PALEONTOLOGICAL TECHNICAL REPORT: INTERSTATE 25 NORTH CORRIDOR ENVIRONMENTAL IMPACT STATEMENT, ADAMS, BOULDER, LARIMER, AND WELD COUNTIES, COLORADO

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1.0 SUMMARY

In order to address local and regional transportation needs, the Colorado Department of Transportation, in cooperation with the Federal Highway Administration, is proposing transportation improvements in portions of Adams, Boulder, Larimer, and Weld counties, Colorado. The environmental effects of the transportation alternatives, including potential impacts on paleontological resources, are being analyzed as part of the I-25 North EIS. The study area includes approximately 60 miles of the I-25 corridor from the US Highway 36 Interchange in Denver to approximately 1000 feet north of the Vine Road overpass in Fort Collins; the Burlington Northern and Santa Fe railway line between Fort Collins and Longmont; the proposed Longmont Metro North rail alternative, and the locations of 27 commuter rail and bus stations located in Brighton, Fort Lupton, Platteville, Evans, Greeley, Fort Collins, Loveland, Berthoud, and Longmont.

The paleontological sensitivity of each geologic unit within the study area was evaluated by reviewing scientific literature, geologic mapping and museum records. Each unit was then classified using the Potential Fossil Yield Classification System (PFYC). According to the geologic mapping of Colton (1978) and Trimble and Machette (1979), the study area contains nine geologic units. These include, from approximately oldest to youngest and in ascending stratigraphic order, the late Cretaceous-age Pierre Shale, Fox Hills Sandstone, and Laramie Formation; the Cretaceous- and Paleocene-age Denver Formation; Pleistocene- and Holocene-age surficial deposits consisting of alluvium, colluvium, loess, and eolian sand; and Recent artificial fill. The Pierre Shale contains abundant invertebrate fossils and less common vertebrate fossils, and thus has moderate paleontological sensitivity in Colorado (PFYC *Class* 3). The Fox Hills Sandstone contains few and mostly poorly preserved invertebrates fossils, and has low paleontological sensitivity (PFYC *Class* 2). The Laramie Formation contains locally abundant plant fossils but few vertebrate fossils, and has moderate paleontological sensitivity (PFYC *Class* 3). The Denver Formation contains locally abundant plant fossils and less common but locally well-preserved vertebrate fossils, and has high paleontological sensitivity (PFYC *Class* 4 and 5). Pleistocene-age surficial deposits are locally fossiliferous in Colorado, but the fossils are typically scattered and poorly preserved; thus these deposits have low sensitivity (PFYC *Class* 2). Holocene-age surficial deposits and Recent artificial fill are too young to contain in situ fossils, and have no paleontological sensitivity (PFYC *Class 2*) (see Table 4).

One hundred forty nine previously recorded fossil localities occur within five miles of the I-25 EIS North study area. Two of these are recorded at the Denver Museum, ten at the University of Colorado Museum, and 137 at the U.S. Geological Survey. Additionally, numerous reports of fossil occurrences from the Pierre Shale, Laramie Formation, Denver Formation, and Pleistocene-age surficial deposits in the Rocky Mountain west are present in the scientific literature (see Appendices C and D). No fossils were observed during the field surveys conducted for this study. Few outcrops of potentially fossiliferous bedrock were documented within the study area, the surface of which consists largely of previously disturbed agricultural/pastoral lands, commercial/residential development, imported fill and paved roadways (see Appendices A and B). At the time of this analysis, specific details regarding the depth and extent of ground disturbance associated with each alternative were unavailable. However, on the basis of available information, it is anticipated that most construction excavations will be shallow, taking place at or near existing grade. Nevertheless, the potential for adverse impacts on scientifically significant paleontological resources exists wherever excavations into paleontologically sensitive bedrock occurs (see Section 10.0). With the implementation of paleontological mitigation (see Section 9.0), adverse impacts on paleontological resources can be reduced to below the level of significance.

2.0 INTRODUCTION

2.1 Purpose and Need

The Colorado Department of Transportation (CDOT), in cooperation with the Federal Highway Administration (FHWA), is proposing transportation improvements along the Interstate 25 (I-25) corridor between Denver and Fort Collins, Colorado in order to address local and regional transportation needs. The purpose of the Interstate 25 North Corridor Environmental Impact Statement (I-25 North EIS) is to study the environmental effects of the proposed improvements. The study area is located within Adams, Boulder, Larimer, and Weld counties, Colorado. It includes approximately 60 miles of the I-25 corridor (including interchanges) from the US Highway 36 Interchange in Denver to approximately 1000 feet north of the Vine Road overpass in Fort Collins; the Burlington Northern and Santa Fe (BNSF) railway line between Fort Collins and Longmont; the proposed Longmont Metro North rail alternative, and the locations of 27 commuter rail and bus stations located in Brighton, Fort Lupton, Platteville, Evans, Greeley, Fort Collins, Loveland, Berthoud, Longmont, and along I-25.

This technical report presents the findings of a paleontological resources assessment that was conducted in support of the I-25 North EIS. Its purpose is to evaluate the potential for adverse effects on scientifically significant paleontological resources that could result from construction-related ground disturbance within I-25 North EIS study area. The scope of this assessment included an analysis of the paleontological sensitivity of the study area based on reviews of published literature, geologic maps, museum records, and field surveys; a review of pertinent laws, ordinances, regulations, and standards relating to paleontological resources, an evaluation of potential adverse impacts under all alternatives, and the development of a paleontological mitigation plan that would reduce potential adverse impacts to below the level of significance.

2.2 Definition and Significance of Paleontological Resources

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 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. 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. Fossils are important scientific and educational resources because they are used to:

- Study the phylogenetic relationships among 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, and 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.
- Identify past and potential future human-caused effects to global environments and climates.

3.0 SCOPE AND METHODS

3.1 Background and Location

This study was conducted under State of Colorado Paleontological permits 2006-5 and 2007-33 (Appendix E) at the request of Carter & Burgess, Inc., Denver, Colorado, in order to evaluate potential impacts on paleontological resources and provide paleontological clearance within the study area for the I-25 North EIS. The scope of this study included a review of scientific literature, technical reports, geologic maps and museum records; and a field survey of the potentially affected areas under all transportation improvement alternatives. Its methodology is generally consistent with the paleontological resource management guidelines if the Society of Vertebrate Paleontology (1995, 1996).

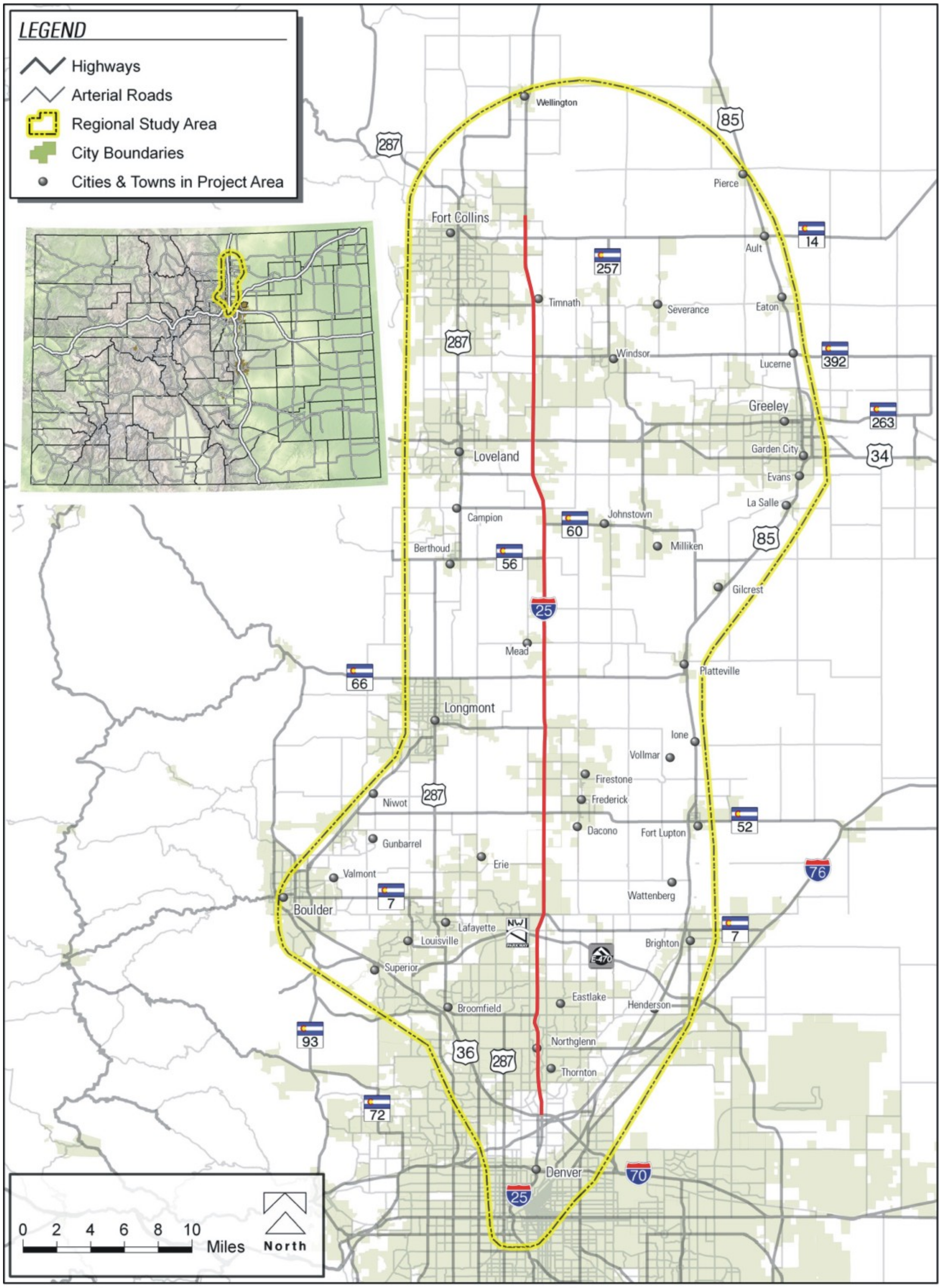
The paleontological study area for the I-25 North EIS includes approximately 60 miles of the I-25 corridor from the US Highway 36 Interchange in Denver to approximately 1000 feet north of the Vine Road overpass in Fort Collins. It includes major interchanges within this section of I-25. Additionally, it includes the BNSF railroad right-of-way between Fort Collins and Longmont, the proposed Longmont Metro North rail alternative, and the locations of 27 commuter rail and bus station facilities located in Brighton, Fort Lupton, Platteville, Evans, Greeley, Fort Collins, Loveland, Berthoud, Longmont, and along I-25 between Denver and Fort Collins. The regional study area for the I-25 North EIS (Figure 1) occurs within Adams, Boulder, Larimer, and Weld counties, Colorado.

3.2 Literature and Museum Record Searches

The literature search for this study was conducted both at libraries and online. The primary libraries used were the Earth Sciences Library at the University of Colorado at Boulder and the library of the Biodiversity Research Center of the Californias, San Diego Natural History Museum. Online resources included primarily GeoRef and the Chinook library catalogue at the University of Colorado, Boulder. Electronic copies of some papers were obtained from online services, including EBSCO (www.ebsco.com), BioOne (www.bioone.com), Blackwell (www.blackwell-synergy.com), and GeoScienceWorld (rmg.geoscienceworld.org). Bibliographic data were compiled with EndNote 9.0 software. Appendix C is a formational bibliography compiled for the Pierre Shale, Fox Hills Sandstone, Laramie Formation, and Denver Formation.

Geologic maps of the study area (primarily Colton, 1978; and Trimble and Machette, 1979) were reviewed in order to determine which bedrock geologic units and surficial sedimentary deposits underlie the study area, and ascertain their distribution.

Paleontological records of the University of Colorado Museum (UCM), and the Denver Museum of Nature and Science (DMNS) were searched to determine the number of previously recorded fossil localities located within the study area, and adjacent to it in the same geologic units. The search parameters included the PLSS legal locations listed in Table 1 combined with Pierre Shale, Fox Hills Sandstone, Laramie Formation, Denver Formation, and Quaternary deposits. USGS geologic maps were reviewed to determine locations of USGS fossil localities in relation to the study area. The CDOT Staff Paleontologist (Steve Wallace) was also consulted about his knowledge of the paleontological sensitivity of geologic units within the study area, and paleontological localities within and near it. Previously recorded fossil localities are listed in Table 5 and Appendix B.



Map Document - C&B: (Study_Area_eis.mxd)
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Figure 1 Map showing the boundary of the I-25 North EIS regional study area. The segment of I-25 surveyed for paleontological resources is highlighted in red. Other locations surveyed include the BNSF railroad right-of-way between Fort Collins and Longmont, the proposed Longmont Metro North rail alternative, and the commuter bus and rail stations listed in Table 2 and plotted on Figures 2-10.

Table 1 PLSS legal locations for which the fossil locality search for the I-25 North EIS was conducted.

Sections	Township	Range
3, 10, 15, 22	2 S.	68 W.
2, 3, 10, 15, 22, 27	1 S.	68 W.
2, 3, 10, 11, 14, 15, 22, 23, 26, 27, 34, and 35	1 N.	68 W.
2, 3, 10, 11, 14, 15, 22, 23, 26, 27, 34, and 35	2 N.	68 W.
2, 3, 10, 11, 14, 15, 22, 23, 26, 27, 34, and 35	3 N.	68 W.
2, 3, 10, 11, 14, 15, 22, 23, 26, 27, 34, and 35	4 N.	68 W.
3, 9, 10, 11, 15, 22, 26, 27, 34, and 35	5 N.	68 W.
2, 3, 4, 10, 15, 22, 27, and 34	6 N.	68 W.
3, 4, 9, 10, 15, 16, 21, 22, 27, and 34	7 N.	68 W.
3	2 N.	69 W.
2, 11, 14, 15, 22, 23, 26, 27, 34, and 35	3 N.	69 W.
2, 11, 14, 23, 24, 25, 26, 35, and 36	4 N.	69 W.
2, 11, 12, 13, 14, 23, 24, 26, 35, and 36	5 N.	69 W.
1, 2, 11, 14, 22, 23, 26, and 35	6 N.	69 W.
11, 14, 23, 26, and 25	7 N.	69 W.
5, 6, 7, and 8	5 N.	66 W.
10, 11, 14, and 15	5 N.	67 W.
31 and 32	6 N.	65 W.
5, 6, 7, 8, 17, 18, 19, 20, and 29	5 N.	65 W.
19	3 N.	66 W.
31 and 32	2 N.	66 W.

Appendix D contains taxonomic lists of fossils known from the Pierre Shale, Fox Hills Sandstone, Laramie Formation, and Denver Formation compiled from published literature and museum records.

3.3 Field Survey

The paleontological field surveys for the I-25 North EIS were conducted between September, 2006 and March, 2007. These surveys consisted of systematic inspections of the I-25 North EIS study area for 1) surface fossils; 2) exposures of potentially fossiliferous rocks; and 3) areas in which fossiliferous rocks or younger potentially fossiliferous surficial deposits could be exposed or otherwise impacted during construction. All areas of CDOT/FHWA and some portions of BNSF right-of-way were inspected. Note that with the exception of certain segments where visual clearance was possible without fouling right-of-way, significant portions of BNSF, including areas containing rock outcrops exposed in cut slopes, were not surveyed because repeated requests to schedule site visits with BNSF personnel were not answered. Privately-owned lands were inspected only if permission to enter had been granted at the time of survey. Because permission to enter was not granted for the majority of parcels at the time of survey, most private properties have not been surveyed for paleontological resources (unless visual clearance was . All locations surveyed for this study area listed in Table 2, and the results of the field surveys are summarized in Appendix A. The footprints of the all areas surveyed were delimited on alignment diagrams provided by Carter & Burgess, Inc.

Table 2 Areas surveyed for paleontological resources for the I-25 North EIS.

Survey Area Location	Facility Type
Interstate 25 corridor from the US Highway 36 interchange north to approximately 1,000 feet north of the Vine Road overpass in Fort Collins	Interstate highway right-of-way
Portions of the BNSF Railroad ROW between Fort Collins and Longmont	Railroad right-of-way
Longmont Metro North rail alternative	Railroad right-of-way
Fort Collins Downtown Transit Center	Commuter Rail Station
Fort Collins South Transit Center	Commuter Rail Station
Loveland-29th St. and BNSF	Commuter Rail Station
Loveland-US 34 and BNSF	Commuter Rail Station
Berthoud-State Highway 56 and BNSF	Commuter Rail Station
Longmont-State Highway 66 and BNSF	Commuter Rail Station
BNSF and Sugar Mill-Part A	Commuter Rail Station
BNSF and Sugar Mill-Part B	Commuter Rail Station
State Highway 52 and Dent Line	Commuter Rail Station
Fort Collins South Transit Center (new)	Commuter Rail Station
Harmony Road and Timberline	Commuter Rail Station
Harmony Road and I-25	Commuter Bus Facility Adjacent to I-25 Interchange
Windsor-State Highway 392 and I-25	Commuter Bus Facility Adjacent to I-25 Interchange
Crossroads Blvd and I-25-Part A	Commuter Bus Facility Adjacent to I-25 Interchange
Crossroads Blvd and I-25-Part B	Commuter Bus Facility Adjacent to I-25 Interchange
I-25 and State Highway 56/60-Part A	Commuter Bus Facility Adjacent to I-25 Interchange
I-25 and State Highway 56/60-Part B	Commuter Bus Facility Adjacent to I-25 Interchange
State Highway 119 and I-25	Commuter Bus Facility Adjacent to I-25 Interchange
Frederick/Dacono-State Highway 52	Commuter Bus Facility Adjacent to I-25 Interchange
State Highway 7 and I-25	Commuter Bus Facility Adjacent to I-25 Interchange
US 257 and US 34	Commuter Bus Station
US 34 and 83rd Ave	Commuter Bus Station
US 85 and D Street	Commuter Bus Station
Greeley South	Commuter Bus Station
Evans	Commuter Bus Station
Platteville	Commuter Bus Station
Ft. Lupton	Commuter Bus Station

The width of the survey corridor for the I-25 right-of-way extended 100 feet to the west and east of the highway shoulder, or to the right-of-way fence if permission to enter the adjacent property had not been granted. For the BNSF corridor, the width of the survey corridor was 100 feet (50 feet on either side of centerline), or to the edge of the adjacent property if permission to enter had not been granted. For locations of commuter rail and bus stations, only the footprint of each facility as shown on alignment diagrams provided to Rocky Mountain Paleontology prior to the survey was inspected.

Areas where geologic units of moderate and high paleontological sensitivity (PFYC *Class* 3-5, see Section 6.0) outcrop at or near the ground surface were inspected more intensively than those underlain by units of low sensitivity (PFYC *Class* 1 and 2, see Section 5.0). Potentially fossiliferous exposures of PFYC *Class 3* and higher were subject to a 100% pedestrian inspection, while other areas (PFYC *Class* 1 and 2) were spot-checked or subject to drive-by inspections. These include areas that are vegetated, visibly disturbed such as ploughed fields, paved, or otherwise covered with existing construction.

Potentially fossiliferous outcrops of Pierre, Fox Hills, Laramie, and Denver formations are not abundant within the study area. However, they do occur locally, and are typically highly weathered and/or consist only of localized weathered small rock fragments mixed with surficial deposits of loess, sand or colluvium. Numerous locations were tested for the presence of fossils by digging test excavations of less than one square meter in area to the depth necessary to expose unweathered bedrock which could be inspected for fossils including vertebrate bones and teeth; plants consisting of leaves and wood; and molluscan invertebrates such as clams and ammonites. By design, no fossils were collected during the field survey because if any were discovered, fossil collection would occur during the mitigation phase of paleontological work after the selection of the final alternative if adverse impacts on any recorded fossil localities are anticipated. The survey results and previously recorded fossil localities are listed in Confidential Appendices A and B.

3.4 Personnel

Paul C. Murphey, Ph.D., Principal Investigator, directed the research and data acquisition, field work, data analysis, prepared this technical report, and the paleontological resources sections of the EIS. David Daitch, M.S., conducted the literature and museum record searches, geologic map reviews, compiled the data, and conducted most of the field surveys.

3.5 Evaluation

The paleontological sensitivity of each geologic unit mapped as occurring within the I-25 North EIS study area by Colton (1978) and Trimble and Machette (1979) were evaluated using the widely used Potential Fossil Yield Classification system (PFYC) developed by the U.S. Forest Service. This classification system is summarized in Section 5.0.

3.6 Recommendations

The following are typical recommendations made in a paleontological assessment for all or portions of any study area. Recommendations resulting from this study are listed in Section 10.0:

3.6.1 Clearance

If before a field survey based on existing data, or after a field survey based on new data, adverse impacts on paleontological resources are anticipated to be non-existent or below the level of significance for a given project, no further consideration of paleontological resources for the project is necessary, and immediate paleontological clearance is recommended.

3.6.2 Sampling

Microfossils (vertebrate, invertebrate, plant, or trace fossils) may be identified in rock matrix during a field survey; or, if they are known to occur elsewhere in the same geologic unit or type of deposit in the general area, a determination of their presence or absence may require the use of test sampling of rock matrix for screen-washing in a paleontological laboratory even if microfossils are not visible in the field. The fossils found, if any, are then inspected and evaluated in order to determine their significance and make additional mitigation recommendations, if any. Mitigation may include collection of additional matrix for screen-washing.

3.6.3 Monitoring

If significant (well preserved, uncommon, and/or identifiable) paleontological resources are known to be present, or if there is a high likelihood that they are present at a given project site based on prior field surveys, museum records, or scientific or technical literature, paleontological monitoring of construction-related excavations during ground disturbance may be recommended. Once construction begins, the project paleontologist should have the authority to downgrade the monitoring level of effort if the sensitivity of the site is less than anticipated. If this occurs, construction personnel should be instructed that if any sub-surface bones or other potential fossils are found, they should cease work in the immediate area and immediately notify their supervisor, who should then contact the project paleontologist. The project paleontologist will inspect the fossils and make further recommendations.

3.6.4 Salvage

If small-, medium- or large-sized fossils are discovered within a given project site, and they are determined to be scientifically significant, they should be salvaged. Fossil salvages may involve the systematic excavation of fossil remains as determined on a case-by-case basis, and they should be designed in such a way as to prevent construction delays while properly collecting the fossil and associated provenance data. Construction equipment can often be used to assist with the salvage (for example moving fossil-bearing blocks of rock off of construction sites, or loading large fossils onto trucks). This expedites the salvage process. Salvage may also include the collection of macrofossils which were observed during an initial field survey but were not collected at the time of discovery.

3.6.5 Avoidance

If the cost of salvage or other mitigation strategy is determined to be too high, or permanent damage to the resource caused by ground disturbance is considered to be unavoidable, it may be necessary to reroute the project to prevent adverse impacts on the resource. Avoidance should also be considered if a known fossil locality contains critical scientific information and should be left undisturbed for subsequent scientific evaluation.

4.0. LAWS, ORDINANCES, REGULATIONS AND STANDARDS

Fossils are non-renewable scientific resources and are protected by various laws, ordinances, regulations and standards (LORS) across the country. Professional standards for the assessment, management and mitigation of adverse impacts to paleontological resources have been established by the U.S. Forest Service (1996), the Bureau of Land Management (1998), and the Society of Vertebrate Paleontology (1995). This paleontological study was conducted in accordance with the LORS which are applicable to paleontological resources within the study area for the I-25 North EIS (see Table 3). Pertinent federal, state, county and city LORS are summarized below:

4.1. 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). 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:

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

Federal Land Policy and Management Act 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:

a) 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));
b) periodically inventory public lands so that the data can be used to make informed land-use decisions (Section 102(a)(2)); and
c) 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.

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 seven federal agencies including the Bureau of Indian Affairs, the Bureau of Land Management, the Bureau of Reclamation, the U.S. Fish and Wildlife Service, the U.S. Forest Service (USFS), the National Park Service, the U.S. Geological Survey, 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:

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

Federal protection for scientifically significant paleontological resources applies 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. Federal protections apply to paleontological resources within the I-25 North EIS study area because the FHWA is a cooperating agency, and Federal funds are being contributed.

4.2. State

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 even 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 which have the potential to contain significant paleontological resources, and mitigation monitoring during ground disturbance in these areas. This paleontological study was requested by, and will be reviewed by CDOT because CDOT is a cooperating agency for the I-25 North EIS, and must fulfill FHWA's NEPA requirements.

4.3. County

There are no Adams, Boulder, Larimer, or Weld county LORS that specifically address potential adverse impacts on paleontological resources. Therefore, no county-level protections of paleontological resources pertain to the I-25 North EIS.

4.4. City

There are no city-level LORS within Adams, Boulder, Larimer, or Weld counties that specifically address potential adverse impacts on paleontological resources. Therefore, no city-level protections of paleontological resources pertain to the I-25 North EIS.

4.5 Private Lands

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

Table 3 Summary of paleontological laws, ordinances, regulations and standards applicable to the I-25 North EIS.

Agency/Owner	Pertinent Paleontological LORS
Federal	Assessment required by FHWA under NEPA
State	Assessment required by CDOT under CHPA
County	None
City	None
Private	None

4.6 Permits and Approvals

A State of Colorado Paleontological Permit is required to collect fossils on state owned or administered lands in Colorado. If paleontological mitigation is requested by the CDOT, the Project Paleontologist and other paleontological personnel would be required to possess a State of Colorado paleontological permit. The paleontological mitigation program would need approval by the CDOT Staff Paleontologist, who would also review and approve the final mitigation report. All fossils collected during mitigation would be required to be housed in an approved repository such as the UCM or DMNS, where they would be curated and permanently stored. This would ensure their availability for future scientific research, education and display.

5.0 RESOURCE ASSESSMENT CRITERIA

The paleontological sensitivity of each geologic unit within the study area for the I-25 North EIS was evaluated using the Potential Fossil Yield Classification (PFYC) system. This system is summarized below:

5.1 Potential Fossil Yield Classification

Occurrences of paleontological resources are closely related to the geologic units that contain them. The potential for finding important paleontological resources can therefore be broadly predicted by the presence of the pertinent geologic units at or near the surface. Therefore, geologic mapping can be used as a proxy for assessing the potential for the occurrence of important paleontological resources. The Potential Fossil Yield Classification system was originally developed by the USFS's Paleontology Center of Excellence and the Region 2 (USFS) Paleo Initiative (1996). It is in the process of being considered for formal adoption as policy by the BLM to promote consistency between agencies and throughout the BLM. The PFYC should be utilized for land use planning efforts and for the preliminary assessment of potential impacts and mitigation needs for specific projects.

Under the PFYC system, geologic units are classified based on the relative abundance of vertebrate fossils or uncommon invertebrate or plant fossils and their sensitivity to adverse impacts, with a higher class number indicating a higher potential. This classification should be applied at the geologic formation or member level. It is not intended to be an assessment of whether important fossils are known to occur occasionally in these units (i.e., a few important fossils or localities widely scattered throughout a formation does not necessarily indicate a higher class), nor is it intended to be applied to specific sites or areas. The classification system is intended to provide baseline guidance to assessing and mitigating impacts on paleontological resources. In many situations, the classification should be an intermediate step in the analysis, and should be used to assess additional mitigation needs.

- ***Class 1:*** Geologic units that are not likely to contain recognizable fossil remains. This includes units that are igneous or metamorphic in origin (but excludes tuffs), as well as units that are Precambrian in age or older. Management concern for paleontological resources in *Class 1* units is negligible or not applicable. No assessment or mitigation is needed except in very rare circumstances. The occurrence of significant fossils in *Class 1* units is non-existent or extremely rare.

- ***Class 2:*** Sedimentary geologic units that are not likely to contain vertebrate fossils or scientifically significant nonvertebrate fossils. This includes units in which vertebrate or significant nonvertebrate fossils are unknown or very rare, units that are younger than 10,000 years before present, units that are aeolian in origin, and units that exhibit significant diagenetic alteration. The potential for impacting vertebrate fossils or uncommon invertebrate or plant fossils is low. Management concern for paleontological resources is low, and management actions are not likely to be needed. Localities containing important resources may exist, but would be rare and would not influence the classification.

- ***Class 3:*** Fossiliferous sedimentary geologic units where fossil content varies in significance, abundance, and predictable occurrence; or sedimentary units of unknown fossil potential. These units are often marine in origin with sporadic known occurrences of vertebrate fossils. Vertebrate fossils and uncommon nonvertebrate fossils are known to occur inconsistently, and predictability is known to be low. *Class 3* includes units that are poorly studied and/or poorly documented, so that the potential yield cannot be assigned without ground reconnaissance. Management concern for paleontological resources in these units is moderate, or cannot be determined from existing data. Surface-disturbing activities may require field assessment to determine a further course of action.

The *Class 3* category includes a broad range of potential impacts. Geologic units of unknown potential, as well as units of moderate or infrequent fossil occurrence are included. Assessment and mitigation efforts also include a broad range of options. Surface-disturbing activities will require sufficient assessment to determine whether significant fossil resources occur in the area of a proposed action, and whether the action could affect the paleontological resources. Authorizations for any surface-disturbing activities should include the following statement, or one similar in nature: "The operator shall immediately bring any paleontological resources discovered as a result of operations under this authorization to the attention of the BLM authorized officer. The operator shall suspend all activities in the vicinity of such discovery until notified to proceed by the authorized officer, and shall protect the site from damage or looting. The authorized officer will evaluate, or will have evaluated, such discoveries as soon as possible but not later than five working days after being notified. Appropriate measures to mitigate adverse effects to significant paleontological resources will be determined by the authorized officer after consulting with the operator. The operator is responsible for the cost of any investigation necessary for the evaluation and for any mitigation measures. There is no need to suspend operations if the operator can avoid further impacts to a discovered site, however, the discovery shall be brought to the attention of the authorized officer as soon as possible and protected from damage or looting."

- ***Class 4:*** These are *Class 5* geologic units (see below) that have lowered risks of human-caused adverse impacts and/or lowered risk of natural degradation. They include bedrock units with extensive soil or vegetative cover, bedrock exposures that are limited or not expected to be impacted, units with areas of exposed outcrop that are smaller than two contiguous acres, units in which outcrops form cliffs of sufficient height and slope so that impacts are minimized by topographic effects, and units where other characteristics are present that lower the vulnerability of both known and unidentified fossil localities.

  The potential for impacting significant fossils is moderate to high, and is dependent on the proposed action. The bedrock unit is *Class 5*, but a protective layer of soil, thin alluvial material, or other mitigating circumstances may lessen or prevent potential impacts to the bedrock resulting from the activity. Mitigation efforts must include assessment of the disturbance, such as removal or penetration of protective surface alluvium or soils, potential for future accelerated erosion, or increased ease of access resulting in greater looting potential. If impacts to significant fossils are anticipated, on-the-ground surveys prior to authorizing the surface-disturbing action will usually be necessary. On-site monitoring may also be necessary during construction activities. Management prescriptions for resource preservation and conservation through controlled access or special management designation should be considered. *Class 4* and *Class 5* units are often combined as *Class 5* for general application, such as planning efforts or preliminary assessments, as *Class 4* is determined from local mitigating conditions and the impacts of the planned action.

- ***Class 5:*** Highly fossiliferous geologic units that regularly and predictably produce vertebrate fossils or uncommon invertebrate or plant fossils, and that are at risk of human-caused adverse impacts or natural degradation. These include units in which vertebrate fossils or uncommon invertebrate or plant fossils are known and documented to occur consistently, predictably, or abundantly. *Class 5* pertains to highly sensitive units that are well exposed with little or no soil or vegetative cover, units in which outcrop areas are extensive, and exposed bedrock areas that are larger than two contiguous acres.

Management concern for paleontological resources in *Class 5* units/areas is high, because the potential for impacting significant fossils is high. Vertebrate fossils or uncommon nonvertebrate fossils are known from the impacted area, or can reasonably be expected to occur in the impacted area. Assessment by a qualified paleontologist is required in advance of surface-disturbing activities or land tenure adjustments, and mitigation will often be necessary before and/or during surface-disturbing actions. Field surveys prior to authorizing any surface-disturbing activities will usually be necessary. On-site monitoring may also be necessary during construction activities. Designation of areas of special interest and concern may be appropriate.

6.0 PALEONTOLOGICAL RESOURCE ASSESSMENT

Ground disturbance associated with the proposed transportation improvements being analyzed under the I-25 EIS has the potential to impact nine mapped geologic units. These include, from approximately oldest to youngest and in ascending stratigraphic order, the late Cretaceous-age Pierre Shale, Fox Hills Sandstone, and Laramie Formation; the Cretaceous- and Paleocene-age Denver Formation; and Pleistocene- and Holocene-age surficial deposits consisting of alluvium, colluvium, loess, eolian sand; and Recent artificial fill (Colton, 1978; Trimble and Machette, 1979).

The paleontological potential (known fossil content, taxonomic affinities, abundance, and scientific significance) of the potentially affected units within the study area is well-documented in museum records, the scientific literature, and previous paleontological assessments. Using this information, each geologic unit was classified using the PFYC, which was presented in Section 5.1. The results are summarized in Table 4. The geology and paleontology of these units is discussed in greater detail in Section 7.3.

In summary, the Pierre Shale contains abundant invertebrate fossils and less common vertebrate fossils, and thus has moderate paleontological sensitivity in Colorado (PFYC *Class* 3). The Fox Hills Sandstone contains few and mostly poorly preserved invertebrates fossils, and has low paleontological sensitivity (PFYC *Class* 2). The Laramie Formation contains locally abundant plant fossils but few vertebrate fossils, and has moderate paleontological sensitivity (PFYC *Class* 3). The Denver Formation contains locally abundant plant fossils and less common but locally well-preserved vertebrate fossils, and has high paleontological sensitivity (PFYC *Class* 4 and 5). Pleistocene-age surficial deposits are locally fossiliferous in Colorado, but the fossils are typically scattered and poorly preserved; thus these deposits have low sensitivity (PFYC *Class* 2). Holocene-age surficial deposits are too young to contain in situ fossils, and have no paleontological sensitivity (PFYC *Class 2*).

Table 4 Summarized paleontological sensitivities of geologic units using the PFYC (map abbreviations and ages of units are from Colton, 1978; and Trimble and Machette, 1979).

Geologic Unit	Map Abbreviation	Age	Fossils	PFYC
Artificial Fill	af	Recent	None	*Class* 2
Alluvium, colluvium, loess, sand	Qes, Qe, Qco, Qc, Qp, Qpc, Qpp	Holocene	Contains unfossilized remains of modern taxa. Holocene-age deposits are too young to contain in situ fossils	*Class* 2
Alluvium, colluvium, loess, sand	Qrf, Qv, Qs, Qlo, Ql, Qb, Qes, Qe, Qc	Pleistocene	Localized occurrences of vertebrates, invertebrates, and plants	*Class* 2
Denver Formation	TKd/Tkda	Cretaceous, Paleocene (D1), **Eocene (D2)	Locally abundant and diverse plants, less common vertebrates (reptiles, mammals) and invertebrates	**Class 5*
Laramie Formation	Kl	Cretaceous	Locally abundant plants, less common vertebrates, invertebrates and plants	*Class 3*
Fox Hills Sandstone	Kf, Kfh	Cretaceous	Locally common invertebrates, plants, ichnofossils; uncommon vertebrates	*Class 2*
Pierre Shale	Kp, Kpu, Kptz	Cretaceous	Locally common invertebrates and ichnofossils, less common plants; locally common vertebrates in Sharon Springs Mbr.	*Class 3*

*Where *Class* 5 units are too deeply buried to be impacted during construction, they should be locally classified as *Class* 4 units
**No Eocene-age Denver Formation rocks occur within the I-25 North EIS study area

7.0 AFFECTED ENVIRONMENT

7.1 Paleontological Significance of Eastern Colorado

The Front Range foothills and adjacent eastern plains region of Colorado is well known for its geologic history and paleontologic importance. Scientists working in this area have conducted numerous studies in geology and paleontology, some of which are now considered classic works, and others that are on the cutting edge of modern paleontological and paleoenvironmental research. Many important fossil specimens, including numerous holotypes, have been collected in this region. These include the type specimens of the dinosaurs *Stegosaurus armatus, Diplodocus, Allosaurus,* and *Apatosaurus ajax*, which were collected during the late nineteenth century from historic quarries near the town of Morrison. These and many other fossils from the Front Range and eastern plains region of Colorado are now housed in museums across in Colorado and across the United States.

The geology and paleontology of Colorado is scientifically important because, to cite several examples, it records some of the earliest known vertebrate fossils: small armored fish from the Harding Formation of middle Ordovician age; the uplift and erosion of the ancestral Rocky Mountains, early tetrapod trackways, and the marine fauna of adjacent shallow seas during the late Paleozoic Era; the development of a shallow epeiric seaway which covered much of central North America during the late Cretaceous Period; the uplift of the Rocky Mountains and extinction of the dinosaurs at the end of the Cretaceous Period; the development of tropical rainforest ecosystems and rapid evolutionary radiation of mammals during the Paleocene Epoch; and the glacial and interglacial climates, environments and mammalian faunas of Colorado during the Pleistocene “ice ages.”

Today, these and many other events in the history of ancient Colorado, which are recorded both by both the diversity of fossils and associated well-exposed sedimentary rocks in this area, can be studied at many locations. In central and eastern Colorado, a few representative examples the Kremmling Giant Ammonite Site in Middle Park; the Picketwire Dinosaur Tracksite in Comanche National Grassland; the Garden Park Dinosaur Area north of Cañon City; Florissant Fossil Beds National Monument; Red Rocks Park, the Dakota Hogback, and Dinosaur Ridge just to the west of Denver; and museums including the Dinosaur Depot Museum, Denver Museum of Nature and Science, University of Colorado Museum of Natural History in Boulder, and the Morrison Natural History Museum.

7.2 Summarized History of Paleontological Work in Eastern Colorado

In 1870, during his first dedicated fossil collecting expedition to the west, paleontologist O.C. Marsh and a group of students from Yale University prospected outcrops of Tertiary rocks in northeastern Colorado for a week. While most of the 1870 expedition was spent visiting various locations in Wyoming and Utah, the Marsh party did collect a variety of mammal fossils from western Weld County about five miles south of the Wyoming state line on Little Crow Creek and “along the hills known as Chalk Bluffs.” Marsh noted the presence of “Titanotherium beds” and above these…similar clay deposits…marked by abundant remains of *Oreodon culbertsoni*. His report stated that there were about 150 feet of White River beds and 200 feet of post-Oligocene beds. Most of Chalk Bluffs now lies within Pawnee National Grasslands. E. Berthoud noted the presence of fossils in the Crow Creek area during a search for paleo-indian sites in 1871.

Other early paleontological work in northeastern Colorado was undertaken by paleontologist E.D. Cope of the Academy of Natural Sciences of Philadelphia, who visited the area during the summer and fall of 1873, and then again in the fall of 1879, collecting fossils and studying the geology. Cope recognized the general similarity of the Tertiary deposits to those of Nebraska and South Dakota, and published on the geology and fossils of the area. In 1882, a Princeton University expedition collected in the vicinity of Chalk Bluffs. In 1898, 1901 and 1902, field parties from the American Museum led by W.D. Matthew worked in northeast Colorado in the Chalk Bluffs region.

The first dinosaur fossils reported from the Denver Basin were described in a letter from E. Berthoud to O.C. Marsh as having been discovered in an excavation for a well in Golden in 1867. Berthoud also reported other fossil remains from the Golden area. One specimen, sketched in an 1874 letter to Marsh, is now known to be the first known specimen (a tooth) of *Tyrannosaurus rex*. It had been collected from the Denver Formation by Golden resident Arthur Lakes at South Table Mountain. G.L. Cannon, W. Cross, and G. Eldridge initiated the first study of the geology of the Denver Basin in 1896, and reported additional fossil localities, the richest being on Green Mountain and along the South Platte River.

In March 1877, Arthur Lakes discovered fossil bones near the town of Morrison. After corresponding with Marsh, Lakes sent him 1,500 pounds of dinosaur bone for study, and the specimens were described in the American Journal of Science. The town of Morrison later became the stratotype for the late Jurassic Morrison Formation, a rock unit which is today world renowned for its dinosaur fossils, including the holotypes of many currently recognized taxa.

In 1876, H. Felch, the brother of local rancher M.P. Felch, discovered some dinosaur bones in the area now known as Garden Park to the north of Cañon City (also in the Morrison Formation) that were the subject of an article in the Cañon City Times in 1877. In 1877, O.W. Lucas discovered some more large bones north of Cañon City which he sent to Marsh’s bitter rival, paleontologist E.D. Cope, for study. Between 1887 and 1883, Lucas and his brother excavated many bones for study and scientific description. Among these was the sauropod *Camarasaurus supremas* that Cope described. Cope visited the two quarry sites from which the bones were collected in 1879. In 1877, and between 1882 and 1888, B. Mudge, S. Williston and M.P. Felch worked what became known as the Marsh/Felch quarries #1 and #2, sending the excavated bones to O.C. Marsh for study. Type specimens described by Marsh from these quarries include *Diplodocus longus*, *Allosaurus fragilis*, *Stegosaurus stenops* and *Ceratosaurus nasicornis*. Well known fossil collector J.B. Hatcher and his associate W. Utterback from the Carnegie Museum of Natural History worked in the Garden Park area in 1900 and 1901, expanding the Marsh/Felch Quarry #1 to twice the original size and collecting and describing the type specimens of *Haplocanthosaurus priscus* and *H. utterbacki*.

In 1887, G.L. Cannon found one of the best known early fossil specimens from the Denver Basin. This fossil, first described by O.C. Marsh in 1887 as the type specimen of an extinct bison he named *Bison alticornis*, consists only of a pair of supraorbital horn cores (now USNM 4739). On the basis of this material, he considered the strata Pliocene in age. The location of the discovery remains uncertain, although it is believed to have been found in the Denver area, possibly along Green Mountain Creek. After a more complete skull was discovered in 1888 by J.B. Hatcher in the Lance Formation of Wyoming, Marsh referred the *Bison alticornis* specimen to *Ceratops horridus*. In 1907, Hatcher assigned the specimen to *Triceratops alticornis*.

In 1912, Professor J. Henderson, an invertebrate paleontologist and founder of the University of Colorado Museum, initiated field studies of the Cretaceous-age formations of northeastern Colorado that was finally published in 1920. This was a pioneering study that, although undertaken primarily for the purpose of determining the stratigraphic position of coal beds, led to a large collection of Cretaceous marine invertebrates and helped establish the stratigraphic framework for the Front Range and eastern plains of Colorado.

Arguably the most noteworthy fossil locality in northeastern Colorado was discovered in the White River Formation in the early 1920’s. The Trigonias Quarry locality yielded a large collection of thousands of specimens including well-preserved skeletons of the small rhinoceros *Trigonias osborni*, entelodonts such as *Archaeotherium*, as well as other large and small mammals and birds. The excavations were initiated by the Colorado Museum (now the DMNS), and the first scientific studies of fossils from the quarry were published by Colorado Museum Curator H.J. Cook, Professor W.K. Gregory, and H.E. Wood. The Trigonias Quarry was later re-excavated by amateur paleontologist J. Mellinger in the 1930's and 1950's, resulting in many more fossils which are now housed at the University of Colorado Museum. In the late 1990's, the quarry was re-located and further excavated by crews from the DMNS.

In 1940, G.E. Lewis and R.W. Wilson began an intensive investigation of the Tertiary stratigraphy and mammalian paleontology of northeastern Colorado. This project was interrupted by the second world war, but was then continued by students. E. Galbreath published his doctoral dissertation (University of Kansas) on the Tertiary geology and paleontology of northeastern Colorado in 1953. Galbreath's work greatly refined the stratigraphy with a series of stratigraphic sections and geologic maps, and he described in detail the highly diverse vertebrate fossil fauna of the area and it's biostratigraphic significance. Much of the geographic area that contains Tertiary strata in northeastern Colorado has been unavailable for study since the 1950's primarily due to lack of access to private property.

U.S. Geological Survey paleobotanist F.H. Knowlton made an important contribution to paleontologic work in eastern Colorado with his 1930 publication on the flora of the Denver Formation and associated formations in Colorado. Another USGS paleontologist, R. W. Brown, was an important contributor to the stratigraphy and paleontology of the Denver Basin from the late 1930's to the 1960's. His work led to the recognition of the Cretaceous-Tertiary boundary in the Denver Formation, discoveries of new earliest Paleocene (Puercan) mammal taxa such as *Baioconodon denverensis* Gazin 1941, the discovery of various dinosaur fossils, and he made important contributions to paleobotany with his descriptions of the Paleocene age flora of the rocky mountains and great plains. Many other USGS geologists and paleontologists have made important contributions to paleontological and geological work in eastern Colorado. Two particularly noteworthy examples include W.A. Cobban for his work on Cretaceous molluskan biostratigraphy and G. R. Scott for his geologic mapping and documentation of Quaternary vertebrates and their biostratigraphic significance, and the superpositional relationships and nomenclature of Quaternary deposits.

Since the 1960's, a large number of paleontological studies in Colorado have been completed by scientists, students and avocational paleontologists affiliated with a variety of universities and museums. These include many more contributions than can be discussed here. However, beginning in the 1990's, the Denver Basin Project, spearheaded by paleobotanist and Chief Curator at the Denver Museum of Nature and Science Dr. Kirk Johnson, has brought together a large number of scientists and students with an interdisciplinary research approach (see Section 7.3.4). Since the 1970's, Dr. Kenneth Carpenter of the Denver Museum of Nature and Science has been the primary researcher on Cretaceous vertebrates in eastern Colorado inclusive of the Denver Basin.

7.3 Geology and Paleontology of the I-25 North EIS Study Area

As previously indicated in Section 6.0, according to the geologic mapping of Colton (1978) and Trimble and Machette (1979), the study area is underlain by nine geologic units. These include, from oldest to youngest and in approximate ascending stratigraphic order, the late Cretaceous-age Pierre Shale, Fox Hills Sandstone, and Laramie Formation; the Cretaceous- and Paleocene-age Denver Formation; and Pleistocene- and Holocene-age surficial deposits consisting of alluvium, colluvium, loess, eolian sand; and Recent artificial fill. The following is a general discussion of the geology and paleontology of these units. A bibliography for the Pierre Shale, Fox Hills Sandstone, Laramie Formation, and Denver Formation, is appended to this report (Appendix C).

7.3.1 Pierre Shale

Six subdivisions of the Pierre Shale are mapped as occurring within the I-25 North EIS study area. These include the Pierre Shale undifferentiated, the upper transition member, the upper shale member, the Richard Sandstone Member, the Middle shale member, and the Hygiene Sandstone Member (Colton, 1978; Scott and Cobban, 1965). Generally, lithologies of the Pierre Shale include hard, platy to flaky gray, dark gray, brownish-gray, grayish-black, tan shale and silty shale, light olive gray silty bentonitic shale, limestone, and ironstone concretions (Carroll and Crawford, 2000; Haymes, 1989; Gill and Cobban, 1966; Scott and Wobus, 1973; Thorson et al., 2001; Thorson and Madole, 2002; Wood et al., 1957). The Pierre Shale is variable in thickness, but is locally more than 7,000 feet thick in the Denver area (Trimble and Machette, 1979). The upper transition member in the uppermost member of the Pierre Shale, conformably underlying the Fox Hills Sandstone. It consists of friable sandstone, soft shaly sandstone containing thin-bedded sandy shale and large calcareous sandstone concretions, and is about 2,000 feet thick. The upper shale member consists of gray, concretionary silty shale, and is about 2,800 feet thick. The Richard Sandstone Member consists of four submembers described as 230 to 530 feet of pale brown clayey micaceous siltstone and sandstone. The Middle shale member consists of approximately 1,460 feet of claystone and sandy siltstone. The Hygiene Sandstone Member consists of an upper hard glauconitic ridge-forming sandstone separated with a shale bed from a lower friable sandstone, and with a thickness of approximately 600 to 800 feet (Colton, 1978).

The Pierre Shale is marine in origin, and is Upper Cretaceous in age (Campanian and Maastrichtian). Based on the literature reviewed for this study, a taxonomic list of fossils known from the Pierre Shale was compiled (Appendix D). The invertebrate and vertebrate fossil faunas of the Pierre Shale in Colorado, Wyoming, South Dakota, Montana, Kansas, and New Mexico have been the subject of far more studies than can be cited here (Bergstresser, 1981; Bishop, 1985; Carpenter, 1996; Cobban et al., 1993; Gill and Cobban, 1966; Kauffman and Kesling, 1960; Lammons, 1969; Martz et al., 1999; Scott and Cobban, 1965, 1986a, 1986b; and many others). The invertebrate fauna includes a diverse assemblage of mollusks (primarily ammonites and inoceramids), as well as other bivalves, bryozoans, and gastropods. The ichnofauna consists primarily of trails, burrows, tubes, fecal pellets, and raspings on shells (Gill and Cobban, 1966), and gastroliths. Plant fossils are rare, consisting of logs and wood fragments. The vertebrate fauna is also diverse, containing a variety of fish, turtles, mosasaurs, plesiosaurs, and more rare dinosaurs, pterosaurs, and birds (Carpenter, 1996). Vertebrate fossils are more localized than invertebrates. Most vertebrate fossils have been discovered in the Sharon Springs Member of the Pierre Shale in Wyoming, South Dakota and Kansas. Additional vertebrate material has been discovered in the Pierre Shale in the Walsenburg area, southern Colorado. According to CDOT Staff Paleontologist Steven Wallace (written communication, 2007), the UCM has a mosasaur jaw that was collected from the Pierre Shale north of Pawnee Pass (west of Sterling) in northeastern Colorado, and that this specimen is the only vertebrate fossil known from the Pierre Shale in that part of the state.

The paleontological sensitivity of the Pierre Shale is difficult to ascertain within the I-25 North EIS study area because the members are either not mapped geologically, or not correlated with other members that are known to contain locally abundant vertebrate fossils such as the Sharon Springs Member. Furthermore, the relatively low relief topography of northeastern Colorado greatly limits exposures of the Pierre Shale, so opportunities to prospect for fossils in the unit are few. As a result, the possibility does exist for occurrences of scientifically significant vertebrate fossils within the Pierre Shale underlying the I-25 North EIS study area, and these could be adversely impacted by construction-related excavations. Because the Pierre Shale contains abundant invertebrate fossils, and less common vertebrate fossils, it is considered to have moderate paleontological sensitivity (PFYC *Class* 3) (Kp, Kptz, Kpu, Figures 2-10).

7.3.2 Fox Hills Sandstone

Along the Front Range, the Fox Hills Sandstone is approximately 300 feet thick, consisting of an upper part composed of cross-bedded tan sandstone, which grades downward into brown, fine-grained silty sandstone interbedded with gray fissile shale. Locally, it contains thin coal beds (Colton, 1978; Gill et al., 1970; Scott, 1972). It is commonly exposed as sandstone ridges in areas of steeply dipping beds along the mountain front that are raised above topographically lower areas of Pierre Shale and Laramie Formation (Trimble and Machette, 1979). The Fox Hills Sandstone conformably overlies the Pierre Shale, and conformably underlies the Laramie Formation. It is widely distributed in Colorado, Wyoming, Montana, North Dakota, South Dakota, and Nebraska. In the Green River Basin in Wyoming, the Fox Hills Sandstone consists mostly of quartz sandstone that coarsens upward and contains oyster shells and trace fossils, indicating the eroded remnants of a barrier island depositional environment (Roehler, 1993). In McCone County, Montana, the formation consists mostly of uniform, consistently cross-bedded, well-sorted, very-fine-grained, gray to yellow, ledge-forming sandstone that shows little variation. The unit was deposited in regressive marine and paralic environments, and is Upper Cretaceous in age.

Based on the literature reviewed for this study, a taxonomic list of fossils known from the Fox Hills Sandstone was compiled (Appendix D). Fossils known from the Fox Hills Sandstone include invertebrates including bivalves, gastropods and ammonites (Erickson, 1974, 1977, 1978a, 1978b); bryozoans (Cobban and Kennedy, 1992; Cuffey et al., 1981), echinoids (Holland and Feldmann, 1967); crabs (Feldmann et al., 1976); beetles (Northrop, 1928), and several species of foraminifera. Plant fossils have also been described (Dorf, 1942). Vertebrate fossils include mostly sharks teeth and bony fish scales, although mammalian (multituberculate) reptilian (mosasaur and dinosaur) and amphibian remains have also been reported (Hoganson et al., 1997, 2004; Nelson et al., 2003, Wilson, 1987). The Fox Hills also contains the important trace fossil *Ophiomorpha*, which consist of half- to one-inch diameter burrows formed by the tunneling activities of callanassid shrimp. These fossils indicate a marginal marine to littoral conditions deposited in tidal environments (Rigby and Rigby, 1990). Other reported trace fossils include structures interpreted as sea turtle nests (Bishop and Anonymous, 2002). In Colorado, the Fox Hills Sandstone is less fossiliferous than elsewhere in its distribution, and it is considered to have low paleontological sensitivity (PFYC *Class* 2) (Kf, Kfh, Figures 2-10). Based on the literature reviewed for this study, a taxonomic list of known fossils from the Fox Hills Sandstone was compiled (Appendix X).

7.3.3 Laramie Formation

The Laramie Formation has been subdivided into three informal members (Thorson et al., 2001). The lower member consists of light gray to light brownish-gray very-fine-grained sandstone interbedded with gray sandy shale and minor brown organic-rich shale, as well as sub-bituminous coal. It is approximately 115 feet thick. The middle sandstone member consists of thick- to very-thick-bedded, light-colored, cross-bedded fine to coarse sandstones interbedded with thin-bedded gray and brown shale. It is about 200 feet thick. The upper member consists of brownish-gray sandy shale and very fine-grained shaly sandstone, thin coal beds, and channel fillings of fine- to medium-grained light-colored sandstone. It is about 400 feet thick. In northern Colorado, the Laramie Formation has been described as consisting of an approximately 650 feet thick upper part composed mostly of gray claystone, shale, sandy shale, and scattered lenticular beds of sandstone and lignite; and an approximately 100 foot thick lower part consisting of light-gray to light yellowish-gray sandstone and sandy shale interbedded with clay, shale and several beds of coal (Colton, 1978). The Laramie Formation has been interpreted as a complex of channel, overbank, deltaic, and paludal deposits that were deposited shortly after, and in association with, the retreat of the Western Interior Cretaceous Sea (Weimer and Land, 1975). It was deposited on a low-lying coastal plain in swamps and estuaries that existed before the Laramide uplift of the Rocky Mountains in Colorado. The Laramie Formation is of Upper Cretaceous (Maastrichtian) age, and was deposited between approximately 69 and 68 million years ago.

Based on the literature reviewed for this study, a taxonomic list of fossils known from the Laramie Formation was compiled (Appendix D). The Laramie Formation is important because it is one of the few formations of its age to preserve terrestrial fossil plants (Johnson et al., 2003; Knowlton, 1922). Vertebrate fossils are far less common than plants, consisting mostly of poorly preserved bone fragments. However, a number of identifiable dinosaur fossils including teeth and bones of ceratopsians, hadrosaurs, and other dinosaurian taxa are known from the Laramie Formation in Weld County and from the Denver Basin (Carpenter, 2002). A relatively rich microvertebrate fauna from a locality in Weld County was described by Carpenter (1979), and current field work by Vertebrate Paleontology Curator Dr. Greg Wilson of the DMNS is seeking to discover additional microvertebrate fossil localities in the Laramie Formation in northeastern Colorado. Locally preserved trace fossils including dinosaur and mammal tracks are also preserved in the Laramie Formation, most notably in the City of Golden. Because it contains locally abundant and well-preserved plant fossils but vertebrate fossils are uncommon, the Laramie Formation is considered to have moderate paleontological sensitivity (PFYC *Class* 3) (Kl, Figures 2-10).

7.3.4 Denver Formation

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 I-25 North EIS study area, the Denver Formation is of late Cretaceous age based on superpositional relationships and the topography of the Denver Basin.

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 Raynolds, 1999; Raynolds and Johnson, 2003).

Based on the literature reviewed for this study, a taxonomic list of fossils known from the Denver Formation was compiled (Appendix D). 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 DMNS and UCM have numerous recorded Denver Formation localities from around the Denver Basin.

The geology and paleontology of the Denver Formation remains the subject of active research by scientists and students at the Denver Museum of Nature and Science and University of Colorado

Museum. This work 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 Raynolds, 1999). Future fossil finds from the Denver Formation will add to this ongoing research effort, and because 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 sensitivity (PFYC *Class* 5) (Tkd, Tkda, Figures 2-10).

7.3.5 Pleistocene-Age Alluvial, Colluvial and Eolian Deposits

Mapped geologic units that are of Pleistocene-age or Pleistocene and Holocene-age within the I-25 North EIS study area include, from approximately oldest to youngest, Rocky Flats Alluvium, Verdos Alluvium, Slocum Alluvium, Louviers Alluvium, Broadway Alluvium, and loess and eolian sand (= eolium) (Colton, 1978; Trimble and Machette, 1979). Although generally uncommon, fossil of varying types and abundances are known to occur in each of these units.

The Rocky Flats Alluvium (Aftonian Interglaciation and Nebraskan Glaciation) consists of bouldery cobble gravel which decreases in clast size away from the mountains, and is commonly as much as 10 feet thick and 230 to 325 feet above modern stream drainages. The Verdos Alluvium (Yarmouth Interglaciation and Kansan Glaciation) is composed of brown sand and gravel with boulders, with clasts that are weathered and partially decomposed, and a well-developed soil profile in its upper part. Deposits are as much as 20 feet thick but typically between 10 and 15 feet thick, and are generally 200 to 250 feet above modern stream drainages. The Slocum Alluvium (Sangamon Interglaciation or Illinoian Glaciation) consists of brown to white cobble and boulder gravels that are as much as 20 feet thick, with clasts composed mostly of well-rounded igneous and metamorphic rocks covered with a rind of calcium carbonate and with a well-developed soil profile. Deposits are 100 to 130 feet above modern major stream drainages. The Louviers Alluvium (Bull Lake Glaciation) is composed of reddish-brown pebble to boulder well-stratified alluvium with a well-developed brown soil profile, and forms terraces approximately 70 feet above modern stream drainages near the mountains, but that are buried by the Broadway Alluvium further to the east along the South Platte River. The Broadway Alluvium (Pinedale Glaciation) consists of sand and gravel deposited by the South Platte River and its tributaries. This alluvium is well-sorted and well-stratified, 10 to 35 feet thick, and forms terraces 20 to 40 feet above modern stream drainages. Loess and eolian sand (= eolium) consists of light brown to reddish-brown to olive-gray deposits of windblown clay, silt sand that is generally less than three feet but as much as 15 feet thick. Colluvium is composed of boulder to pebble sandy silt and clay deposited by gravity and sheet wash deposited on slopes, with a thickness range of between five and 25 feet (Colton, 1978; Trimble and Machette, 1979).

Pleistocene-age deposits, particularly alluvium, may contain mineralized or partially mineralized animal bones, invertebrates, and plant remains of paleontological significance. With the exception of some caves, hot springs, and tar deposits, these fossils typically occur in low density and usually consist of scattered and poorly preserved remains. The most common Pleistocene vertebrate fossils include the bones of mammoth, bison, deer, and small mammals; however, other taxa, including horse, lion, cheetah, wolf, camel, antelope, peccary, mastodon, and giant ground sloth, have been reported from the Rocky Mountain region (Cook, 1930, 1931; Emslie, 1986; Gillette and Miller, 1999; Gillette et al., 1999a, b; Graham and Lundelius, 1994; Heaton, 1999; Hunt, 1954; Lewis, 1970; Scott, 1963; Smith et al., 1999; unpublished paleontological data, Denver Museum of Nature and Science, compiled 2002; unpublished paleontological data, University of Colorado Museum, compiled 2001). In Colorado, Pleistocene-age sedimentary deposits contain scattered and typically poorly-preserved fossil remains, and thus have low paleontological sensitivity (PFYC *Class* 2) (Qrf, Qv, Qs, Qlo, Ql, Qb, Qes, Qe, Qc, Figures 2-9).

7.3.6 Holocene-Age Alluvial, Colluvial, and Eolian Deposits

Mapped geologic units that are of Holocene-age or Pleistocene and Holocene-age within the I-25 North EIS study area include, from approximately oldest to youngest, eolium (including eolian sand), colluvium, and Piney Creek and Post-Piney Creek Alluvium (Colton, 1978; Trimble and Machette, 1979).

Eolian sand (eolium = eolian sand and loess) consists of fine- to medium-grained sand derived chiefly from alluvium of major streams and transported by wind. Colluvium is composed of boulder to pebble sandy silt and clay deposited by gravity and sheet wash deposited on slopes, with a thickness range of between five and 25 feet. The Piney Creek Alluvium consists of dark-gray humic sandy to gravelly alluvium containing organic matter and with a thickness of up to 20 feet. The Post-Piney Creek Alluvium consists of dark gray humic, sandy to gravelly alluvium locally containing plant material with a thickness of between five and 15 feet (Colton, 1978; Trimble and Machette, 1979).

Holocene-age deposits are known to contain the unfossilized remains of modern species of animals and plants, and are too young to contain in situ fossils. Therefore, these deposits have no paleontological sensitivity (PFYC *Class* 2) (Qes, Qe, Qco, Qc, Qp, Qpc, Qpp, Figures 2-9).

7.3.7 Artificial Fill

The locations of artificial fill deposits within the I-25 EIS study area were not mapped by Colton (1978) and Trimble and Machette (1979) because of the large scale of these maps. However, many sections of roads, highways and railways within the study area are constructed on imported artificial fill. Generally, artificial fill consists of clay, silt, sand, gravel, and a variety of man-made debris including concrete, brick, wood, metal, plastic, glass, vegetation, and other trash. It includes engineered and compacted fill for highways, buildings, and bridge abutments; engineered and semi-engineered fill for dams, canal and railway embankments; stream channelization dikes, and some landfills. It is generally 5 to 20 feet thick, but up to 90 feet thick (Lindvall, 1979; Trimble and Machette, 1979).

Although imported fill is known to locally contain fossil remains depending upon the source of the native sediment used for the fill at various localities in the western United States, fossils have not been reported from imported fill material in Colorado, and it has no paleontological sensitivity (PFYC *Class* 2) (af, Figures 2-9).

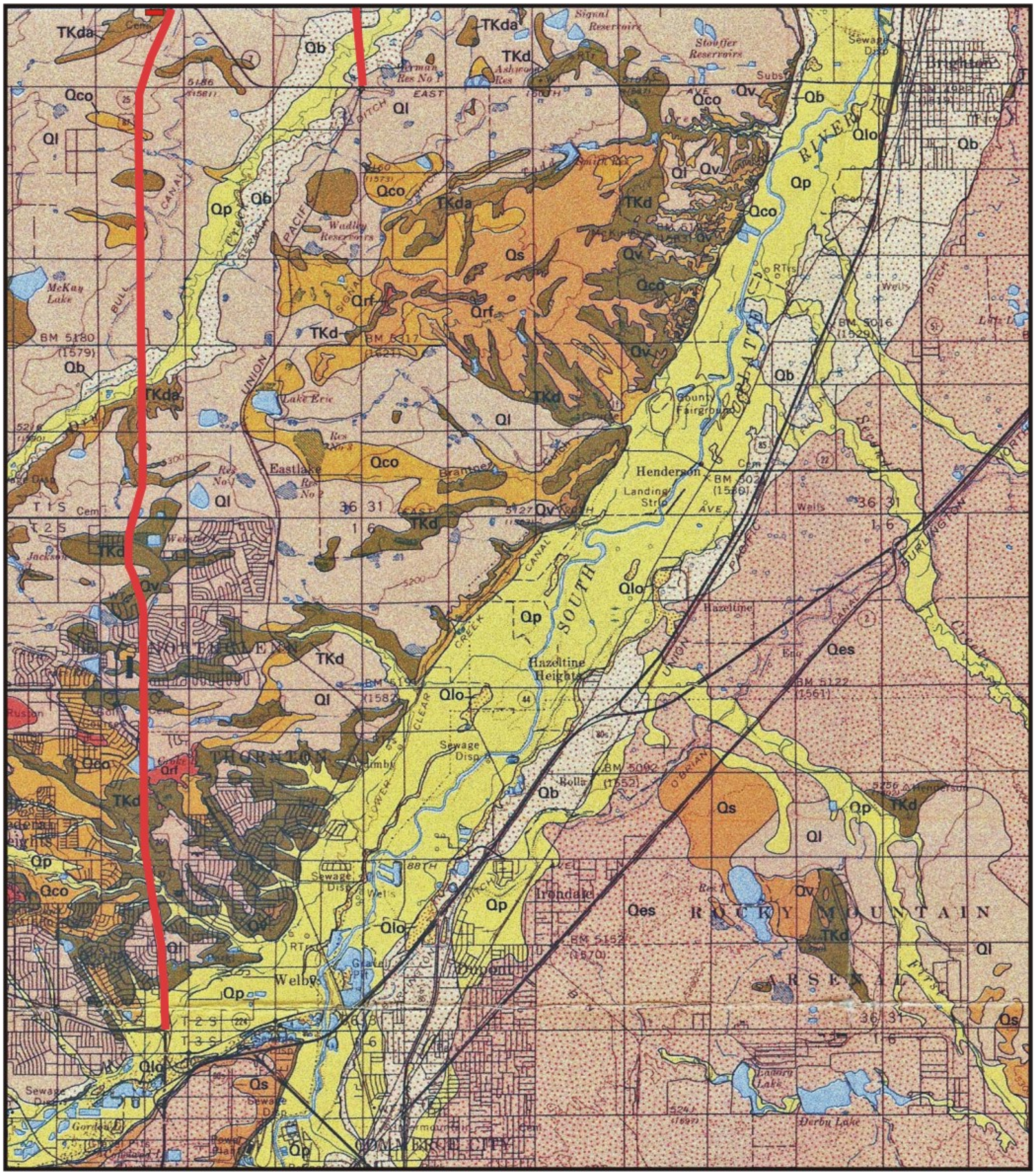

Figure 2 Geologic map showing locations of areas surveyed for paleontological resources within the I-25 North EIS study area (I-25) highlighted in red (from Trimble and Machette, 1979). Tkd, Tkda, Denver Formation; Kl, Laramie Formation, Qrf, Rocky Flats Alluvium; Qv, Verdos Alluvium; Qs, Slocum Alluvium; Qlo, Louviers Alluvium; Ql, Loess; Qb, Broadway Alluvium; Qes, windblown sand; Qco, colluvium; Qp, Post-Piney Creek and Piney Creek Alluvium.

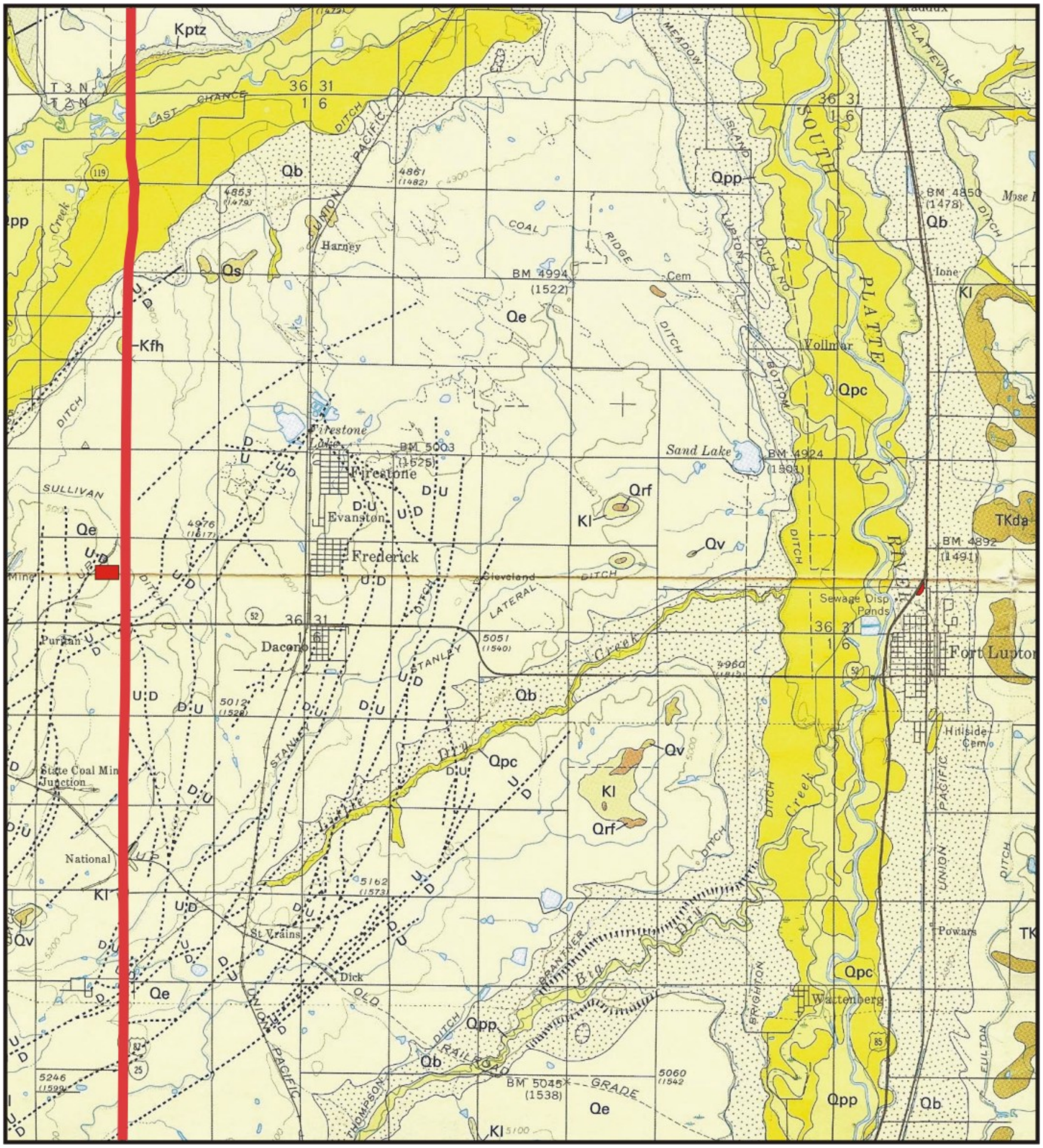

Figure 3 Geologic map showing locations of areas surveyed for paleontological resources within the I-25 North EIS study area (I-25 and Fort Lupton) highlighted in red (from Colton, 1978). Kph, Kpm, Kprl, Kpu, Kptz, Kp, Pierre Shale; Kfh, Fox Hills Sandstone; Kl, Laramie Formation; Tkda, Denver Formation; Qrf, Rocky Flats Alluvium; Qv, Verdos Alluvium; Qs, Slocum Alluvium; Qlo, Louviers Alluvium; Qb, Broadway Alluvium; Qpc, Piney Creek Alluvium; Qe, Eolium; Qc, Colluvium; Qpp, Post-Piney Creek Alluvium; af, artificial fill.

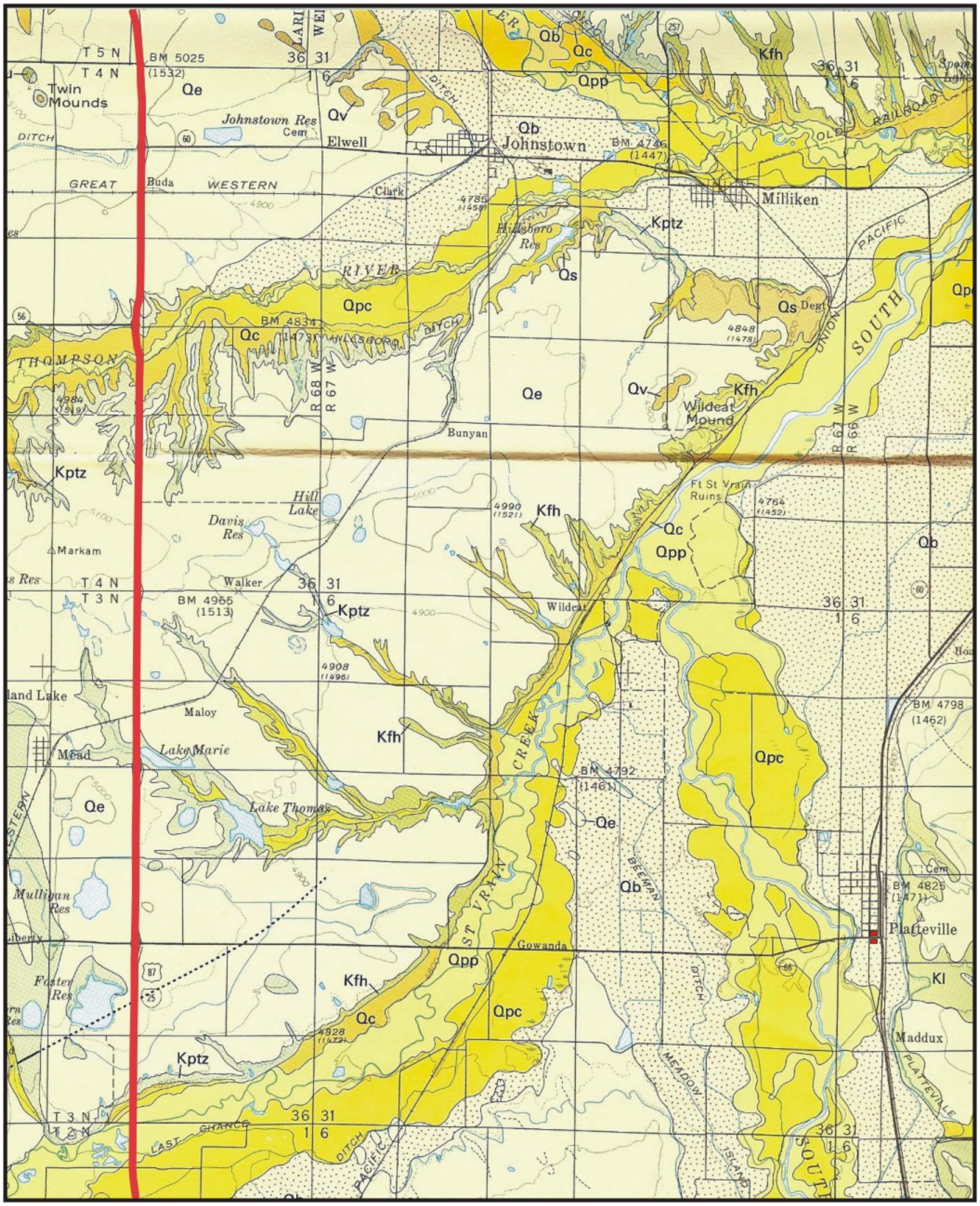

Figure 4 **Geologic map showing locations of areas surveyed for paleontological resources within the I-25 North EIS study area (I-25 and Platteville) highlighted in red (from Colton, 1978). Kph, Kpm, Kprl, Kpu, Kptz, Kp, Pierre Shale; Kfh, Fox Hills Sandstone; Kl, Laramie Formation; Tkda, Denver Formation; Qrf, Rocky Flats Alluvium; Qv, Verdos Alluvium; Qs, Slocum Alluvium; Qlo, Louviers Alluvium; Qb, Broadway Alluvium; Qpc, Piney Creek Alluvium; Qe, Eolium; Qc, Colluvium; Qpp, Post-Piney Creek Alluvium; af, artificial fill.**

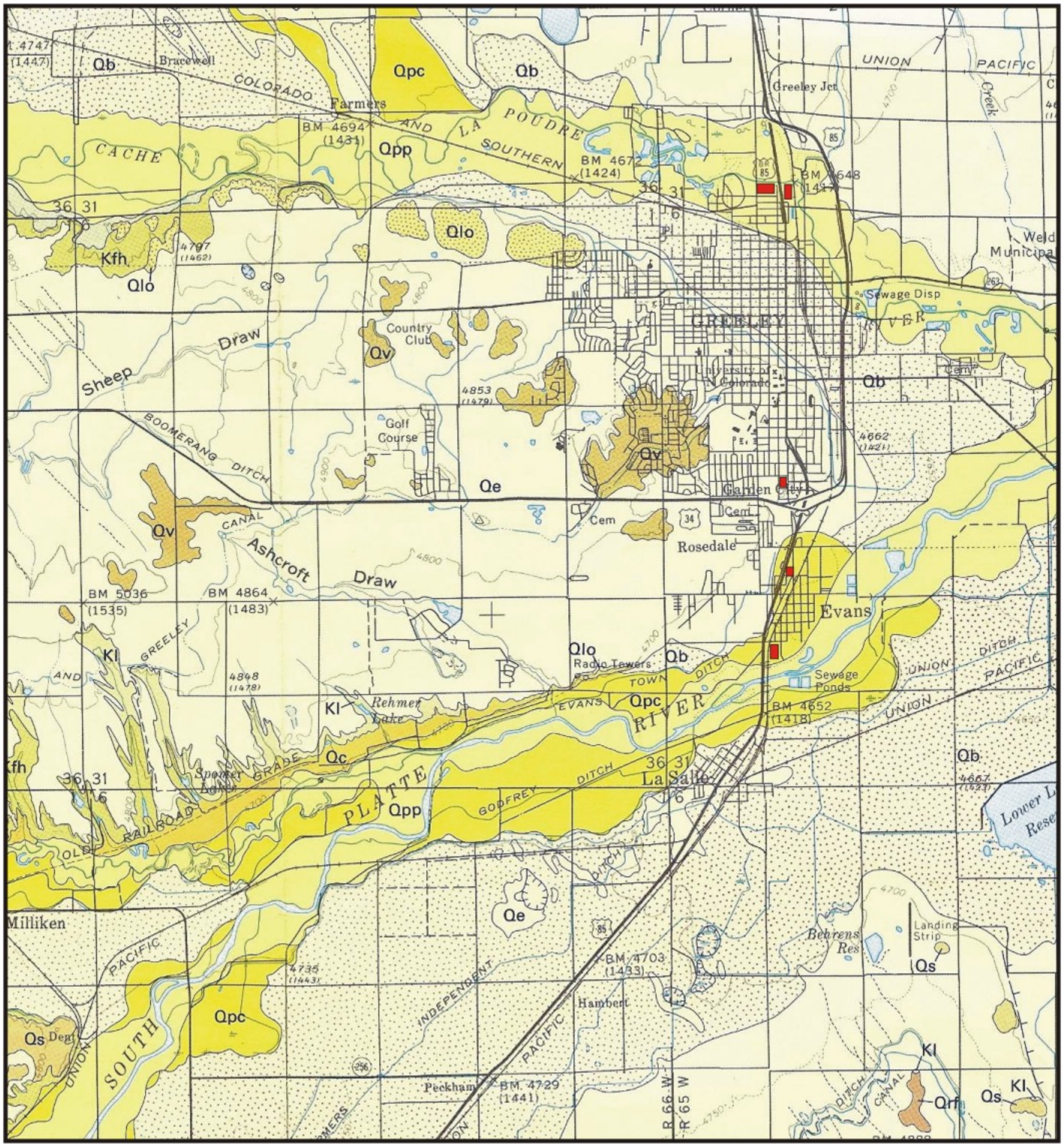

Figure 5 Geologic map showing locations of areas surveyed for paleontological resources within the I-25 North EIS study area (Evans and Greeley) highlighted in red (from Colton, 1978). Kph, Kpm, Kprl, Kpu, Kptz, Kp, Pierre Shale; Kfh, Fox Hills Sandstone; Kl, Laramie Formation; Tkda, Denver Formation; Qrf, Rocky Flats Alluvium; Qv, Verdos Alluvium; Qs, Slocum Alluvium; Qlo, Louviers Alluvium; Qb, Broadway Alluvium; Qpc, Piney Creek Alluvium; Qe, Eolium; Qc, Colluvium; Qpp, Post-Piney Creek Alluvium; af, artificial fill.

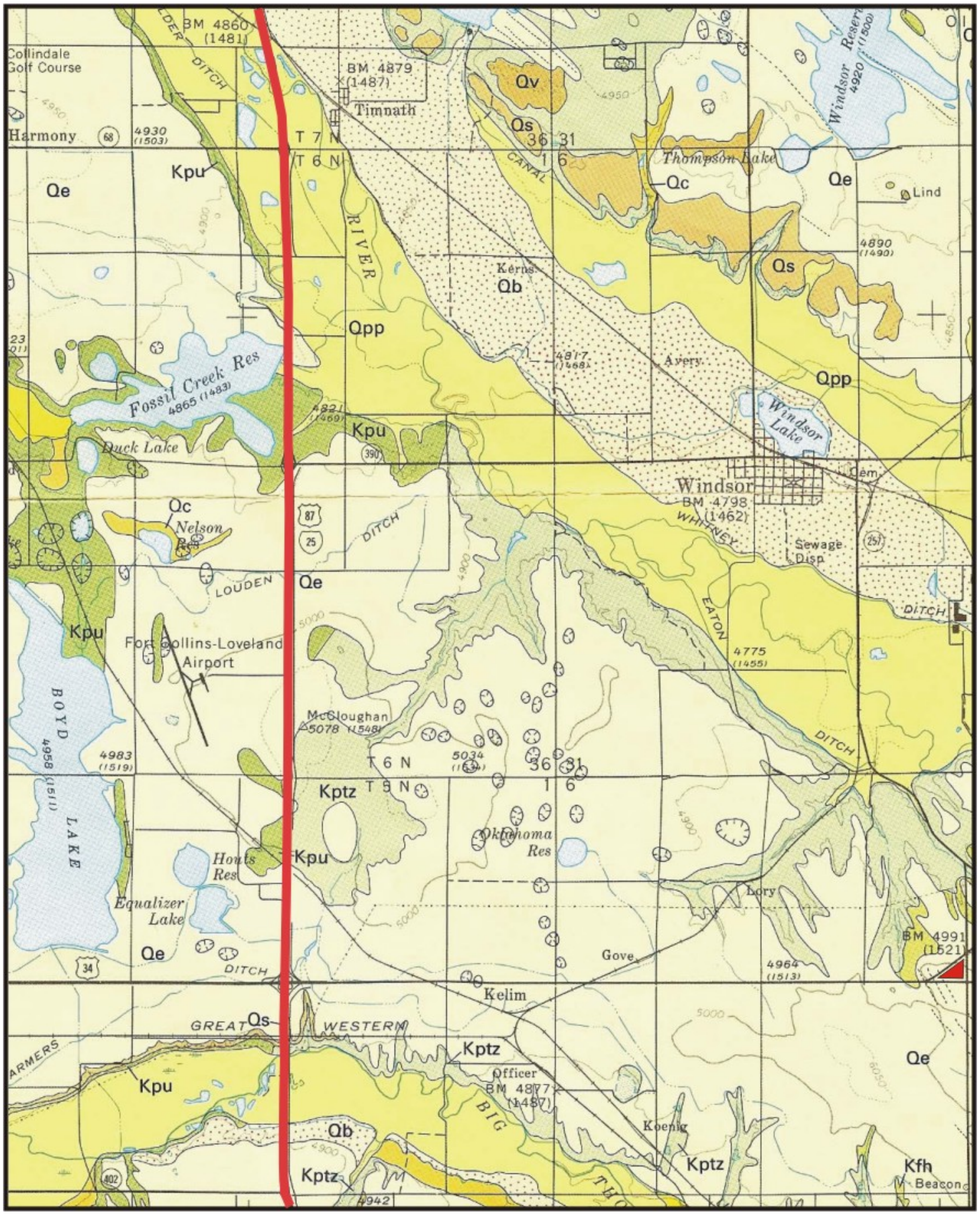

Figure 6 Geologic map showing locations of areas surveyed for paleontological resources within the I-25 North EIS study area (I-25, US Highway 34 south of Windsor) highlighted in red (from Colton, 1978). Kph, Kpm, Kprl, Kpu, Kptz, Kp, Pierre Shale; Kfh, Fox Hills Sandstone; Kl, Laramie Formation; Tkda, Denver Formation; Qrf, Rocky Flats Alluvium; Qv, Verdos Alluvium; Qs, Slocum Alluvium; Qlo, Louviers Alluvium; Qb, Broadway Alluvium; Qpc, Piney Creek Alluvium; Qe, Eolium; Qc, Colluvium; Qpp, Post-Piney Creek Alluvium; af, artificial fill.

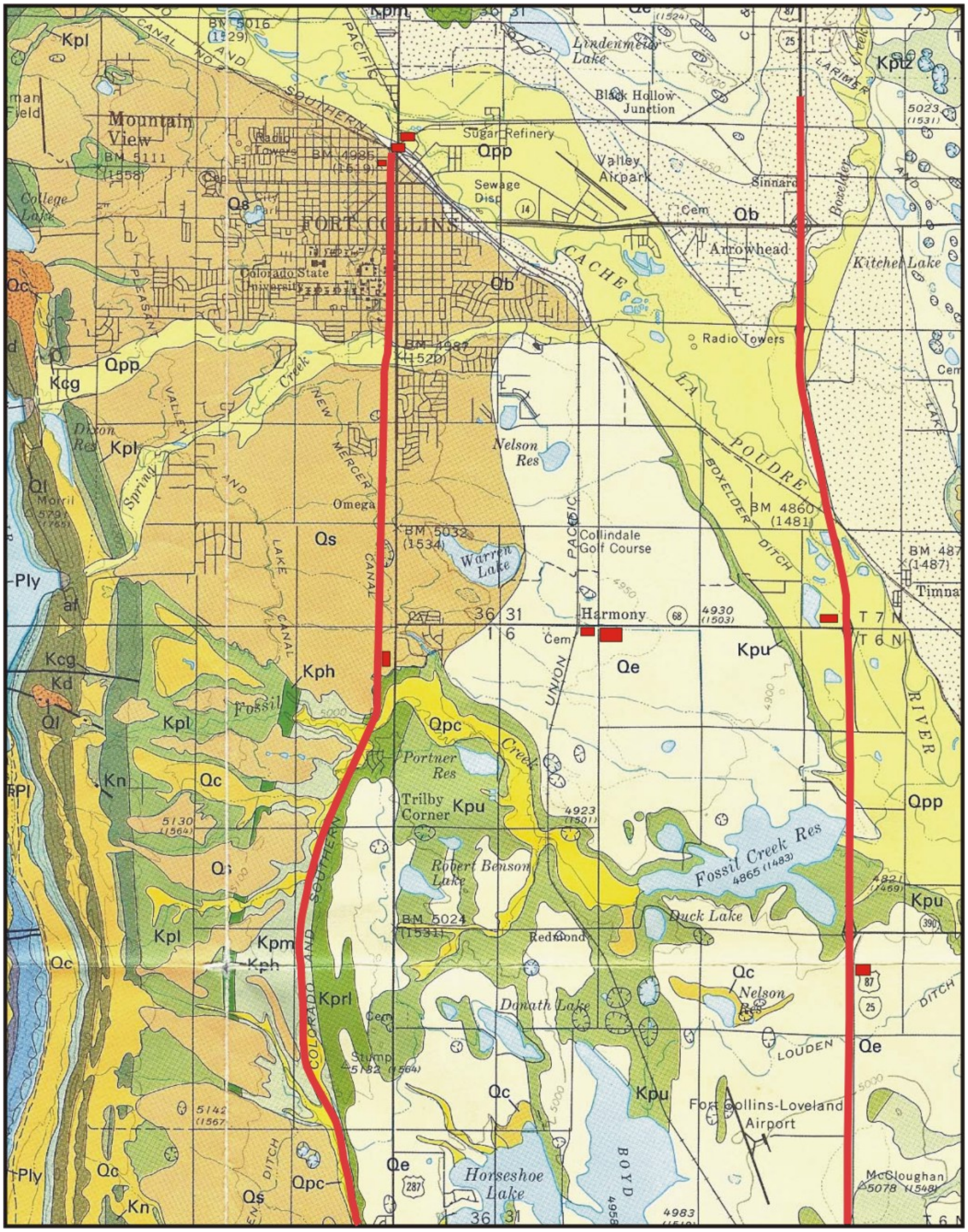

Figure 7 Geologic map showing locations of areas surveyed for paleontological resources within the I-25 North EIS study area (I-25, BNSF, Fort Collins) highlighted in red (from Colton, 1978). Kph, Kpm, Kprl, Kpu, Kptz, Kp, Pierre Shale; Kfh, Fox Hills Sandstone; Kl, Laramie Formation; Tkda, Denver Formation; Qrf, Rocky Flats Alluvium; Qv, Verdos Alluvium; Qs, Slocum Alluvium; Qlo, Louviers Alluvium; Qb, Broadway Alluvium; Qpc, Piney Creek Alluvium; Qe, Eolium; Qc, Colluvium; Qpp, Post-Piney Creek Alluvium; af, artificial fill.

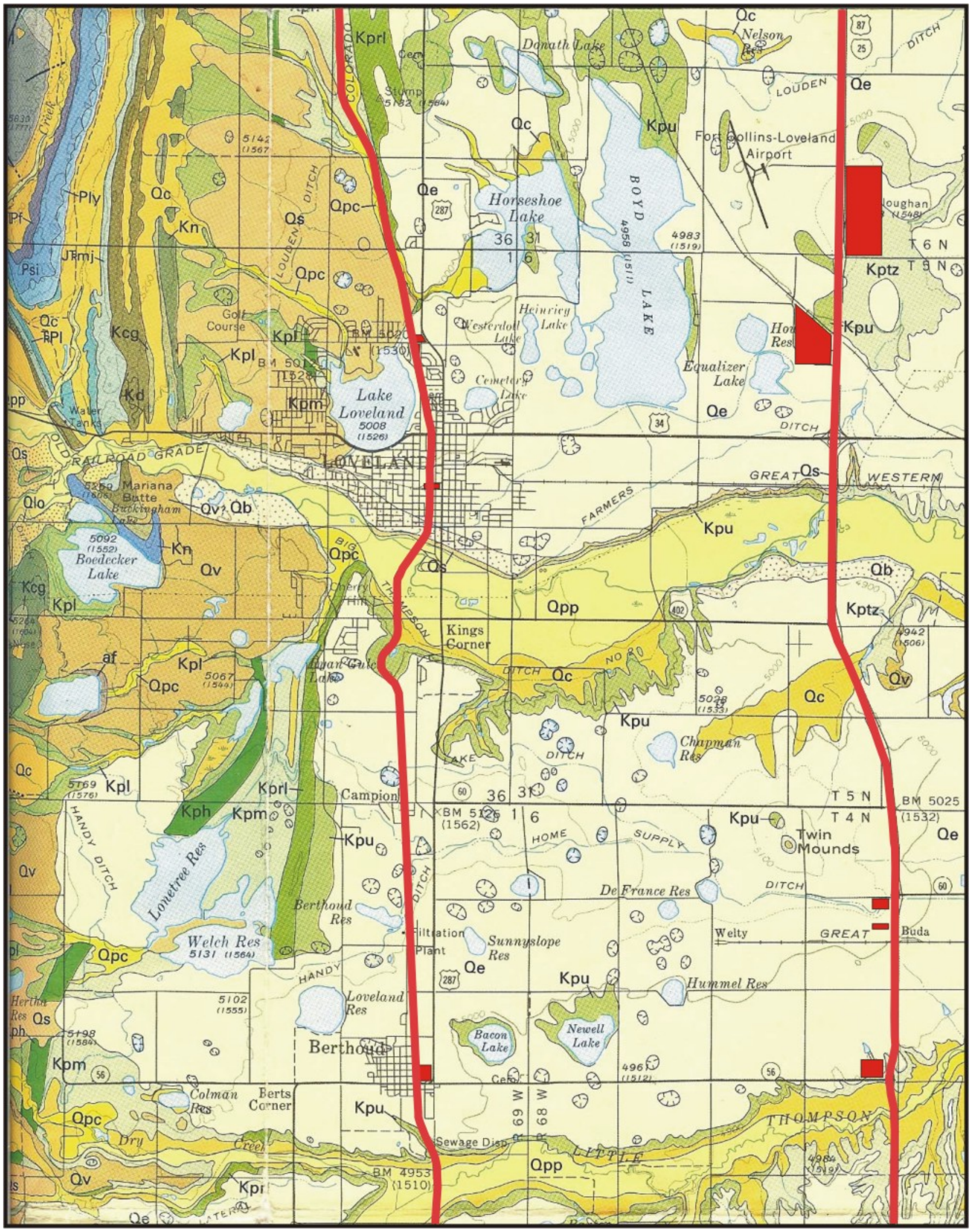

Figure 8 Geologic map showing locations of areas surveyed for paleontological resources within the I-25 North EIS study area (I-25, BNSF, Berthoud, Loveland) highlighted in red (from Colton, 1978). Kph, Kpm, Kprl, Kpu, Kptz, Kp, Pierre Shale; Kfh, Fox Hills Sandstone; Kl, Laramie Formation; Tkda, Denver Formation; Qrf, Rocky Flats Alluvium; Qv, Verdos Alluvium; Qs, Slocum Alluvium; Qlo, Louviers Alluvium; Qb, Broadway Alluvium; Qpc, Piney Creek Alluvium; Qe, Eolium; Qc, Colluvium; Qpp, Post-Piney Creek Alluvium; af, artificial fill.

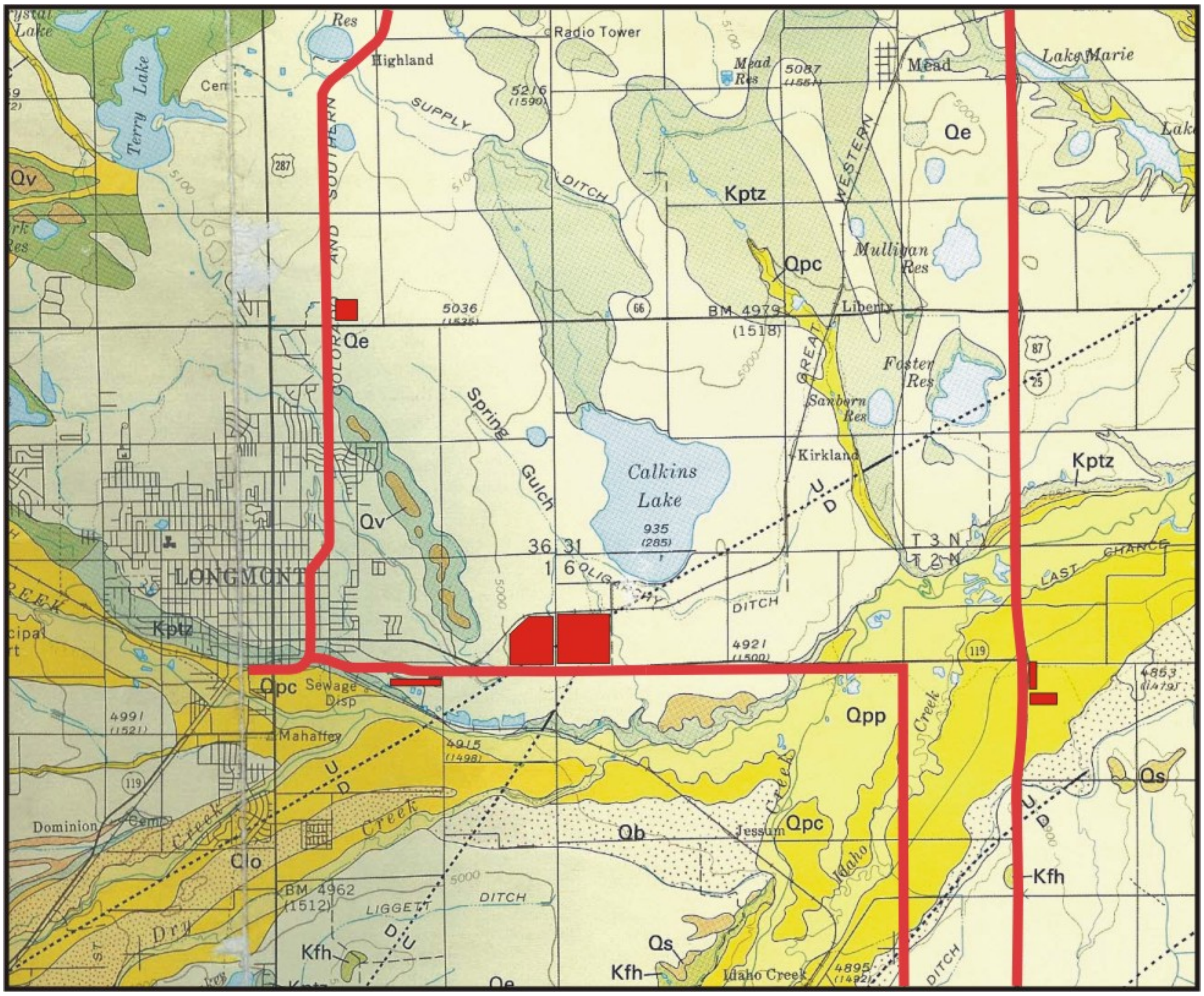

Figure 9 Geologic map showing locations of areas surveyed for paleontological resources within the I-25 North EIS study area (I-25, BNSF, Longmont, the proposed Longmont Metro North rail alternative) highlighted in red (from Colton, 1978). Kph, Kpm, Kprl, Kpu, Kptz, Kp, Pierre Shale; Kfh, Fox Hills Sandstone; Kl, Laramie Formation; Tkda, Denver Formation; Qrf, Rocky Flats Alluvium; Qv, Verdos Alluvium; Qs, Slocum Alluvium; Qlo, Louviers Alluvium; Qb, Broadway Alluvium; Qpc, Piney Creek Alluvium; Qe, Eolium; Qc, Colluvium; Qpp, Post-Piney Creek Alluvium; af, artificial fill.

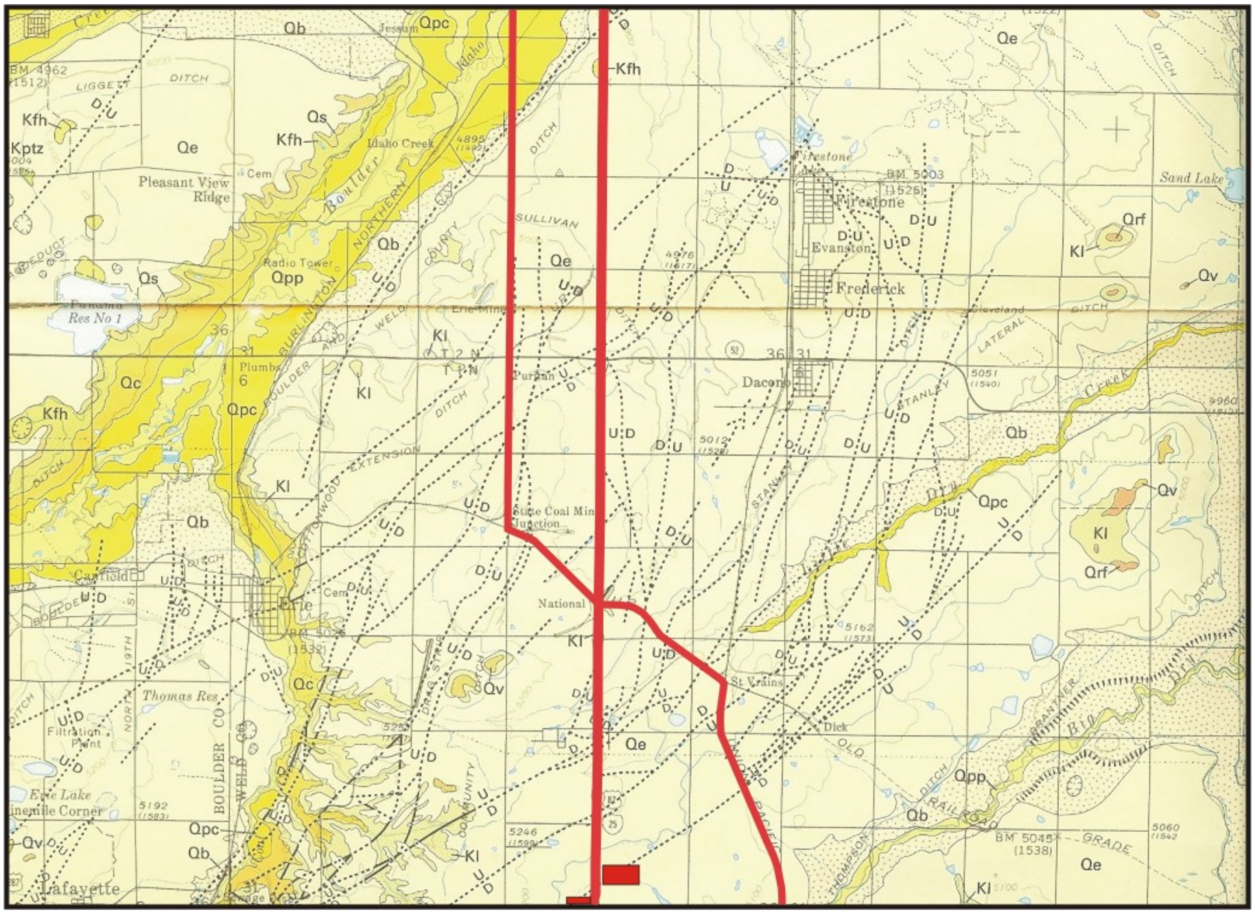

Figure 10 Geologic map showing locations of areas surveyed for paleontological resources within the I-25 North EIS study area (I-25, and proposed Longmont Metro North rail alternative) highlighted in red (from Colton, 1978). Kph, Kpm, Kprl, Kpu, Kptz, Kp, Pierre Shale; Kfh, Fox Hills Sandstone; Kl, Laramie Formation; Tkda, Denver Formation; Qrf, Rocky Flats Alluvium; Qv, Verdos Alluvium; Qs, Slocum Alluvium; Qlo, Louviers Alluvium; Qb, Broadway Alluvium; Qpc, Piney Creek Alluvium; Qe, Eolium; Qc, Colluvium; Qpp, Post-Piney Creek Alluvium; af, artificial fill.

7.4 Museum Record Search Results

In this section of the report, the paleontological sensitivity of the I-25 North EIS study area is evaluated in the context of the fossil locality searches conducted for this study. All fossil localities from within the search area for the I-25 North EIS that were discovered in the Pierre Shale, Fox Hills Sandstone, Laramie Formation, Denver Formation, and Quaternary/Pleistocene deposits are listed in Table 5. Fossil locality data are considered sensitive and are exempted from the Freedom of Information Act. Therefore, geographic coordinates for the localities listed in Table 5 are omitted. However, general (PLSS) coordinates for the museum localities are provided in Confidential Appendix B in order to demonstrate their proximity to the study area.

Note that unlike record searches for Cultural Resources, the purpose of a fossil locality search is not just to determine if any known resources are present within the footprint of a study area, and could be adversely impacted during ground disturbance. Just as important is to determine the likelihood of additional unrecorded surface and sub-surface paleontological resources within the study area based on the types and abundance of fossils that have been collected near the study area in the same geologic units. Therefore, the presence of localities near a study area in the same geologic units is an indication that there is a potential for additional unknown fossil occurrences within a study area.

Twelve previously recorded museum fossil localities occur within five miles of the I-25 EIS North study area as defined in Table 3. Two of these are DMNS localities, and ten are UCM localities. Seven of the localities were discovered in the Pierre Shale. Of these, six yielded marine invertebrates including bivalves and ammonites. One locality, UCM L. 82132, yielded fossil vertebrates including fish scales, sharks teeth, and unidentified reptilian remains (mosasaur?). Four of the six Pierre Shale localities (2768, 2779, 71090, 82132) are located along Fossil Ridge in the Hygiene Sandstone Member, just to the east of South Shield Street south of Fort Collins. UCM L. 92191, L. 92192 and L. 93013 are all within the I-25 ROW, although since recordation, all have been destroyed or modified and revegetated. UCM L. 93037 lay within the SH 287 ROW south of Loveland, but the fossiliferous road cut has been modified since recordation. UCM L. 92203 is outside of CDOT's US 287 ROW, but begins only about 50 m northeast of the US 287 bridge over the 1st canal north of Longmont (the bridge has been replaced since the locality was recorded). UCM L. 2003001 was recorded within a road cut exposure west of the frontage road west of I-15 at the intersection of the west frontage road and 26 Road (Crossroads Boulevard) northeast of Loveland at approximate I-25 milepost 259.3. Only one Denver Formation fossil locality, UCM 2001124, occurs within five miles of the study area. It was discovered by the CDOT Staff Paleontologist and yielded ceratopsian horn core fragments. Four Pleistocene-age fossil localities occur within five miles of the study area, and these yielded mammal remains.

In addition to the museum fossil localities, 137 USGS fossil localities were determined to be within five miles of the study area. These were plotted on USGS geologic maps (Scott and Cobban, 1965, 1986a). Of these 137 localities, 47 are located less than one mile from the I-25 North EIS study area. All of these localities yielded biostratigraphically significant fossil invertebrates (marine mollusks).

In summary, of the 12 museum fossil localities and 137 USGS fossil localities listed in Table 5, 56 localities are located within one mile of the study area, meaning that these could potentially be impacted by project construction depending upon the configuration of final EIS alternative selected and the final project design footprint. Importantly, these localities indicate the potential for

Table 5 Fossil localities within or adjacent to the search area for the I-25 North EIS (DMNS, Denver Museum of Nature and Science; UCM, University of Colorado Museum, USGS, United States Geological Survey [taken from Scott and Cobban, 1965; 1986a]).

Institution	Locality#	Formation and Age	General Description of Fossils	Proximity (see Confidential Appendix B for location)
DMNS	2768	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile
DMNS	2779	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile
UCM	2201124	Cretaceous, Denver	Vertebrates (dinosaur)	< 3 miles
UCM	93013	Pleistocene, unnamed	Vertebrates (mammals)	< 1 mile
UCM	92192	Pleistocene, unnamed	Vertebrates (mammals)	< 1 mile
UCM	92191	Pleistocene, eolian	Vertebrates (mammals)	< 1 mile
UCM	92203	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile
UCM	71090	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 2 miles
UCM	82132	Cretaceous, Pierre Shale	Vertebrates (fish and reptile)	< 1 mile
UCM	93037	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile
UCM	97036	Pleistocene, unnamed	Vertebrates (mammals)	< 4 miles
UCM	2003001	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile
USGS	9203-4	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile
USGS	9197	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile
USGS	9198	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile
USGS	9200	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile
USGS	9199	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile
USGS	9201	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile
USGS	9202	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile
USGS	D2746	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	D4036	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D4035	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D4034	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D2753	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D4037	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D4062	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D3791	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D2750	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D2751	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D2837	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D2752	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D2805	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D355	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D356	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D2803	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 mile
USGS	D2798	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D2799	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D2800	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D2801	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D2843	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D2754	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D2755	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D2804	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	9205	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	9206	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D2802	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles

Table 6 Fossil localities within or adjacent to the search area for the I-25 North EIS (DMNS, Denver Museum of Nature and Science; UCM, University of Colorado Museum, USGS, United States Geological Survey [taken from Scott and Cobban, 1965; 1986a]). (cont'd)

USGS	D4052	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D4053	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	9207	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	9208	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	9211	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D2759	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	D2760	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D2794	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D2756	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	D2757	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	D2839	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D4040	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D2841	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D354	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D3713	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles.
USGS	D1795	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D2838	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D1791	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D1793	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	D1790	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	D2842	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D1792	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	D2796	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	D2795	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D2797	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D2847	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D4050	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D4044	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D4042	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D4041	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D4039	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D4045	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles
USGS	D4049	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D4048	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D4051	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D4072	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D4070	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D4071	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	D648	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	D4069	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D9179	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D9177	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D976	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	9176	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	9178	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	9165	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	9174	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	5859	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	9167	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	5717	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	D3726	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	D977	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles

Table 7 Fossil localities within or adjacent to the search area for the I-25 North EIS (DMNS, Denver Museum of Nature and Science; UCM, University of Colorado Museum, USGS, United States Geological Survey [taken from Scott and Cobban, 1965; 1986a]). (cont'd)

USGS	9168	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	5861	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	9173	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	9171	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	9172	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D3729	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D4060	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D4054	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D3638	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D4061	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles
USGS	D650	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D649	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D4057	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D4056	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D3639	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D3637	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D12403	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile
USGS	D10987	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D10988	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D10989	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D651	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D652	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D10990	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D2848	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D4059	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D4055	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile
USGS	D2849	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile
USGS	D3635	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D3640	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D3636	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D10991	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D10992	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D10993	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	10370	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles
USGS	D298	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile
USGS	D299	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile
USGS	D300	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile
USGS	D301	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile
USGS	D1469	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D1470	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D1471	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile
USGS	D1566	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile
USGS	D1565	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile
USGS	D12378	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D10994	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	12615	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D3728	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	5862	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	9170	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	9169	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles
USGS	D1468	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles.

previously unknown fossil occurrences within the I-25 North study area in the Pierre Shale, Denver Formation, and Pleistocene-age surficial deposits. The aptly named Fossil Ridge, which runs parallel to the BNSF right-of-way south of Fort Collins, and the vicinity of the BNSF railway corridor extending from Fort Collins south to Longmont, contains the highest density of fossil localities of any area included in the locality searches for this study, having produced fossil vertebrates and abundant and diverse invertebrates (marine mollusks) from the Pierre Shale. Based on existing data, this area is the most likely to contain additional paleontological resources that could be impacted during ground disturbance.

Although only one previously recorded Denver Formation fossil locality near the I-25 North EIS study area was revealed by the museum record searches, the overall paleontological sensitivity of the Denver Formation around the Denver Basin is exemplified by the large number and taxonomic diversity of fossils which have been collected from this unit. The UCM has over 600 vertebrate (mostly mammal) fossils from approximately 60 Denver Formation localities. The DMNS has fewer vertebrates, but maintains a large and growing collection of Denver Formation fossil plants from more than 150 fossil localities, a growing collection of Denver Formation dinosaur fossils, and an active paleontological and geological research program focusing on the Denver Basin. Significant fossil plants have been collected from a large number of road and highway and other construction projects around the Denver Metropolitan Area, including Denver International Airport, the TREX Project, the Northwest Parkway, E-470, and others. In 2003, a partial skull of the ceratopsian dinosaur *Triceratops* was collected from an excavation associated with a construction project in Brighton. This specimen is housed at the DMNS. These widespread Denver Formation fossil occurrences indicate the potential for additional fossils within the I-25 North EIS study area.

Based on the results of the record searches, ground disturbance in areas underlain by the Laramie Formation and Fox Hills Sandstone are unlikely to result in adverse impacts on significant paleontological resources within the I-25 EIS study area. However, the Laramie Formation has a higher likelihood of producing well-preserved (diagnostic) fossils than the Fox Hills Sandstone; especially fossil plants, but also potentially fossil vertebrates.

7.5 Field Survey Results

This section of the report details the results of the paleontological field surveys which were undertaken for the I-25 North EIS. The areas surveyed are listed in Table 2 (Section 3.0). The results of the field survey are summarized in Confidential Appendix A.

With the exception of most private lands and portions of BNSF right-of-way (as discussed in Section 3.0), areas identified as having the potential for adverse impacts of paleontological resources associated with construction within the I-25 North EIS study area were inspected for surface fossils or exposures of potentially fossiliferous bedrock and/or surficial sediments. The footprints of the areas surveyed were delimited on alignment diagrams provided by Jacobs. Additional information regarding survey methodology is provided in Section 3.0.

No fossils were observed during the field surveys. However, the lack of fossil discoveries is undoubtedly related to the large number of properties which were not surveyed due to right-of-entry issues, considering the high number of museum and USGS localities which occur within one mile (or potentially within) the study area (see Table 5). Furthermore, topographically, the study area is largely flat or characterized by gently sloping hills. By nature, this type of topography greatly limits the aereal extent of areas of bedrock exposure, and hence, the potential for areas proximate to eroding bedrock outcrops where accumulations of surface fossils typically accumulate.

In terms of utilization, most of the study area consists of vegetated agricultural or rangeland characterized by substantial surface disturbance. Other areas consist of commercial and residential development, or existing paved roadway or railway constructed on artificial fill, especially along the I-25 corridor; but also in Fort Lupton, Platteville, Evans, Greeley, Fort Collins, Loveland, Berthoud, and Longmont.

Because of the nature of the study area topography and its present utilization, we concluded that the potential for occurrences of significant paleontological resources within the study area and the potential for adverse impacts on these resources during project-related ground disturbance was most accurately reflected by the results of the records searches discussed in Section 7.4, not the field surveys.

8.0 Impacts Analysis

The loss of any identifiable fossil that could yield information important to prehistory, or that embodies the distinctive characteristics of a type of organism, environment, period of time, or geographic region, would be a significant adverse environmental impact. Direct adverse impacts on paleontological resources primarily concern the potential destruction of non-renewable paleontological resources and the loss of information associated with these resources. This includes the unlawful or unauthorized collection of fossil remains. If potentially fossiliferous bedrock or surficial sediments are disturbed, the disturbance could result in the destruction of paleontological resources and subsequent loss of information (adverse impact). Direct adverse impacts can typically be mitigated to below a level of significance through the implementation of project-specific paleontological mitigation measures.

In summary, where surface disturbance occurs within the I-25 North EIS study area, impacts/effects on paleontological resources can be either beneficial or adverse. As described above, adverse impacts would be due to ground disturbing actions in paleontologically sensitive areas/geologic units that are unmitigated, and the destruction and permanent loss of these fossils and associated information to science. On the other hand, disturbance of fossiliferous rock units has the potential to result in the exposure of fossils that may never have been unearthed via natural processes. If mitigation measures are implemented, these newly exposed fossils become available for salvage, data recovery, scientific analysis, and preservation into perpetuity at a public museum (beneficial impact). Potential beneficial effects of the results of mitigation include advances in scientific knowledge by both permitted field researchers and paleontologists who study fossils in museum collections, contributions to public education and interpretation, and community involvement and partnerships. Overall, beneficial impacts would be due to advances in scientific understanding and increased knowledge of the spatial distribution (both geographic and stratigraphic) of significant fossil resources.

In general, for project areas which are underlain by paleontologically-sensitive geologic units, the greater the amount of ground disturbance, the higher the potential for adverse impacts to paleontological resources. For project areas which are directly underlain by geologic units with no paleontological sensitivity, there is no potential for impacts on paleontological resources unless sensitive geologic units which underlie the non-sensitive unit are also impacted. When designing project-specific mitigation measures, it is important to take into consideration the fact that significant fossils may be present in moderate and low sensitivity geologic units in addition to high sensitivity units.

Impacts analyzed in this study include direct (ground disturbance-related), indirect (operations-related) and cumulative impacts of the proposed transportation improvements on paleontological resources to the extent that they were identifiable for analysis.

8.1 Direct Impacts

Direct impacts result from ground disturbing projects, and occur at the same time and place as the ground disturbing action. The potential for direct impacts on scientifically-significant surface and sub-surface fossils in fossiliferous sedimentary deposits is controlled by two factors. These include: 1) the depth and lateral extent of disturbance of fossiliferous bedrock and/or surficial sediments; and 2) the depth and lateral extent of occurrence of fossiliferous bedrock and/or surficial sediments beneath the surface. Ground disturbance has the potential to adversely impact an unknown quantity of fossils which may occur on or underneath the surface in areas containing paleontologically sensitive geologic units. Without mitigation, these fossils, as well as the paleontological data they could provide if properly salvaged and documented, could be adversely impacted (destroyed), rendering them permanently unavailable for scientific research. A typical approach to the mitigation of adverse direct impacts would be monitoring of construction excavations and salvage of unearthed fossils.

8.2 Indirect Impacts

Indirect impacts are caused by actions and occur later in time or further away in distance than direct impacts, but are still reasonably foreseeable. They typically include those impacts which result from the continuing implementation of management decisions and associated activities, and/or the normal ongoing operations of facilities constructed within a specific project area. An example of an indirect adverse impact on paleontological resources would be the construction of a new road which increases public access to a previously inaccessible area, and results in unauthorized long-term fossil collecting and vandalism. Mitigation strategies could include surveys by permitted and qualified paleontologists to collect significant surface fossils, transfer them to a public museum, and identify locations of fossil localities which have the potential to yield additional fossils as erosion occurs; and the construction of protective fencing or other barriers around known paleontological sites. Indirect impacts on paleontological resources within the I-25 North EIS study area are anticipated to be negligible.

8.3 Cumulative Impacts

Cumulative impacts occur when there are multiple impacts on the same resources. These are incremental impacts of proposed activities or projects when combined with past, present, and future actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. In general, if previously unknown scientifically-significant paleontological resources were discovered within the I-25 North EIS study area, the potential cumulative impacts would be low, so long as mitigation was implemented to salvage the resources. The mitigation measures in Section 9.0 would effectively recover the value to science and society of significant fossils that would otherwise have been destroyed by ground disturbing actions.

8.4 Impacts Common to All Alternatives

At the time of this analysis, precise information regarding the depth of excavations required for the construction of the proposed transportation improvements and the thickness and depth of underlying fossiliferous bedrock and/or surficial sediments within the study area was unavailable. Ground disturbance is anticipated to occur at varying depths, be of varying lateral extent, and locally impact different geologic units of varying paleontological sensitivity. Generally, excavations associated with highway and railway widening and/or rehabilitation are anticipated to occur at or near existing grade, and will have less of a potential for significant bedrock disturbance than more localized deeper excavations for bridge abutments, underpasses, and building foundations.

Under all I-25 North EIS alternatives, potential direct and cumulative adverse impacts are possible in areas containing potentially fossiliferous bedrock of the Pierre Shale, Fox Hills Sandstone, Laramie Formation, and Denver Formation; and Pleistocene-age surficial sediments (see Figures 2-9). Direct impacts would result from unmitigated ground disturbance, and the resulting destruction of fossils. Indirect adverse impacts on significant paleontological resources are anticipated to be negligible under all alternatives. Cumulative impacts would occur as the result of the loss of non-renewable scientifically significant paleontological resources and associated information, and the consequent permanent unavailability of these resources for scientific research, education, and display.

Potential direct and cumulative impacts within all I-25 North EIS alternatives can be reduced to below the level of significance with the design and implementation of project-specific mitigation measures based on those outlined in Section 9.0.

8.5 Alternatives Impacts

The differing impacts of each of the I-25 North EIS alternatives are outside of the scope of this technical report, and will be analyzed individually and presented in the Environmental Consequences chapter of the EIS.

9.0 Mitigation Measures

As a nonrenewable resource, paleontological resources are unique. At the time fossils are discovered during paleontological surveys or mitigation-monitoring of ground disturbing activities, many have already been subjected to a variety of destructive processes. These include predation, scavenging, disarticulation of skeletal remains, transport, primary weathering, diagenesis (physical changes in rock which occur over time such as compaction, cementation, mineral replacement), erosion, secondary weathering, and if discovered during monitoring, additional damage that may have occurred during the ground disturbing action that led to the fossil discovery.

Unlike other resources, it is difficult to develop measurable performance standards for paleontological mitigation because 1) fossils have been damaged by natural processes prior to their discovery during a paleontological survey or during paleontological monitoring; 2) sub-surface fossils are often further damaged by construction activities that reveal their presence to paleontological monitors; and 3) there is no way to quantify how many fossils are preserved in the sedimentary deposits underlying a given site but were not exposed during the ground-disturbing action. Therefore, the absence of fossils would not indicate failure of the mitigation measures. Paleontological mitigation seeks to discover, via survey or monitoring, as many significant fossils as possible prior to their destruction during human-caused surface disturbance. Measurable performance standards in paleontology apply to survey and mitigation-monitoring procedures, which ensure that fossil localities are documented thoroughly and accurately, and that fossils are collected according to professional paleontological standards.

The following are mitigation measures that have been developed to reduce adverse impacts on paleontological resources to a less than significant level. They have been successfully implemented by the authors for surface-disturbing projects throughout the Western United States.

9.1 Preconstruction Survey and Assessment

This study completes the paleontological resources pre-construction survey and assessment for the I-25 North EIS. As stated in Section 10, number 2, modifications to the mitigation recommendations listed in Table 6, including additional site-specific and/or project specific assessments, may be recommended by the CDOT staff paleontologist when the final alternative is selected and project design plans are finalized.

9.2 Construction Monitoring

As outlined in Table 6, continuous monitoring or spot checking during construction is recommended for the Pierre Shale, Laramie Formation, and Denver Formation (or portions thereof). Paleontological clearance is recommended for the Fox Hills Sandstone and Pleistocene-age surficial deposits. When the final I-25 North EIS alternative is selected and the project design plans are finalized, the CDOT staff paleontologist should re-evaluate the recommendations listed in Section 10 and modify them as appropriate on a site-specific and/or project-specific basis. .

All paleontological monitoring work should be performed by a qualified and permitted paleontologist (Project Paleontologist). Paleontological monitoring should include inspection of exposed rock units and microscopic examination of matrix to determine if fossils are present. This work would take place during surface disturbing activities such as excavations for the construction of roads, railways, bridges, underpasses, and buildings. Depending upon the paleontological sensitivity of the project area based on its geology and the types and significance of potential fossils that could be present in sub-surface sedimentary deposits, monitoring should be scheduled to take place continuously or to consist of spot-checks of construction excavations. Paleontological monitors should follow earth-moving equipment and examine excavated sediments and excavation sidewalls for evidence of significant paleontological resources. The monitors should have authority to temporarily divert grading away from exposed fossils in order to efficiently and professionally recover the fossil specimens and collect associated data. All efforts to avoid delays to project schedules should be made.

Paleontological monitors should be equipped with the necessary tools for the rapid removal of fossils and retrieval of associated data in order to prevent construction delays. This equipment should include handheld GPS receivers, digital cameras, cell phones, and laptop computers; as well as a toolkit containing specimen containers and matrix sampling bags, field labels, field tools (awl, hammer, chisels, shovel, etc.); and a plaster kit. The collected fossils should be transported to a paleontological laboratory for processing.

In the laboratory, all fossils should be prepared, identified, inventoried, and a determination of significance made. Specimen preparation and stabilization methods should be recorded for use by the paleontological repository. All fossil specimens should then be transferred to a public museum or other approved paleontological repository such as the DMNS or UCM accompanied by a copy of the final paleontological monitoring report and all data in hard and electronic copy.

The final paleontological monitoring report should provide all necessary paleontological data. This includes, but is not limited to, a discussion of the results of the mitigation-monitoring plan, an evaluation and analysis of the fossils collected (including an assessment of their significance, age, and geologic context), an itemized inventory of fossils collected, a confidential appendix of locality and specimen data with locality maps and photographs, an appendix of curation agreements and other appropriate communications, and a copy of the project-specific paleontological monitoring and mitigation plan.

If any sub-surface bones or other potential fossils are found by construction personnel during construction, work in the immediate area should cease immediately, and the CDOT staff paleontologist should be contacted to evaluate the significance of the find. Once salvage or other mitigation measures (including sampling) is complete, the CDOT staff paleontologist should notify the construction supervisor that paleontological clearance has been granted.

10.0 RECOMMENDATIONS

1) Potential adverse impacts on paleontological resources within the I-25 North EIS study area can be reduced to below the level of significance with the implementation of the mitigation measures outlined in Section 9.0. Table 6 summarizes the paleontological resource mitigation recommendations by geologic formation.

2) When the final EIS alternative has been selected and the project design plans have been finalized, the CDOT Staff Paleontologist should review these documents and determine the extent and depth of ground disturbance associated with construction of the propose transportation improvements. Based on these findings, the mitigation approach should be modified as appropriate, and additional site-specific and/or project-specific paleontological studies may be recommended.

3) The vast majority of privately owned lands within the I-25 North EIS study area, and some segments of BNSF right-of-way, were not surveyed for paleontological resources because access to these parcels had not been granted at the time of this analysis. When the final alternative is selected, the CDOT Staff paleontologist should determine which of these parcels, if any, could contain exposures of potentially fossiliferous bedrock and/or surface fossils, and should be surveyed prior to construction.

4) If any sub-surface bones or other potential fossils are found anywhere within the I-25 North EIS study area during construction-related ground disturbance, the CDOT paleontologist should be notified immediately to assess their significance and make further recommendations.

Table 6. Summarized paleontological resource mitigation recommendations for the I-25 North EIS by geologic formation.

Formation	**Location**	**Approach**
Pierre Shale, Hygiene Sandstone Member	Fossil Ridge, BNSF corridor south of Fort Collins and North of Loveland	Monitor all excavations during construction
Pierre Shale	All locations where unit occurs within study area except Fossil Ridge	Spot-check large excavations for significant fossils during construction. Immediately notify CDOT paleontologist if fossils found by construction personnel during construction
Fox Hills Sandstone	All locations where unit occurs within study area	Paleontological clearance recommended. Immediately notify CDOT paleontologist if fossils found by construction personnel during construction
Laramie Formation	All locations where unit occurs within study area	Spot-check large excavations for significant fossils during construction. Immediately notify CDOT paleontologist if fossils found by construction personnel during construction
Denver Formation	All locations where unit occurs within study area	Monitor all excavations during construction
Pleistocene-age surficial deposits	All locations where unit occurs within study area	Paleontological clearance recommended. Immediately notify CDOT paleontologist if fossils found by construction personnel during construction

11.0 GLOSSARY

Biochronology	The relative dating of geologic events based on fossil evidence.
Biostratigraphy	The science of dating rocks by using the fossils contained within them. Usually the aim is correlation, that is, demonstrating that a particular horizon in one geological section represents the same period of time as another horizon at some other section. The fossils are useful because sediments of the same age can look completely different because of local variations in the sedimentary environment.
Diagenesis	With regards to the Earth Sciences, diagenesis refers to all the chemical, physical, and biological changes undergone by a sediment after its initial deposition, and during and after its lithification, exclusive of surface alteration (weathering). Diagenesis is the lowest grade of metamorphism.
Epeiric	An epicontinental seaway; or large shallow sea that overlies part of a continent
Evolution	The sequence of events involved in the evolutionary development of a species or taxonomic group of organisms. In the context of the life sciences, evolution is change in the genetic makeup of a group—a population of interbreeding individuals within a species. Such a population shares a common gene pool and members exhibit a degree of genetic relatedness.
Extinction	The disappearance of a species or group of species. The moment of extinction is generally considered to be the death of the last individual of that species.
Facies	Every depositional environment puts its own distinctive imprint on the sediment, making a particular facies. Thus, a facies is a distinct kind of rock for that area or environment.
Holotype	A holotype (sometimes simply *type*) is the single physical example or illustration of an organism that defines the characteristics of the whole species. It is the definitive member of that species. Other specimens can be compared with the holotype to determine whether they are actually a member of that species.
Ichnofossil	Trace fossil. A fossil which preserves animal behavior (footprints, burrows, bite marks, scratches, etc.).
Ma BP	Millions of years before present.
Paleoecology	The study of the interactions between fossil organisms and their environments, including their life cycle, their interactions, their natural environment, their manner of death and burial. Paleoecology's aim is to build the most detailed model possible of the life environment of those organisms we find today as fossils.
Phylogenetics	The study of the evolutionary interrelationships of living things in order to interpret the way in which life has diversified and changed over time.
Speciation	The process leading to the creation of new species. It is one form of biological evolution. Speciation occurs when a parent species splits into two (or more) reproductively-isolated populations, each of which then accumulates changes from sexual reproduction and/or random mutation until the populations are no longer capable of interbreeding.
Surficial	Pertaining to or lying in or on the surface. Sediments covering bedrock.
Taphonomy	The study of what happens to an organism's remains from the time of death until discovery by a paleontologist in an attempt to better interpret the fossil record and conditions responsible for fossil preservation. It includes processes such as scavenging, weathering, transport, and diagenesis.
Temporal	Refers to geologic time for the purposes of this report.
Tectonic	Tectonics is a field of study within geology concerned generally with the structure of the crust of the Earth and particularly with the forces and movements that have operated in a region to create geomorphic features.
Vertebrate	Animals with vertebrae (back bones), including fish, amphibians, reptiles, birds and mammals.

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CONFIDENTIAL APPENDIX A

FIELD SURVEY SUMMARY

Appendix A. Paleontological survey summary for the I-25 North Corridor EIS. Geologic mapping by Colton (1978) and Trimble and Machette (1979). I-25 North EIS alignment diagrams provided by Carter & Burgess, Inc., Denver. UTM's recorded using NAD27 datum.

I-25 North Location Name	UTM's (NAD27)	Present Use	Photographs	Bedrock Geology	Surficial Geology	Surface Paleontological Sensitivity	Bedrock Paleontological Sensitivity	Localities and Fossils	Comments
Fort Lupton Jump Station	516126 mE 4438099 mN	Paved road, dirt lots, Phillips 66 Station, Liquor Store,warehouse	Photographed (2), view looking east across CR14.5 across SH85	Laramie Formation?	Broadway Alluvium	low (PFYC Class 2)	moderate (PFYC Class 3)	none	gravel exposed on surface of dirt lot, surface appears to be previously disturbed
Plateville Jump Station	515234 mE 4450466 mN	South parcel dirt lot, north parcel gas station and undeveloped dirt lot	Photographed (2), looking east at south plot and north at north plot	Laramie Formation	Broadway Alluvium	low (PFYC Class 2)	moderate (PFYC Class 3)	none	gravel exposed on surface of dirt lot, surface appears to be previously disturbed
US 34 and 83rd Avenue	515898 mE 4474031 mN	Undeveloped, partially disturbed, irrigation canal	Views north and east from southwest corner of parcel	Fox Hills Sandstone	Eolian Sand	low (PFYC Class 2)	moderate (PFYC Class 3)	none	mostly vegetated, no exposures
US 85 and D Street	526123 mE 4476435 mN	Bar, access roads, commercial and industrial development, highway 85 (business loop), vacant vegetated lots	View south from NE corner of west parcel	Pierre Shale?	Post-Piney Creek Alluvium	low (PFYC Class 2)	moderate (PFYC Class 3)	none	mostly vegetated, gravel and dirt on surface locally, no bedrock
Greeley South	526103 mE 4471438 mN	Mostly paved parking lot	View west from NE corner	Pierre Shale?	Eolian Sand	low (PFYC Class 2)	moderate (PFYC Class 3)	none	pavement
Evans	526230 mE 4469801 mN	Bar, industrial lot, house	View NE from near SW corner	Laramie Formation?	Piney Creek Alluvium	low (PFYC Class 2)	moderate (PFYC Class 3)	none	Gravel exposed at surface locally, other parts vegetated, no bedrock
US 257 and US 34	510980 mE 4472948 mN	Park n' Ride, undeveloped vegetated lot	View from Park n' Ride looking southwest	Fox Hills Sandstone	Eolian Sand	low (PFYC Class 2)	moderate (PFYC Class 3)	none	Possible bedrock along US 34 south and west of 257, sands and artificial fill
I-25 south of 84th Ave (east side)	501493 mE 4409457mN	Highway shoulder	N/A	Denver Formation	Loess or Denver Formatio	high (PFYC Class 4/5	high (PFYC Class 4/5	none	mostly vegetated with artificial fill, test hole with soil
I-25 at 84th Ave exit (east side)	501421 mE 4410151 mN	Highway shoulder	View south	Denver Formation	Loess or Denver Formation	high (PFYC Class 4/5	high (PFYC Class 4/5	none	mostly vegetated, test hole with sand

Appendix A. Paleontological survey summary for the I-25 North Corridor EIS. Geologic mapping by Colton (1978) and Trimble and Machette (1979). I-25 North EIS alignment diagrams provided by Carter & Burgess, Inc., Denver. UTM's recorded using NAD27 datum. (cont'd)

I-25 south of Thorton Parkway exit (east side)	501138 mE 4412098 mN	Highway shoulder	View north	Denver Formation	Denver Formation	high (PFYC Class 4/5	high (PFYC Class 4/5	none	mostly vegetated, with artificial fill, test hole with sand/art. fill mix
I-25 south of 120th Ave (east side)	501055 mE 4416629 mN	Highway shoulder	View south	Denver Formation	Denver Formation	high (PFYC Class 4/5	high (PFYC Class 4/5	none	mostly vegetated, with artificial fill, test hole with sand
I-25 north of 120th Ave (east side)	501139 mE 4418808 mN	Highway shoulder	View northeast	Dawson/ Denver Arapahoe Formation	Dawson/ Denver Arapahoe Formation	high (PFYC Class 4/5	high (PFYC Class 4/5	none	mostly vegetated, test hole with sand
I-25 south of 136th Ave (east side)	501115 mE 4420728 mN	Highway shoulder	View south	Denver Formation	Piney Creek/ Post Piney Creek Alluvium or Broadway Alluvium	low (PFYC Class 2)	high (PFYC Class 4/5	none	mostly vegetated, test hole with sand
I-25 north of exit 232 (east side)	501745 mE 4432688 mN	Highway shoulder	View south	Laramie Formation	Eolian Sand	low (PFYC Class 2)	moderate (PFYC Class 3)	none	mostly vegetated, with artificial fill, test hole with sand
I-25 3 miles south of SH 56 exit (east side)	501745 mE 4456836 mN	Highway shoulder	N/A	Pierre Shale	Eolian Sand	low (PFYC Class 2)	moderate (PFYC Class 3)	none	mostly vegetated, with artificial fill, test hole with AF
I-25 1 mile south of SH 56 exit (east side)	501785 mE 4459891 mN	Highway shoulder	View south	Pierre Shale	Eolian Sand	low (PFYC Class 2)	moderate (PFYC Class 3)	none	mostly vegetated, test hole with sand
I-25 south of exit 250, SH 56 (east side)	501759 mE 4461214 mN	Highway shoulder	View east	Pierre Shale	Colluvium	low (PFYC Class 2)	moderate (PFYC Class 3)	none	mostly vegetated, with sands, soil and artificial fill, test hole with sand
I-25 1 mile north of SH 392 exit (east side)	500780 mE 4482480 mN	Highway shoulder	View south	Pierre Shale	Eolian Sand	low (PFYC Class 2)	moderate (PFYC Class 3)	none	mostly vegetated, with sands and artificial fill, test hole with sand
I-25 west of highway at Off Road Club (land owner HFE LLC)	501624 mE 4459971 mN	Off Road/Dirt Bike club	View east	Pierre Shale	Pierre Shale	low (PFYC Class 2)	moderate (PFYC Class 3)	none	Abundant exposed blocks of bedrock. Tan to orange fine to coarse grained sandstone.

Appendix A. Paleontological survey summary for the I-25 North Corridor EIS. Geologic mapping by Colton (1978) and Trimble and Machette (1979). I-25 North EIS alignment diagrams provided by Carter & Burgess, Inc., Denver. UTM's recorded using NAD27 datum. (cont'd)

I-25 north of Windsor exit 262 (west side)	500700 mE 4481733 mN	Highway shoulder	View northwest	Pierre Shale	Pierre Shale	moderate (PFYC Class 3)	moderate (PFYC Class 3)	none	mostly vegetated, test hole with sand
I-25 2.5 miles south of SH 56 exit (west side)	501702 mE 4457321 mN	Highway shoulder	View south	Pierre Shale	Eolian Sand	low (PFYC Class 2)	moderate (PFYC Class 3)	none	mostly vegetated, with sands, soil and artificial fill, test hole with sand
I-25 2.5 miles north of SH 52 (west side)	501715 mE 4441266 mN	Highway shoulder	View north	Fox Hills Formation	Eolian Sand	low (PFYC Class 2)	moderate (PFYC Class 3)	none	mostly vegetated, test hole with sandy, shaley, clay mix
I-25 north of Erie exit (west side)	501679 mE 4434825 mN	Highway shoulder	View northwest	Laramie Formation	Eolian Sand	low (PFYC Class 2)	moderate (PFYC Class 3)	none	mostly vegetated, test hole with clay/sand mix
I-25 south of E470 (west side)	501045 mE 4424277 mN	Highway shoulder	View west	Dawson/ Denver Arapahoe Formation	Loess or Dawson/ Arapahoe Formation	High (PFYC Class 4/5	high (PFYC Class 4/5	none	mostly vegetated, with soil and artificial fill, test hole with soil
I-25 north of 120th St exit (west side)	501076 mE 4418843 mN	Highway shoulder	View southwest	Dawson/ Denver Arapahoe Formation	Loess or Dawson/ Denver Arapahoe Formation	high (PFYC Class 4/5	high (PFYC Class 4/5	none	mostly vegetated, with soil, test hole with soil
I-25 north of Thorton Parkway (west side)	501079 mE 4413774 mN	Highway shoulder	View northwest	Denver Formation	Loess	low (PFYC Class 2)	high (PFYC Class 4/5	none	mostly vegetated, with soil, test hole with soil
Longmont metro north/ Union Pacific RR	502611 mE 4432743 mN	Out of use RR bed	View northwest	Laramie Formation	Eolian Sand	low (PFYC Class 2)	moderate (PFYC Class 3)	none	mostly vegetated, with soil, sand and artificial fill, test hole with soil and sand
Longmont metro north/ Union Pacific RR	503631 mE 4431879 mN	Out of use RR bed	View southeast	Laramie Formation	Eolian Sand	low (PFYC Class 2)	moderate (PFYC Class 3)	none	mostly vegetated, with soil, test hole with soil
Longmont metro north/ Union Pacific RR	503951 mE 4430603 mN	Out of use RR bed	View south	Laramie Formation	Eolian Sand	low (PFYC Class 2)	moderate (PFYC Class 3)	none	artificial fill

CONFIDENTIAL APPENDIX B

FOSSIL LOCALITY SUMMARY

Fossil localities within or adjacent to the search area for the I-25 North EIS (DMNS, Denver Museum of Nature and Science; UCM, University of Colorado Museum).

Institution	**Locality#**	**Formation and Age**	**General Description of Fossils**	**Proximity and Location**
DMNS	2768	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile, Sec. 11, T. 6 N., R. 69 W.
DMNS	2779	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile, Sec. 11, T. 6 N., R. 69 W.
UCM	2201124	Cretaceous, Denver	Vertebrates (dinosaur)	< 3 miles, Sec. 13, T. 2 S., R. 68 W.
UCM	93013	Pleistocene, unnamed	Vertebrates (mammals)	< 1 mile, Sec. 10, T. 1 N., R. 68 W.
UCM	92192	Pleistocene, unnamed	Vertebrates (mammals)	< 1 mile, Sec. 23, T. 1 N., R. 68 W.
UCM	92191	Pleistocene, eolian	Vertebrates (mammals)	< 1 mile, Sec. 26, T. 1 N., R. 68 W.
UCM	92203	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 2 miles, Sec. 3, T. 3 N., R. 69 W.
UCM	71090	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 2 miles, Sec. 3, T. 6 N., R. 69 W.
UCM	82132	Cretaceous, Pierre Shale	Vertebrates (fish and reptile)	< 1 mile, Sec. 11, T. 6 N., R. 69 W.
UCM	93037	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 2 miles, Sec. 25, T. 5 N., R. 69 W.
UCM	97036	Pleistocene, unnamed	Vertebrates (mammals)	< 4 miles, Sec. 7, T. 5 N., R. 67 W.
USGS	9203-4	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile, Sec. 7, T. 2 N., R. 68 W.
USGS	9197	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile, Sec. 7, T. 2 N., R. 68 W.
USGS	9198	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile, Sec. 8, T. 2 N., R. 68 W.
USGS	9200	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile, Sec. 8, T. 2 N., R. 68 W.
USGS	9199	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile, Sec. 8, T. 2 N., R. 68 W.
USGS	9201	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile, Sec. 4, T. 2 N., R. 68 W.
USGS	9202	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	< 1 mile, Sec. 3, T. 2 N., R. 68 W.
USGS	D2746	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 32, T. 3 N., R. 69 W.
USGS	D4036	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 29, T. 3 N., R. 69 W.
USGS	D4035	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 30, T. 3 N., R. 69 W.
USGS	D4034	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 30, T. 3 N., R. 69 W.
USGS	D2753	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 19, T. 3 N., R. 69 W.

Fossil localities within or adjacent to the search area for the I-25 North EIS (DMNS, Denver Museum of Nature and Science; UCM, University of Colorado Museum).

USGS	D4037	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 25, T. 3 N., R. 70 W.
USGS	D4062	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 16, T. 3 N., R. 69 W.
USGS	D3791	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 9, T. 3 N., R. 69 W.
USGS	D2750	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 24, T. 3 N., R. 70 W.
USGS	D2751	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 24, T. 3 N., R. 70 W.
USGS	D2837	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 24, T. 3 N., R. 70 W.
USGS	D2752	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 13, T. 3 N., R. 70 W.
USGS	D2805	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 12, T. 3 N., R. 70 W.
USGS	D355	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 12, T. 3 N., R. 70 W.
USGS	D356	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 12, T. 3 N., R. 70 W.
USGS	D2803	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 mile, Sec 7, T. 3 N., R. 69 W.
USGS	D2798	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 35, T. 4 N., R. 69 W.
USGS	D2799	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 miles, Sec 35, T. 4 N., R. 69 W.
USGS	D2800	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 miles, Sec 2, T. 3 N., R. 69 W.
USGS	D2801	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 2, T. 3 N., R. 69 W.
USGS	D2843	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 3, T. 3 N., R. 69 W.
USGS	D2754	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 5, T. 3 N., R. 69 W.
USGS	D2755	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 5, T. 3 N., R. 69 W.
USGS	D2804	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 5, T. 3 N., R. 69 W.
USGS	9205	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 31, T. 4 N., R. 68 W.
USGS	9206	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 33, T. 4 N., R. 68 W.
USGS	D2802	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 33, T. 4 N., R. 68 W.
USGS	D4052	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 30, T. 4 N., R. 68 W.
USGS	D4053	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 29, T. 4 N., R. 68 W.

Fossil localities within or adjacent to the search area for the I-25 North EIS (DMNS, Denver Museum of Nature and Science; UCM, University of Colorado Museum).

USGS	9207	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 28, T. 4 N., R. 68 W.
USGS	9208	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 22, T. 4 N., R. 68 W.
USGS	9211	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 22, T. 4 N., R. 68 W.
USGS	D2759	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 28, T. 4 N., R. 69 W.
USGS	D2760	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 22, T. 4 N., R. 69 W.
USGS	D2794	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 21, T. 4 N., R. 69 W.
USGS	D2756	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 21, T. 4 N., R. 69 W.
USGS	D2757	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 21, T. 4 N., R. 69 W.
USGS	D2839	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 19, T. 4 N., R. 69 W.
USGS	D4040	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 18, T. 4 N., R. 69 W.
USGS	D2841	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 18, T. 4 N., R. 69 W.
USGS	D354	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 18, T. 4 N., R. 69 W.
USGS	D3713	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 18, T. 4 N., R. 69 W.
USGS	D1795	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 20, T. 4 N., R. 69 W.
USGS	D2838	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 20, T. 4 N., R. 69 W.
USGS	D1791	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 8, T. 4 N., R. 69 W.
USGS	D1793	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 9, T. 4 N., R. 69 W.
USGS	D1790	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 9, T. 4 N., R. 69 W.
USGS	D2842	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 8, T. 4 N., R. 69 W.
USGS	D1792	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 9, T. 4 N., R. 69 W.
USGS	D2796	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 9, T. 4 N., R. 69 W.
USGS	D2795	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 3, T. 4 N., R. 69 W.
USGS	D2797	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 34, T. 5 N., R. 69 W.
USGS	D2847	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 3, T. 4 N., R. 69 W.

Fossil localities within or adjacent to the search area for the I-25 North EIS (DMNS, Denver Museum of Nature and Science; UCM, University of Colorado Museum).

USGS	D4050	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 34, T. 5 N., R. 69 W.
USGS	D4044	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 32, T. 5 N., R. 69 W.
USGS	D4042	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 32, T. 5 N., R. 69 W.
USGS	D4041	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 32, T. 5 N., R. 69 W.
USGS	D4039	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 32, T. 5 N., R. 69 W.
USGS	D4045	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<5 miles, Sec 32, T. 5 N., R. 69 W.
USGS	D4049	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 33, T. 5 N., R. 69 W.
USGS	D4048	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 33, T. 5 N., R. 69 W.
USGS	D4051	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 33, T. 5 N., R. 69 W.
USGS	D4072	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 33, T. 5 N., R. 69 W.
USGS	D4070	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 33, T. 5 N., R. 69 W.
USGS	D4071	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 27, T. 5 N., R. 69 W.
USGS	D648	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 30, T. 5 N., R. 68 W.
USGS	D4069	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 25, T. 5 N., R. 69 W.
USGS	D9179	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 10, T. 5 N., R. 67 W.
USGS	D9177	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 2, T. 5 N., R. 67 W.
USGS	D976	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 2, T. 5 N., R. 67 W.
USGS	9176	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 2, T. 5 N., R. 67 W.
USGS	9178	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 3, T. 5 N., R. 67 W.
USGS	9165	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 4, T. 5 N., R. 67 W.
USGS	9174	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 5, T. 5 N., R. 67 W.
USGS	5859	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 34, T. 6 N., R. 67 W.
USGS	9167	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 34, T. 6 N., R. 67 W.
USGS	5717	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 35, T. 6 N., R. 67 W.

Fossil localities within or adjacent to the search area for the I-25 North EIS (DMNS, Denver Museum of Nature and Science; UCM, University of Colorado Museum).

USGS	D3726	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 35, T. 6 N., R. 67 W.
USGS	D977	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 36, T. 6 N., R. 67 W.
USGS	9168	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 2, T. 5 N., R. 67 W.
USGS	5861	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 1, T. 5 N., R. 67 W.
USGS	9173	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 29, T. 6 N., R. 67 W.
USGS	9171	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 30, T. 6 N., R. 67 W.
USGS	9172	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 30, T. 6 N., R. 67 W.
USGS	D3729	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 30, T. 6 N., R. 67 W.
USGS	D4060	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 21, T. 5 N., R. 68 W.
USGS	D4054	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 20, T. 5 N., R. 68 W.
USGS	D3638	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 20, T. 5 N., R. 68 W.
USGS	D4061	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<4 miles, Sec 20, T. 5 N., R. 69 W.
USGS	D650	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 26, T. 5 N., R. 69 W.
USGS	D649	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 26, T. 5 N., R. 69 W.
USGS	D4057	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 23, T. 5 N., R. 69 W.
USGS	D4056	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 23, T. 5 N., R. 69 W.
USGS	D3639	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 17, T. 6 N., R. 68 W.
USGS	D3637	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 17, T. 6 N., R. 68 W.
USGS	D12403	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile, Sec 10, T. 6 N., R. 68 W.
USGS	D10987	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 35, T. 6 N., R. 69 W.
USGS	D10988	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 36, T. 6 N., R. 69 W.
USGS	D10989	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 26, T. 6 N., R. 69 W.
USGS	D651	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 26, T. 6 N., R. 69 W.
USGS	D652	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 23, T. 6 N., R. 69 W.

Fossil localities within or adjacent to the search area for the I-25 North EIS (DMNS, Denver Museum of Nature and Science; UCM, University of Colorado Museum).

USGS	D10990	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 21, T. 6 N., R. 69 W.
USGS	D2848	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 22, T. 6 N., R. 69 W.
USGS	D4059	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 15, T. 6 N., R. 69 W.
USGS	D4055	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile, Sec 22, T. 6 N., R. 69 W.
USGS	D2849	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile, Sec 23, T. 6 N., R. 69 W.
USGS	D3635	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 12, T. 6 N., R. 69 W.
USGS	D3640	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 7, T. 6 N., R. 68 W.
USGS	D3636	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 12, T. 6 N., R. 69 W.
USGS	D10991	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 9, T. 6 N., R. 69 W.
USGS	D10992	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 9, T. 6 N., R. 69 W.
USGS	D10993	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 4, T. 6 N., R. 69 W.
USGS	10370	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 4, T. 6 N., R. 69 W.
USGS	D298	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile, Sec 11, T. 6 N., R. 69 W.
USGS	D299	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile, Sec 2, T. 6 N., R. 69 W.
USGS	D300	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile, Sec 2, T. 6 N., R. 69 W.
USGS	D301	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile, Sec 1, T. 6 N., R. 69 W.
USGS	D1469	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 2, T. 6 N., R. 69 W.
USGS	D1470	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 2, T. 6 N., R. 69 W.
USGS	D1471	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<1 mile, Sec 2, T. 6 N., R. 69 W.
USGS	D1566	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile, Sec 1, T. 6 N., R. 69 W.
USGS	D1565	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<0.5 mile, Sec 1, T. 6 N., R. 69 W.
USGS	D12378	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 36, T. 7 N., R. 69 W.
USGS	D10994	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 26, T. 7 N., R. 68 W.
USGS	12615	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 13, T. 6 N., R. 68 W.

Fossil localities within or adjacent to the search area for the I-25 North EIS (DMNS, Denver Museum of Nature and Science; UCM, University of Colorado Museum).

USGS	D3728	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 24, T. 6 N., R. 68 W.
USGS	5862	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 24, T. 6 N., R. 68 W.
USGS	9170	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 25, T. 6 N., R. 68 W.
USGS	9169	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<2 miles, Sec 35, T. 6 N., R. 68 W.
USGS	D1468	Cretaceous, Pierre Shale	Invertebrates (marine mollusks)	<3 miles, Sec 36, T. 8 N., R. 69 W.

APPENDIX C

PALEONTOLOGICAL BIBLIOGRAPHY FOR THE PIERRE SHALE, FOX HILLS SANDSTONE, LARAMIE FORMATION, AND DENVER FORMATION

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APPENDIX D

TAXONOMIC LISTS FOR THE PIERRE SHALE, FOX HILLS SANDSTONE, LARAMIE FORMATION, AND DENVER FORMATION

Pierre Shale

Order Foraminiferida

Haplophragmoides

Bathysiphon

Saccammina

Textularia

Buliminella

Eouvigerina

Neobulimina

Glomospirella

Dorothia

Trochammina

Ammobaculites

Haplophragmoides

Rugoglobigerina

Globiogerinelloides

Neobulimina

Gyroidina

Cibicides

Heterohelix

Lenticulina

Pseudoclavulina

Stilostomella

Lagenammina

Reophax

Spiroplectammina

Pseudobolivina

Bulimina

Alabamina

Anomalinoides

Astacolus

Caucasina

Dentalina

Lagena

Nodosaria

Oolina

Saracenaria

Fissurina

Frondicularia

Glomospira

Silicosigmoilina

Nonionella

Verneuilinoides

Gaudryina

Marginulina

Phylum Brachiopoda

Class Inarticulata

Order Atremata

Family Lingulidae

Lingula

Phylum Coelenterata

Class Anthozoa

Order Scleractinia

Scleractinia indet.

Phylum Mollusca

Class Bivalvia

Bivalvia indet.

Order Arcoida

Family Arcidae

Arcidae indet.

Order Mytiloidia

Family Pinnidae

Pinna

Order Prionodesmac

Family Nuculanidae

Nuculana

Order Pterioida

Family indet

Archastropecten

Family Inoceramidae

Inoceramus

Endocostea

Family Mytilidae

Crenella

Family Ruclistidae

Ichthyosarcolite

Family Ruclistidae

Ichthyosarcolite

Order Veneroida

Family Mactridae

Cymbophora

Phylum Cephalopoda

Class Cephalopoda

Order Ammonoidea

Family indet.

Jeletzkyites

Family Baculitidae

Baculites

Family Diplomoceratidae

Solenoceras

Family Nostoceratidae

Axonoceras

Didymoceras

Exiteloceras

Nostoceras

Oxybeloceras

Solenoceras

Family Pachydiscidae

Anapachydiscus

Menuites

Family Placentericidae

Placenticeras

Family Scaphitidae

Hoploscaphites

Jeletzkytes

Order Nautiloidea

Family Nautilidae

Eutrephoceras

Teuthida

Family indet.

Tusoteuthis

Class Gastropoda

Order Mesogastropoda

Family Aporrhaidae

Tibiaporrhais

Family Cerithidae

Drepanocheilus

Family Xenophoridae

Xenophora

Family Aporrhaidae

Anchura

Order Rachiglossa

Family Pyropsidae

Pyropis

Class Scaphopoda

Family Dentaliidae

Dentalium

Phyllum Protista

Class Sarcodina

Order Foraminifer

Family Alabaminidae

Gyroidina

Anomalina

Family Astrorhizidae

Bathysiphon

Hyperammina

Saccorhiza

Family Ataxophragmiid

Dorothia

Gaudryina

Family Bolivinitidae

Bolivina

Family Buliminidae

Bulimina

Family Discorbidae

Valvulineria

Family Globorotaliidae

Globorotalia

Family Globotruncanidae

Archaeoglobigeri

Family Heterohelicidae

Heterohelix

Family Hormosinidae

Reophax

Family Lituolidae

Ammobaculites

Family Lituolidae

Haplophragmoides

Trochamminoides

Family Miliolidae

Quinqueloculina

Family Nodosariidae

Dentalina

Lenticulina

Nodosaria

Family Nonionidae

Pullenia

Family Osangulariidae

Globorotalites

Family Polymorphinidae

Ramulina

Family Saccaminidae

Saccammina

Family Textulariidae

Bigenerina

Spiroplectammina

Textularia

Family Trochamminidae

Dorothia

Marssonella

Trochammina

Family Turrilinidae

Praebulimina

Class Chondrichthyes

Chondrichthyes indet

Order Batoidea

Family Hybodontidae

Hybodus

Order Galeoidea indet.

Order Lammiformes

Family Cretoxyrhinidae

Cretoxyrhina

Family Alopiidae

Paranomotodon

Order Selachii

Selachii indet.

Family Cretoxyrhinidae

Cretolamna

Family Isuridae

Lamna

Corax

Squalicorax

Class Osteichthyes

Osteichthyes indet.

Order Amiiformes

Family Pachycormidae

Protosphyraena

Order Clupeiformes

Family Chirocentridae

Order Holosteii

Holosteii indet.

Order Osteoglossiformes

Family Ichthyodectidae

Ichthyodectidae indet.

Gillicus

Portheus

Ichthyodectes

Xiphactinus

Family Pachyrhizodontidae

Pachyrhizodus

Family Plethodontidae

Anogmius

Order Salmoniformes

Family Chirocentridae

Ichthyodectes

Order Salmoniformes

Family Cimolichthyidae

Cimolichthyes

Family Dercetidae

Stratodus

Family Enchodontida

Enchodus

Class Amphibia

Order Anura

Family Plethodontidae

Class Reptilia

Reptilia indet.

Order Chelonia

Chelonia indet.

Family Baenidae

Baenidae indet.

Family Toxochelyidae

Toxochelys

Order Ornithopoda

Family Hadrosauridae

Hadrosauridae indet.

Family Elasmosauridae

Elasmosauridae indet.

Family Polycotylidae

Trinacromerum

Order Sauropoda

Family Diplodocidae

Apatosaurus

Order Plesiosauria

Family Plesiosauridae

Plesiosaurus

Dolichorhrynchus

Family Brachaucheniidae

Brachauchenius

Plesiopleurodon

Family Polycotylidae

Polycotylus

Dolichorhynchops

Trinacromerum

Family Elasmosauridae

Elasmosaurus

Hydralmosaurus

Libonectes

Styxosaurus

Thalassomedon

Order Pterosauria

Family Pteranodontidae

Pteranodon

Order Squamata

Squamata indet.

Family Mosasauridae

Mosasauridae indet.

Mosasaurus

Platecarpus

Clidastes

Thylosaurus

Class Aves

Order Hesperornithiformes

Family Hesperornithidae

Hesperornis

Class Mammalia

Order Insectivora

Insectivora indet.

Order Leptictida

Leptictida indet.

Family Leptictidae

Leptictidae indet.

Pierre Shale taxonomic lists by member (from Scott and Cobban, 1986)

Unnamed Shale Member
Inoceramus
Limopsis
Nymphalucina
Thetiopsis
Aporrhais
Baculites
Hoploscaphites

Terry Sandstone Member
Serpula
echinoid
bryozoan
Agerostrea
Anomia
Clisocolus
Cuspidaria
Dentalium
Homolopsis
Inoceramus
Limopsis
Nemodon
Nucula
Nuculana
Nymphalucina
Ostrea
Pecten
Syncyclonema
Phelopteria
Thetiopsis
Acmaea
Acteon
Anisomyon
Aporrhais
Atira
Cryptorhytis
Ellipsoscapha
Oligoptycha
Polinices
Xenophora
Eutrephoceras
Anapachydiscus
Baculites
Hoploscaphites
Exiteloceras
Placenticeras
Solenoceras
fish scales

Unnamed Shale Member

Serpula
Anomia
Cymbophora
Inoceramus
Modiolus
Cryptorhytis
Eutrephoceras
Baculites
Hoploscaphites
Placenticeras
crab

Rocky Ridge Sandstone Member

Dysnoetopora
Agerostrea
Anatina
Anomia
Crassatella
Cymbophora
Dosiniopsis
Ethmocardium
Exogyra
Goniochasma
Inoceramus
Modiolus
Ostrea
Pachymya
Panope
Pecten
Phelopteria
Pinna
Polinices
Tancredia
Tellina
Thracia
Amauropsis
Anchura
Anisomyon
Aporrhais
Bellifusus
Cylichna
Gyrodes
Volutoderma
Hoploscaphites
Placenticeras

Unnamed Sandy Shale Member

Serpula
Dysnoetopora
Anatina
Anomia
Crenella
Cuspidaria
Cymbophora

Ethmocardium
Inoceramus
Leda
Legumen
Leptosolen
Modiolus
Nemodon
Nucula
Nuculana
Nymphalucina
Ostrea
Pachymya
Panope
Pecten
Pinna
Protocardia
Oxytoma
Pteria
Tellina
Thetiopsis
Veniella
Akera
Anisomyon
Atira
Drepanochilus
Ellipsoscapha
Medionapus
Polinices
Pyropsis
Tornatellaea
Baculites
Cirroceras
Hoploscaphites
Eomunidopsis
crustacean undet.
fish scales

Larimer Sandstone Member
Serpula
Websteria
Dysnoetopora
Anatina
Anomia
Crenella
Cuspidaria
Cyclorisma
Cymbophora
Ethmocardium
Exogyra
Inoceramus
Leda
Legumen
Modiolus
Nemodon
Nucula
Nuculana

Nymphalucina
Ostrea
Pachymya
Pectin
Phelopteria
Pteria
Solemya
Tellina
Thetiopsis
Veniella
Anisomyon
Atira
Cylichna
Drepanochilus
Ellipsoscapha
Tornatellaea
Baculites
Hoploscaphites
Nostoceras
Rhaeboceras
Solenoceras
Eomunidopsis
crab undet
ophiomorpha
fish scales

Second level above the Larimer Sandstone Member (Bubbles Lake Level)
Dysnoetopora
Lingual
Anomia
Aphrodina
Astarte
Cadulus
Crassatella
Crenella
Cuspidaria
Cymbophora
Cymella
Ethmocardium
Exogyra
Inoceramus
Leda
Legumen
Lima
Modiolus
Nemodon
Nucula
Nuculana
Nymphalucina
Opertochasma
Ostrea
Oxytoma
Pachymya
Pectin
Phelopteria
Pinna

Pseudoptera
Pteria
Pyropsis
Solemya
Tellina
Thetiopsis
Acteon
Akera
Anisomyon
Aporrhais
Atira
Bellifusus
Capulus
Cylichna
Drepanochilus
Ellipsoscapha
Fasciolaria
Gyrodes
Lomirosa
Nonacteonina
Polinices
Pyrifusus
Spironema
Tornatellaea
Turritella
Volutoderma
Eutrephoceras
Anaklinoceras
Baculites
Cirroceras
Hoploscaphites
Nostoceras
Rhaeboceras
Solenoceras
Eomunidopsis
crab
barnacle
fish bones and scales
mosasaur bone
undet. Dicotyledon fruit
bored wood

Third level above the Larimer Sandstone Member
Serpula
Anatine
Anomia
Cuspidaria
Cymbophora
Exogyra
Inoceramus
Legumen
Modiolus
Nucula
Nuculana
Ostrea
Oxytoma

Pachymya
Pectin
Pteria
Solemya
Tellina
Thetiopsis
Veniella
Anisomyon
Atira
Capulus
Drepanochilus
Fasciolaria
Pyropsis
Tornatellaea
Eutrephceras
Baculites
Hoploscaphites
Eomunidopsis
fish scales
bored wood

Unnamed Shaly Sandstone Member
Serpula
Dysnoetopora
Lingual
Anomia
Clisocolus
Cuspidaria
Cymbophora
Inoceramus
Limatula
Modiolus
Nemodon
Nucula
Nuculana
Nymphalucina
Ostrea
Oxytoma
Pectin
Periploma
Perrisonota
Phelopteria
Protocardia
Solemya
Tellina
cf. Tenuiptera
Atira
Drepanochilus
Dentalium
Anaklinoceras
Baculites
Hoploscaphites
Nostoceras
Rhaeboceras
Solenoceras
aptychus

crab
barnacle
fish remains
dicot fruit

Richard Sandstone Member
Baculites
Pseudobaculites
Rhaeboceras
Inoceramus
Drepanochilus

Unnamed Shale Member
worm burrow
Cymbophora
Inoceramus
Nymphalucina
Pteria
Phelopteria
Anisomyon
Polinices
Baculites
Hoploscaphites

Unnamed Sandstone Member
Cymbophora
Inoceramus
Phelopteria
Hoploscaphites
Palaeonephrops

Unnamed Upper Shale Member
pyriporoid bryozoan
Cymbophora
Inoceramus
Nymphalucina
Spyridoceramus
Goniomya
Baculites
Hoploscaphites

Upper Transition Member
Anatine
Astarte
Clisocolus
Crassostrea
Crenella
Cylichna
Cymbophora
Ethmocardium
Goniomya
Modiolus
Nemodon
Nonacteonina
Nucula

Malletia
Ostrea
Oxytoma
Pholadomya
Protocardia
Tancredia
Tellinimera
Thracia
Veniella
Drepanochilus
Polinices
Dentalium
Baculites
Discoscaphites
Hoploscaphites
Spenodiscus
fish bones

<u>Fox Hills Formation</u>

<u>Plants</u>

Conifer twig

<u>Invertebrates</u>

Class Porifera

Cliona

Class Bryozoa indet.

Bryozoa indet

Class Annelida

Annelida indet.

Class Bivalvia

Crassostrea

Anomia

Corbicula

Tellina

Tancredia

Cardium

Corbula

Gervillia

Pteria

Tancredia

Tellina

Yoldia

Dosiniopsis

Legumen

Mactra

Modiola

Ostrea

Thetis

Class Gastropoda

Melania

Acteon

Euspira

Piestochilus

Oligoptycha

Cancellaria

Lunatia

Anchura

Class Cephalopoda

Baculites

Discoscaphites

Class Scaphopoda

Dentalium

Class Scleractinia

Micrabacia

Vertebrates

Class Chondrichthyes

Chondrichthyes indet

Order Selachii

Selachii indet.

Family Isuridae

Lamna

Class Osteichthyes

Osteichthyes indet.

Class Reptilia

Dinosaur bone fragments

Order Chlonia

Chlonia indet.

Order Crocodilia

Crocodilia indet.

Class Mammalia

Order Multituberculata

Family Neoplagiaulacidae

Mesodma

Cimexomys

Family indet.

Bubodens

Family Cimolodontidae

Cimolodon

Family Cimolomyidae

Meniscoessus

Laramie Formation

Class Chondrichthyes

Order Batoidea

Family Dasyatidae

Myledaphus

Ptychotrygon

Order Selachii

Family Hybodontidae

Lonchidion

Family Orectolobidae

Squatirhina

Family Pristidae

Ischyrhiza

Class Osteichthyes

Osteichthyes indet.

Order Acipenseriformes

Family Acipenseridae

Acipenser

Order Amiiformes

Family Amiidae

Amia

Platacodon

Order Lepisosteiformes

Family Lepisosteidae

Lepisosteidae indet.

Atractosteus

Class Amphibia

Amphibia indet.

Order Caudata

Caudata indet.

Order Urodela

Family Batrachosauridae

Opisthotriton

Family Plethodontidae

Prodesmodon

Family Scapherpetodontidae

Scapherpetodontidae indet.

Scapherpeton

Lisserpeton

Class Reptilia

Subclass Diapsida

Order Ceratopsia

Family Ceratopsidae

Ceratopsidae indet.

Triceratops

Order Ornithopoda

Ornithopoda indet

Family Hadrosauridae

Hadrosauridae indet.

Anatosaurus

Hadrosaurus

Thescalosaurus

Edmontosaurus

Order Saurischia

Saurischia indet.

Order Sauropoda

Family Diplodocidae

Diplodocus

Order Theropoda

Family Coeluridae

Paronychodon

Family Dromaeosauridae

Dromaeosauridae indet.

Dromaeosaurus

Family Tyrannosauridae

Tyrannosauridae indet.

Tyrannosaurus

Order Squamata

Squamata indet.

Family Anguidae

Odaxosaurus

Pancelosaurus

Order Choristodera

Family Champsosauridae

Champsosauridae indet.

Champsosaurus

Order Crocodilia

Crocodilia indet.

Family Alligatoridae

Brachychampsa

Family Crocodylidae

Crocodylidae indet.

Leidyosuchus

Subclass Anapsida

Order Chelonia

Chelonia indet.

Family Trionychidae

Aspideretes

Family Baenidae

Baenidae indet.

Adocus

Baena

Family Dermatemydidae

Dermatemydidae indet.

Compsemys

Basilemys

Family Trionychidae

Trionychidae indet.

Aspideretes

Trionyx

Fossil plants

Sequoia longifolia

Tracheophyta indet.

Denver Formation

Class Osteichthyes

Order Lepisosteiformes

Family Lepisosteidae

Lepisosteidae indet.

Lepisosteus

Order Amiiformes

Family Amiidae

Amia

Class Reptilia

Subclass Diapsida

Order Choristodera

Family Champsosauridae

Champsosauridae indet.

Champsosaurus

Order Crocodilia

Crocodilia indet.

Family Alligatoridae

Allognathosuchus

Family Crocodylidae

Crocodylidae indet.

Akanthosuchus

Leidyosuchus

Suborder Ceratopsia

Family Ceratopsidae

Triceratops

Order Squamata

Squamata indet.

Family Anguidae

Odaxosaurus

Family Scincidae

Palaeoscincosaurus

Subclass Anapsida

Order Chelonia

Chelonia indet.

Family Baenidae

Baenidae indet.

Adocus

Palatobaena

Family Dermatemydidae

Compsemys

Hoplochelys

Family Trionychidae

Trionychidae indet.

Trionyx

Class Mammalia

Order Condylarthra

Condylarthra indet.

Family Arctocyonidae

Arctocyonidae indet.

Baioconodon

Desmatoclaenus

Loxolophus

Oxyclaenus

Oxyprimus

Protungulatum

Family Periptychidae

Periptychidae indet.

Alticonus

Ampliconus

Anisonchus

Carsioptychus

Conacodon

Ectoconus

Hemithlaeus

Oxyacodon

Periptychus

Tinuviel

Order Didelphodonta

Family Cimolestidae

Procerberus

Order Insectivora indet.

Order Leptictida

Family Leptictidae indet

Subclass Marsupialia

Family Didelphidae

Didelphidae indet

Thylacodon

Order Multituberculata

Family Neoplagiaulacidae

Neoplagiaulacidae indet.

Cimexomys

Mesodma

Xyronomys

Ptilodontidae

Kimbetohia

Family Taeniolabididae

Taeniolabididae indet.

Catopsalis

Fossil plants

Rhammus goldianus

Ficus affinis

Ficus praetrinervis

Populus zaddachii

Planatus

Sabalites

Hamamelacea indet.

fossil seed

APPENDIX E

COPIES OF STATE OF COLORADO PALEONTOLOGICAL PERMITS 2006-5 AND 2007-33

No. 2006-5

COLORADO
HISTORICAL
SOCIETY

The Colorado History Museum 1300 Broadway Denver, Colorado 80203-2137

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 David Daitch ,
(Project Paleontologists)

of: 4614 Lonespur Ct., Oceanside, CA 92056

representing: Rocky Mountain Paleontology

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, and the University of Colorado Museum-Boulder, CO

Other condition(s): ______

Issued this 9th day of January, 2006.

The Permit is valid through February 28, 2007.

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

Susan M. Collins
State Archaeologist of Colorado

Rev. 1/06

No. 2007-33

COLORADO HISTORICAL SOCIETY

The Colorado History Museum 1300 Broadway Denver, Colorado 80203-2137

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.*

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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 20th day of February, 2007.

The Permit is valid through February 29, 2008.

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

[signature]
State Archaeologist of Colorado

Rev. 12/06