBA including modeled air pollution exposures across Denver and literature review of exposure-response relationships.
Deliverable 2.6: Community Environmental Burden Assessment (CEBA): Burden of Disease and Future Scenarios	As the final installment of the CEBA, this deliverable highlights the extent to which health outcomes are attributable to air pollution in GES.
Deliverable 2.7: Data and Literature Evaluation	As a continuation of Deliverable 2.1, this document evaluates data sources and literature used in Deliverables 2.2-2.6. It includes a data gap analysis that analyzes the availability of data on environmental stressors, health outcomes, and health disparities in GES.
Deliverable 2.8: Root Cause Analysis	This document investigates a root cause analysis of the environmental causes of concerns and health outcomes in GES. Informed by community members and previous deliverables (2.2-2.7).
Deliverable 2.10: Dynamic Maps	This document details the process for creating the study's web-based, interactive mapping tool that investigates environmental health concerns.

STATIC MAPS: DELIVERABLE 2.2

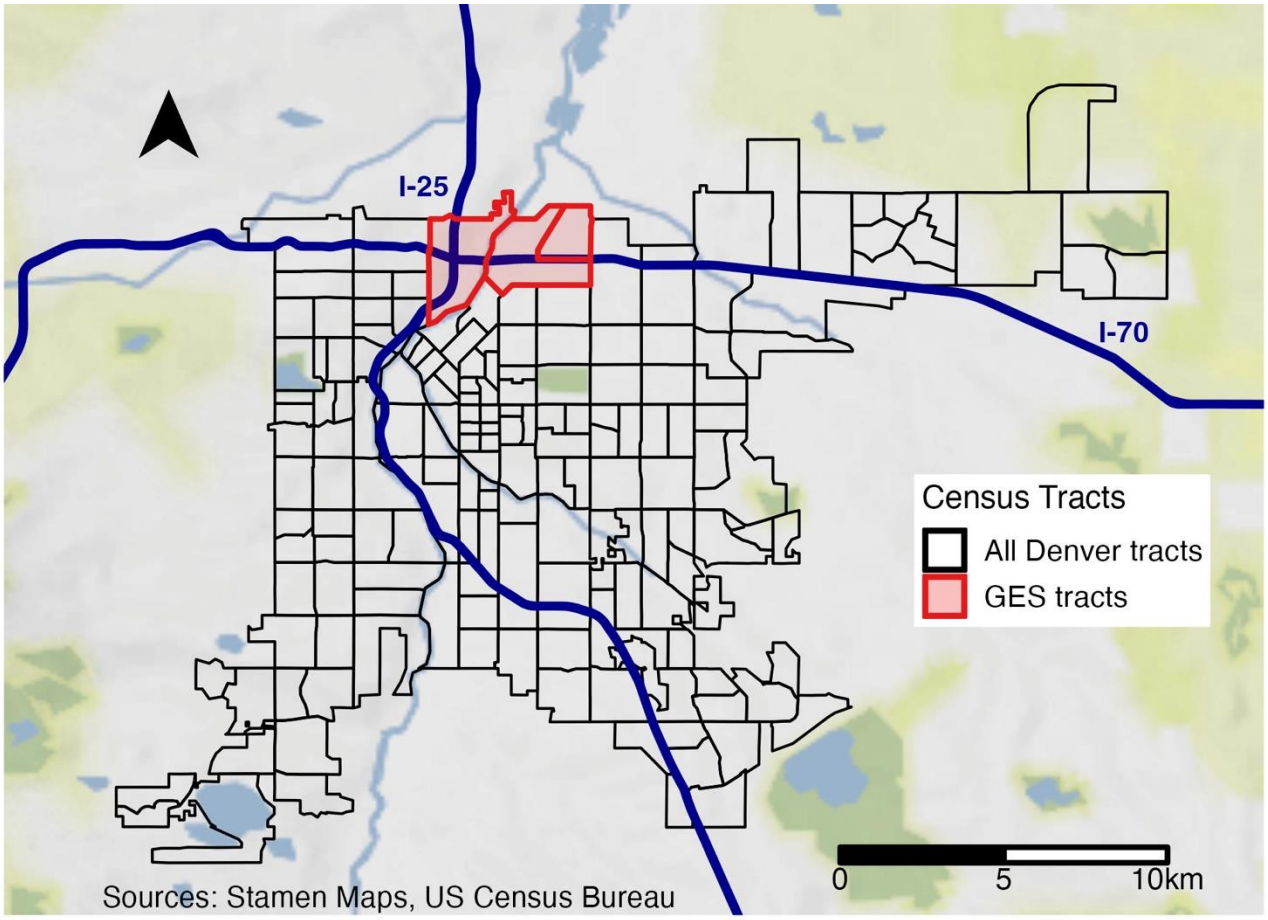


Figure 1. Globeville, Elyria, and Swansea (GES) neighborhoods in relation to the Denver area. (Figure 1 in Deliverable 2.2)

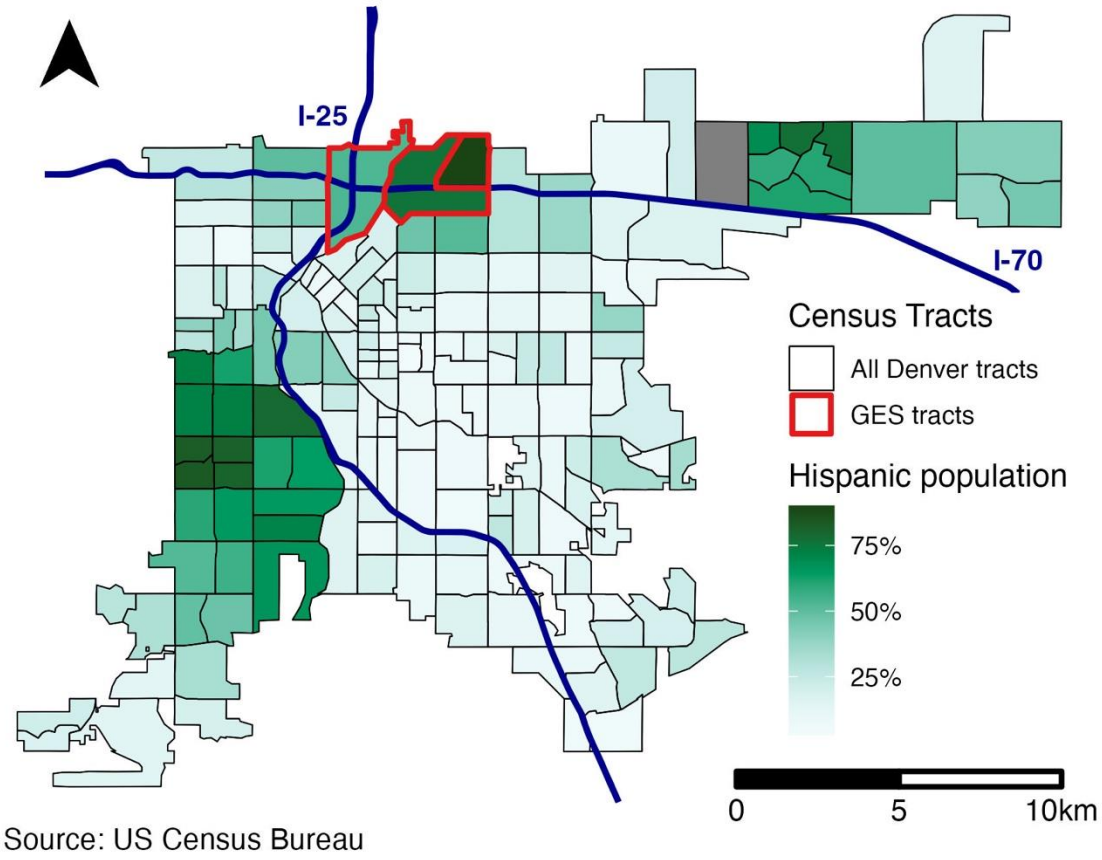


Figure 2. Hispanic/Latino population in Denver, Colorado, 2017-2021 5-year estimates. (Figure 3 in Deliverable 2.2)

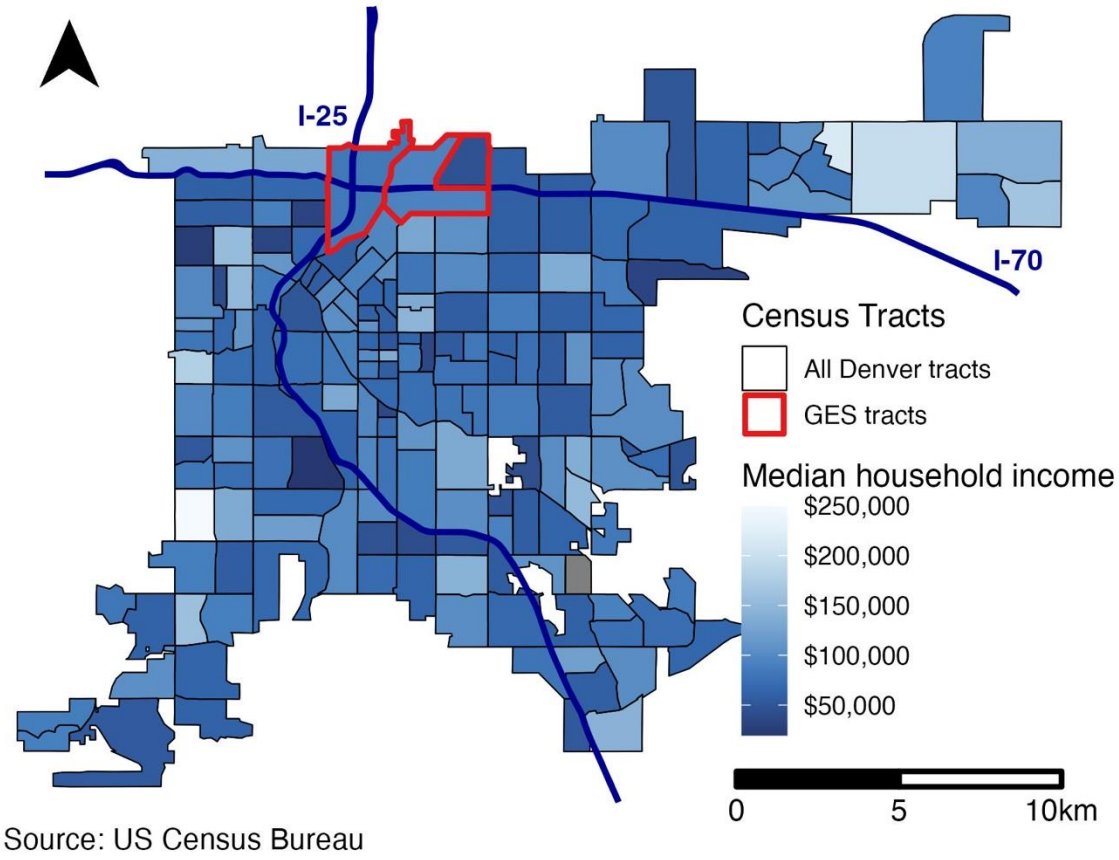


Figure 3. Median household income in Denver, Colorado, 2017-2021 5-year estimates. (Figure 4 in Deliverable 2.2)

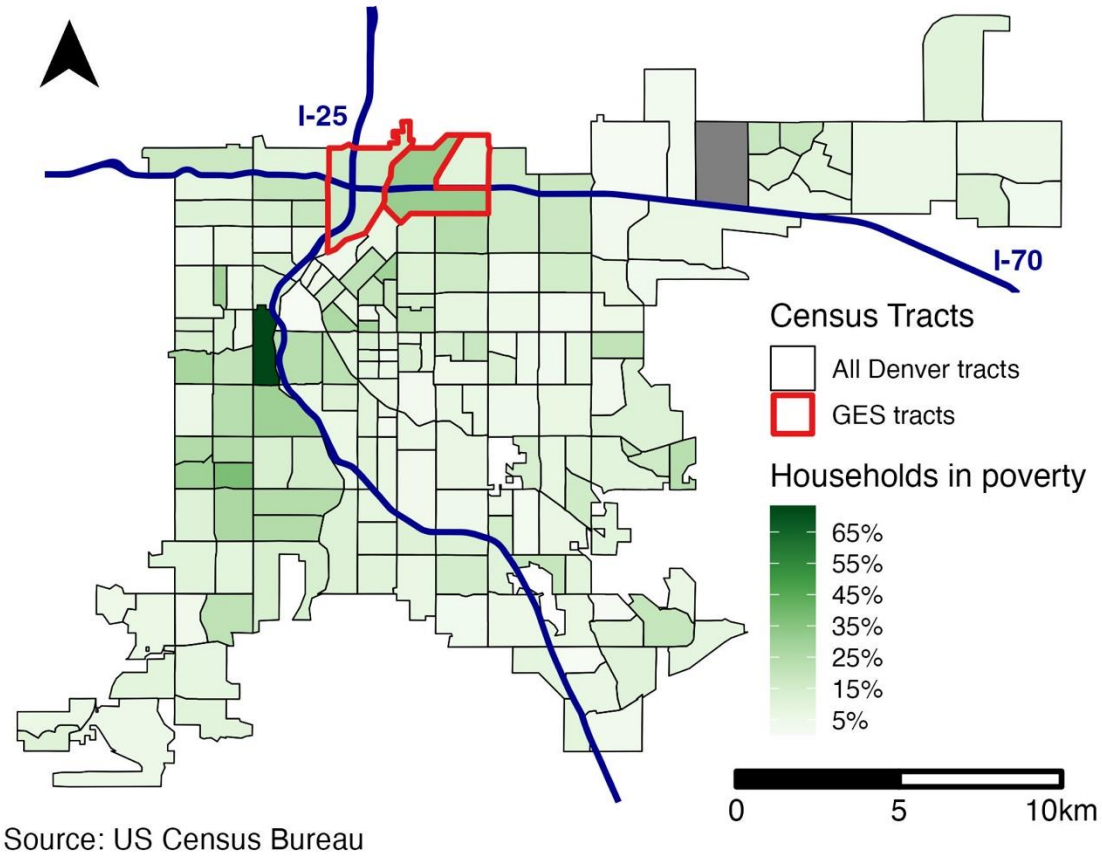


Figure 4. Household in poverty in Denver, Colorado, 2017-2021 5-year estimates. (Figure 5 in Deliverable 2.2)

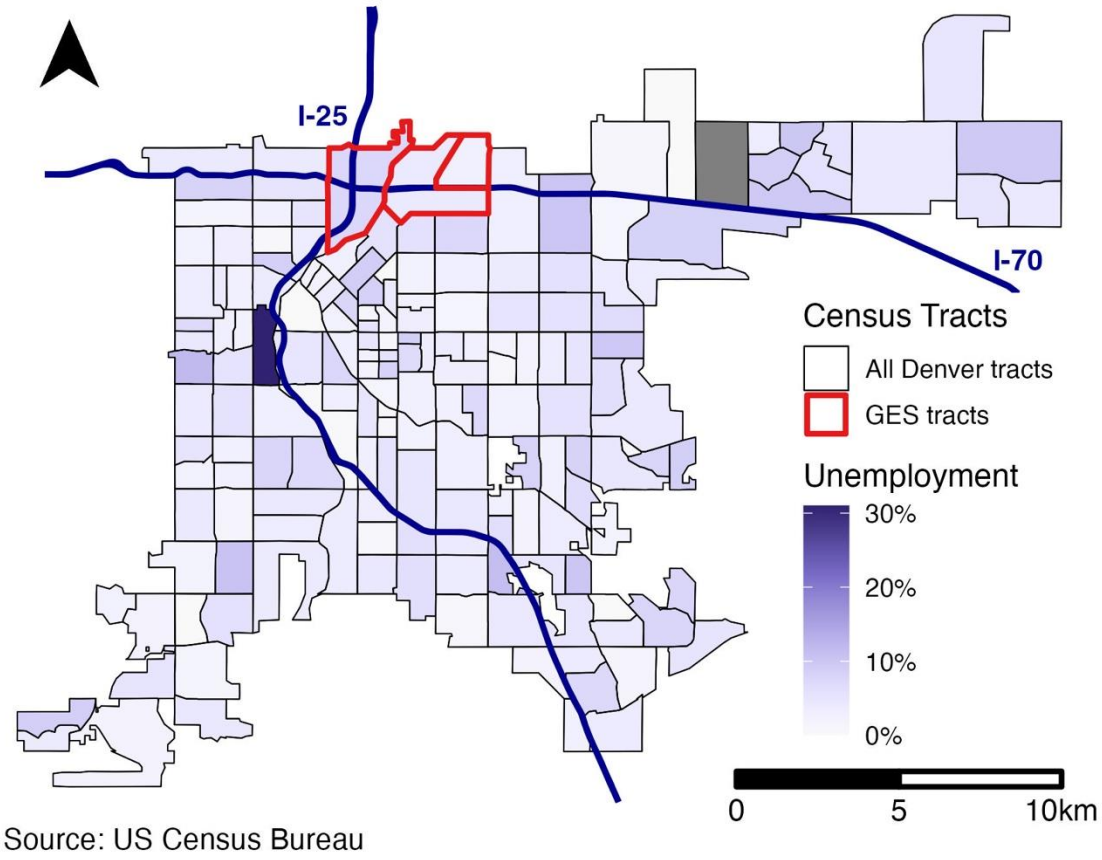


Figure 5. Unemployment rate in Denver, Colorado, 2017-2021 5-year estimates. (Figure 6 in Deliverable 2.2)

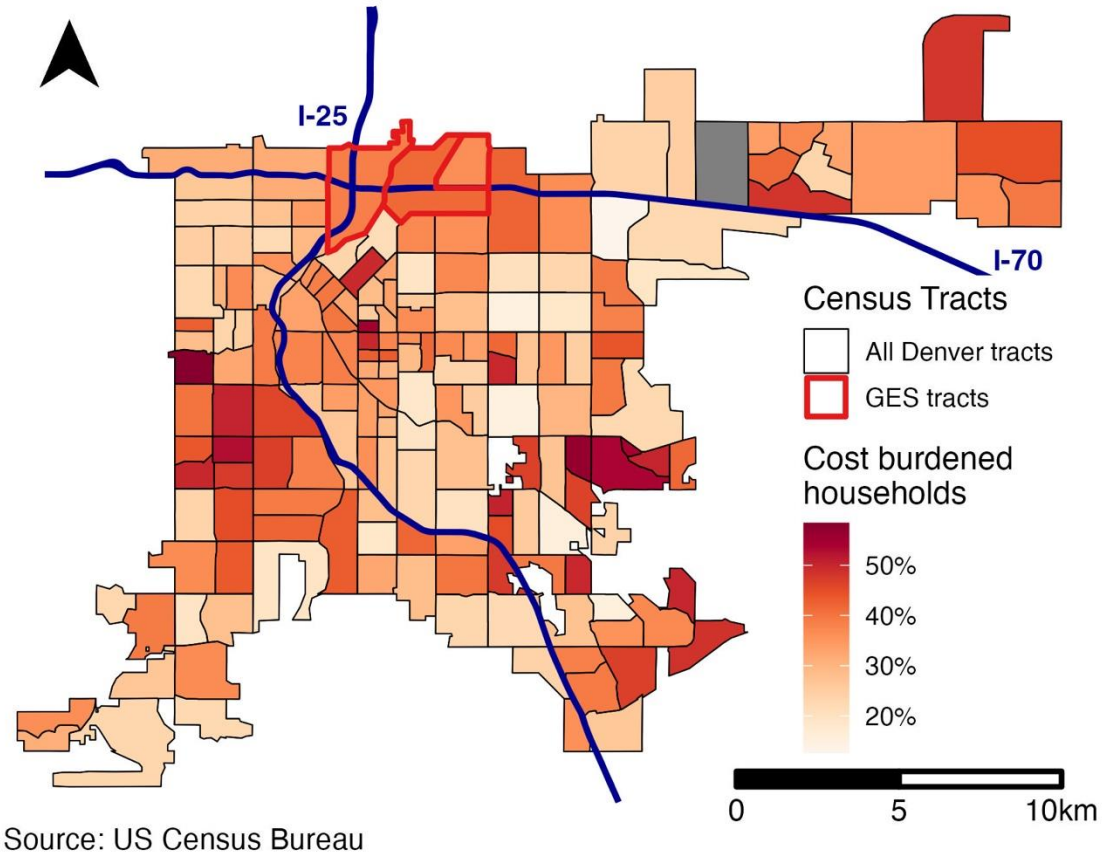


Figure 6. Cost burdened households in Denver, Colorado, 2017-2021 5-year estimates. (Figure 7 in Deliverable 2.2)

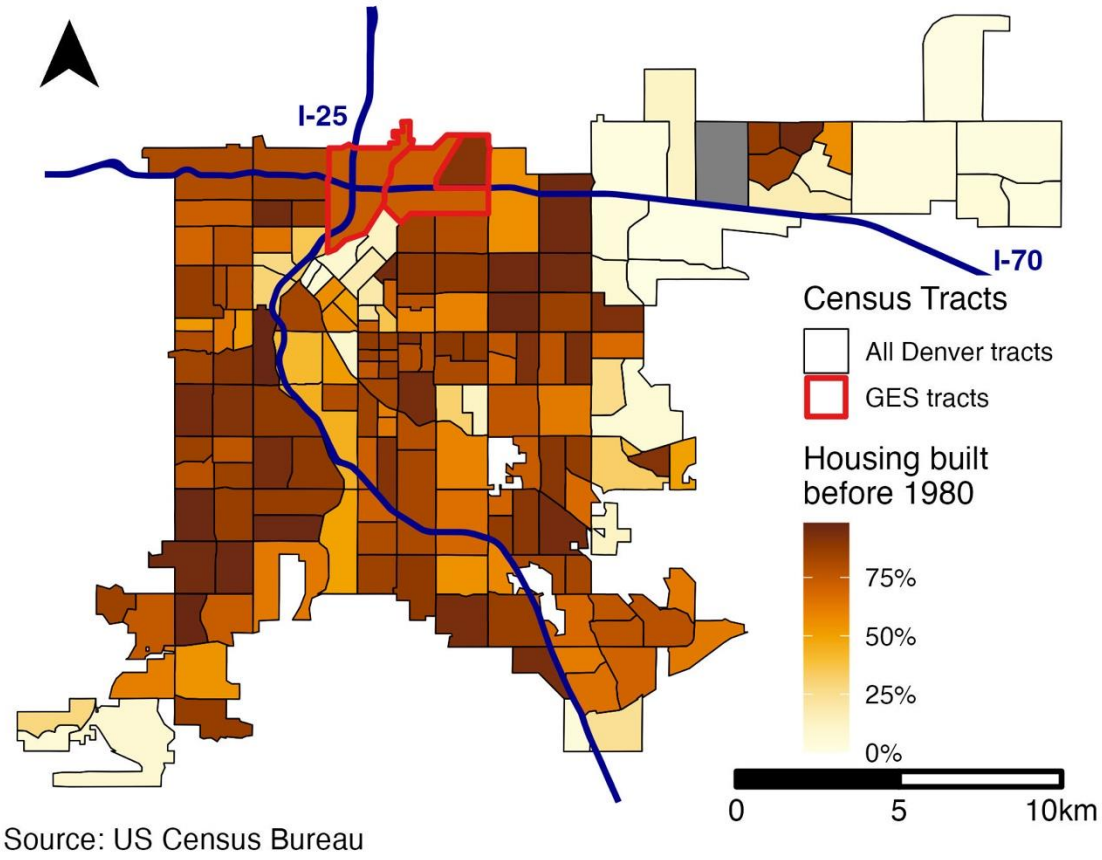


Figure 7. Housing built before 1980 in Denver, Colorado, 2017-2021 5 - year estimates. (Figure 9 in Deliverable 2.2)

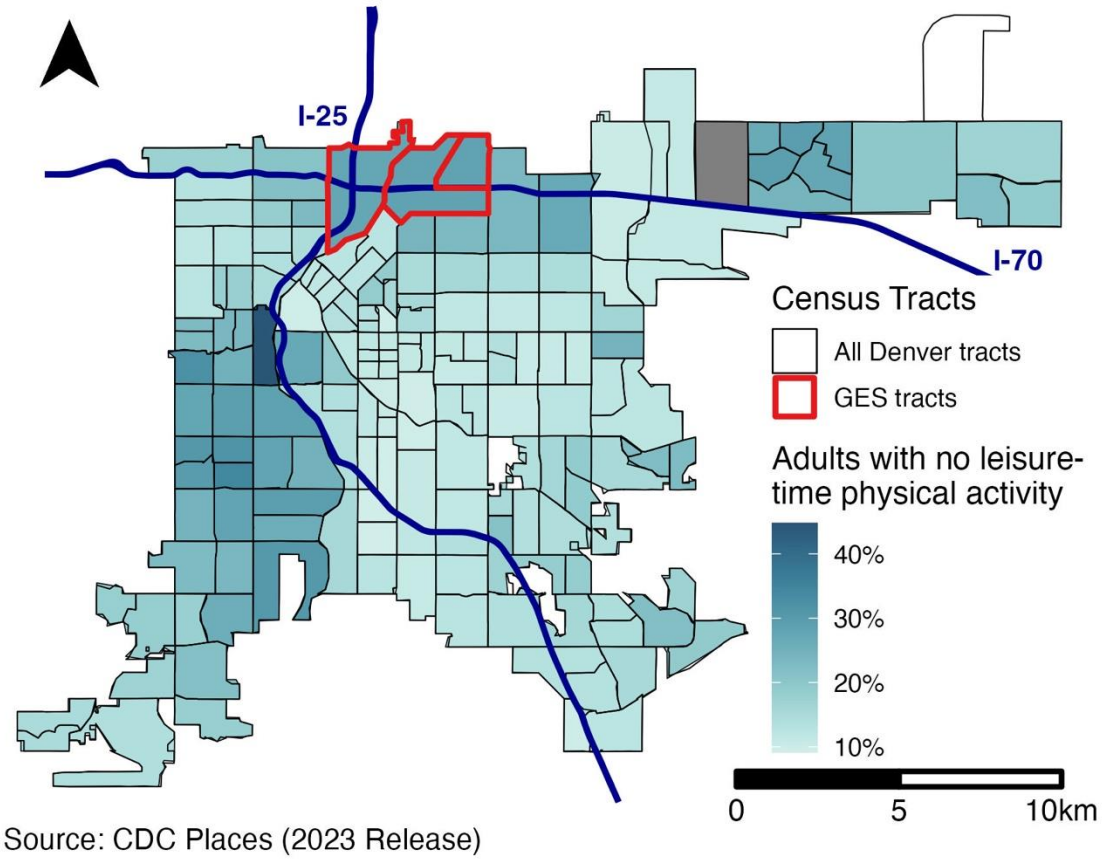


Figure 8. Adults with no leisure time physical activity in Denver, Colorado, 2021 BRFSS. (Figure 9 in Deliverable 2.2)

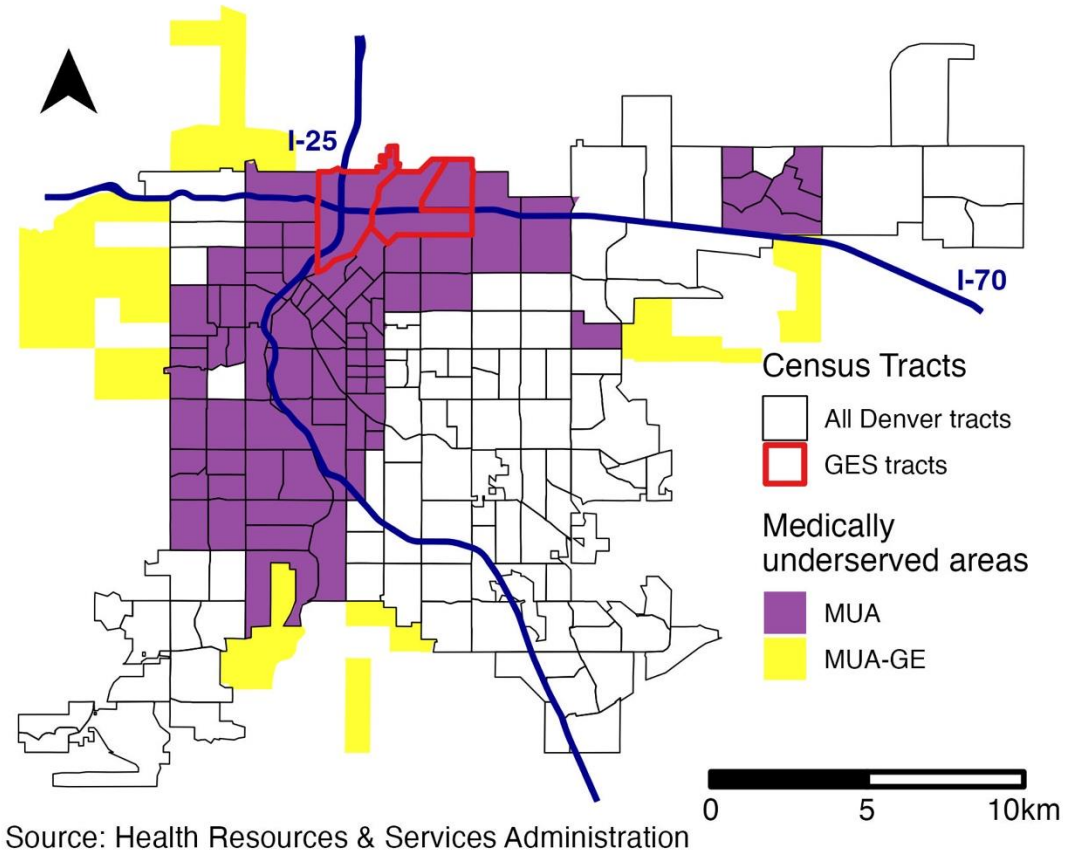


Figure 9. Medically underserved areas in Denver, Colorado 2021. (Figure 10 in Deliverable 2.2)

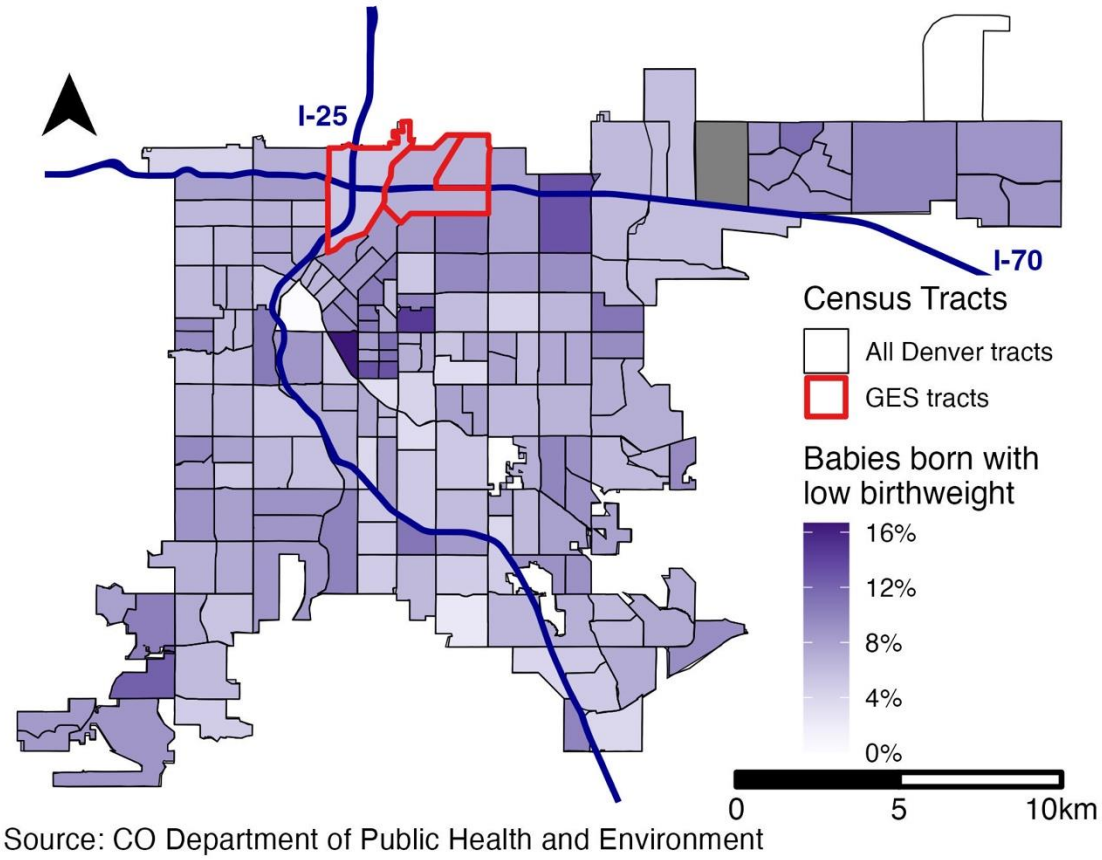


Figure 10. Babies born with low birthweight in Denver, Colorado, 2015-2019. (Figure 12 in Deliverable 2.2)

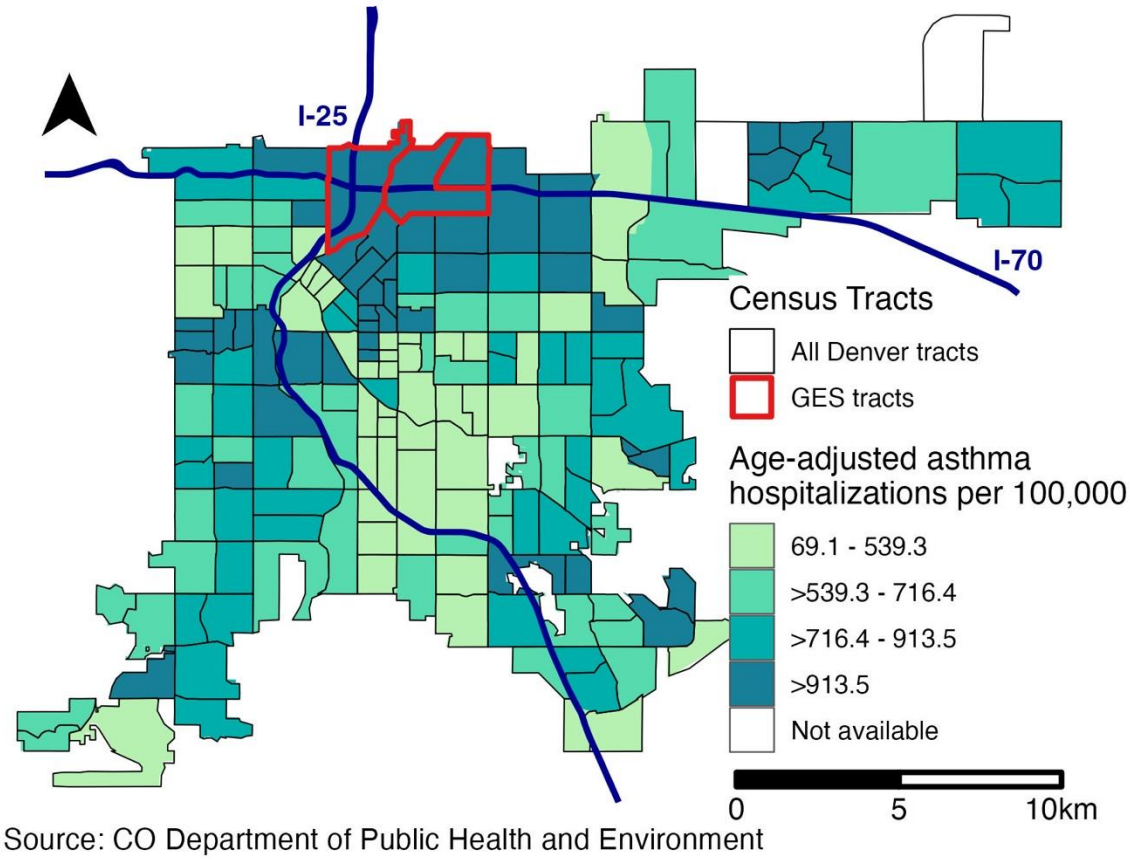


Figure 11. Age-adjusted asthma hospitalizations in Denver, Colorado, 2015-2019. (Figure 13 in Deliverable 2.2)

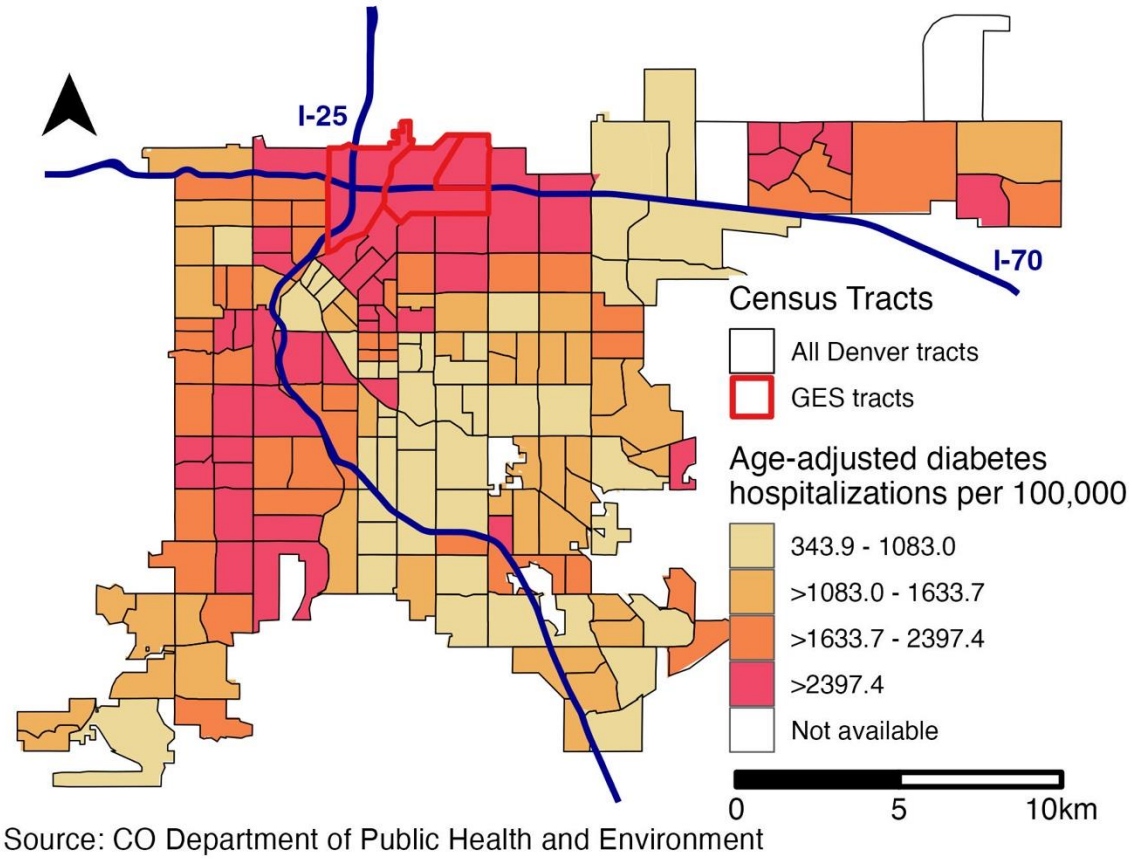


Figure 12. Age-adjusted diabetes hospitalizations in Denver, Colorado, 2015-2019. (Figure 14 in Deliverable 2.2)

BR

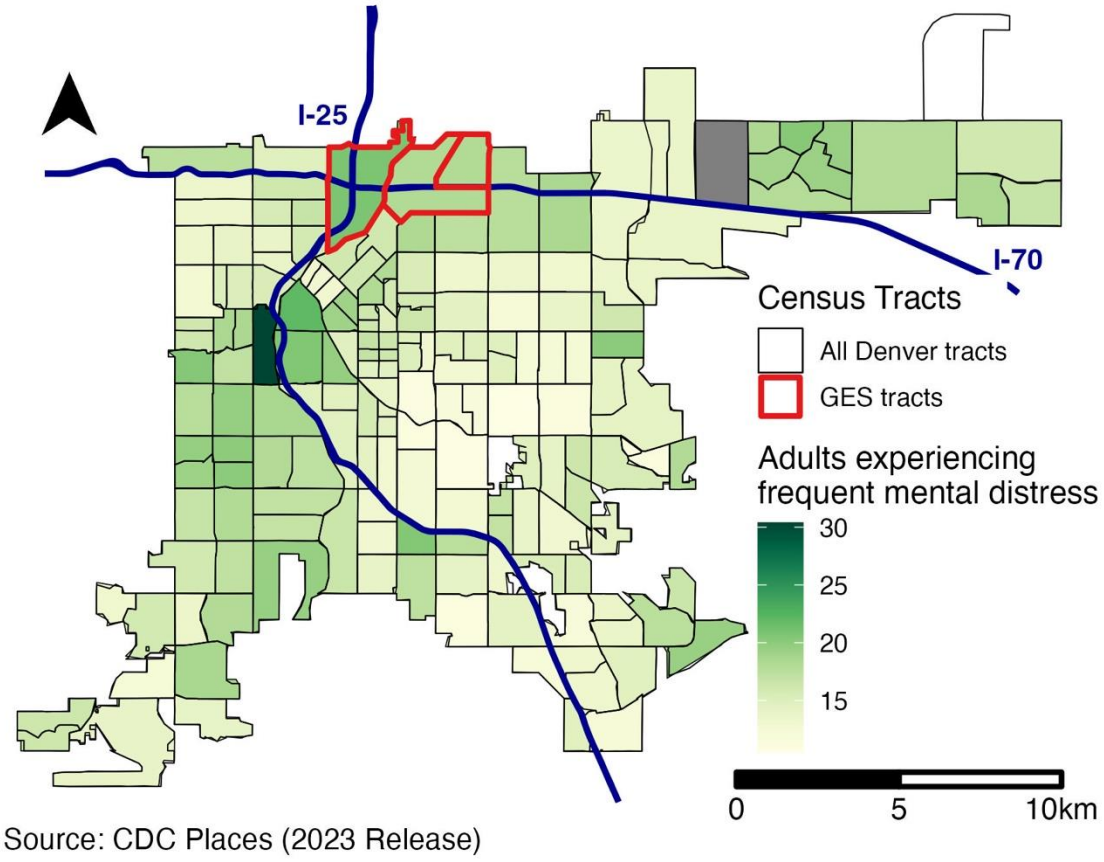


Figure 13. Percentage of adults experiencing frequent mental distress in Denver, Colorado, 2021 BRFSS. (Figure 15 in Deliverable 2.2)

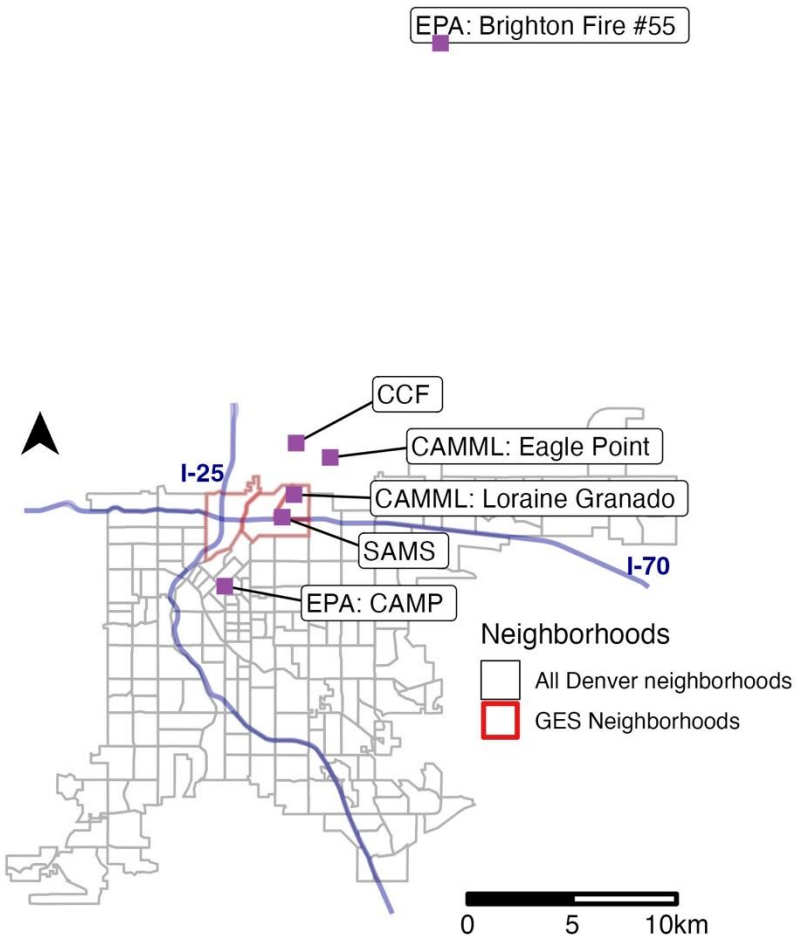


Figure 14. Map of benzene measurement sites, 2020-2023, US EPA. (Figure 17 in Deliverable 2.2)

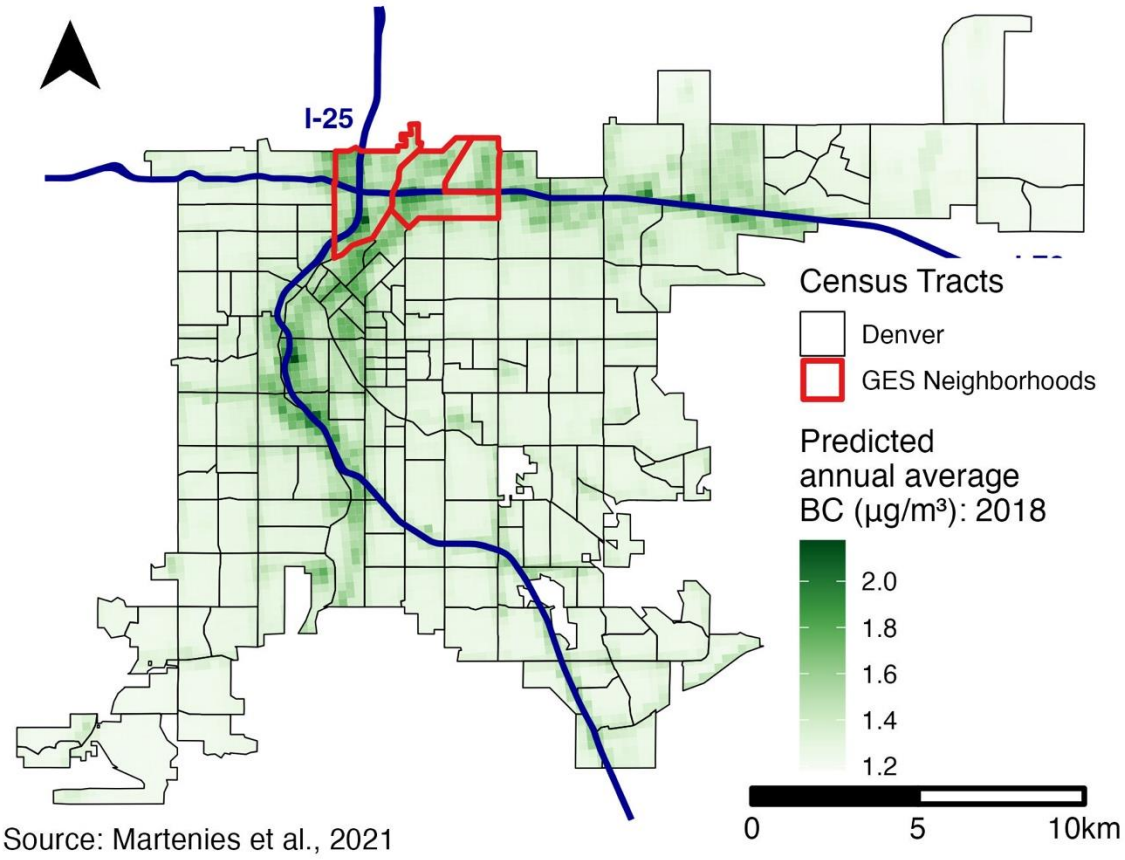


Figure 15. Map showing the predicted annual mean black carbon (BC) concentrations for a 250 m grid covering the city and county of Denver in 2018. (Figure 19 in Deliverable 2.2)

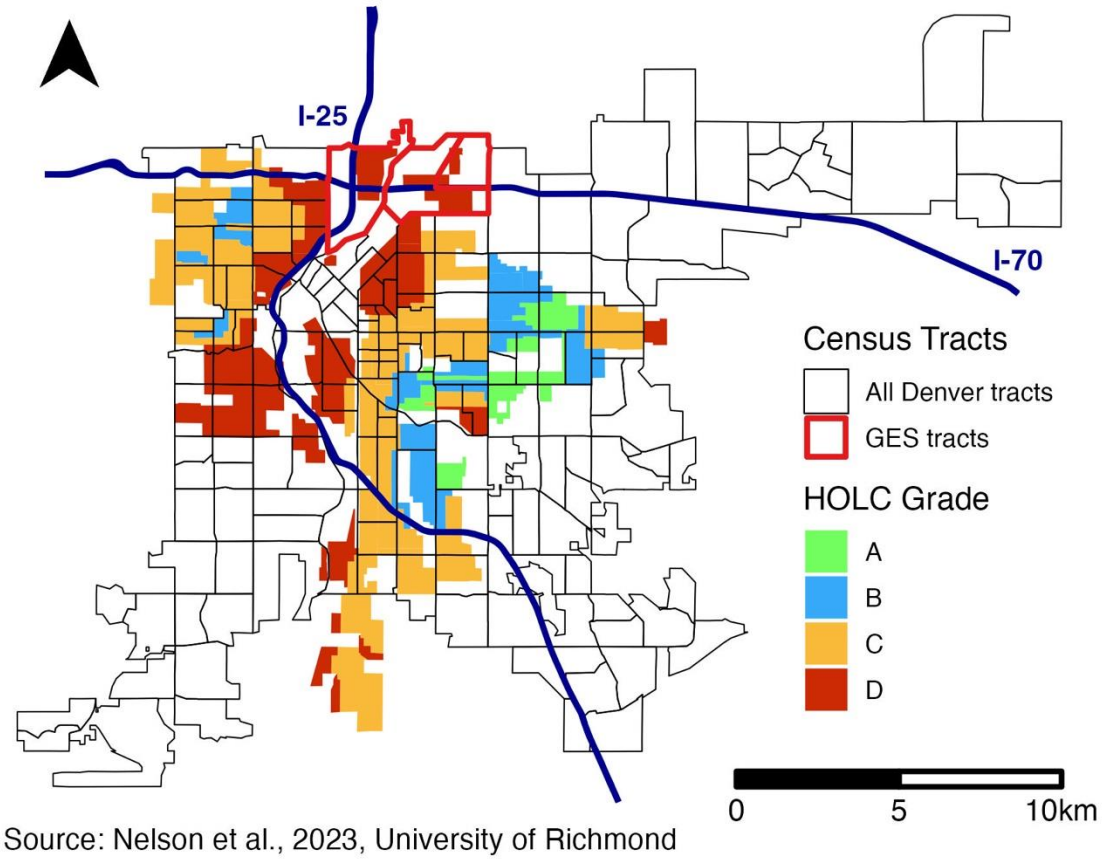


Figure 16. Former Home Owners Loan Corporation (HOLC) redlining status in Denver, Colorado by 2023 census tracts. (Figure 20 in Deliverable 2.2)

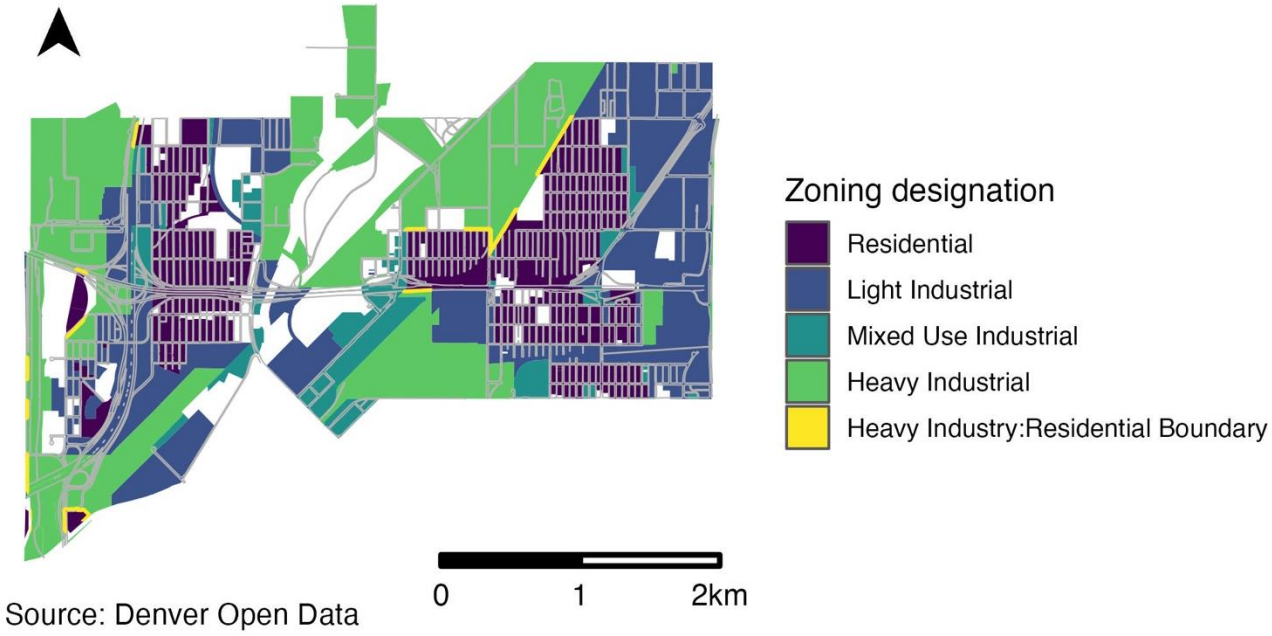


Figure 17. Summary of 2023 zoning designations in GES showing the boundary between residential and heavy industrial zoned areas. (Figure 21 in Deliverable 2.2)

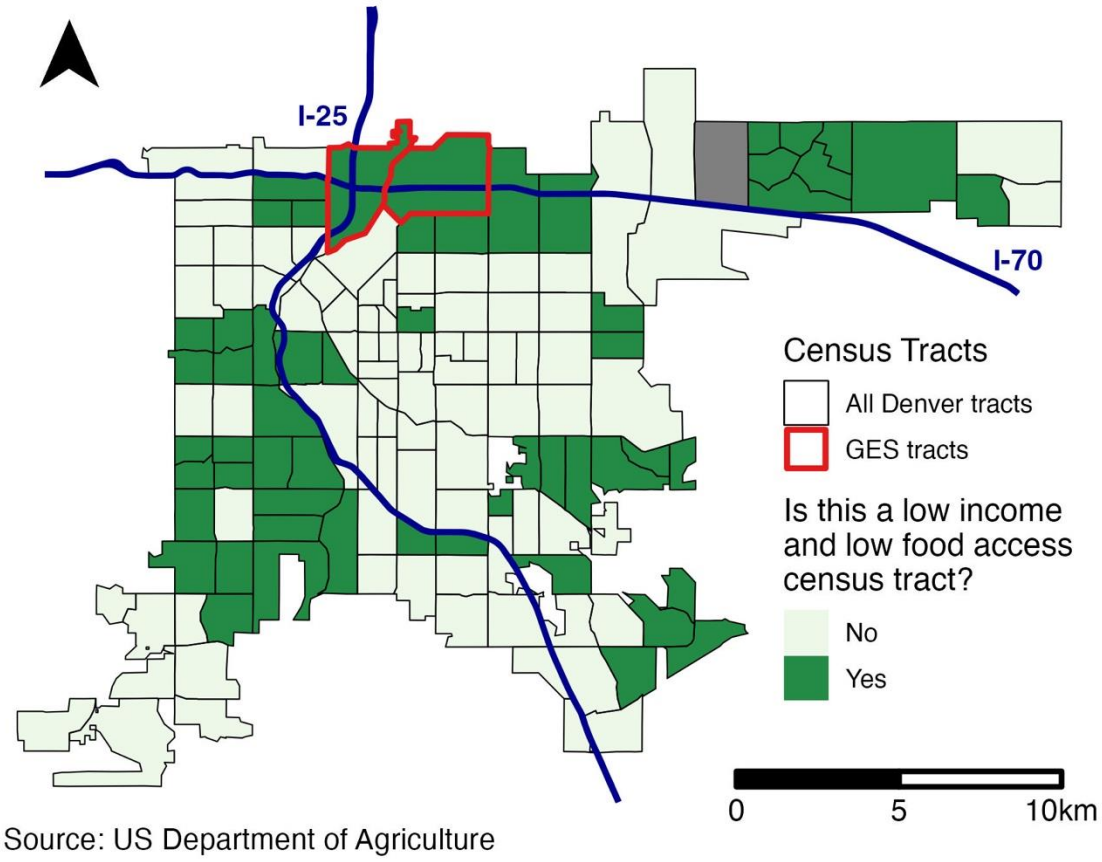


Figure 18. Low income and low food access census tracts in Denver, Colorado, 2019. (Figure 22 in Deliverable 2.2)

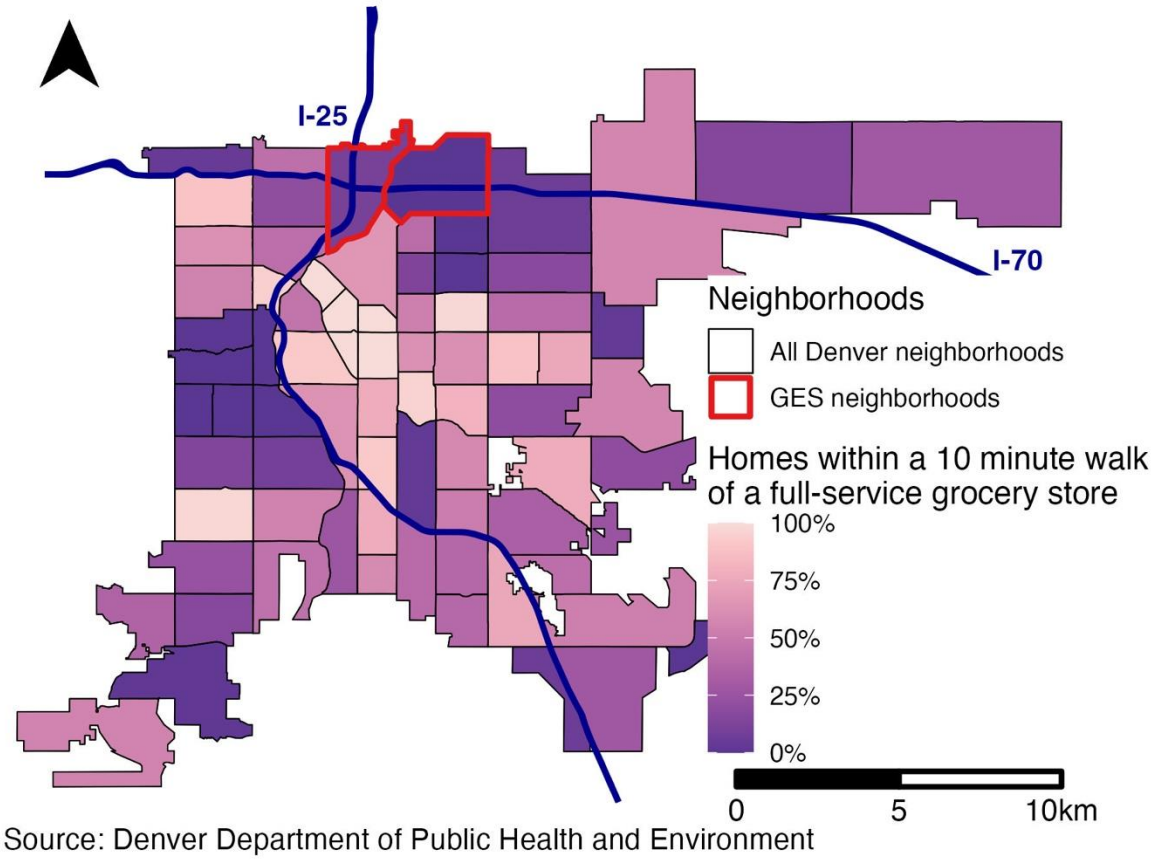


Figure 19. Homes within a 10-minute walk of a full-service grocery store in Denver, Colorado, 2021. (Figure 23 in Deliverable 2.2)

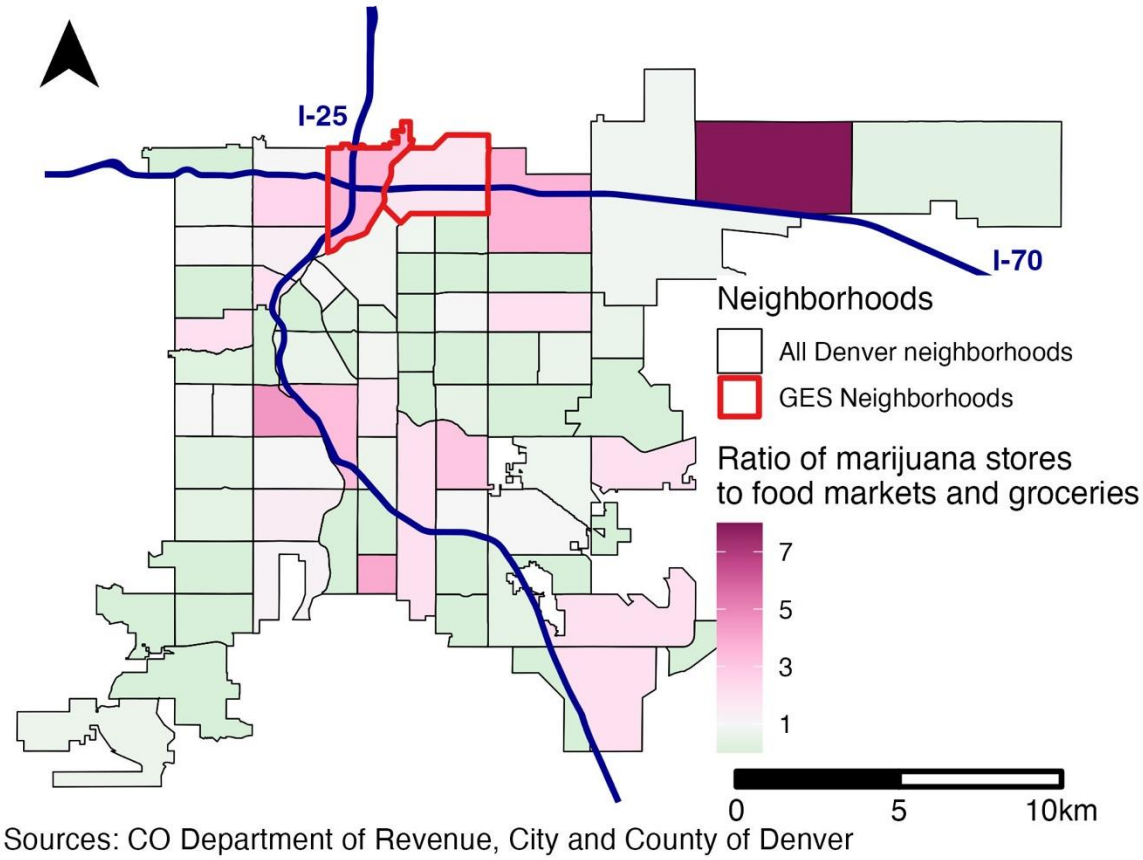


Figure 20. Ratio of marijuana stores (2023) to food markets and groceries (2021) in Denver, Colorado. (Figure 24 in Deliverable 2.2)

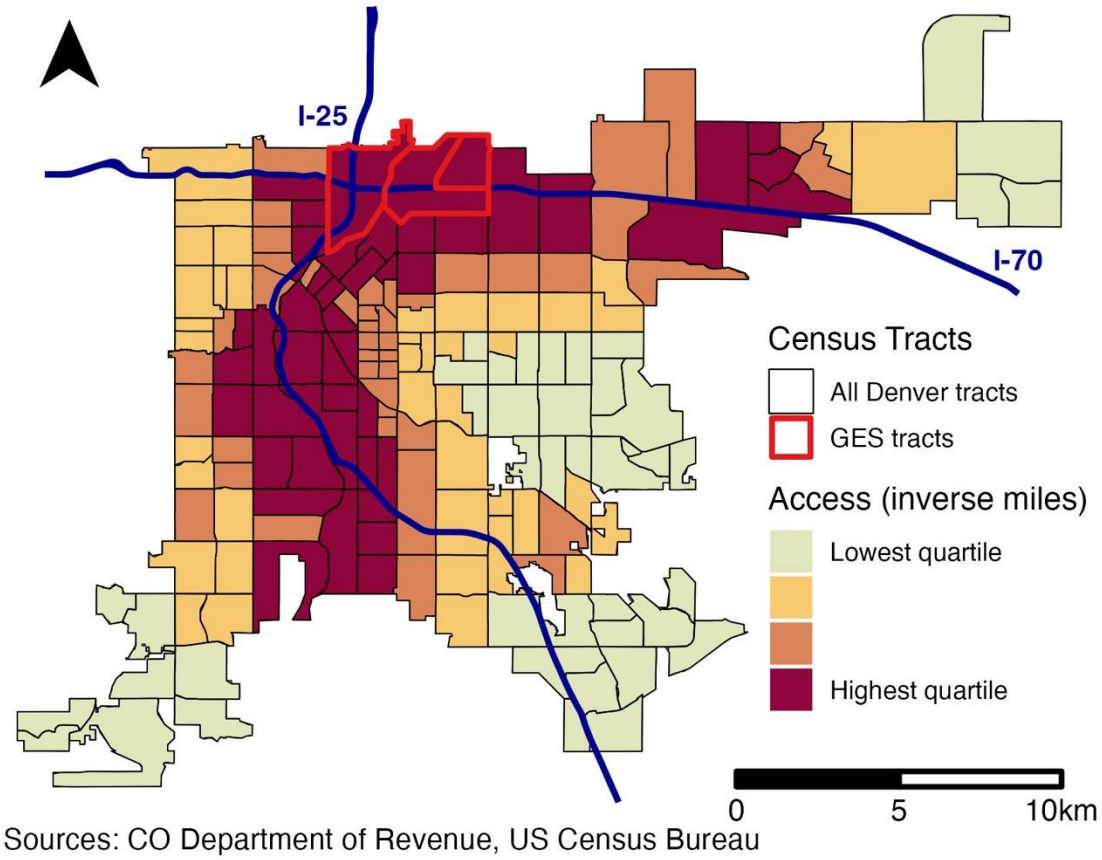


Figure 21. Access to marijuana cultivations in Denver, Colorado, 2023. (Figure 25 in Deliverable 2.2)

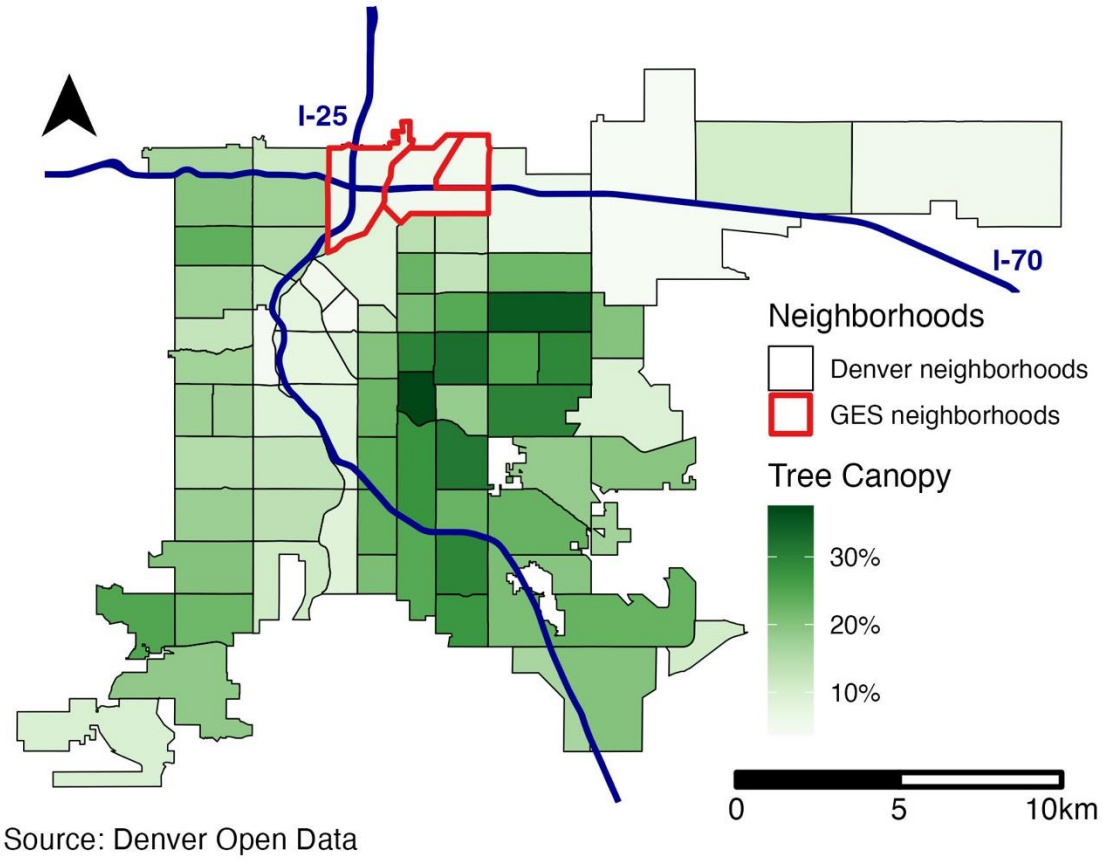


Figure 22. Percent tree canopy in Denver, Colorado, 2020. (Figure 26 in Deliverable 2.2)

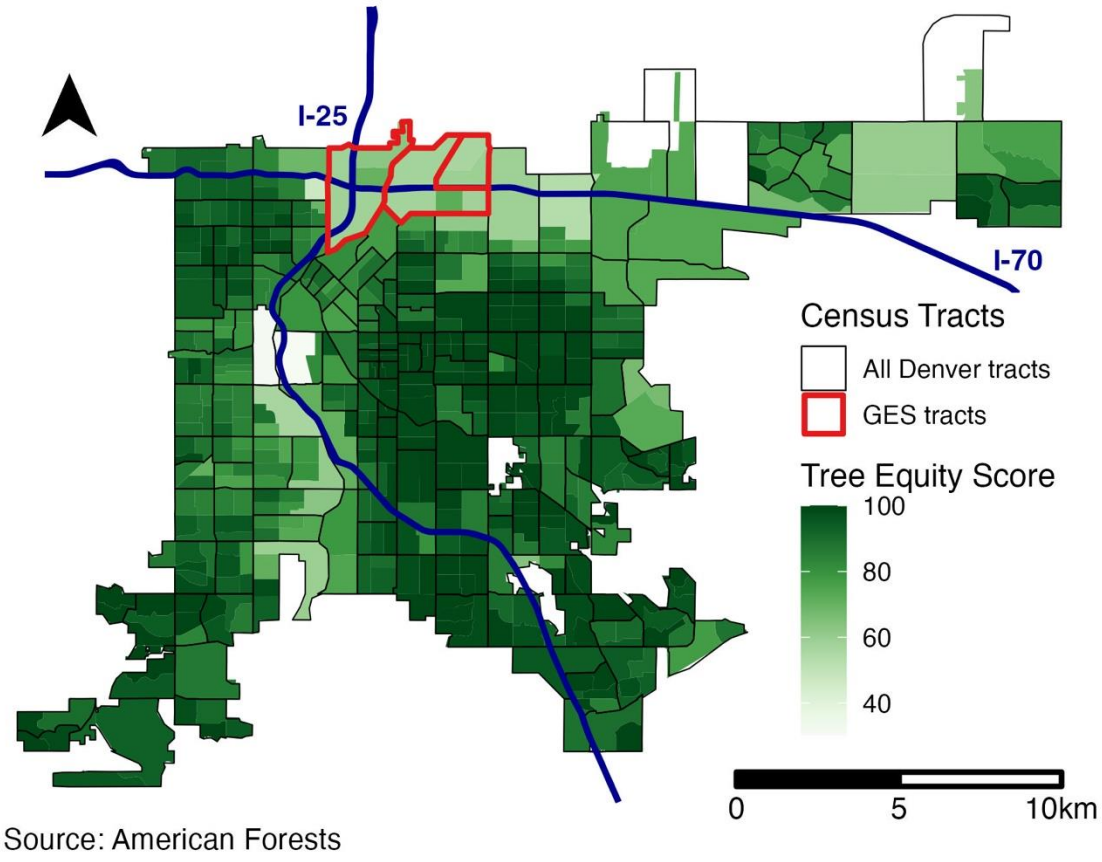


Figure 23. Tree Equity Score in Denver, Colorado, 2020. (Figure 27 in Deliverable 2.2)

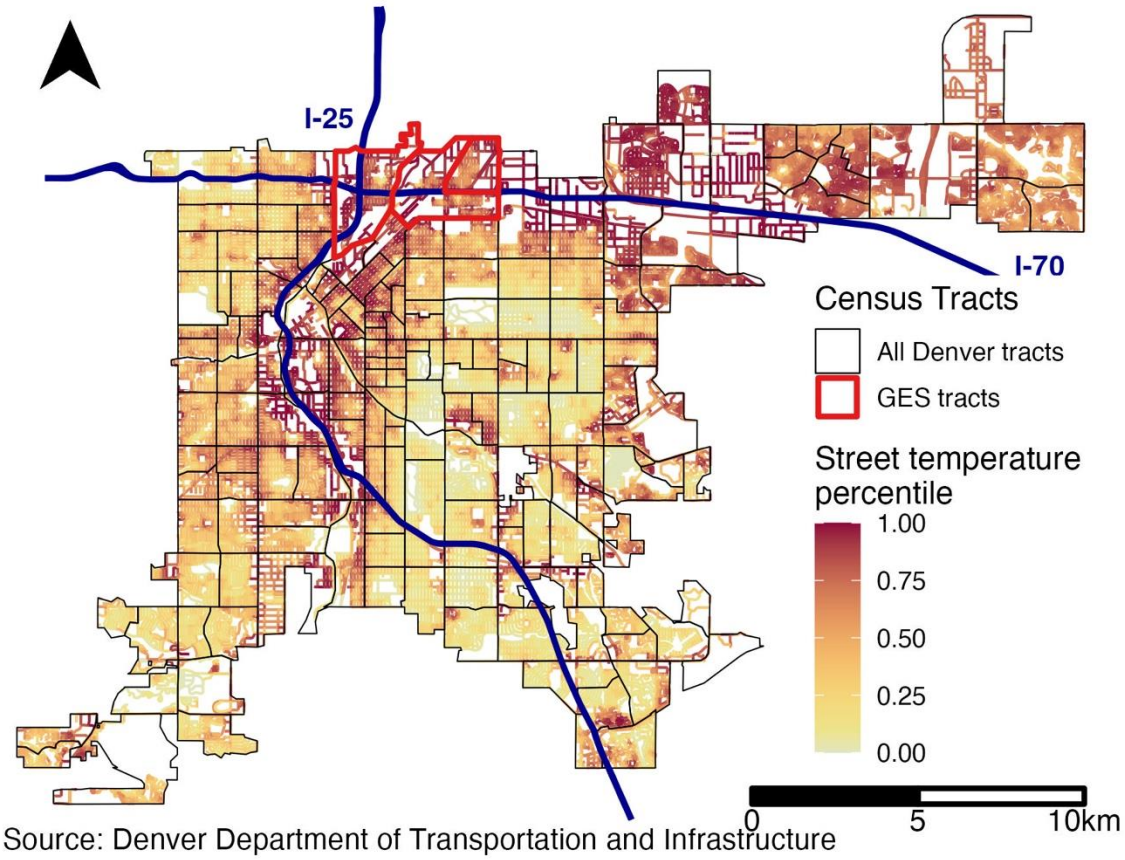


Figure 24. Relative ranking of Denver street segments based on long-term average land surface temperatures measured during July and August, 2000-2019. (Figure 28 in Deliverable 2.2)

Higher percentiles correlate with hotter surface temperatures. Note: This figure excludes the census tract containing the Denver International Airport; street temperatures in this census tract are among the hottest 25% of streets in Denver

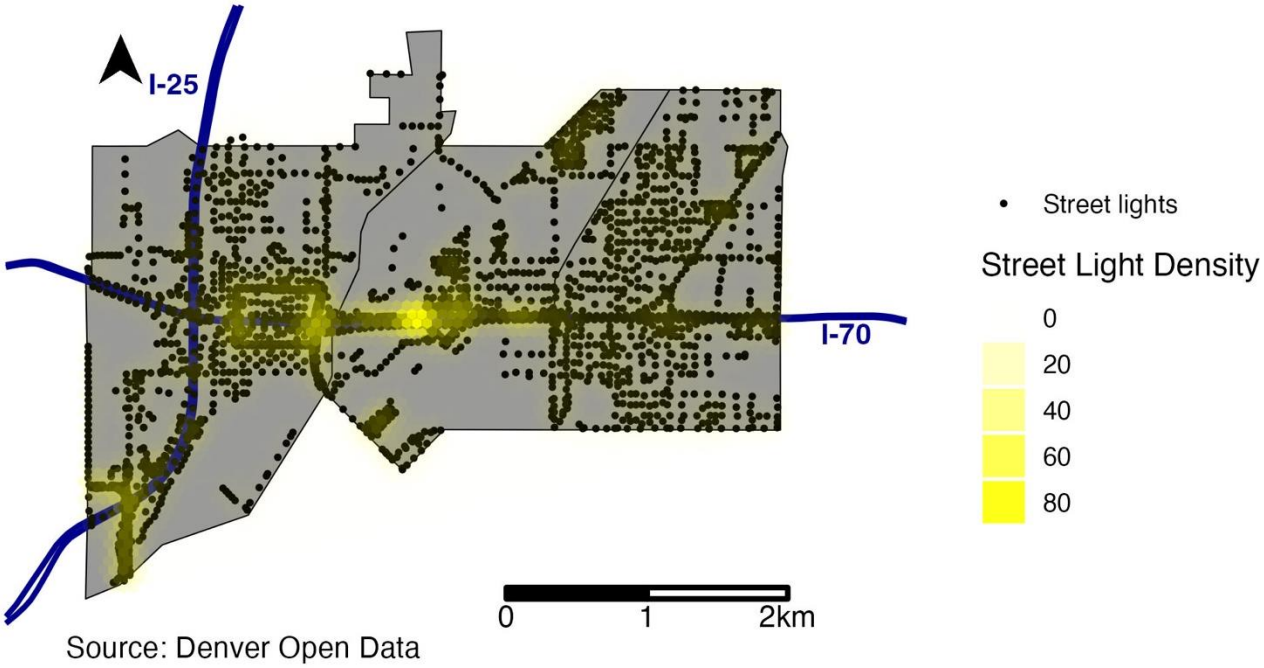


Figure 25. Street light density in GES census tracts, 2019. (Figure 30 in Deliverable 2.2)

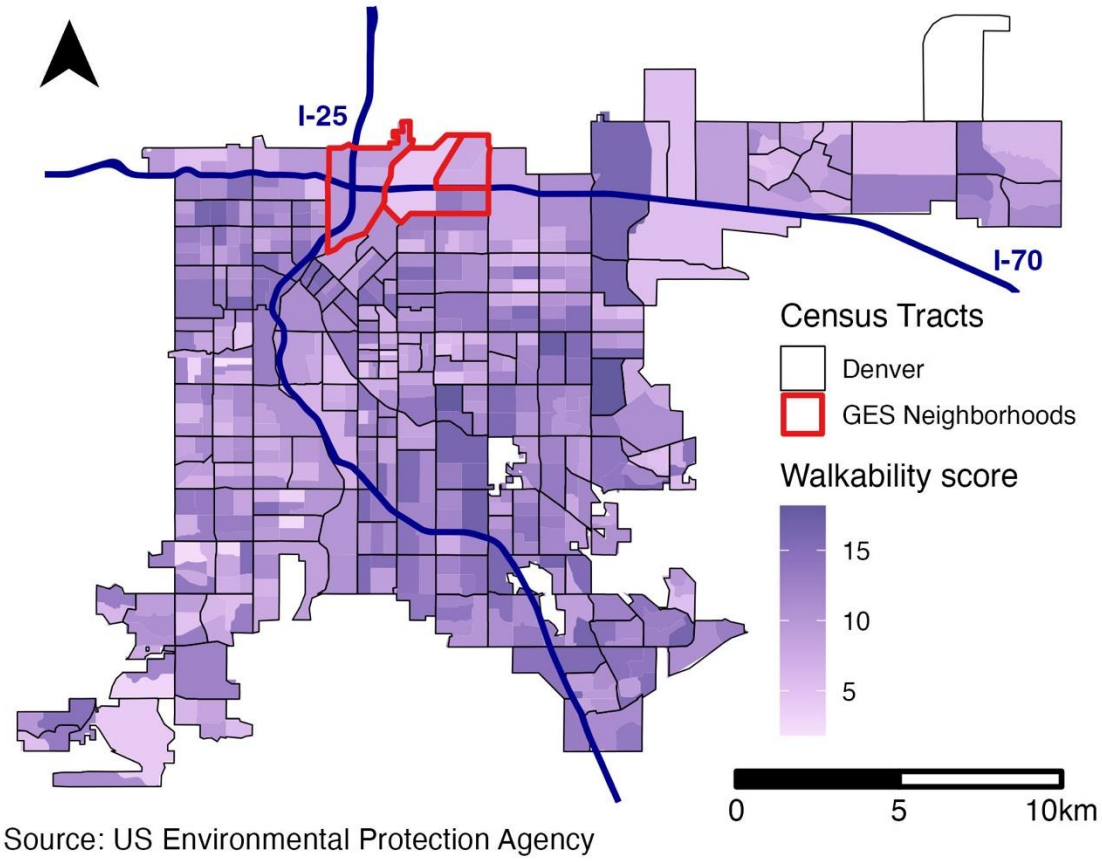


Figure 26. National Walkability Index score in Denver, Colorado, 2023. (Figure 32 in Deliverable 2.2)

The US EPA Walkability Index characterizes 2019 census block groups based on their relative walkability, which is dependent on built environment characteristics that influence the likelihood of people using walking as a mode of transportation.

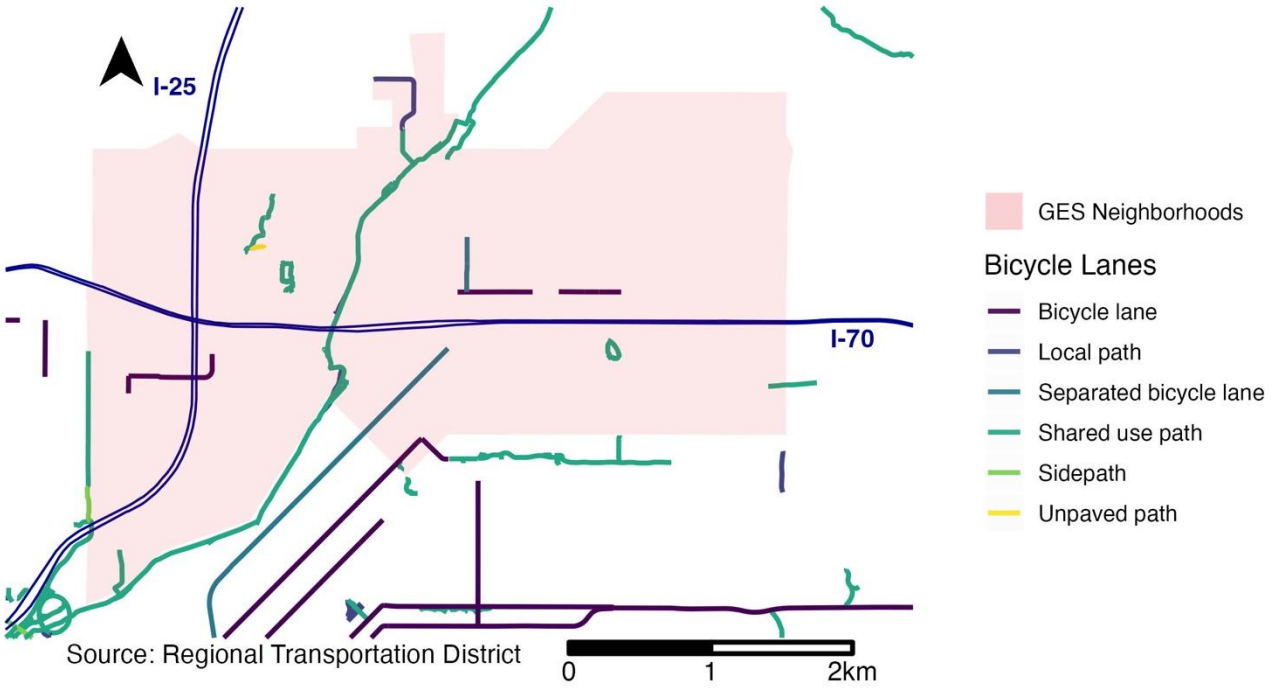


Figure 27. Existing bicycle infrastructure in GES census tracts, 2023. (Figure 33 in Deliverable 2.2)

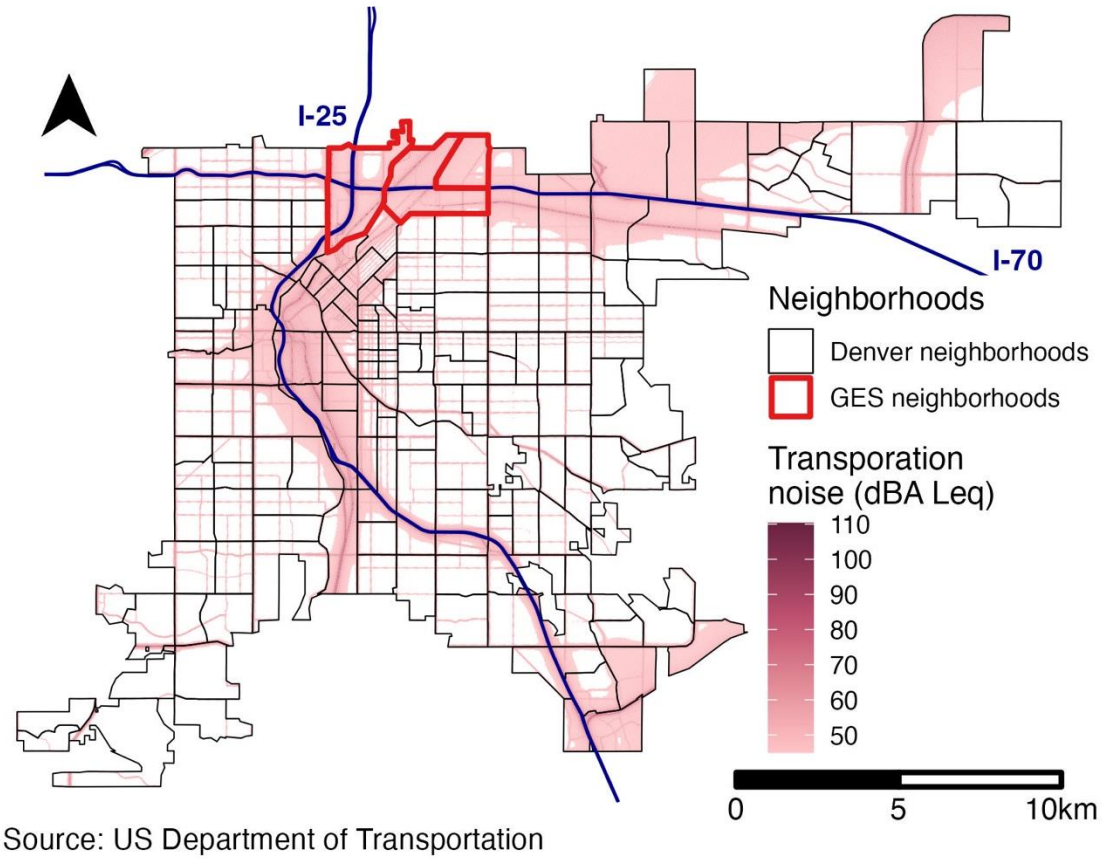


Figure 28. Modeled transportation related noise in Denver, Colorado, 2020. (Figure 34 in Deliverable 2.2)

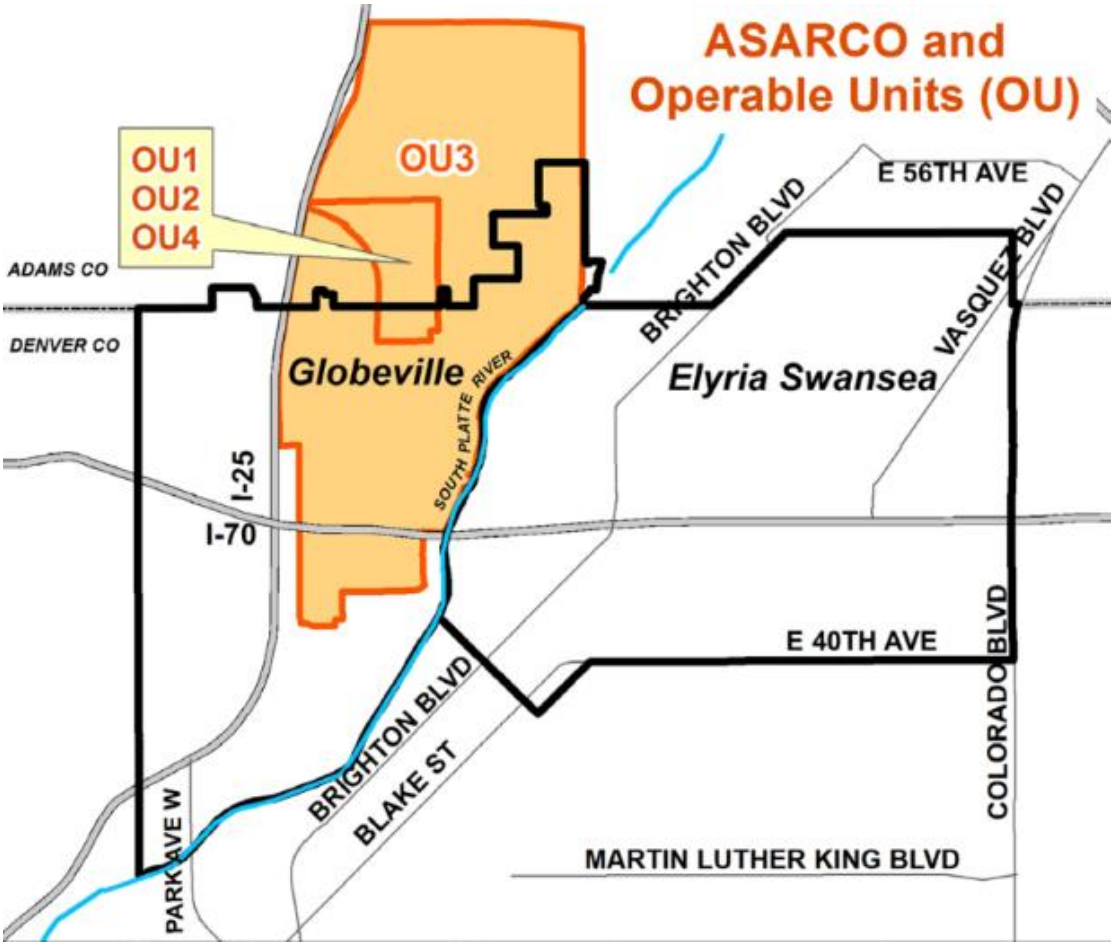


Figure 29. Map of ASARCO Operable Units (OU). (Figure 35 in Deliverable 2.2)

Figure from Denver Department of Environmental Health. How Neighborhood Planning Affects Health in Globeville and Elyria Swansea.; 2014

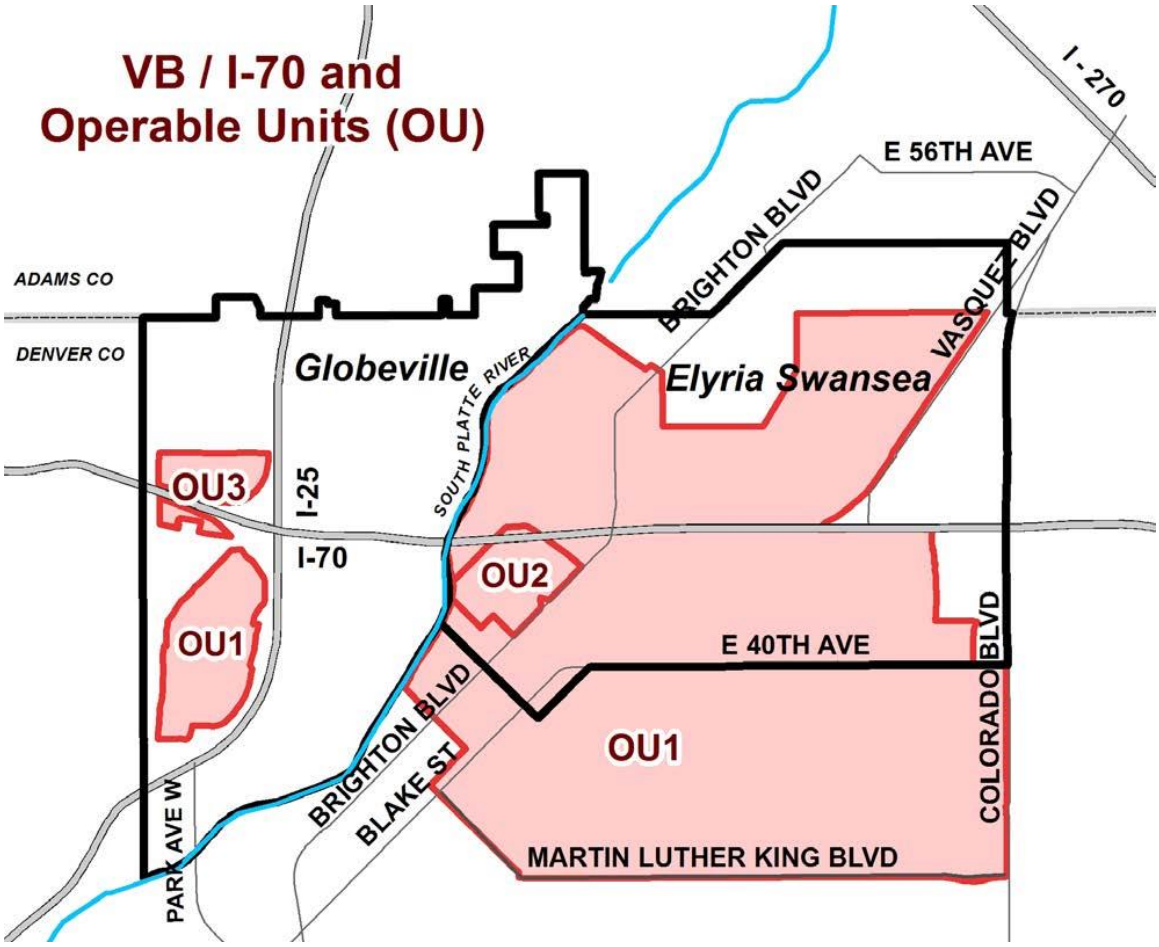


Figure 30. Site boundary for Vasquez Blvd. and I-70 Superfund Site. (Figure 37 in Deliverable 2.2)

This site is next to ASARCO Superfund site. Figure from Denver Department of Environmental Health. How Neighborhood Planning Affects Health in Globeville and Elyria Swansea.; 2014

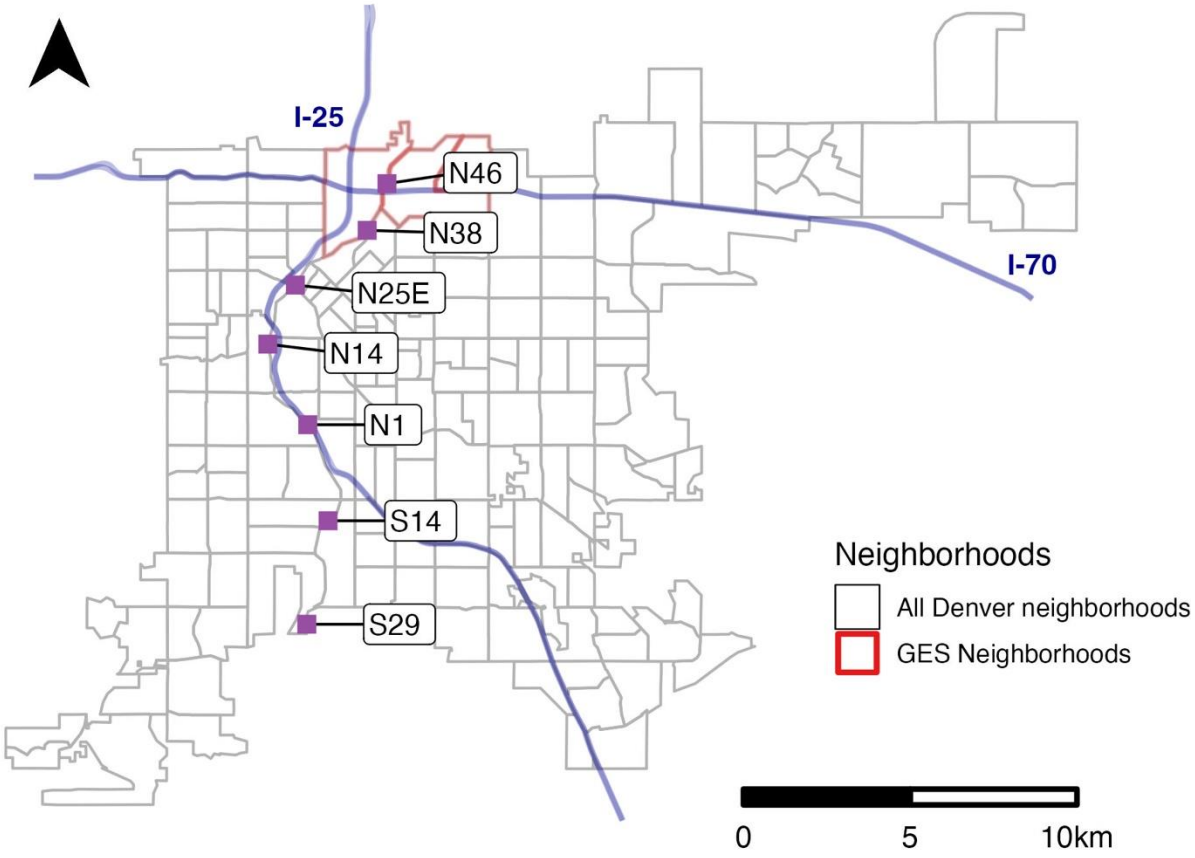


Figure 31. Water quality monitoring sites along the South Platt River, 2014-2022. (Figure 38 in Deliverable 2.2)

The South Platte River flows south to north.

STATIC MAPS: DELIVERABLE 2.3

No maps were presented in GES Community Health Study Deliverable 2.3.

STATIC MAPS: DELIVERABLE 2.4

No maps were presented in GES Community Health Study Deliverable 2.4.

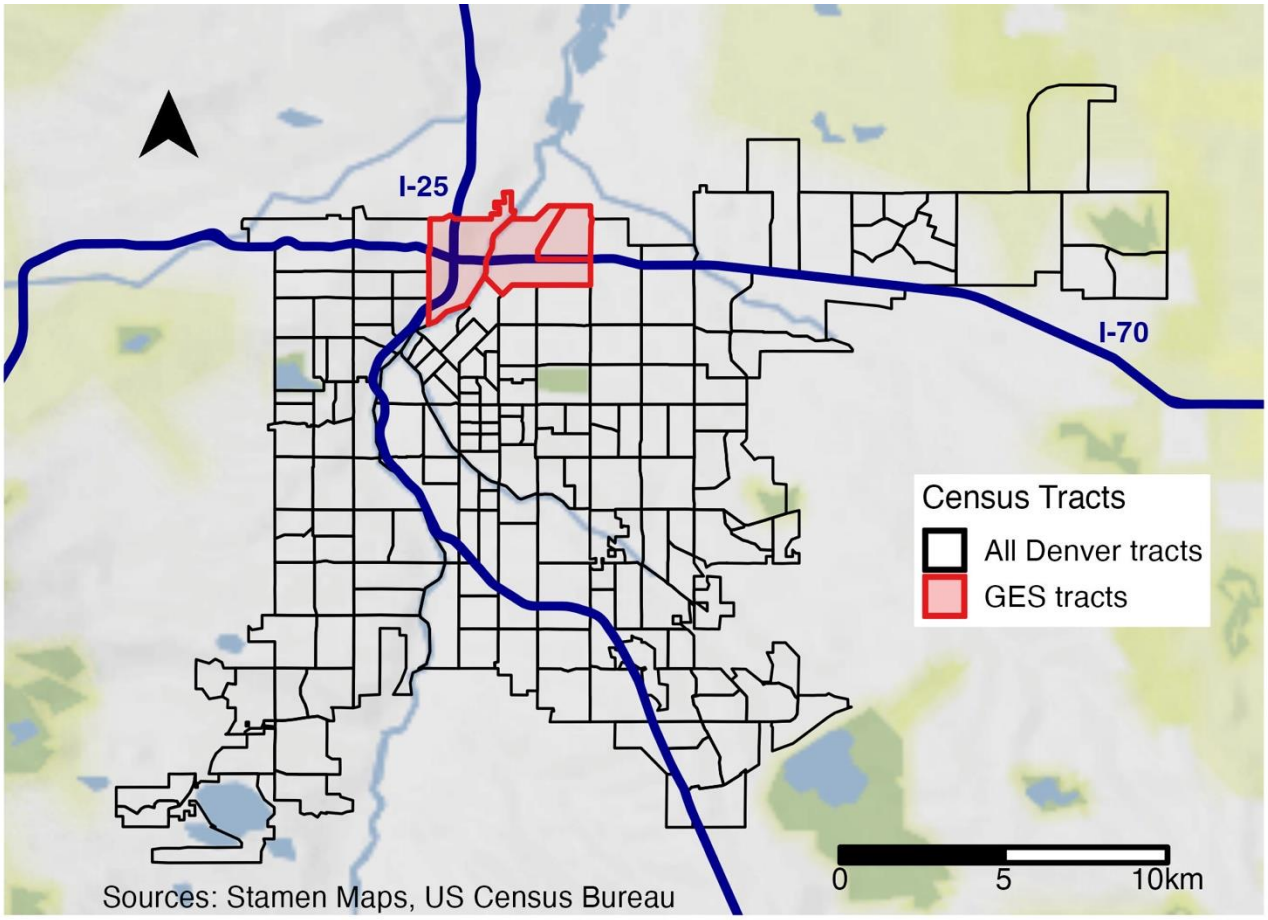


Figure 32. Globeville and Elyria Swansea census tracts in relation to City and County of Denver area. (Figure 1 in Deliverable 2.5)

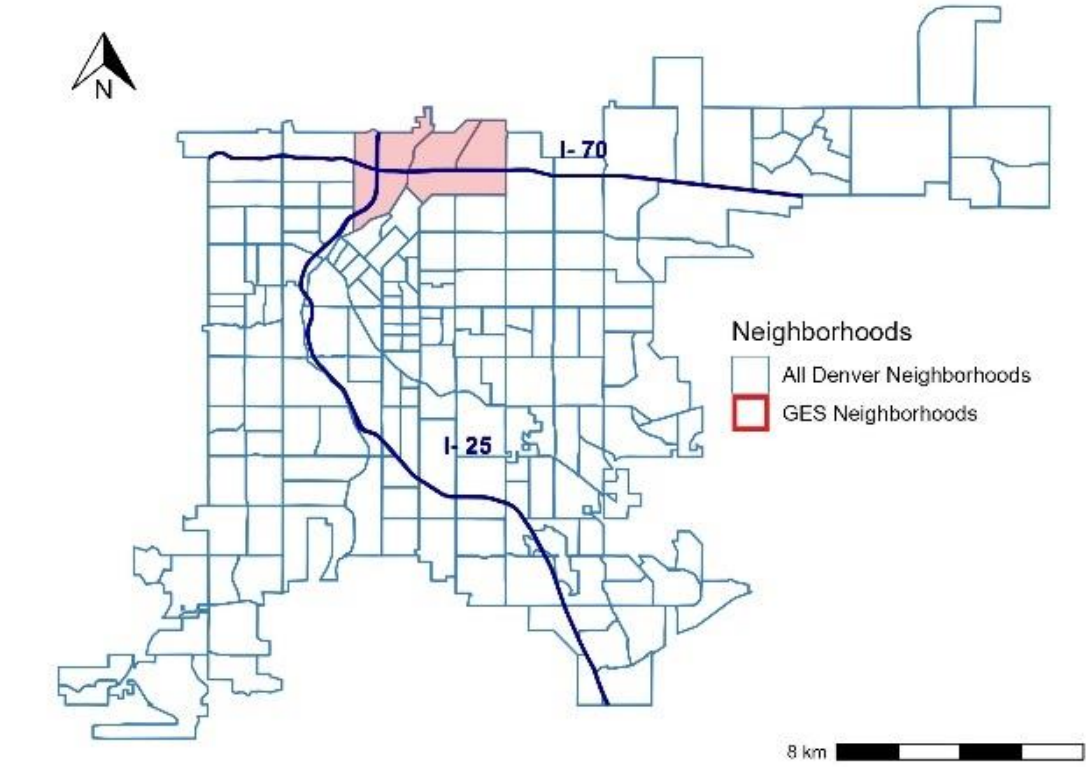


Figure 33. Map of Globeville, Elyria, and Swansea (GES) census tracts relative to others in Denver. (Figure 4 in Deliverable 2.5)

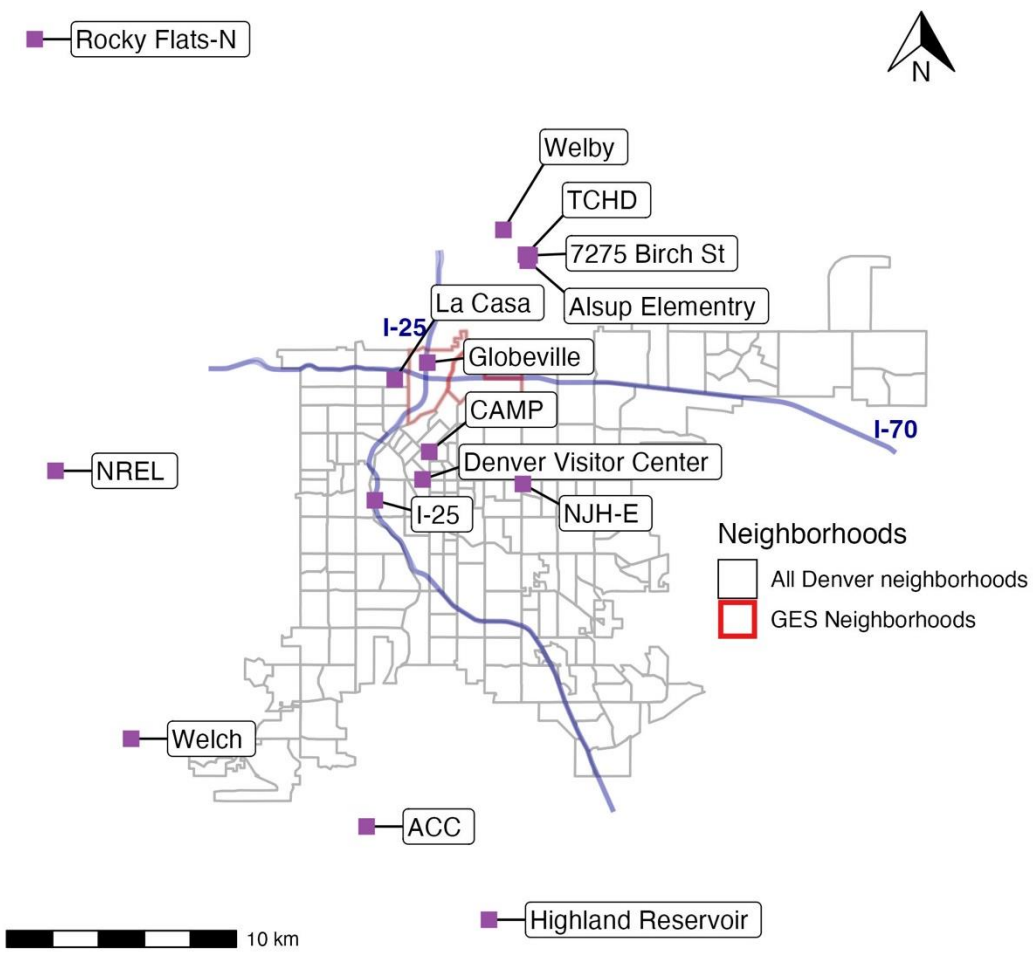


Figure 34. Environmental Protection Agency (EPA) air monitoring stations along Colorado front range region. (Figure 5 in Deliverable 2.5)

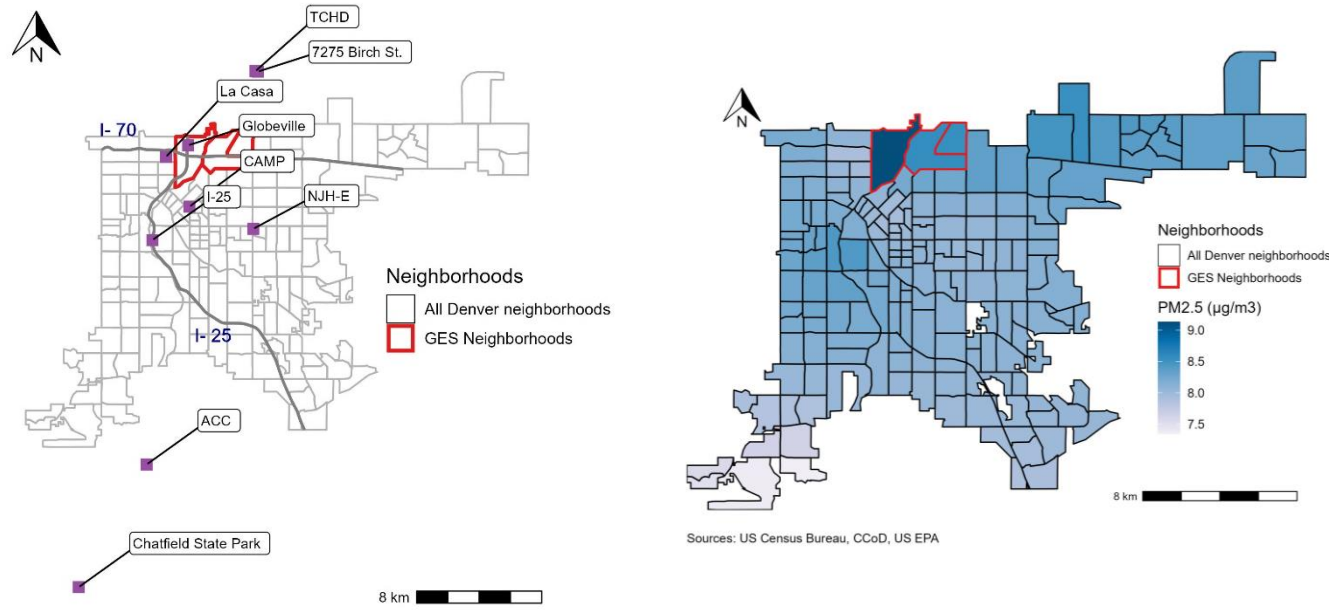


Figure 35. PM2.5 exposure model results. (Figure 6 in Deliverable 2.5)

The map on the left illustrates the nine EPA air monitoring stations which collect particulate matter with an aerodynamic diameter of less than 2.5 microns ($PM_{2.5}$) measurements. The map on the right illustrates the inverse-distance weighted $PM_{2.5}$ ($\mu g/m^3$) 5-year average exposure levels model estimates, 2017-2021. The darker colors indicate higher concentrations whereas the lighter colors indicate lower concentrations.

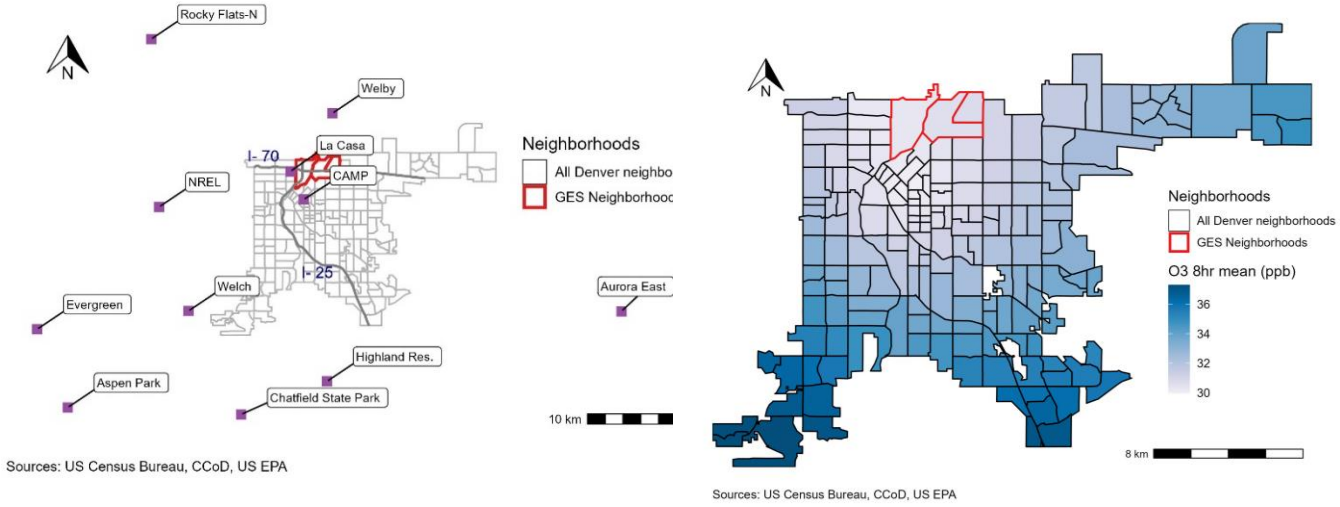


Figure 36. O_3 model results. (Figure 7 in Deliverable 2.5)

The map on the left illustrates the EPA air monitoring stations which collect ozone (O_3) measurements. The map on the right illustrates the inverse-distance weighted O_3 (ppb) 5-year average exposure levels model estimates, 2017-2021. The darker colors indicate higher concentrations whereas the lighter colors indicate lower concentrations.

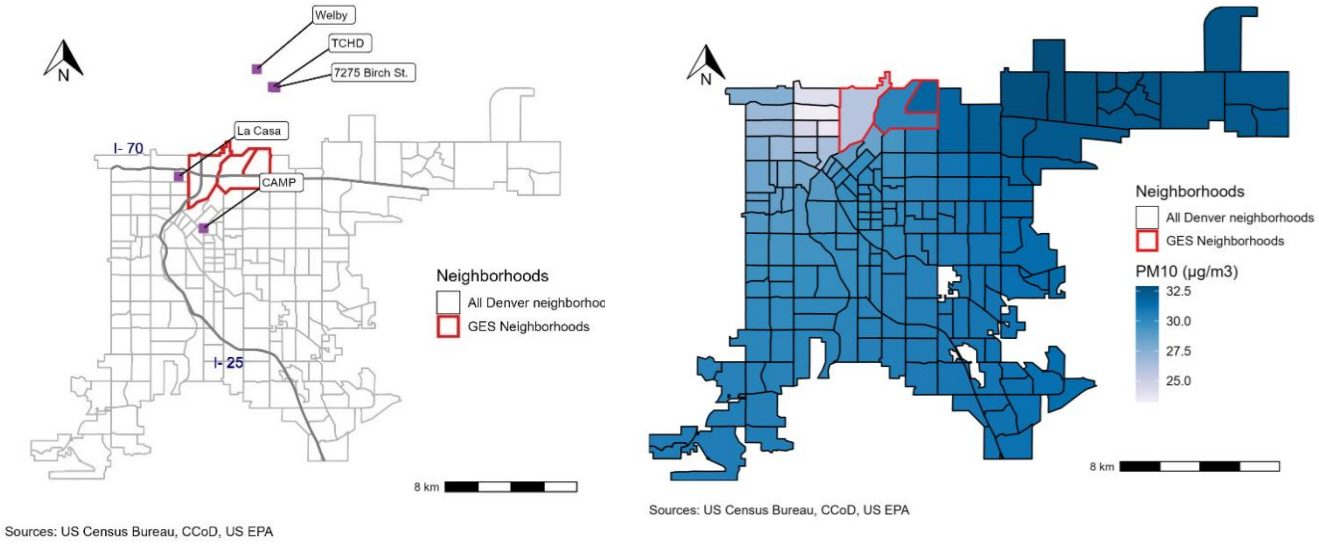


Figure 37. PM_{10} model results. (Figure 8 in Deliverable 2.5)

The map on the left illustrates the EPA air monitoring stations which collect particulate matter with an aerodynamic diameter of less than 10 microns (PM_{10}) measurements. The map on the right illustrates the inverse-distance weighted PM_{10} ($\mu g/m^3$) 5-year average exposure levels model estimates, 2017-2021. The daker colors indicate higher concentrations whereas the lighter colors indicate lower concentrations.

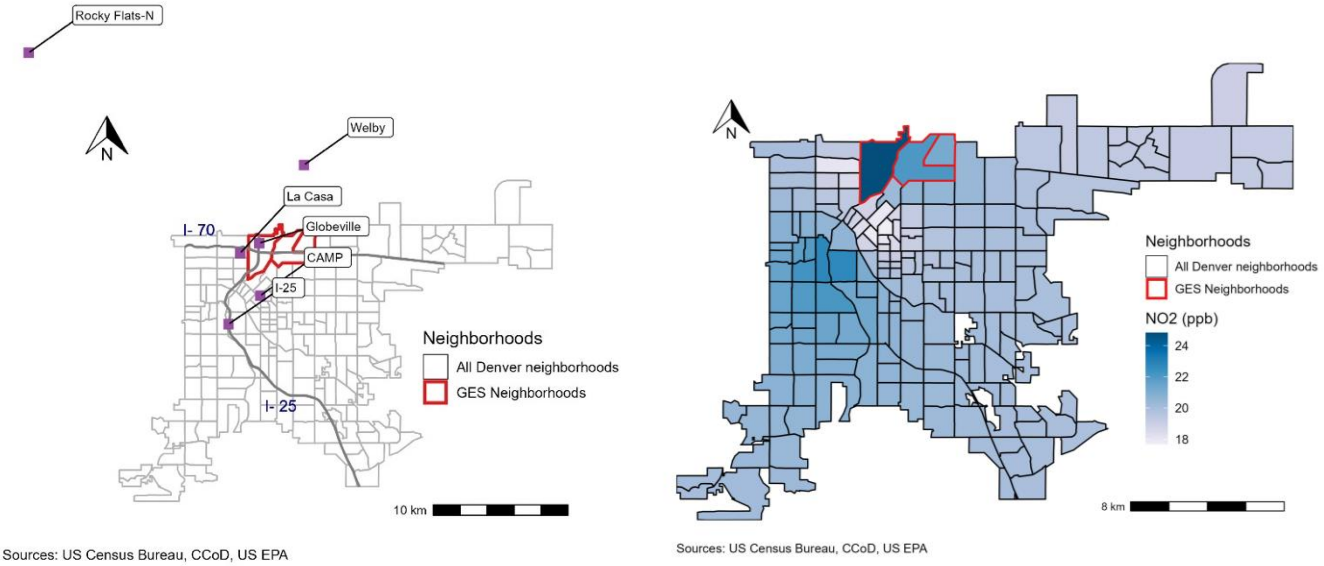


Figure 38. NO_2 model results. (Figure 9 in Deliverable 2.5)

The map on the left illustrates the EPA air monitoring stations which collect nitrogen dioxide (NO_2) measurements. The map on the right illustrates the inverse-distance weighted NO_2 (ppb) 5-year average exposure levels model estimates, 2017-2021. The darker colors indicate higher concentrations whereas the lighter colors indicate lower concentrations.

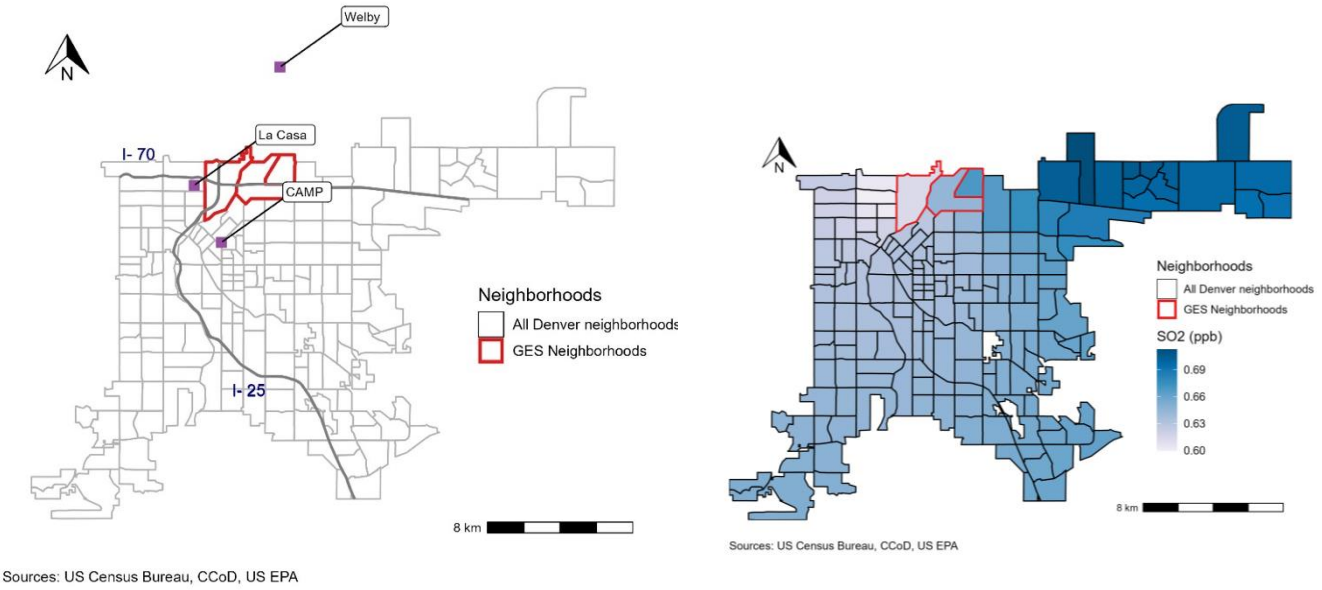


Figure 39. SO_2 model results. (Figure 10 in Deliverable 2.5)

The map on the left illustrates the EPA air monitoring stations which collect sulfur dioxide (SO_2) measurements. The map on the right illustrates the inverse-distance weighted SO_2 (ppb) 5-year average exposure levels model estimates, 2017-2021. The darker colors indicate higher concentrations whereas the lighter colors indicate lower concentrations.

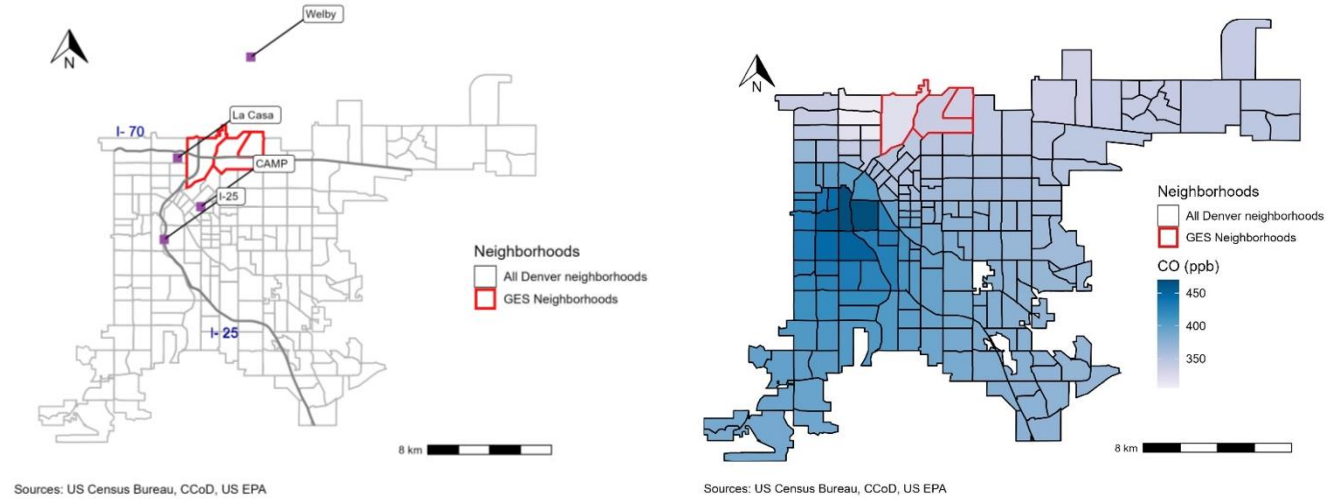


Figure 40. CO model results. (Figure 11 in Deliverable 2.5)

The map on the left illustrates the EPA air monitoring stations which collect carbon monoxide (CO) measurements. The map on the right illustrates the inverse-distance weighted CO (ppb) 5-year average exposure levels model estimates, 2017-2021. The darker colors indicate higher concentrations whereas the lighter colors indicate lower concentrations.

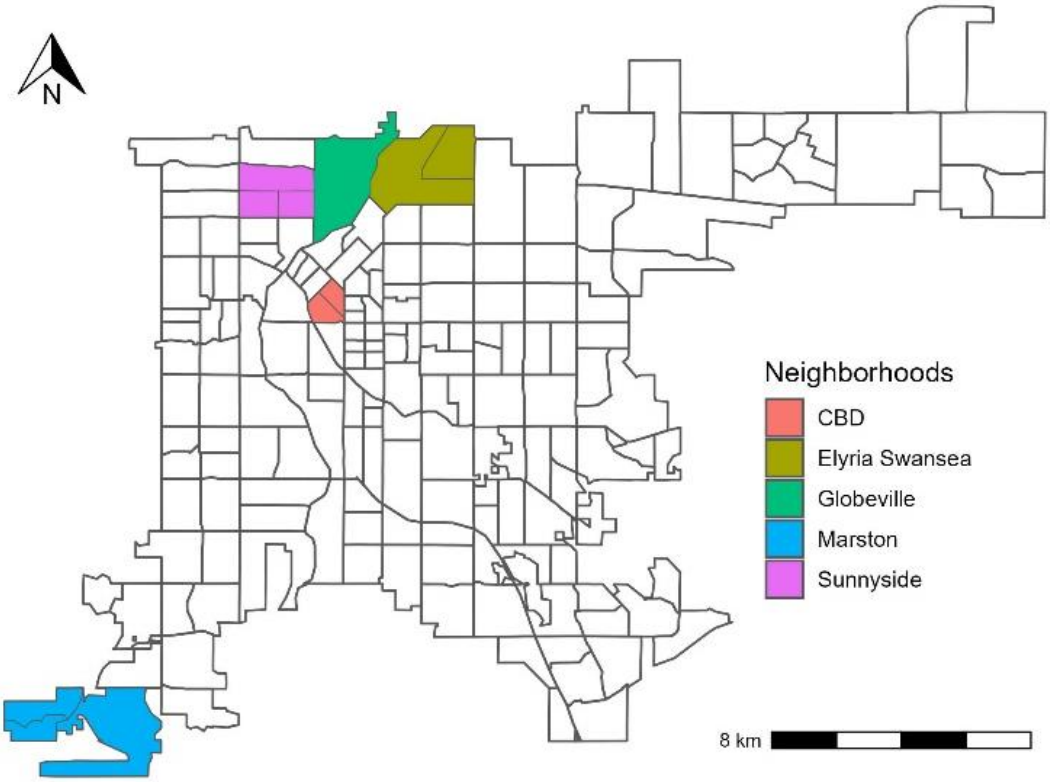


Figure 41. Neighborhoods with the lowest five-year average air pollution concentration exposure levels across the six criteria air pollutants in reference to GES, 2017-2021. (Figure 12 in Deliverable 2.5)

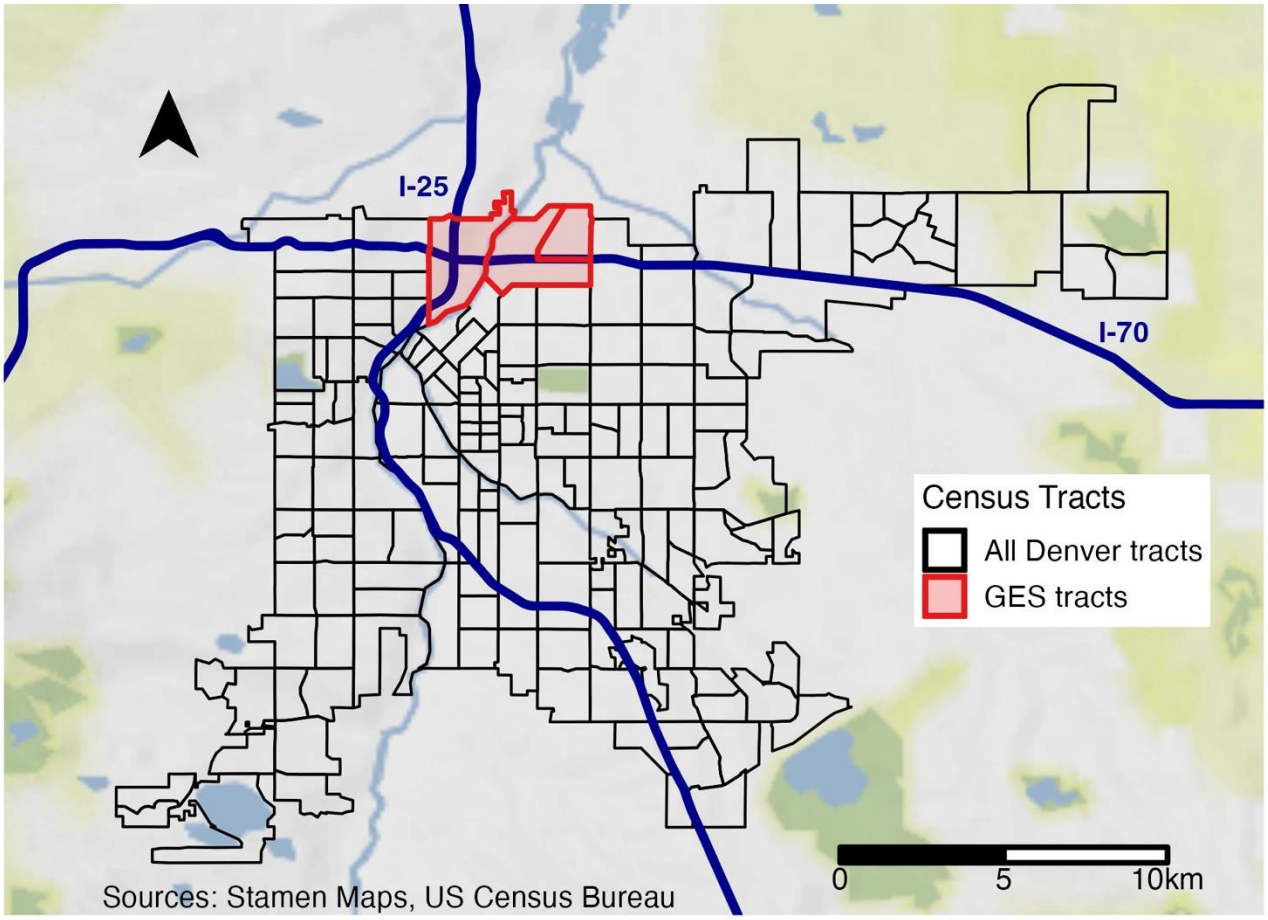
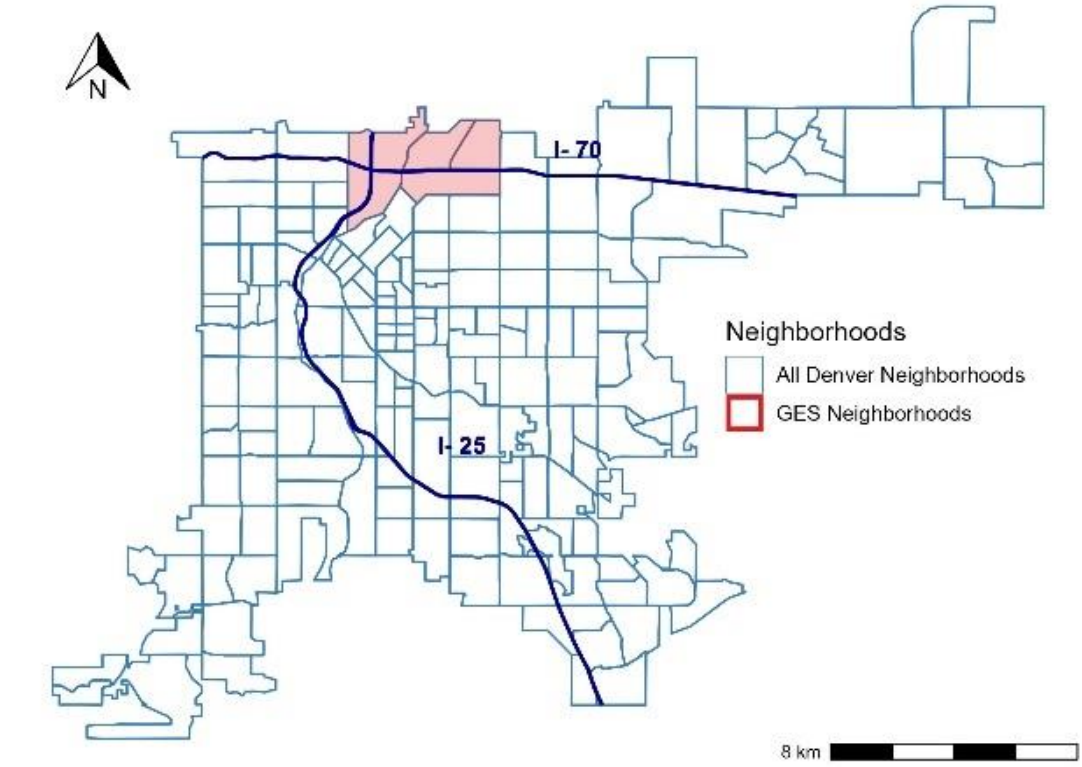


Figure 42. Globeville and Elyria Swansea census tracts in relation to City and County of Denver area. (Figure 1 in Deliverable 2.6)



Source: US Census Bureau & City and County of Denver

Figure 43. Denver neighborhoods. (Figure 4 in Deliverable 2.6)

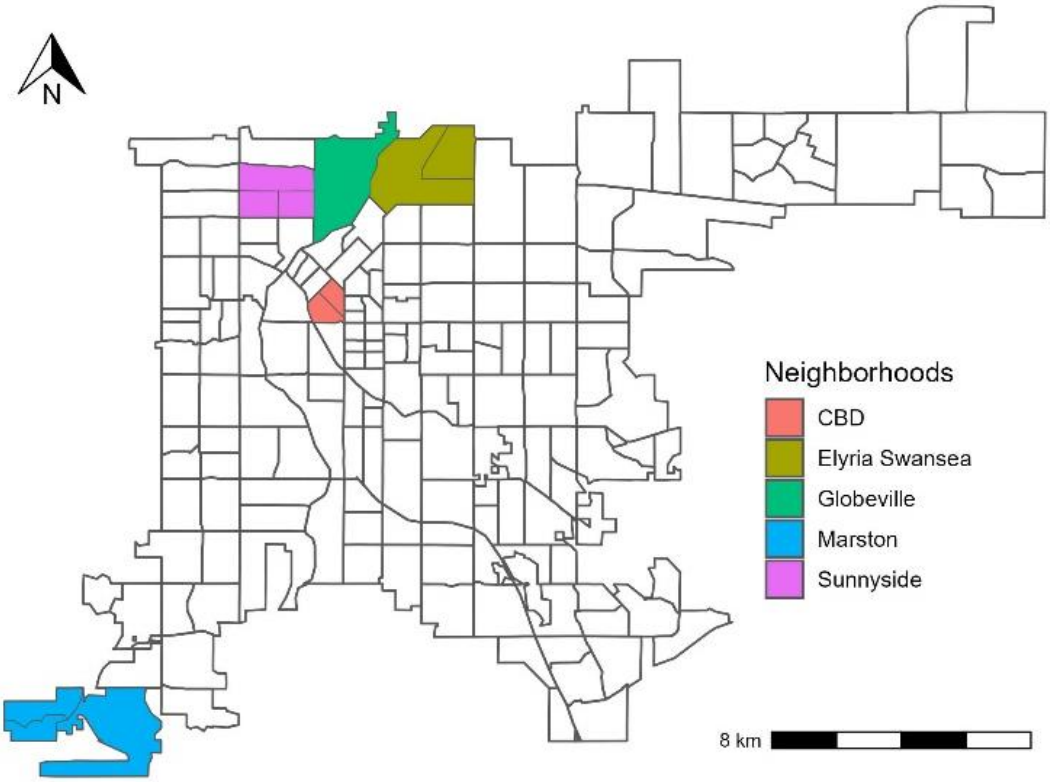


Figure 44. Neighborhoods with the lowest five-year average air pollution concentration exposure levels across the six criteria air pollutants in reference to GES, 2017-2021. (Figure 5 in Deliverable 2.6)

STATIC MAPS: DELIVERABLE 2.7

No maps were presented in GES Community Health Study Deliverable 2.7.

STATIC MAPS: DELIVERABLE 2.8

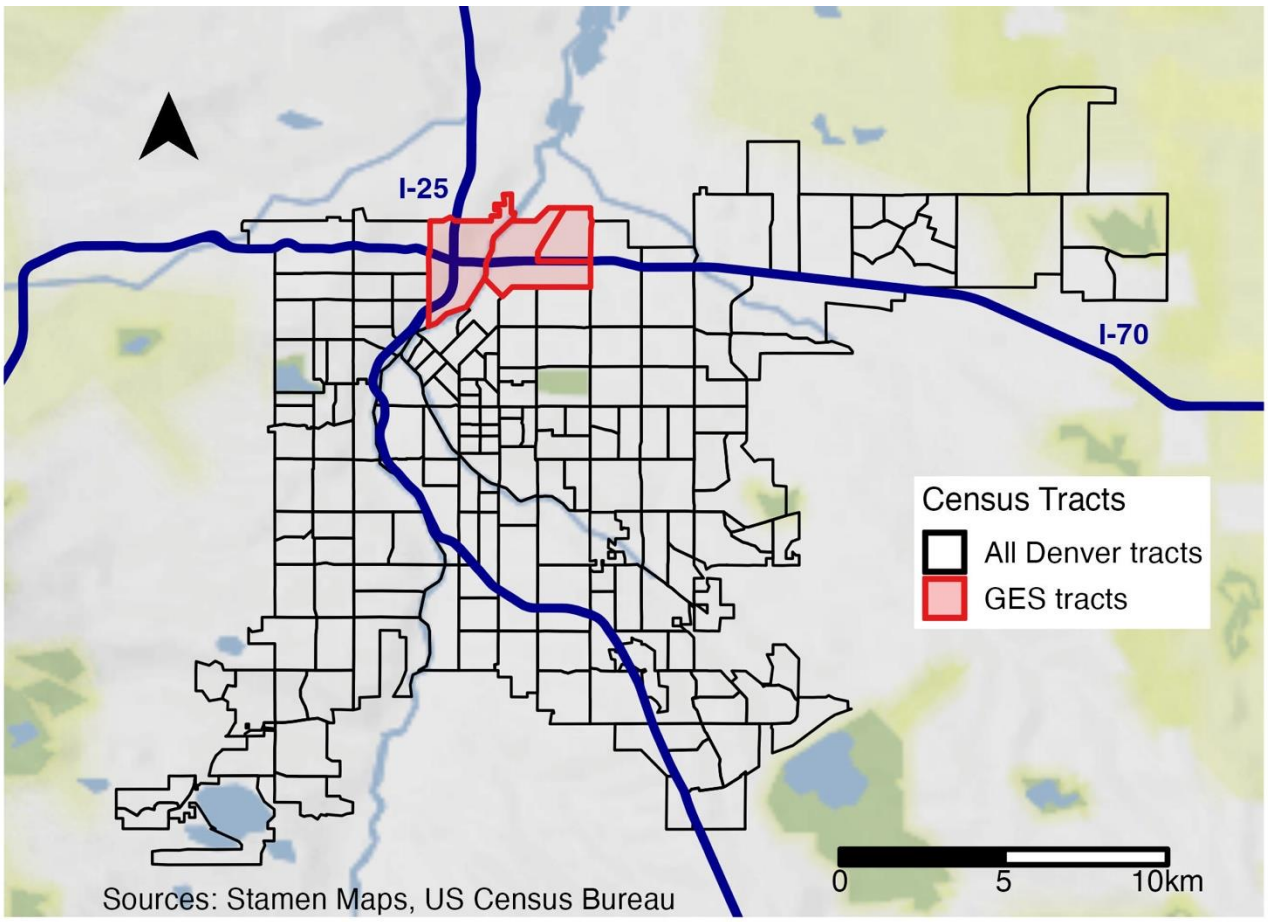


Figure 45. Globeville, Elyria, and Swansea neighborhoods in relation to the Denver area. (Figure 1 in Deliverable 2.8)

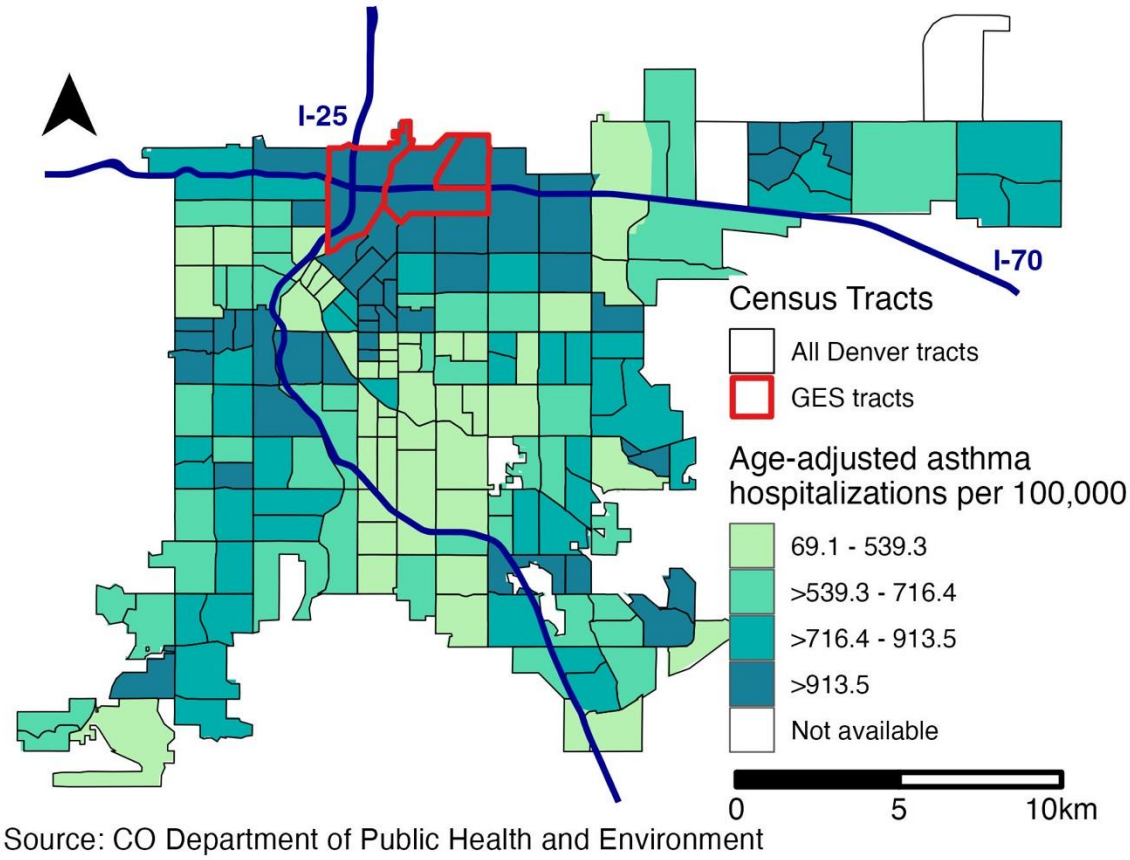


Figure 46. Age-adjusted asthma hospitalizations in Denver, Colorado, 2015-2019. (Figure 5 in Deliverable 2.8)

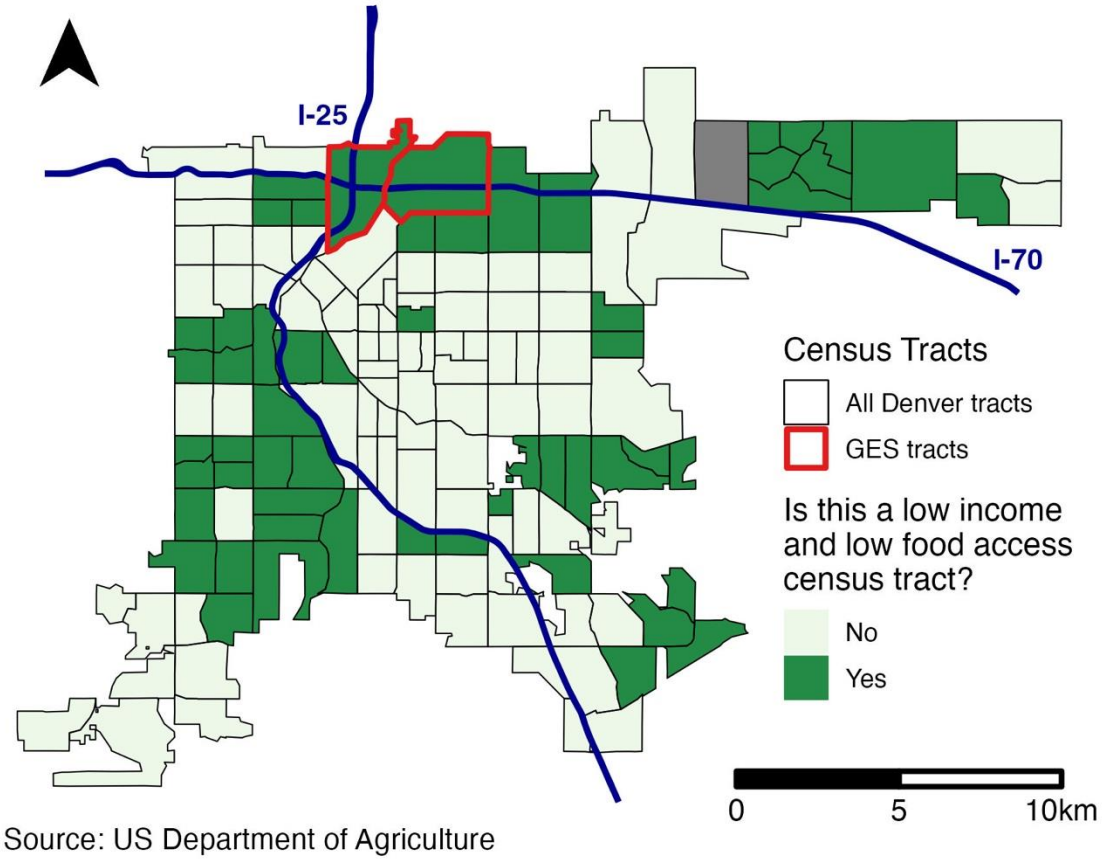


Figure 47. Low income and low food access census tracts in Denver, Colorado, 2019. (Figure 6 in Deliverable 2.8)