



**PALEONTOLOGICAL TECHNICAL REPORT
FOR THE
6TH AVENUE EXTENSION ENVIRONMENTAL ASSESSMENT**

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State of Colorado Paleontological Permit No. 2015-55

RMPS Report No. CO15ArapahoeFHU01R

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June 2016

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LIST OF ACRONYMS

ARPA.....	Archaeological Resources Protection Act
BIA.....	Bureau of Indian Affairs
BLM.....	Bureau of Land Management
BOR	Bureau of Reclamation
CDOT.....	Colorado Department of Transportation
CFR.....	Code of Federal Regulations
CHPA.....	Colorado Historical, Prehistorical and Archaeological Resources Act
DMNS.....	Denver Museum of Nature and Science
DOI	Department of Interior
E-470	E-470 Tollway
EA	Environmental Assessment
FHU.....	Felsburg Holt and Ullevig
FHWA.....	Federal Highway Administration
FLPMA	Federal Land Policy and Management Act
I-225	Interstate 225
I-70	Interstate 70
LORS	laws, ordinances, regulation, and standards
NPS	National Park Service
NEPA	National Environmental Policy Act
PFYC.....	Potential Fossil Yield Classification
PLSS	Public Land Survey System
PRPA.....	Paleontological Resources Preservation Act
SH 30	State Highway 30
SVP	Society of Vertebrate Paleontology
UCM	University of Colorado Museum
USDA.....	United States Department of Agriculture
USDI.....	United States Department of Interior
USFS.....	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

1.0 INTRODUCTION

This technical report has been prepared in support of the 6th Avenue Parkway Extension Environmental Assessment (EA) extending 6th Avenue from State Highway 30 (SH 30) to the E-470 Tollway (E-470). This technical report evaluates the effects of the Proposed Action and the No Action Alternative with respect to paleontological resources.

Proposed Action

The Proposed Action would extend the 6th Avenue Parkway for approximately 2 miles along a new alignment, connecting existing 6th Avenue/SH 30 to the west with the existing 6th Avenue Parkway at E-470 to the east. This would close a gap in the existing major arterial street system, reducing out of direction travel and improving the efficiency and reliability of the transportation system. The Proposed Action would be a six-lane arterial roadway with a raised median and sidewalks.

Six initial alternatives were developed and screened through three screening levels to identify the Proposed Action. The alternatives screening is summarized in **Appendix A1 Alternatives Technical Report** of the EA. Details of the Proposed Action are presented in **Appendix A2 Conceptual Design Plans** of the EA.

The Proposed Action is shown on **Figure 1**. Major elements of the Proposed Action are identified by number from west to east on **Figure 1**, and include the following:

Element 1. Tie into existing 6th Avenue/SH 30: 6th Avenue/SH 30 is an existing two-lane arterial. At the western end of the Proposed Action, a signalized “thru-tee” type intersection would be constructed connecting the Proposed Action roadway to existing 6th Avenue/SH 30. This new signalized intersection would include bypass lanes for the eastbound SH 30 through movement or a thru-tee signalized intersection with bypass lanes for both the eastbound SH 30 through movement. The tie-in would be an urban curb and gutter section with three 12-foot travel lanes in each direction to connect to future 6-lane section to the west. A 10-foot sidewalk would be located on both the north and south sides of the roadway.

Element 2. Triple Creek Trail realignment and connections: A portion of the existing Triple Creek Trail would be realigned and would pass beneath the Proposed Action roadway which would be on a bridge at this location (see Element 3 in **Figure 1**). The Triple Creek Trail would be connected to 6th Avenue via a spur trail to the sidewalk constructed along the south side of the new roadway. The Triple Creek Trail is a 10-foot wide soft surface trail that serves equestrians, bicyclists and pedestrians. The realigned portion would match the existing width and surface. A 10-foot sidewalk on both sides of the bridge (Element 3) would provide connections to the trail. The southern terminus of the trail is currently at the Coal Creek Arena, and further extension to the south is planned by the City of Aurora.

Element 3. Roadway bridge over Sand Creek: Immediately east of the new intersection with existing 6th Avenue/SH 30 (Element 1 in **Figure 1**), the roadway would be elevated onto a six-lane bridge crossing over Sand Creek and its associated floodplain/floodway, and over the Triple Creek Trail. The bridge length and profile would be set to minimize impacts to Sand Creek, while still providing a minimum 10-foot vertical clearance over the Triple Creek Trail. The bridge would have a median and sidewalks. The bridge would be approximately

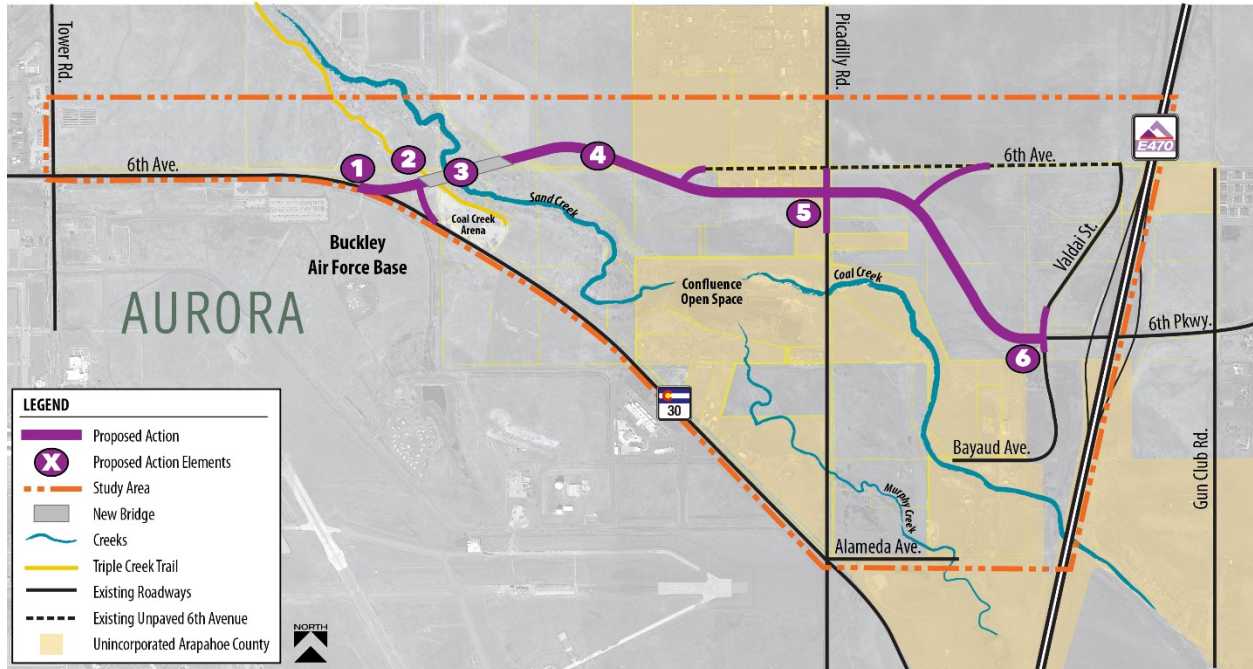
680 feet in length with 5 variable length spans supported on four piers. The bridge would be designed to be compatible with the surrounding environment and to allow wildlife connectivity along Sand Creek and the Triple Creek Trail.

Element 4. 6th Avenue Parkway arterial roadway: The 6th Avenue Parkway extension would consist of a 144-foot wide, six-lane arterial roadway (three lanes in each direction) with a raised vegetated median. There would be curb and gutter and 10-foot wide sidewalks on the north and south sides of the roadway. The Proposed Action would provide two new access connections from the Proposed Action to two existing portions of 6th Avenue. One of these connections would provide access to the existing residences along unpaved 6th Avenue, west of Picadilly Road. The second connection would extend northeast from the Proposed Action to unpaved 6th Avenue to areas planned for development east of Picadilly Road.

Element 5. Intersection with Picadilly Road: The Proposed Action roadway would cross Picadilly Road, which is an existing north-south road. A signalized intersection would be constructed at this location. Picadilly Road is currently two lanes, but the City of Aurora anticipates that expansion to six lanes would occur in the future as a different project. Therefore, the intersection would be configured such that future expansion of Picadilly Road to six lanes can be accommodated and is not precluded.

Element 6. Tie into existing 6th Avenue Parkway at E-470: On its eastern end, the Proposed Action roadway would tie into the existing E-470 interchange, which currently truncates at this location, forming a connection with the existing 6th Parkway to the east of the interchange. The intersection tie-in at Valdai Street and 6th Avenue Parkway would be signalized. This connection would allow access from the west via the Proposed Action to the E-470 interchange and to the existing 6th Avenue Parkway extending to the east of E-470.

In addition to these transportation elements, the Proposed Action would include permanent roadway stormwater drainage with water quality features for roadway runoff and accommodate offsite stormwater flows. Details of drainage and water quality features are presented in **Appendix A6 Floodplains and Drainage Assessment Technical Report** of the EA.



Note: Numbers in graphic correspond with text above.

Figure 1. Proposed Action and Study Area

No Action Alternative

If the Proposed Action is not selected for implementation, there would be no improvements made to 6th Avenue beyond the existing and committed transportation system. The No Action Alternative was carried forward as a baseline comparison for environmental analysis purposes.

2.0 DEFINITION AND SIGNIFICANCE OF PALEONTOLOGICAL RESOURCES

The objective of this paleontological resource analysis, summarized in Table 1, is to evaluate the potential for construction-related adverse impacts on previously recorded, and currently undiscovered, scientifically important paleontological resources within the study area. Paleontology is a multidisciplinary science that combines elements of geology, biology, chemistry, and physics in an effort to understand the history of life on earth. Paleontological resources, or fossils, are the remains, imprints, or traces of once living organisms that have been preserved in rocks and sediments. These include mineralized, partially mineralized, or unmineralized bones and teeth, soft tissues, shells, wood, leaf impressions, footprints, burrows, and microscopic remains. Paleontological resources include not only fossils themselves, but also the associated rocks or organic matter and the physical characteristics of the fossils' associated sedimentary matrix. The fossil record is the only evidence that life on earth has existed for more than 3.6 billion years. Fossils are considered non-renewable resources because the organisms they represent no longer exist. Thus, once destroyed, a fossil can never be replaced (Murphey and Daitch, 2007). Fossils are important scientific and educational resources and can be used to:

- Study the phylogenetic relationships amongst extinct organisms, as well as their relationships to modern groups;
- Elucidate the taphonomic, behavioral, temporal, and diagenetic pathways responsible for fossil preservation, including the biases inherent in the fossil record;
- Reconstruct ancient environments, climate change, and paleoecological relationships;
- Provide a measure of relative geologic dating which forms the basis for biochronology and biostratigraphy, which is an independent and corroborating line of evidence for isotopic dating;
- Study the geographic distribution of organisms and tectonic movements of land masses and ocean basins through time;
- Study patterns and processes of evolution, extinction, and speciation; and
- Identify past and potential future human-caused effects to global environments and climates (Murphey and Daitch, 2007).

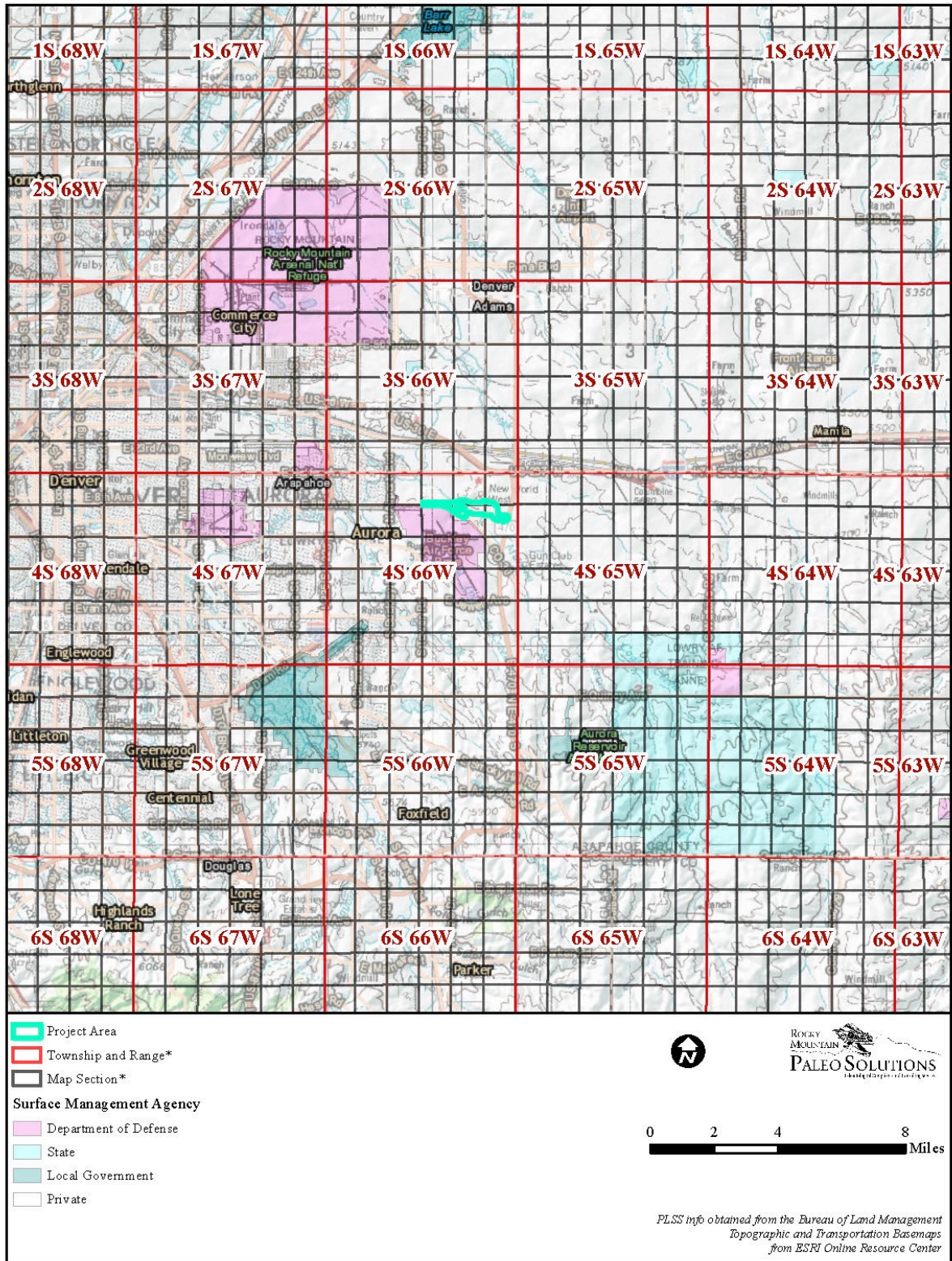


Figure 2. Overview Map of the Proposed Action Study Area.

TABLE 1. PROJECT SUMMARY

Project Name	6 th Avenue Extension Project				
Project Description	Paleontological resource analysis of existing data and field surveys to locate scientifically significant surface fossils and identify areas in which subsurface fossils could be adversely impacted during construction				
Location (PLSS) and Land Owner/Managing Agency	Quarter-Quarter	Section	Township	Range	Land Agency/Private Land Owner
	SESW, SWSW	1	4S	66W	Private
	SESE, SWSE	2	4S	66W	Private/City of Aurora
	NENE	10	4S	66W	Private/City of Aurora/Buckley Air Force Base
	NENW, NWNE, NWNW, SENE, SENW, SWNW	11	4S	66W	Private/City of Aurora
	NWNW, NWNE, SWNW, NENW, SWNE	12	4S	66W	Private
Geologic Maps	Trimble, D. E. and Machette, M. N., 1979, Geologic map of the greater Denver area, Front Range Urban Corridor, Colorado: U.S. Geological Survey, Miscellaneous Investigations Series Map I-856-H, scale 1:100,000.				
Geology	Denver Formation (TKd), Louviers Alluvium (Qlo), Broadway Alluvium (Qb), Windblown Sand (Qes) and Post-Piney and Piney Creek Alluvium (Qp)				
Surveyor	Kate D. Zubin-Stathopoulos, M.S.				
Survey Dates	4/09/2015, 10/20/2015				
Area Surveyed	The survey area is defined as the proposed locations for Alternatives 1a, 2a, 2b and 4a including additional changes to 2a from data received July and October, 2015. These areas were surveyed with no buffer				
Previously Documented Fossil Localities Within the Project Area	No previously documented fossil localities are located within the Project area (3 previous localities are documented within the same township)				
Fossil Localities Discovered During Survey	Non-significant Fossil Occurrence: 0 Significant Fossil Locality: 0				

PLSS = Public Land Survey System

3.0 LAWS, ORDINANCES, REGULATIONS, AND STANDARDS

Fossils are classified as non-renewable scientific resources, and are protected by various laws, ordinances, regulations, and standards (LORS) across the country. Professional procedures for the assessment and mitigation of adverse impacts to paleontological resources have been established by the Society of Vertebrate Paleontology (SVP) (2010). This paleontological study was conducted in accordance with the LORS that are applicable to paleontological resources within the 6th Avenue Extension Project area, as well as established best practices in mitigation paleontology (Murphey et al., 2014). Pertinent federal, state, county, and city LORS are summarized below.

3.1 FEDERAL

The National Environmental Policy Act of 1969, as amended (Pub. L. 91-190, 42 U.S.C. 4321-4347, January 1, 1970, as amended by Pub. L. 94-52, July 3, 1975, Pub. L. 94-83, August 9, 1975, and Pub. L. 97-258 § 4(b), Sept. 13, 1982). National Environmental Policy Act (NEPA) recognizes the continuing responsibility of the Federal Government to “preserve important historic, cultural, and natural aspects of our national heritage...” (Sec. 101 [42 USC § 4321] (#382).

The goal of the NEPA process is to make informed, publicly supported decisions regarding environmental issues. Under NEPA, the Federal government requires that:

- all Federal agencies consider the environmental impacts of proposed actions;
- the public be informed of the potential environmental impacts of proposed actions; and
- the public be involved in planning and analysis relevant to actions that impact the environment.

Federal Land Policy and Management Act (FLPMA) of 1976 (43 U.S.C. 1712[c], 1732[b]); sec. 2, Federal Land Management and Policy Act of 1962 [30 U.S.C. 611]; Subpart 3631.0 et seq.), Federal Register Vol. 47, No. 159, 1982. The FLPMA does not refer specifically to fossils. However, “significant fossils” are understood and recognized in policy as scientific resources. Permits, which authorize the collection of significant fossils for scientific purposes, are issued under the authority of FLPMA.

Under FLPMA, Federal agencies are charged to:

- manage public lands in a manner that protects the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, archaeological, and water resources, and, where appropriate, preserve and protect certain public lands in their natural condition (Section 102 (a)(8) (11));
- periodically inventory public lands so that the data can be used to make informed land-use decisions (Section 102(a)(2); and

- regulate the use and development of public lands and resources through easements, licenses, and permits (Section 302(b)).

CFR Title 43

Under the Code of Federal Regulations (CFR) Title 43, Section 8365.1-5, the collection of scientific resources, including vertebrate fossils, is prohibited without a permit. Except where prohibited, individuals are also authorized to collect some fossils for their personal use. The use of fossils found on Federal lands for commercial purposes is also prohibited.

Department of Interior (DOI) Report – Fossils on Federal & Indian Lands

In 2000, the Secretary of the Interior submitted a report to Congress entitled “Assessment of Fossil Management on Federal and Indian Lands.” This report was prepared with the assistance of nine federal agencies, including the Bureau of Indian Affairs (BIA), the Bureau of Land Management (BLM), the Bureau of Reclamation (BOR), the United States Fish and Wildlife Service (USFWS), the United States Forest Service (USFS), the National Park Service (NPS), the United States Geological Survey (USGS), and the Smithsonian Institution. The consulting agencies concluded that administrative and Congressional actions with respect to fossils should be governed by these seven basic principles:

- Fossils on Federal land are a part of America's heritage.
- Most vertebrate fossils are rare.
- Some invertebrate and plant fossils are rare.
- Penalties for fossil theft should be strengthened.
- Effective stewardship requires accurate information.
- Federal fossil collections should be preserved and available for research and public education.
- Federal fossil management should emphasize opportunities for public involvement.

Paleontological Resources Preservation, Title VI, Subtitle D in the Omnibus Public Lands Act of 2009, Public Law 111-011. Purpose: The Secretary (Interior and Agriculture) shall manage and protect paleontological resources on Federal land using scientific principles and expertise.

The Paleontological Resources Preservation Act (PRPA) is modeled after the Archaeological Resources Protection Act (ARPA) and incorporates the recommendations of the May 2000 Report of the Secretary of the Interior, “Assessment of Fossil Management on Federal and Indian Lands,” regarding future actions to formulate a consistent paleontological resources management framework. With the passage of the PRPA, Congress officially recognizes the importance of paleontological resources on federal lands (United States Department of Interior (USDI), United State Department of Agriculture (USDA) excluding Tribal lands) by declaring that fossils from federal lands are federal property that must be preserved and protected using scientific principles

and expertise. The PRPA essentially codifies existing policies of the BLM, NPS, USFS, BOR, and FWS. The PRPA provides:

- Uniform definitions for “paleontological resources” and “casual collecting.”
- Uniform minimum requirements for paleontological resource use permit issuance (terms, conditions, and qualifications of applicants).
- Uniform criminal and civil penalties for illegal sale and transport, and theft and vandalism of fossils from Federal lands.
- Uniform requirements for curation of federal fossils in approved repositories.

Federal protections for scientifically significant paleontological resources apply to projects if any construction or other related project impacts occur on federally owned or managed lands, involve the crossing of state lines, or are federally funded. Because this project has Federal Highway Administration (FHWA) involvement, federal protections under NEPA apply to paleontological resources within the Project area.

3.2 STATE

The Colorado Historical, Prehistorical and Archaeological Resources Act of 1973 (CRS 24-80-401 to 411, and 24-80-1301 to 1305), defines permitting requirements and procedures for the collection of prehistoric resources, including paleontological resources, on state lands, and actions that should be taken in the event that resources are discovered in the course of state-funded projects and on state-owned/administered lands. Based on this legislation, the Colorado Department of Transportation (CDOT) requests assessments on state owned and/or administered lands that have the potential to contain significant paleontological resources, and mitigation monitoring during ground disturbance in these areas. This study will be reviewed by CDOT and the City of Aurora. The CDOT must fulfill FHWA’s NEPA requirements under the Colorado Historical, Prehistorical and Archaeological Resources Act (CHPA).

3.3 COUNTY

There are no Arapahoe County LORS that specifically address potential adverse impacts on paleontological resources. Therefore, no county-level protections of paleontological resources pertain to the Project.

3.4 CITY

There are no City of Aurora LORS that pertain to the Project.

3.5 PRIVATE LANDS

There are no LORS applicable to paleontological resources that occur on privately owned lands in the state of Colorado.

4.0 METHODS

This section describes the methods used to complete the paleontological work, all of which was completed under the State of Colorado Paleontological Permit # 2015-55.

4.1 ANALYSIS OF EXISTING DATA METHODS

The analysis of existing paleontological data included the following elements: 1) an agency records search to determine the presence of previously recorded fossil localities within and adjacent to the Project area; 2) a museum records search to determine the presence of previously recorded fossil localities within and adjacent to the Project area; 3) a geologic map review to determine the distribution of geologic units within the Project area; and 4) a literature search to document the paleontological sensitivity of the Project area and the same geologic units in adjacent areas of Colorado. The Potential Fossil Yield Classification (PFYC) assignments for the geologic units within the study area were determined using the statewide PFYC classification prepared by the Bureau of Land Management (BLM, 2007). The PFYC is a predictive resource management tool that classifies geologic units on their likelihood to contain paleontological resources on a scale of 1 (low potential) to 5 (very high potential). The geologic map review included Trimble and Machette (1979). The literature search emphasized publications on paleontological resources from the geologic units that are present within, and adjacent to, the Project area.

4.2 PERSONNEL

The field survey was conducted by RMPS paleontologist Kate D. Zubin-Stathopoulos, M.S., under the direction of Principal Investigator Dr. Paul C. Murphey. The data analysis was completed, and this report was prepared by Kate D. Zubin-Stathopoulos. Document review was provided by Paul C. Murphey. GIS support was provided by RMPS GIS specialist Paul R. Nesbit, M.S. Technical editing was completed by Katie Schortmann, B.S.

4.3 FIELD SURVEY METHODS

The analysis of existing data was followed by a pedestrian field survey. The field survey included an examination of the Project area for surface fossils and potentially fossiliferous exposures of bedrock and surficial deposits within the area of the four proposed alternatives for the 6th Avenue Extension Project. A buffer around the locations of the alternatives was not surveyed. Only areas for which permission to enter had been granted and that were safely accessible were surveyed. The pedestrian survey focused on areas with greatest potential for exposures of bedrock and surficial sediments. Areas that were previously disturbed, such as residential areas or farmland, and areas that were completely vegetated, were cleared visually. During the field survey, overlapping alternatives were treated as separate survey areas, and areas where an alternative exists with no overlap was treated as a separate survey area. As a result, there were 8 separate survey areas. The fieldwork was completed on April 09, 2015 and October 20, 2015 under the State of Colorado Paleontological Permit # 2015-55.

4.4 DISTRIBUTION OF DATA

Copies of this report will be submitted to Felsburg Holt and Ullevig (FHU) and the Colorado Historical Society. RMPS will retain an archival copy of all Project information including field notes, maps, and other data.

5.0 LITERATURE RESEARCH RESULTS

The Project area is located in Arapahoe County, Colorado, and is underlain by four mapped geologic units. These include the Denver Formation (TKd) and three surficial units: Louviers Alluvium (Qlo), Broadway Alluvium (Qb), Windblown Sand (Qes), and Post-Piney and Piney Creek Alluvium (Qp). The general geology and paleontologic content of these units is described in this section, and a map showing the distribution of the geologic units within the Project area is provided in Figure 3 (see Section 6.0). The paleontological potential of the geologic units within the Project area is summarized in Table 2.

5.1 GEOLOGY AND PALEONTOLOGY

The Denver Formation was deposited in the Denver basin, an asymmetrical Laramide-aged structural basin that contains sedimentary bedrock from Pennsylvanian through Pliocene in age and is unconformably overlain by Pleistocene and Holocene surficial deposits. The geology of the strata deposited within the Denver Basin is scientifically important because, for example, it records the erosion of the ancestral Rocky Mountains, development of a vast interior seaway, which covered much of central North America, and the uplift of the Front Range of the Rocky Mountains during the Laramide Orogeny. Significant paleontologic events recorded within Denver Basin units include extinction of the dinosaurs at the end of the Cretaceous Period, development of tropical rainforest ecosystems and evolutionary radiation of mammals during the Paleocene, and the environments and animals which lived in the region during the Pleistocene ice ages.

TABLE 2. GEOLOGIC UNITS WITHIN THE PROJECT AREA
(Trimble and Machette, 1979)

Geologic Unit Name	Map Unit Abbreviation	Typical Fossils	Age	Highest PFYC
Post-Piney and Piney Creek Alluvium	Qp	Too young to contain in-situ fossils	Upper Holocene	2 <i>(low potential)</i>
Windblown Sand	Qes	Mammoth, camel, bison, horse, badger, and several species of rodents	Lower Holocene to Upper Pleistocene	2 <i>(low potential)</i>
Broadway Alluvium	Qb	Pleistocene	Mammoth, horse, bison, camel, and small mammals	3 <i>(moderate potential)</i>
Louviers Alluvium	Qlo	Mammoth, bison, horse, camel, jackrabbit, ground squirrel, gopher, and prairie dogs	Upper Pleistocene	3 <i>(moderate potential)</i>
Denver Formation	TKd	Well preserved plants; vertebrates including reptiles (including dinosaurs) and mammals	Cretaceous to Paleocene	5 <i>(very high potential)</i>

5.1.1. Denver Formation (Tkd)

The Denver Formation consists of dark brown, yellowish-brown, and grayish-olive tuffaceous claystone, mudstone, and sandstone beds interbedded with scattered conglomerate (Bryant et al., 1981; Colton, 1978; Soister, 1978; Trimble and Machette, 1979). The unit is reported to be as much as 565 feet thick (Colton, 1978). The Denver Formation is unconformably underlain by the Laramie and Arapahoe formations, and is unconformably overlain by widely distributed Pleistocene- and Holocene-age surficial sedimentary deposits to the east of the Front Range foothills in the Denver Basin. Within the 6th Ave Extension Project area, the Denver Formation purportedly is of Paleocene age based on the geologic mapping of the K-T Boundary by Dechesne et al. (2011) This is contrary to ages reported for previously recorded fossil localities in the area (see section 6.0 Record Search Results).

The Denver Formation is largely composed of altered andesitic (volcanic) debris, and was deposited during the Laramide uplift of the Rocky Mountains in rivers and on alluvial floodplains in a tropical forest environment. Spanning from the latest Cretaceous (Maastrichtian) to the Paleocene (Puercan), “D1” deposits of the Denver Formation preserve the Cretaceous-Tertiary boundary (dinosaur mass extinction event), which is reflected by the presence of dinosaur fossils below the boundary and early Paleocene-age mammal fossils above the boundary. “D1” Denver Formation strata are unconformably overlain by “D2” strata, which are early Eocene in age based on scant fossil evidence. The boundary between “D1” and “D2” strata consists of a widely distributed paleosol deposit (Johnson and Reynolds, 1999; Reynolds and Johnson, 2003).

The Denver Formation preserves locally abundant and scientifically significant plant fossils (Brown, 1943; 1962; Ellis et al., 2003; Johnson and Ellis, 2002; Knowlton, 1930), and a less abundant, but scientifically important, fossil vertebrate fauna (Eberle, 2003; Middleton, 1983). The flora is highly diverse, and has been documented from 149 stratigraphically controlled localities, including the well-publicized Castle Rock Rainforest Site along I-25, south of Denver (Johnson et al., 2003). Vertebrate fossils include a diversity of Cretaceous-age dinosaurs and early Paleocene-age mammals (Carpenter and Young, 2002; Eberle, 2003). Both the Denver Museum of Nature and Science (DMNS) and University of Colorado Museum (UCM) have numerous recorded Denver Formation localities from around the Denver Basin.

The geology and paleontology of the Denver Formation was the subject of active research by scientists and students at the DMNS and UCM from the 1990’s up until approximately 2012. This work, collectively part of the NSF-funded Denver Basin Project, has added considerably to the scientific understanding of the geologic and biologic history of the Denver Basin and surrounding areas during the late Cretaceous Period and Paleocene Epoch (Eberle, 2003; Ellis et al., 2003; Johnson and Ellis, 2002; Johnson and Reynolds, 1999). Future fossil discoveries in the Denver Formation will augment the data available for study. Since it is largely covered throughout its distribution in the Denver area, excavations associated with new construction that expose Denver Formation rocks are an important data source. Because it contains locally abundant and well-preserved plant fossils and less common, but locally well-preserved and scientifically important fossil vertebrates, the Denver Formation has high paleontological potential (PFYC 5). The distribution of the Denver Formation is shown in Figure 3.

5.1.2. Louviers Alluvium (Qlo)

The Pleistocene (Wisconsin) Louviers Alluvium consists of reddish to yellowish brown pebbly arkosic sand, coarse sand, cobble-sized gravel, and occasional boulders. It includes lenticular masses of silt and clay, commonly with contorted bedding (Trimble and Machette, 1979; Lindvall, 1979). The coarse-grained clasts are locally stained and cemented by manganese and iron oxide, are cross-bedded, and generally contain abundant mica. The unit is generally 15 to 35 feet thick (Lindvall, 1979), and is as much as 60 feet above modern stream drainages (Trimble and Machette, 1979). It has produced scattered vertebrate fossils including the remains of mammoth, bison, horse, camel, jackrabbit, ground squirrel, and prairie dogs in the Denver area (Scott, 1972, 1963, 1960; unpublished UCM paleontological data). Because it contains few fossils, the Louviers Alluvium is considered to have low paleontological potential (PFYC 3). The distribution of the Louviers Alluvium within the Project area is shown in Figure 3.

5.1.3. Broadway Alluvium (Qb)

The Pleistocene (Wisconsin) Broadway Alluvium is locally composed of dark to light brown, coarse pebbly to fine sand interbedded with lenses of clay that ranges between 10 to 30 feet thick (Trimble and Machette, 1979). It is known to contain rare and mostly isolated fossil remains including mammoth, horse, bison, camel, and small mammals, but these fossils are generally uncommon and poorly preserved although scientifically important (Hunt, 1954; unpublished UCM paleontological data). Therefore, the Broadway Alluvium is considered to have moderate paleontological potential (PFYC 3). The distribution of this unit is shown in Figure 3.

5.1.4. Windblown Sand (Qes)

Windblown Sand consists of eolian deposits of fine to medium sand mainly derived from major streams and distributed east and southeast of the source by wind (Trimble and Machette, 1979). They are generally structureless, but are locally cross-bedded. Eolian deposits are known to contain mammalian fossils, although fossils are uncommon in windblown deposits. In Colorado, eolian deposits of Pleistocene age are known to contain scattered fossil bones including those of mammoth, camel, bison, horse, badger, and several species of rodents (Hunt, 1954). Because fossils are sparse in eolian deposits, they are generally considered to have low paleontological potential (PFYC 2). The distribution of eolian deposits within the Project area is shown in Figure 3.

5.1.5. Post-Piney Creek and Piney Creek Alluvium

Holocene-aged Piney Creek Alluvium consists of brown, light brown, and light to dark gray interbedded sand, silt and clay. Humic material is common in its upper 2 feet, and it contains interbedded gravel in its lower part. The Piney Creek Alluvium is typically 5 to 10 feet thick (Lindvall, 1979; Trimble and Machette, 1979). Holocene-aged Post-Piney Creek Alluvium consists of light to dark grayish-brown clay, sand, silt and small amounts of gravel, and dark brown and dark bluish-black humic bog clays, locally interbedded with sand and silt. The unit is present in most minor tributary stream valleys, and is as much as 5 feet thick (Lindvall, 1979; Trimble and Machette, 1979). These units are too young to contain in-situ fossils. They are known to contain the unfossilized remains of modern species, and thus have low paleontological potential (PFYC 2). The distribution of Post-Piney and Piney Creek Alluvium within the Project area is shown in Figure 3.

6.0 RECORD SEARCH RESULTS

There are no previously recorded fossil localities within the Project area, and three previously recorded Denver Museum of Nature and Science (DMNS) fossil localities within the same Township approximately 4.5 miles from the Project area. There are 14 University of Colorado Museum (UCM) fossil localities within Arapahoe County consisting of plants from the Denver Formation, rodents from the Louviers Alluvium and bison and horse from the Broadway Alluvium. DMNS fossil localities both produced fossil plants from the Denver Formation, one locality reportedly of Late Cretaceous age and the other two of Paleocene age (Table 3). Despite the reported ages of these localities, more recent mapping of the K-T boundary by Dechesne et al. (2011) indicates that all of these localities are of Paleocene age, and places the K-T Boundary further to the west in the vicinity of Interstate 225 (I-225). In addition, the Paleobiology Database (paleobiodb.org) has a record of a theropod dinosaur within the Denver Formation in Arapahoe County.

TABLE 3. PREVIOUSLY RECORDED FOSSIL LOCALITIES WITHIN THE SAME TOWNSHIP AS THE PROJECT AREA

Locality Number	Data Provided By	Data Collected By	Fossils	Formation
1682	DMNS	DMNS	Plants: Late Cretaceous	Denver
2235	DMNS	DMNS	Plants: Paleocene	Denver
2236	DMNS	DMNS	Plants: Paleocene	Denver

7.0 FIELD SURVEY RESULTS

This section of this report presents the results of the pedestrian field survey. The surface of the Project area is mostly covered by vegetation, and many portions are previously disturbed by residential construction and agricultural use. There are no exposures of sedimentary bedrock within the Project area, but there are exposures of surficial sedimentary deposits. The field survey results are summarized in Tables 4-12. Representative photos are provided in Tables 4-12, and photo point locations are provided in Figures 2 and 3. Additional areas surveyed on October 20, 2015 are described in Table 12 and depicted in Figure 4. No new fossil localities were discovered during the field survey. Each alternative is described separately below.

Alternative 1a is underlain by the Denver Formation (TKd), Louviers Alluvium (Qlo), Windblown Sand (Qes), and Post-Pine and Piney Creek Alluvium (Qp). This area consists of rolling agricultural land predominantly covered in grasses to the east with more robust vegetation including cottonwood trees and low bushes to the west. There are no bedrock or surficial sediments exposed within Alternative 1a (See Tables 4, 5, 10 and 11).

Alternative 2a is underlain by Denver Formation (TKd), Louviers Alluvium (Qlo), Broadway Alluvium (Qb), Windblown Sand (Qes), and Post-Pine and Piney Creek Alluvium (Qp). This area consists of rolling, open agricultural land becoming more residential to the west and gently sloping to the south toward Coal Creek. It is predominantly covered in grasses and crops to the east with more robust vegetation including cottonwood trees and low bushes to the west. There is 5% surficial sedimentary deposits exposed along Coal Creek in SENW QtrQtr of section 12 within Alternative 2a. (See Tables 4, 6, 10, 11 and 12).

Alternative 4a is underlain by Louviers Alluvium (Qlo), Windblown Sand (Qes), and Post-Piney and Piney Creek Alluvium (Qp). This area consists of rolling farmland to the east with a prominent drainage in the center where there is 5-10% surficial sediment exposure of Post-Piney and Piney Creek Alluvium (Qp) in the NENW of Section 11 along Coal Creek. Wetlands and stands of cottonwood trees are present in a wildlife preserve to the west (See Tables 4, 7 and 9).

Alternative 4b is underlain by the Denver Formation (TKd), Louviers Alluvium (Qlo), Windblown Sand (Qes), and Post-Pine and Piney Creek Alluvium (Qp). This area consists of rolling agricultural land gently sloping to the north and residential areas to the east with a prominent drainage in the center where there is 5-10% surficial sediment exposure of Post-Piney and Piney Creek Alluvium (Qp) in the NENW of Section 11 and the NW quarter of Section 12 along Coal Creek (See Tables 4, 8, 9 and 11).

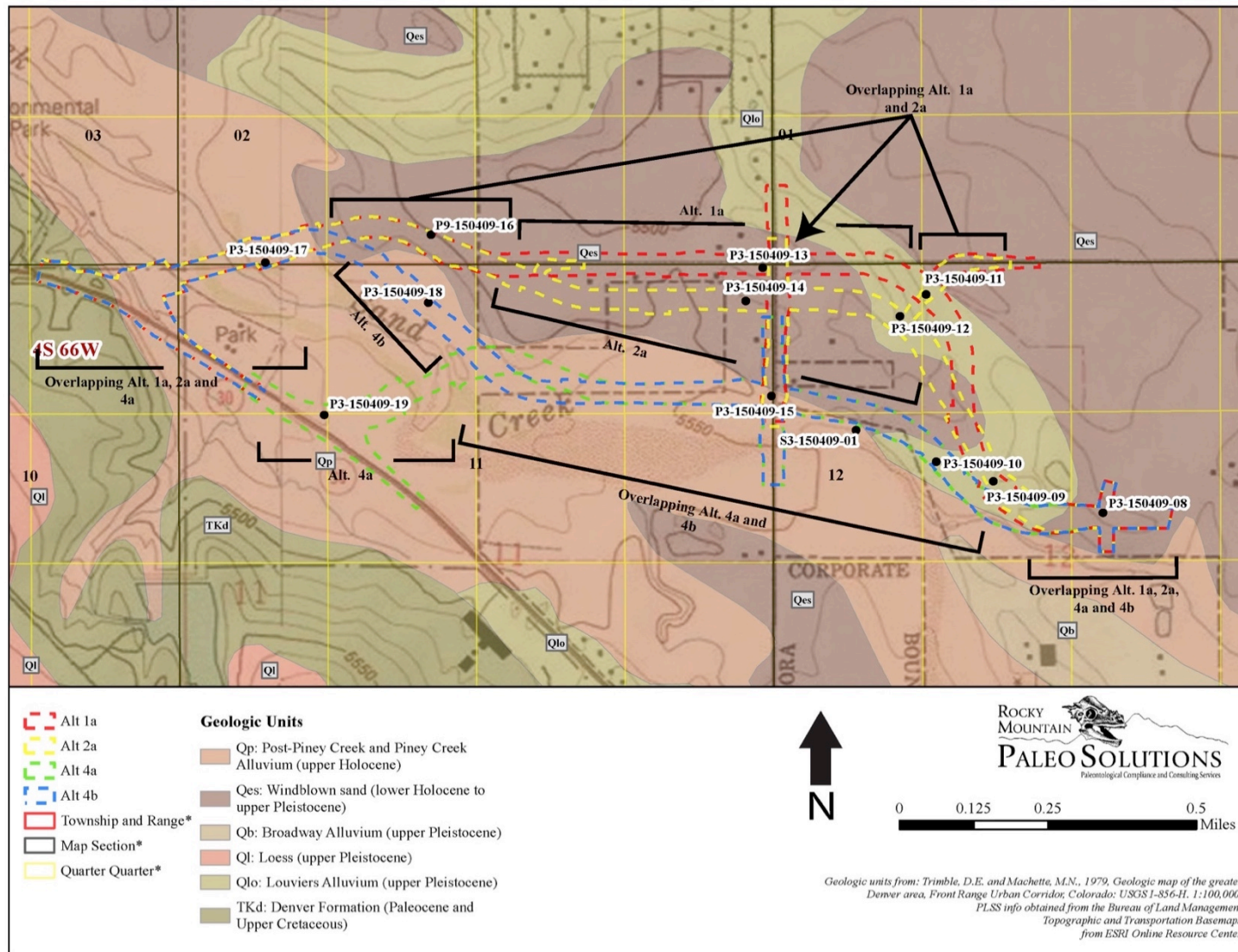


Figure 3. Overview of the Proposed Action study area showing alternatives and geology. Survey areas indicated on the map correspond to survey summary tables (see Tables 4-11).

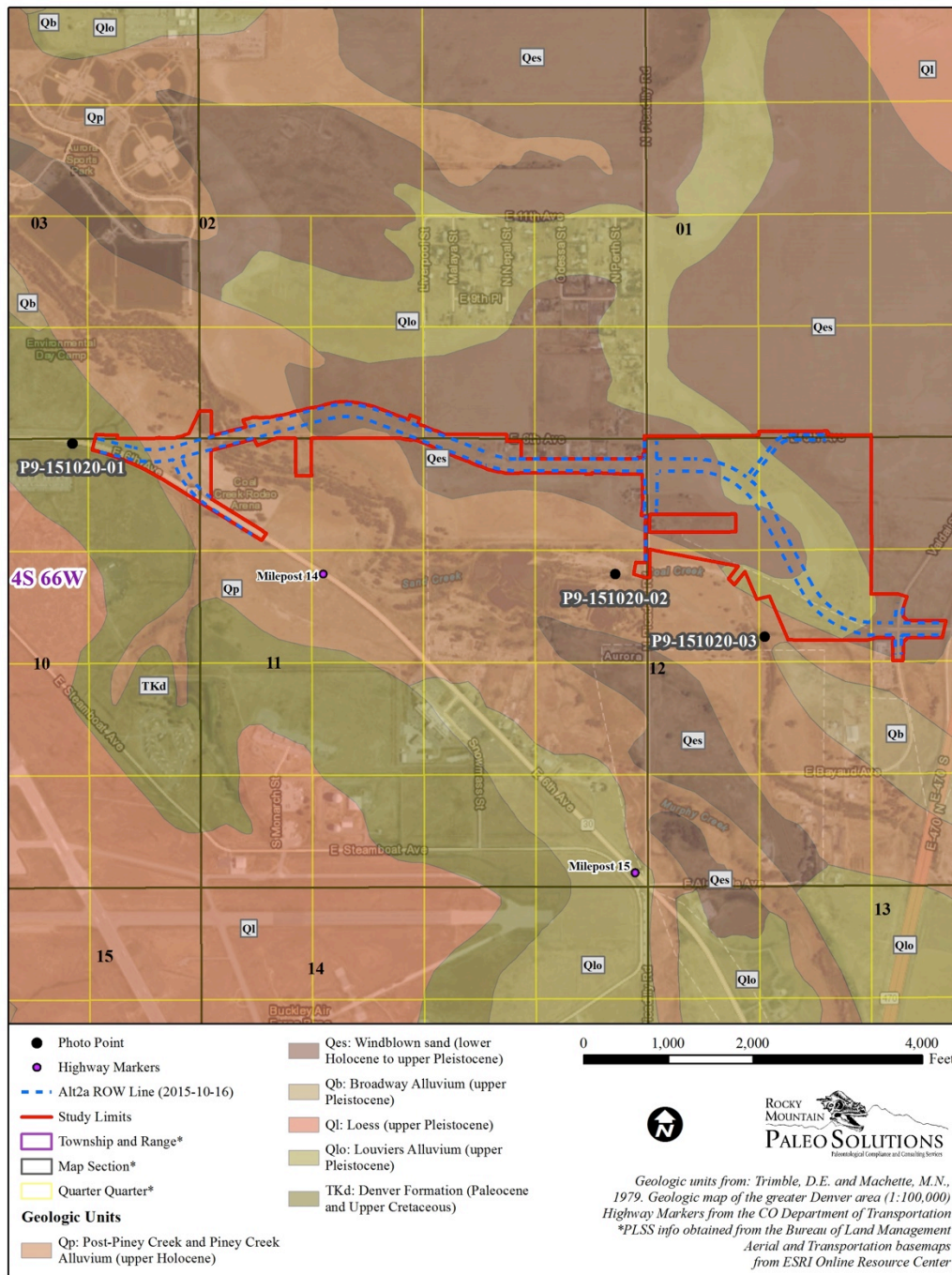


Figure 4. Overview of the Proposed Action study area showing additions to Alternative 2A surveyed on October 20, 2015 with geology.

TABLE 4. OVERLAPPING PORTIONS OF ALTERNATIVES 1A, 2A, 4A and 4B
(See Figure 3 For Photo Point Locations)

Survey Area Name	Overlapping Alternatives 1a, 2a, 4a and 4b
Survey Date(s)	4/9/2015
Formation(s)	Windblown Sand (Qes), Louviers Alluvium (Qlo)
Topography	Developed on the east end (Intersection of E 6th Parkway and E-470) with rolling agricultural land to the west covered by grass and gently sloping to the south toward Coal Creek
% Bedrock and Exposure Location	0%, no bedrock or surficial sediment exposure
Lithology(ies)	N/A
Photo Points/Stratigraphy Points	P3-150409-08
NFO's	None
SFL's	None
Land Ownership	Private
PLSS	NWNW, SWNW, SWNE, SENW of Section 12; NENE, SENE of Section 11 T4S R66W
Topographic Quad	USGS Coal Creek, Colorado 7.5' (1966)
Geologic Map	Trimble and Machette, 1979



Figure 1. View of the east end of the Project area from photo point P3-150409-08 view facing north



Figure 2. View of the east end of the Project area from photo point P3-150409-08 view facing south

TABLE 5. ALTERNATIVE 1A (See Figure 3 For Photo Point Locations)

Survey Area Name	Alternative 1a
Survey Date(s)	4/9/2015
Formation(s)	Louviers Alluvium (Qlo), Windblown Sand (Qes)
Topography	Rolling, pasture land becoming more residential to the west along E 6th Ave (unpaved road)
% Bedrock and Exposure Location	0%, No bedrock exposure or surficial sediment exposure
Lithology(ies)	N/A
Photo Points/Stratigraphy Points	P3-150409-11 P3-150409-13
NFO's	None
SFL's	None
Land Ownership	Private
PLSS	SESE, SWSE of Section 2, SWSW of Section 1; NWNE, NENE of Section 11; NWNW, NENW of section 12, T4S R66W
Topographic Quad	USGS Coal Creek, Colorado 7.5' (1966)
Geologic Map	Trimble and Machette, 1979



Figure 1. Overview of Alt. 1a at photo point P3-150409-11 view facing north



Figure 2. Overview of Alt. 1a at photo point P3-150409-13 view facing east

TABLE 6. ALTERNATIVE 2A (See Figure 3 For Photo Point Locations)



Survey Area Name	Alternative 2a	 <p>Figure 1. Overview of Alt. 2a at photo point P3-150409-12 view facing south</p>  <p>Figure 2. Overview of Alt. 2a from photo point P3-150409-14 view facing east</p>
Survey Date(s)	4/9/2015	
Formation(s)	Louviers Alluvium (Qlo), Windblown Sand (Qes)	
Topography	Rolling, open agricultural land becoming more residential to the west, gently sloping to the south toward Coal Creek.	
% Bedrock and Exposure Location	0%, No bedrock exposure or surficial sediment exposure	
Lithology(ies)	N/A	
Photo Points/Stratigraphy Points	P3-150409-12 P3-150409-14	
NFO's	None	
SFL's	None	
Land Ownership	Private	
PLSS	NWNE, NENE of Section 11; NWNW, NENW of Section 12, T4S R66W	
Topographic Quad	USGS Coal Creek, Colorado 7.5' (1966)	
Geologic Map	Trimble and Machette, 1979	

TABLE 7. ALTERNATIVE 4A (See Figure 3 For Photo Point Locations)

Survey Area Name	Alternative 4a
Survey Date(s)	4/9/2015
Formation(s)	Post-Piney Creek and Piney Creek Alluvium (Qp)
Topography	Flat, prairie dog town with cottonwood trees and wetland area to the east (wildlife preserve)
% Bedrock and Exposure Location	0% bedrock exposure, 5% surficial sediment exposure in the NENW of Section 11
Lithology(ies)	Post-Piney Creek and Piney Creek Alluvium: Tan to white medium- to coarse-grained, well sorted arkosic unconsolidated sand
Photo Points/Stratigraphy Points	P3-150409-19
NFO's	None
SFL's	None
Land Ownership	Private/City of Aurora
PLSS	NWNW, NENW, SENW, SWNW, NWNE of 11, T4S R66W
Topographic Quad	USGS Coal Creek, Colorado 7.5' (1966)
Geologic Map	Trimble and Machette, 1979



Figure 1. Overview of Alt. 4a from photo point P3-150409-19 view facing north



Figure 2. Overview of Alt. 4a from photo point P3-150409-19 view facing east

TABLE 8. ALTERNATIVE 4B (See Figure 3 For Photo Point Locations)

Survey Area Name	Alternative 4b
Survey Date(s)	4/9/2015
Formation(s)	Windblown Sand (Qes), Post-Piney Creek and Piney Creek Alluvium (Qp)
Topography	Residential development and topographically flat farm land (crops) to the east and rolling pasture land and wildlife preserve with cottonwood trees to the west
% Bedrock and Exposure Location	0% bedrock exposure, 5% surficial sediment exposure in the NENW of Section 11
Lithology(ies)	Post-Piney Creek and Piney Creek Alluvium: Tan to white medium- to coarse-grained, well sorted arkosic unconsolidated sand
Photo Points/Stratigraphy Points	P3-150409-18
NFO's	None
SFL's	None
Land Ownership	Private/City of Aurora
PLSS	SESW of Section 2; NENW NWNE of Section 11 T4S R66W
Topographic Quad	USGS Coal Creek, Colorado 7.5' (1966)
Geologic Map	Trimble and Machette, 1979



Figure 1. Overview of Alt. 4b from photo point P3-150409-18 view facing south



Figure 2. Overview of Alt. 4b from photo point P3-150409-18 view facing west

TABLE 9. OVERLAPPING PORTIONS OF ALTERNATIVES 4A AND 4B
(See Figure 3 For Photo Point Locations)

Survey Area Name	Overlapping Alternatives 4a and 4b
Survey Date(s)	4/9/2015
Formation(s)	Post-Piney Creek and Piney Creek Alluvium (Qp), Louviers Alluvium (Qlo), Windblown Sand (Qes)
Topography	Sloping to the north, rolling hills, agricultural land, residential development, and Coal Creek with high side wall cut in the NE of Section 11 and the NW quarter of Section 12
% Bedrock and Exposure Location	0% bedrock exposure, 10% surficial sediment exposure in drainage wall cut in the NE Quarter of Section 11 and NW quarter of Section 12
Lithology(ies)	Post-Piney Creek and Piney Creek Alluvium: 0.5-3.0 meters of massive compacted sand, mottled color, cross bedded and planar laminated, fine to coarse grained with occasional gravel sized clasts, poorly sorted, bottom contact not exposed
Photo Points/Stratigraphy Points	P3-150409-10 P3-150409-15 S3-150409-01
NFO's	None
SFL's	None
Land Ownership	Private
PLSS	NWNE, NENE, SENE, NENW of Section 11; NWNW, SWNW, SENW of Section 12, T4S R66W
Topographic Quad	USGS Coal Creek, Colorado 7.5' (1966)
Geologic Map	Trimble and Machette, 1979



Figure 1. Overview of Alt. 4a/4b showing exposure of Qp from point S3-150409-01 view facing north



Figure 2. Overview of Alt. 4a/4b showing exposure of Qp from point S3-150409-01 view facing west

TABLE 10. OVERLAPPING PORTIONS OF ALTERNATIVES 1A AND 2A
(See Figure 3 For Photo Point Locations)

Survey Area Name	Overlapping Alternatives 1a and 2a
Survey Date(s)	4/9/2015
Formation(s)	Louviers Alluvium (Qlo), Windblown Sand (Qes), Denver Formation (TKd)
Topography	Flat, prairie dog town with solar farm on west end, gently sloping to the east into lower areas and rolling pasture land in Section 12 to the east
% Bedrock and Exposure Location	0% bedrock exposure, 5% surficial sediment exposure in the NW of Section 11 and SW of Section 2
Lithology(ies)	Tan to white medium- to coarse-grained, well sorted arkosic unconsolidated sand (likely Post-Piney and Piney Creek Aluvium, though not mapped within this area)
Photo Points/Stratigraphy Points	P3-150409-09 P3-150409-16
NFO's	None
SFL's	None
Land Ownership	Private
PLSS	SWSW, SESW of Section 1; SESW, SWSE, SESE of Section 2; NWNW, NENW, SENW of Section 12, T4S R66W
Topographic Quad	USGS Coal Creek, Colorado 7.5' (1966), USGS Fitzsimons, Colorado 7.5' (1965)
Geologic Map	Trimble and Machette, 1979



Figure 1. Overview of Alt. 1a/2a from photo point P3-150409-09 view facing south



Figure 2. Overview of Alt. 1a/2a from photo point P3-150409-16 view facing west

TABLE 11. OVERLAPPING PORTIONS OF ALTERNATIVES 1A, 2A and 4B
(See Figure 3 For Photo Point Locations)



Survey Area Name	Overlapping Alternatives 1a, 2a, and 4b	
Survey Date(s)	4/9/2015	
Formation(s)	Post-Piney Creek and Piney Creek Alluvium (Qp), Windblown Sand (Qes), Denver Formation (TKd)	
Topography	Rolling pasture land with abundant cottonwood trees lining Sand Creek	
% Bedrock and Exposure Location	0%, no bedrock exposure, no surficial sediment exposure	Figure 1. Overview of Alt. 1a/2a/4b at photo point P3-150409-17 view facing north
Lithology(ies)	N/A	
Photo Points/Stratigraphy Points	P3-150409-17	Figure 2. Overview of Alt. 1a/2a/4b at photo point P3-150409-17 view facing east
NFO's	None	
SFL's	None	
Land Ownership	Private/City of Aurora	
PLSS	SWSW of Section 2; SESE of Section 3; NENE of Section 10; NWNW of Section 11, T4S R66W	
Topographic Quad	USGS Coal Creek, Colorado 7.5' (1966), USGS Fitzsimons, Colorado 7.5' (1965)	
Geologic Map	Trimble and Machette, 1979	

TABLE 12. ADDITIONS TO ALTERNATIVE 2A
(See Figure 4 For Photo Point Locations)

Survey Area Name	Additions to Alternative 2a surveyed in October, 2015
Survey Date(s)	10/20/2015
Formation(s)	Post-Piney Creek and Piney Creek Alluvium (Qp), Windblown Sand (Qes), Denver Formation (TKd), Broadway Alluvium (Qb)
Topography	Rolling pasture land with abundant cottonwood trees lining Sand Creek and Coal Creek, moderate relief drainage in the southeast portion
% Bedrock and Exposure Location	0%, no bedrock exposure, 5% surficial sediment exposure in the southeast
Lithology(ies)	Tan to white medium- to coarse-grained, well sorted arkosic unconsolidated sand (likely Post-Piney and Piney Creek Aluvium, though not mapped within this area)
Photo Points/Stratigraphy Points	P9-151020-01, P9-151020-02, P9-151020-03
NFO's	None
SFL's	None
Land Ownership	Private/City of Aurora
PLSS	SENE of Section 11 T4S R66W, SWNW of Section 12, T4S R66W
Topographic Quad	USGS Coal Creek, Colorado 7.5' (1966), USGS Fitzsimons, Colorado 7.5' (1965)
Geologic Map	Trimble and Machette, 1979



Figure 1. Overview of Alt. 2a at photo point P9-151020-02) view facing north



Figure 2. Overview of Alt. 2a at photo point P9-151020-03 view facing north

8.0 RECOMMENDATIONS

1. No fossils were observed during the field survey and there are no previously recorded fossil localities within the Project area as summarized in **Appendix B** to include in the EA. According to the UCM and DMNS, only three previously recorded fossil localities have been recorded within the same Township, and all produced fossil plants from the Denver Formation. The majority of the Project area is immediately underlain by Quaternary surficial deposits with low and moderate paleontological potential, and adverse impacts on paleontological resources in these areas is unlikely. Immediate paleontological clearance is recommended for all areas underlain by Louviers Alluvium, Broadway Alluvium, Windblown Sand and Piney Creek and Post-Piney Creek Alluvium. The fossil rich Denver Formation is mapped at the surface towards the westernmost end of the Project area (**Figure 3**), although no exposures were observed during the field survey. When the project design plans are finalized, the CDOT Staff Paleontologist should examine them and determine the amount (lateral extent and depth) of impact to the Denver Formation, and the amount of construction monitoring, if any, which is required to reduce potential adverse impacts on scientifically important paleontological resources to a less than significant level.
2. If any sub-surface bones or other potential fossils are found anywhere within the Project area during construction, the CDOT Staff Paleontologist should be notified immediately to assess their significance and make further recommendations. This mitigation measure is referenced in **Appendix C** to include in the EA.

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- The Paleobiology Database: Available at <https://paleobiodb.org/#/>. Accessed October, 2015.
- University of Colorado Museum, unpublished paleontological specimen and locality data, compiled in 2003.

Appendix A
Copy of the State of Colorado Paleontological Permit



No. 2015-55

STATE OF COLORADO PALEONTOLOGICAL PERMIT

Issued under the authority of the Colorado Historical, Prehistorical, and Archaeological Resources Act, CRS 1973 24-80-401 *et seq.*, and under the procedures of the State Administrative Procedures Act, CRS 1973 24-4-101 *et seq.*

THIS IS TO CERTIFY that: Paul C. Murphey and
(Principal Investigator[s])

same plus Kate D. Zubin-Stathopoulos
(Project Paleontologists)

of: 1216 E. 10th Ave., Denver, CO 80218

representing: Rocky Mountain Paleo Solutions

has/have been found to be qualified for the conduct of Paleontological studies and is/are hereby authorized to conduct paleontological investigations as described below, subject to: (a) the terms and conditions listed below, and (b) the Rules and Procedures published by the Colorado State Archaeologist.

Nature of investigation and location: Paleontological Survey and Testing, statewide

Disposition of materials collected (subject, however, to such reservation as the State Archaeologist may impose under CRS 1973 24-80-406d):

Denver Museum of Nature & Science-Denver, CO

Other condition(s): _____

Issued this 3rd day of March, 2015.

The Permit is valid through February 29, 2016.

NOTE: Keep a copy of this Permit
in your field possession.

State Archaeologist of Colorado

Rev. 4/10

C.R.S. 24–80–406. Permits. (2) Stipulations:

- (a) The investigations, excavations, gatherings, and removals shall be undertaken only for the benefit of reputable museums, universities, colleges, or other recognized scientific or educational institutions, with a view to increasing the knowledge of such resources; and such activities shall be conducted for permanent preservation, either on the site or in museums, open to the public and available to qualified students.
- (b) All permit holders shall provide the state archaeologist, within one year after the start of the investigation, excavation, gathering, or removal, with a preliminary report of progress. If such activity continues for more than one year, an annual progress report shall be made. The permit holder shall furnish a final report of the activity undertaken within three years after termination of the field work.
- (c) An inventory of all materials recovered during the course of the investigation, excavation, gathering, or removal shall be supplied to the state archaeologist.
- (d) Upon receipt of the final report of the activity undertaken by a permit holder, the state archaeologist may require that a representative collection of the materials recovered be delivered to the state of Colorado and shall determine a repository for the same.
- (e) Any permit issued by the society may be revoked by the society, pursuant to article 4 of this title, at any time if there is evidence that the activity authorized by the permit is being unlawfully or improperly conducted or if the permit holder does not honor the conditions of the permit. When a permit is revoked, all recovered materials, catalogues, maps, field notes, and other records necessary to identify the same shall be surrendered immediately to the society.

Appendix B Resource Impact Table

Resource	Context	No Action Alternative	Proposed Action
<p>Paleontological Resources (Rocky Mountain PaleoSolutions, 2016 – Appendix A11)</p>	<p>The study area is underlain by Quaternary age alluvial deposits with low to moderate potential to contain fossils. The alluvial deposits are immediately underlain by Denver Formation bedrock, which has very high potential to contain fossils. There are no previously recorded fossil localities in the study area, and no fossil localities were discovered during the field survey.</p>	<p>Would not affect paleontological resources.</p>	<p>Fossils could possibly be unearthed during construction, with the most likely being from the Denver Formation. The Denver Formation would only be expected to be encountered with surface construction at the westernmost end of the study area, or with excavations such as for bridge piers extending to depths of 15 feet or more in other part of the study area. Unearthing of fossils from the alluvial deposits is less likely.</p>

Appendix C Resource Mitigation Table

Mitigation Category	Proposed Action Impact	Mitigation Commitments for the 6 th Avenue Extension Project	Responsible Branch	Timing/Phase that Mitigation will be Implemented
Paleontological Resources	The potential to impact previously unknown resources.	If disturbance yields any subsurface bones or other potential fossils anywhere within the Project area during construction, then work in the area should cease and the CDOT Staff Paleontologist Nicole Peavey 303-747-9632 should be notified immediately to assess their significance and make further recommendations. When the project design plans are finalized, the CDOT Staff Paleontologist will examine them and determine the amount (lateral extent and depth) of impact to the Denver Formation, and the amount of construction monitoring, if any.	City of Aurora CDOT Environmental	Construction