PALEONTOLOGICAL TECHNICAL REPORT: 6th AVENUE AND WADSWORTH BOULEVARD INTERCHANGE PHASE II ENVIRONMENTAL ASSESSMENT, CITY OF LAKEWOOD, JEFFERSON COUNTY, COLORADO

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1.0 SUMMARY

The Colorado Department of Transportation, in cooperation with the Federal Highway Administration, is proposing transportation improvements to the 6th Avenue (U.S. Highway 6) and Wadsworth Boulevard interchange in order to address local and regional transportation needs. This paleontological resources assessment is an evaluation of potential impacts on scientifically significant non-renewable paleontological resources which could result from ground disturbance within the study area for the 6th Avenue and Wadsworth Boulevard Interchange Phase II Environmental Assessment (EA). The study area is located on the USGS Fort Logan 7.5' Topographic Quadrangle within sections 2, 3, 10, and 11, T. 4 S., R. 69 W. (Sixth Principal Meridian), in the City of Lakewood, Jefferson County, Colorado (see Figure 1). Details regarding the depth and lateral of ground disturbance within the study area were unavailable at the time of this analysis. However, potential impacts to both surface and subsurface on paleontological resources are evaluated in this report.

The paleontological sensitivities of the geologic units within the study area were evaluated by reviewing the scientific literature, geologic mapping and museum records. Based on the geologic mapping of Lindvall (1978) and Trimble and Machette (1979), the study area contains five geologic units. These include, from oldest to youngest and in approximate ascending stratigraphic order, late Cretaceous-age rocks of the Denver Formation, Pleistocene-age Verdos Alluvium (lower terrace or pediment deposit), Holocene- and Pleistocene-age loess, Holocene-age Piney Creek Alluvium, and recent imported artificial fill. The Denver Formation contains locally abundant and well-preserved fossil plants, and less common but scientifically important fossil vertebrates, and is considered to have high paleontological sensitivity (PFYC Class 5). Pleistocene-age alluvium and loess deposits are known to contain fossils in Colorado, but because fossils are uncommon in these types of sediments, they are considered to have low paleontological sensitivity (PFYC Class 3a). Holocene-age loess, alluvium and artificial fill are too young to contain in-situ fossils, and have low paleontological sensitivity (PFYC Class 2) (see Table 2).

No fossils were observed within the study area during the field survey, no reports of fossils from within the study area were found in the literature reviewed for this study, and no records of fossils from within the study area were found during the museum record searches conducted for this study. However, there are numerous reports of fossils from the Denver Formation and Pleistocene-age surficial deposits in the scientific and technical literature, and numerous recorded museum localities from the Denver area.

Although thicknesses of low sensitivity Pleistocene- and Holocene-age surficial deposits in the vicinity of the project are highly variable (Lindvall, 1978), the fact that high sensitivity Denver Formation is mapped at the surface just to the southwest of the study area suggests that it is not deeply buried within the study area, and could be impacted by construction excavations associated with the proposed interchange improvements. When the project design plans are finalized, the CDOT Staff Paleontologist should examine them and determine the extent of impact to bedrock Denver Formation, and the scope of paleontological monitoring, if any, which is required. If any sub-surface bones or other potential fossils are found anywhere within the study area during ground disturbance, the CDOT Staff Paleontologist should be notified immediately to assess their significance and make further recommendations.

2.0 INTRODUCTION

The Colorado Department of Transportation, in cooperation with the Federal Highway Administration, is proposing transportation improvements to the 6th Avenue (U.S. Highway 6) and Wadsworth Boulevard interchange in order to address local and regional transportation needs. This paleontological resources assessment is an evaluation of potential impacts on scientifically significant non-renewable paleontological resources which could result from ground disturbance within the study area for the 6th Avenue and Wadsworth Boulevard Interchange Phase II Environmental Assessment (EA), located in the City of Lakewood, Jefferson County, Colorado (Figure 1). No specific details regarding the depth and geographic extent of anticipated ground disturbance within the study area were available at the time of this analysis. Therefore, potential adverse impacts on both surface and subsurface impacts are evaluated in this report. Geologically, the study area is underlain by late Cretaceous-age rocks of the Denver Formation, Pleistocene-age Verdos Alluvium (lower terrace or pediment deposit), Holocene- and Pleistocene-age loess, Holocene-age Piney Creek Alluvium, and recent imported artificial fill. The Denver Formation, Verdos Alluvium, and Pleistocene-age loess deposits are known to contain scientifically significant fossil remains of varying preservation, taxonomic affinity, abundance, and scientific significance.

2.1 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 (Murphey and Daitch, 2007). 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 (Murphey and Daitch, 2007).

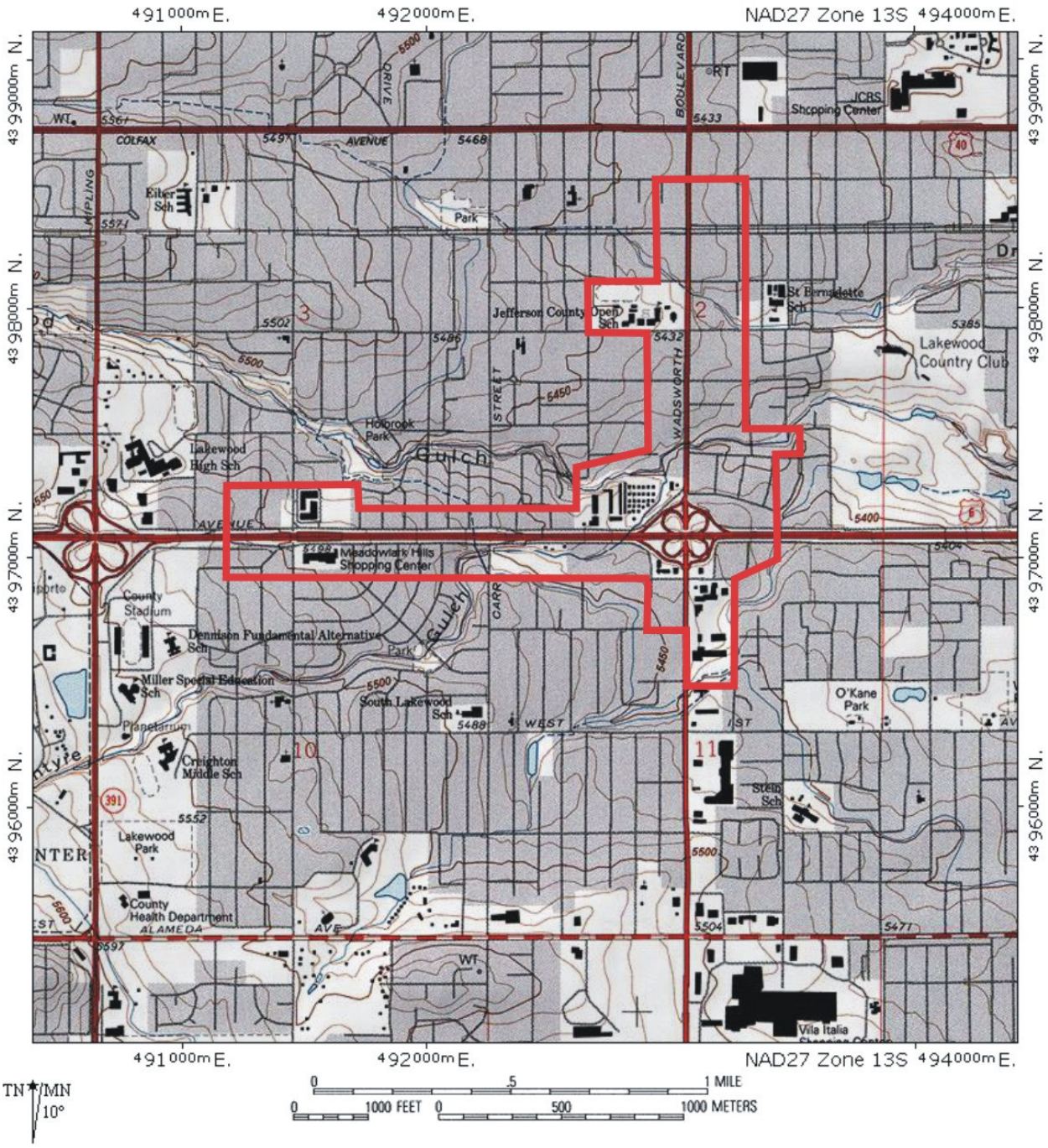

Figure 1. Location map showing the approximate boundaries of the paleontological study area for the 6th Avenue and Wadsworth Boulevard Interchange EA in red (Base map: USGS Fort Logan 7.5' Topographic Quadrangle).

3.0 METHODS

The purpose of this study is to evaluate the paleontological sensitivity of the geologic units within the study area for the 6th Avenue and Wadsworth Boulevard Interchange EA by researching their known fossil potential and paleontological significance, and by determining the number and significance of fossil localities within the study area and elsewhere in the same geologic units. The scope of the study included a review of relevant scientific literature, geologic maps, museum records, and a field survey. The museums included in the record search were the Denver Museum of Nature and Science (DMNS) and the University of Colorado Museum of Natural History (UCM). The paleontological evaluation procedures for this study were conducted in accordance with SVP (1995) guidelines by qualified and permitted paleontologists (State of Colorado Paleontological Permit 2007-33). This study was conducted at the request of TEC Inc., Golden, Colorado.

The study area is located on the USGS Fort Logan 7.5' Topographic Quadrangle within sections 2, 3, 10, and 11, T. 4 S., R. 69 W. (Sixth Principal Meridian), in the City of Lakewood, Jefferson County, Colorado (see Figure 1).

The field survey for this study was conducted on January 6 and 7, 2008, and consisted of an inspection of the study area for 1) surface fossils; 2) exposures of potentially fossiliferous rock; and 3) areas in which fossiliferous rocks or younger potentially fossiliferous surficial deposits could be exposed or otherwise impacted during construction-related ground disturbance.

For paleontological surveys in general, areas where geologic units of moderate and high paleontological sensitivity are exposed are subject to a 100% pedestrian inspection; areas with exposures of low sensitivity deposits are spot-checked; and areas with no paleontological sensitivity are not inspected. If the geology of an area is uncertain, it is subject to a 100% pedestrian inspection. For this study, all portions of the study area that were not covered by pavement or existing construction were subject to a 100% pedestrian inspection.

4.0. LAWS, ORDINANCES, REGULATIONS AND STANDARDS

Fossils are classified as non-renewable scientific resources and are protected by various laws, ordinances, regulations and standards (LORS) across the country. Professional standards for the assessment and mitigation of adverse impacts to paleontological resources have been established by the Society of Vertebrate Paleontology (SVP) (1995, 1996). This paleontological study was conducted in accordance with the LORS which are applicable to paleontological resources within the study area for the 6th Avenue and Wadsworth Boulevard Interchange EA (see Table 1). 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 Management and Policy 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 eight federal agencies including the Bureau of Indian Affairs, the BLM, the Bureau of Reclamation, the United States Fish and Wildlife Service, the United States Forest Service, 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. Because this project is partially funded by the FHWA, Federal protections under NEPA apply to paleontological resources within the study area for the 6th Avenue and Wadsworth Boulevard Interchange EA.

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 study will be reviewed by the CDOT because the CDOT is a cooperating agency for this project, and must fulfill FHWA's NEPA requirements.

4.3. County

There are no Jefferson County LORS that specifically address potential adverse impacts on paleontological resources. Therefore, no county-level protections of paleontological resources pertain to the 6th Avenue and Wadsworth Boulevard Interchange EA.

4.4. City

There are no City of Lakewood LORS that specifically address potential adverse impacts on paleontological resources. Therefore, no city-level protections of paleontological resources pertain to the 6th Avenue and Wadsworth Boulevard Interchange EA.

4.5 Private Lands

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

Table 1. Summary of paleontological laws, ordinances, regulations and standards applicable to the 6th Avenue and Wadsworth Boulevard Interchange EA.

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 or other state agency, 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 or other state agency, including review and approval the final mitigation report. All fossils collected during mitigation would be required to be housed in an approved repository such as the DMNS or UCM, 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 6th Avenue and Wadsworth Boulevard Interchange EA was evaluated using the Potential Fossil Yield Classification system. This PFYC system was originally developed by the Forest Service's Paleontology Center of Excellence and the Region 2 Paleontology Initiative in 1996. Modifications have been made by the BLM's Paleontological Resources staff in subsequent years. The PFYC version used for this analysis was recently approved as policy by the BLM (IM 2008-009). This classification system is summarized below:

5.1 Potential Fossil Yield Classification

Occurrences of paleontological resources are closely tied to the geologic units (i.e., formations, members, or beds) that contain them. The probability for finding paleontological resources can be broadly predicted from the geologic units present at or near the surface. Therefore, geologic mapping can be used for assessing the potential for the occurrence of paleontological resources.

Using the Potential Fossil Yield Classification (PFYC) system, geologic units are classified based on the relative abundance of vertebrate fossils or scientifically significant invertebrate or plant fossils and their sensitivity to adverse impacts, with a higher class number indicating a higher potential. This classification is applied to the geologic formation, member, or other distinguishable unit, preferably at the most detailed mappable level. It is not intended to be applied to specific paleontological localities or small areas within units. Although significant localities may occasionally occur in a geologic unit, a few widely scattered important fossils or localities do not necessarily indicate a higher class; instead, the relative abundance of significant localities is intended to be the major determinant for the class assignment.

The PFYC system is meant to provide baseline guidance for predicting, assessing, and mitigating paleontological resources. The classification should be considered at an intermediate point in the analysis, and should be used to assist in determining the need for further mitigation assessment or actions.

The descriptions for the classes below are written to serve as guidelines rather than as strict definitions. Knowledge of the geology and the paleontological potential for individual units or preservational conditions should be considered when determining the appropriate class assignment. Assignments are best made by collaboration between land managers and knowledgeable researchers.

Class 1 – **Very Low**. Geologic units that are not likely to contain recognizable fossil remains.

- Units that are igneous or metamorphic, excluding reworked volcanic ash units.
- Units that are Precambrian in age or older.

(1) Management concern for paleontological resources in Class 1 units is usually negligible or not applicable.

(2) Assessment or mitigation is usually unnecessary except in very rare or isolated circumstances.

The probability for impacting any fossils is negligible. Assessment or mitigation of paleontological resources is usually unnecessary. The occurrence of significant fossils is non-existent or extremely rare.

Class 2 – **Low**. Sedimentary geologic units that are not likely to contain vertebrate fossils or scientifically significant nonvertebrate fossils.

- Vertebrate or significant invertebrate or plant fossils not present or very rare.
- Units that are generally younger than 10,000 years before present.
- Recent aeolian deposits.
- Sediments that exhibit significant physical and chemical changes (i.e., diagenetic alteration).

(1) Management concern for paleontological resources is generally low.

(2) Assessment or mitigation is usually unnecessary except in rare or isolated circumstances.

The probability for impacting vertebrate fossils or scientifically significant invertebrate or plant fossils is low. Assessment or mitigation of paleontological resources is not likely to be necessary. Localities containing important resources may exist, but would be rare and would not influence the classification. These important localities would be managed on a case-by-case basis.

Class 3 – **Moderate** or **Unknown**. Fossiliferous sedimentary geologic units where fossil content varies in significance, abundance, and predictable occurrence; or sedimentary units of unknown fossil potential.

- Often marine in origin with sporadic known occurrences of vertebrate fossils.
- Vertebrate fossils and scientifically significant invertebrate or plant fossils known to occur intermittently; predictability known to be low.

(or)

- Poorly studied and/or poorly documented. Potential yield cannot be assigned without ground reconnaissance.

Class 3a – **Moderate Potential.** Units that are known to contain vertebrate fossils or scientifically significant nonvertebrate fossils, but these occurrences are widely scattered. Common invertebrate or plant fossils may be found in the area, and opportunities may exist for hobby collecting. The potential for a project to be sited on or impact a significant fossil locality is low, but is somewhat higher for common fossils.

Class 3b – **Unknown Potential.** Units exhibit geologic features and preservational conditions that suggest significant fossils could be present, but little information about the paleontological resources of the unit or the area is known. This may indicate the unit or area is poorly studied, and field surveys may uncover significant finds. The units in this Class may eventually be placed in another Class when sufficient survey and research is performed. The unknown potential of the units in this Class should be carefully considered when developing any mitigation or management actions.

(1) Management concern for paleontological resources is moderate; or cannot be determined from existing data.

(2) Surface-disturbing activities may require field assessment to determine appropriate course of action.

This classification includes a broad range of paleontological potential. It includes geologic units of unknown potential, as well as units of moderate or infrequent occurrence of significant fossils.

Management considerations cover a broad range of options as well, and could include pre-disturbance surveys, monitoring, or avoidance. Surface-disturbing activities will require sufficient assessment to determine whether significant paleontological resources occur in the area of a proposed action, and whether the action could affect the paleontological resources. These units may contain areas that would be appropriate to designate as hobby collection areas due to the higher occurrence of common fossils and a lower concern about affecting significant paleontological resources.

Class 4 – **High**. Geologic units containing a high occurrence of significant fossils. Vertebrate fossils or scientifically significant invertebrate or plant fossils are known to occur and have been documented, but may vary in occurrence and predictability. Surface disturbing activities may adversely affect paleontological resources in many cases.

Class 4a – Unit is exposed with little or no soil or vegetative cover. Outcrop areas are extensive with exposed bedrock areas often larger than two acres. Paleontological resources may be susceptible to adverse impacts from surface disturbing actions. Illegal collecting activities may impact some areas.

Class 4b – These are areas underlain by geologic units with high potential but have lowered risks of human-caused adverse impacts and/or lowered risk of natural degradation due to moderating circumstances. The bedrock unit has high potential, but a protective layer of soil, thin alluvial material, or other conditions may lessen or prevent potential impacts to the bedrock resulting from the activity.

- Extensive soil or vegetative cover; bedrock exposures are limited or not expected to be impacted.
- Areas of exposed outcrop are smaller than two contiguous acres.
- Outcrops form cliffs of sufficient height and slope so that impacts are minimized by topographic conditions.
- Other characteristics are present that lower the vulnerability of both known and unidentified paleontological resources.

(1) Management concern for paleontological resources in Class 4 is moderate to high, depending on the proposed action.

(2) A field survey by a qualified paleontologist is often needed to assess local conditions.

(3) Management prescriptions for resource preservation and conservation through controlled access or special management designation should be considered.

(4) Class 4 and Class 5 units may be combined as Class 5 for broad applications, such as planning efforts or preliminary assessments, when geologic mapping at an appropriate scale is not available. Resource assessment, mitigation, and other management considerations are similar at this level of analysis, and impacts and alternatives can be addressed at a level appropriate to the application.

The probability for impacting significant paleontological resources is moderate to high, and is dependent on the proposed action. Mitigation considerations 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 can be anticipated, on-the-ground surveys prior to authorizing the surface disturbing action will usually be necessary. On-site monitoring or spot-checking may be necessary during construction activities.

Class 5 – **Very High**. Highly fossiliferous geologic units that consistently and predictably produce vertebrate fossils or scientifically significant invertebrate or plant fossils, and that are at risk of human-caused adverse impacts or natural degradation.

Class 5a – Unit is exposed with little or no soil or vegetative cover. Outcrop areas are extensive with exposed bedrock areas often larger than two contiguous acres. Paleontological resources are highly susceptible to adverse impacts from surface disturbing actions. Unit is frequently the focus of illegal collecting activities.

Class 5b – These are areas underlain by geologic units with very high potential but have lowered risks of human-caused adverse impacts and/or lowered risk of natural degradation due to moderating circumstances. The bedrock unit has very high potential, but a protective layer of soil, thin alluvial material, or other conditions may lessen or prevent potential impacts to the bedrock resulting from the activity.

- Extensive soil or vegetative cover; bedrock exposures are limited or not expected to be impacted.
- Areas of exposed outcrop are smaller than two contiguous acres.
- Outcrops form cliffs of sufficient height and slope so that impacts are minimized by topographic conditions.
- Other characteristics are present that lower the vulnerability of both known and unidentified paleontological resources.

(1) Management concern for paleontological resources in Class 5 areas is high to very high.

(2) A field survey by a qualified paleontologist is usually necessary prior to surface disturbing activities or land tenure adjustments. Mitigation will often be necessary before and/or during these actions.

(3) Official designation of areas of avoidance, special interest, and concern may be appropriate.

The probability for impacting significant fossils is high. Vertebrate fossils or scientifically significant invertebrate fossils are known or can reasonably be expected to occur in the impacted area. On-the-ground surveys prior to authorizing any surface disturbing activities will usually be necessary. On-site monitoring may be necessary during construction activities.

6.0 PALEONTOLOGICAL RESOURCE ASSESSMENT

According to the geologic mapping of Lindvall (1978) and Trimble and Machette (1979), ground disturbance associated with construction activities within the study area for the 6th Avenue and Wadsworth Boulevard Interchange EA has the potential to impact five mapped geologic units. These include, from approximately oldest to youngest, and in approximate ascending stratigraphic order, late Cretaceous-age rocks of the Denver Formation, Pleistocene-age Verdos Alluvium (lower terrace or pediment deposit), Holocene- and Pleistocene-age loess, Holocene-age Piney Creek Alluvium, and recent imported artificial fill.

The paleontological sensitivity of all geologic units within the study area was evaluated using the recently revised PFYC, which was presented in Section 5.1. The results are summarized in Table 2. The geology and paleontology of the potentially affected geologic units is discussed in Section 7.0. The Denver Formation contains locally abundant and well-preserved fossil plants, and less common but scientifically important fossil vertebrates (primarily reptiles and mammals), and is considered to have high paleontological sensitivity (PFYC Class 5). Pleistocene-age alluvium and loess deposits are known to contain widely scattered and typically poorly preserved vertebrate, invertebrate and/or plant fossils in Colorado, but because significant fossils are uncommon in these units, they are considered to have low paleontological sensitivity (PFYC Class 3a). Holocene-age loess, alluvium and artificial fill contain the unfossilized remains of modern species of animals and plants, and are too young to contain in-situ fossils. These units have low paleontological sensitivity (PFYC Class 2) (see Table 2).

Table 2. Summarized paleontological sensitivities of geologic units within the study area for the 6th Avenue and Wadsworth Boulevard Interchange EA using the Potential Fossil Yield Classification System (map abbreviations and ages of units are from Lindvall (1978).

Geologic Unit	**Map Abbreviation**	**Age**	**Typical Fossils**	**PFYC**
Artificial Fill	af	Recent	No in-situ fossils	*Class* 2
Piney Creek Alluvium	Qp	Holocene	Contains unfossilized remains of modern species of animals and plants; no in-situ fossils	*Class* 2
Loess	Ql	Holocene	Uncommon vertebrate (mammal) bones	*Class* 2
Loess	Ql	Pleistocene	Uncommon vertebrate (mammal) bones	*Class* 3a
Verdos Alluvium (lower terrace or pediment deposit)	Qvl	Pleistocene	Generally uncommon occurrences of mostly poorly preserved vertebrates, invertebrates, and plants	*Class* 3a
Denver Formation	TKda	Late Cretaceous, *Paleocene (D1), *Eocene (D2)	Locally abundant and diverse plants, less common vertebrates (reptiles, mammals) and invertebrates	*Class* 5

*Denver Formation within the 6th Avenue and Wadsworth Boulevard Interchange EA is believed to be late Cretaceous in age

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 leading 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; the development of grassland savannah ecosystems during the Oligocene and Miocene; and the glacial and interglacial climates, environments and megafaunas of 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 Geology and Paleontology

On the basis of the geologic mapping of Lindvall (1978) and Trimble and Machette (1979), the study area contains five geologic units, in approximate ascending stratigraphic order: late Cretaceous-age rocks of the Denver Formation, Pleistocene-age Verdos Alluvium (lower terrace or pediment deposit), Pleistocene- and Holocene-age loess, Holocene-age Piney Creek Alluvium, and recent imported artificial fill. The following is a general discussion of the geology and paleontology of these units.

7.2.1 Denver Formation

Of synorogenic origin, 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; 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 study area for the 6th Avenue and Wadsworth Boulevard Interchange EA, the Denver Formation is believed to be of late Cretaceous age based on topography, superpositional relationships, Cretaceous-age plant fossils that have been recovered from localities along I-25 several miles to the east, and the elevation of the Cretaceous-Tertiary boundary on North Table Mountain and South Table Mountain to the west.

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 (the famous 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 which 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). The surficial distribution of the Denver Formation within the study area is shown in Figure 2 (TKda).

7.2.2 Verdos Alluvium

The Pleistocene (Kansan) Verdos Alluvium consists of light brown to reddish-brown poorly sorted stratified gravel containing lenses of clay, silt and sand, with larger and more abundant boulders near the mountains (Lindvall, 1979). Clasts are mostly weathered and coated with calcium carbonate (Lindvall, 1978; Scott, 1972). It is as much as 30 feet thick, and contains a 2 to 4 feet thick calcium

carbonate enriched zone (relict soil) near its top. As mapped within the study area, the lower Verdos terrace or pediment deposit is described as having an elevation of approximately 180 to 200 feet above modern major stream drainages. Locally, the Verdos Alluvium contains thin beds of white volcanic ash, and has been dated at approximately 600,000 years old based on its correlation with the Pearlette Ash of Kansas (Scott, 1963).

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; unpublished paleontological data, University of Colorado Museum). In the Verdos Alluvium specifically, fossils are uncommon. Fossil specimens identified as horse and camel have been discovered in the Verdos Alluvium in eastern Colorado (Scott, 1978; unpublished USGS fossil locality data). Like other sedimentary deposits of Pleistocene-age in Colorado, the Verdos Alluvium is considered to have low paleontological sensitivity (PFYC Class 3a). The distribution of Verdos Alluvium within the study area is shown in Figure 2 (Qvl).

7.2.3 Loess Deposits

Loess deposits described as Pleistocene to Holocene age occur within the study area, and are common in eastern Colorado, consisting of windblown sand and silt. In the study area vicinity, loess deposits consist of yellowish-brown to light-grayish brown sandy silt, with clay and silty clay in the upper 2 to 4 feet. These sediments range in thickness from 10 to 25 feet (Lindvall, 1978, 1979). Although fossils are uncommon in Pleistocene-age loess, fossil horse and camel bones have been collected south of Littleton, Colorado (Scott, 1963). The CDOT staff paleontologist has documented a much more diverse fauna from Pleistocene loess deposits in eastern Colorado which includes badger, cottontail, jackrabbit, black-tailed prairie dog, the extinct white-tailed prairie dog, Richardsons ground squirrel, pocket gopher, vole, sagebrush vole, field mouse, and possibly Bison (Steven Wallace, CDOT, written communication, 2000). Hunt (1954, p. 111) documents additional fossils including mammoth and camel that were discovered in eolian deposits in the Denver area. Because fossils are uncommon in loess, these deposits are considered to have low paleontological sensitivity (PFYC Class 3a). Holocene-age loess deposits contain the unfossilized remains of modern species of animals and plants, are too young to contain in-situ fossils, and also have low paleontological sensitivity (PFYC Class 2). The distribution of loess deposits within the study area is shown in Figure 2 (Ql).

7.2.4 Piney Creek Alluvium

Holocene-age Piney Creek Alluvium consists of brown, light brown, and light to dark gray interbedded sand, silt and clay. Humic material is common in its upper 2 feet, and it contains interbedded gravel in its lower part. The Piney Creek Alluvium is typically 5 to 10 feet thick (Lindvall, 1978, 1979; Trimble and Machette, 1979). Although it contains animal and plant remains, these are the unfossilized remains of modern species, and deposits of Holocene age are considered too young to contain in-situ fossils. As such, the Piney Creek Alluvium has low paleontological sensitivity (PFYC Class 2). The distribution of Piney Creek Alluvium within the study area is shown in Figure 2 (Qp).

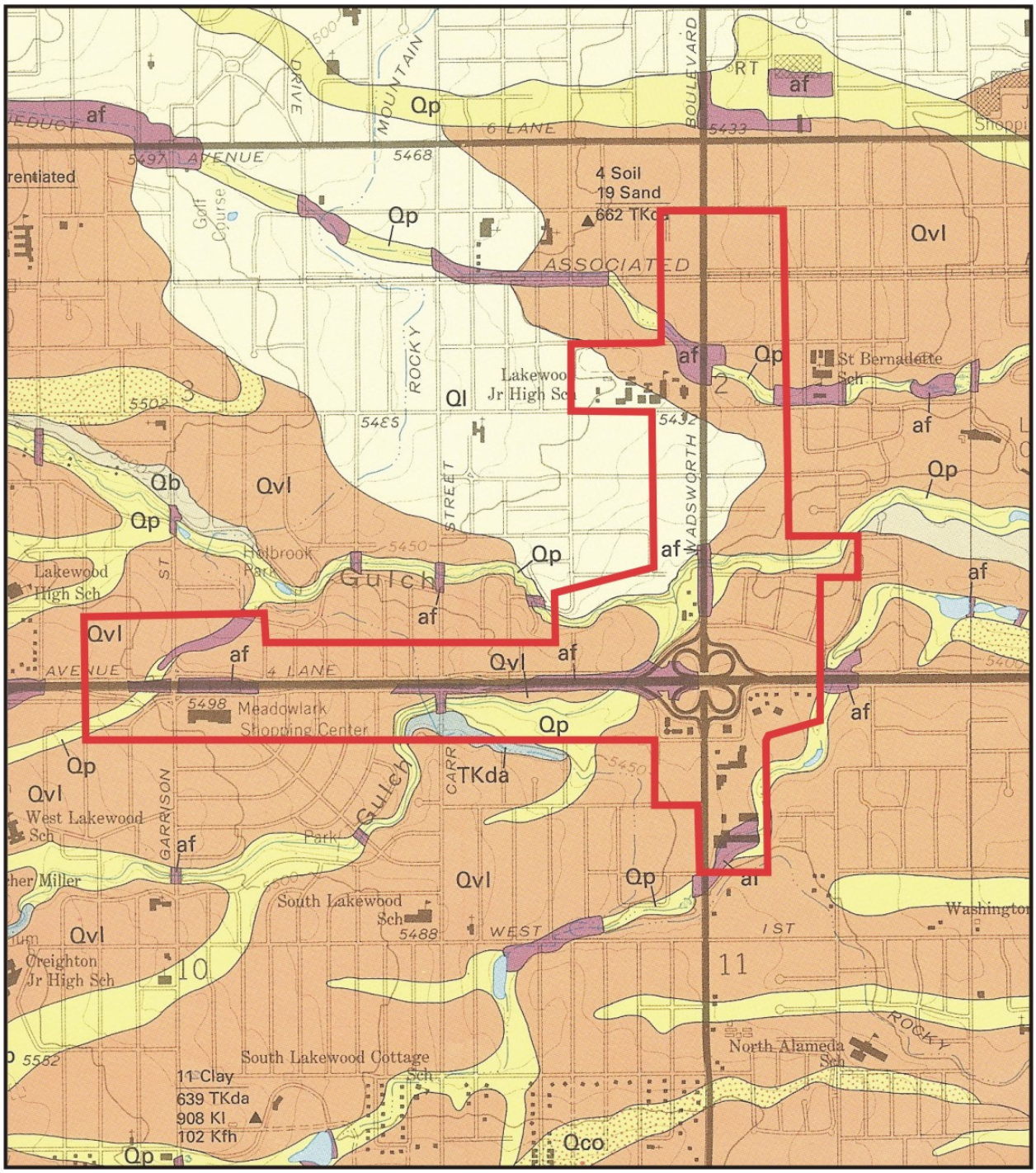

Figure 2. Geologic map of the study area for the 6th Avenue and Wadsworth Boulevard Interchange EA (from Lindvall, 1978). The approximate study area boundaries are shown in red.

7.2.5 Artificial Fill

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, 1978, 1979; Shroba, 1980; Trimble and Machette, 1979). Although imported fill is known to 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. Artificial fill within the NW Corridor APE has low paleontological sensitivity (PFYC Class 2). The distribution of artificial fill within the study area is shown in Figure 2 (af).

7.3 Museum Record and Literature Locality Searches

Because paleontological locality data are confidential and are exempt from the Freedom of Information Act, only general fossil locality information is provided in this report.

The paleontological sensitivity of the Denver Formation is exemplified by the large number and taxonomic diversity of fossils which have been collected from it. The UCM has over 600 vertebrate fossils from 59 localities in the Denver Formation from around the Denver Basin. The DMNS has fewer fossil vertebrates, but maintains a large and growing collection of Denver Formation fossil plants consisting of thousands of fossils from over 150 recorded fossil localities, and has an active stratigraphic and paleobotanical research program.

Cannon (1906) made reference to dinosaur fossils which he collected in 1887 from what is now known as the Denver Formation. These include the famous type specimen of *Bison alticornis* originally described by O.C. Marsh (1887), which consists of a pair of supraorbital horn cores (USNM specimen # 4739) which Marsh originally misidentified as belonging to an extinct species of Pleistocene bison, but that he later correctly re-identified as a Cretaceous-age ceratopsian dinosaur (*Triceratops alticornis*). Cannon (1906) questioned the accuracy of locality information printed on labels of specimens he had collected from near Denver which were then housed at the USNM that he had sent to O.C. Marsh for study, including the data for the horn cores. The USNM database does presently list the specimen as being collected from the Denver Formation "near Denver," Colorado. The CDOT staff paleontologist has researched the provenance of the famous *Bison alticornis* discovery, and his findings indicate that the specimen was collected from along Lakewood Gulch about half way between Federal and Sheridan boulevards on land that now belongs to Denver Parks (Steve Wallace, CDOT, written communication, 2006).

Both the UCM and DMNS have numerous recorded fossil localities in sedimentary deposits of Pleistocene-age in Colorado. Additionally, published reports exemplify the potential for sedimentary deposits of Pleistocene-age to contain significant vertebrate fossils in the Denver area. For example, C.B. Hunt reported that more than 100 "collections" of Pleistocene and recent mammal remains were made during the field work for his 1954 study, with an additional 32 in the collections of the Denver Museum of Natural History (now DMNS). These were mostly collected from alluvium (Hunt, 1954, p. 118), and he notes that practically all consisted of "single bones, and a large proportion of them are fragmentary." Hunt's report attests to the mostly isolated nature of Pleistocene skeletal remains in the Denver area. Scott (1978) published a report of fossils from approximately 1.5 miles to the

southwest of the study area at the intersection of Alameda Avenue and Kipling Street. These included fragments of a camel vertebra from the Verdos Alluvium found in the southeast quadrant of the intersection (USGS fossil locality D778). Hunt (1954, p. 107) lists other fossils discovered in Pleistocene-age alluvium in the general vicinity of the study area west of the South Platte River. These were identified by paleontologist C.L. Gazin of the U.S. National Museum, and include camel bones from 8th Avenue and Federal Boulevard, bison teeth and bones from Lakewood Gulch 800 feet east of Sheridan Boulevard, camel bones from Weir Gulch between 8th Avenue and Alameda Avenue, bison teeth and bones from Weir Gulch at 3rd Avenue and Federal Boulevard, and bison and antelope remains from Weir Gulch 800 feet south of Alameda Avenue. Additionally, Hunt (1954) reported fossils of mammal and camel that were collected from Pleistocene-age eolian deposits at five localities in the Denver area.

In combination, the numerous recorded paleontological localities that have been discovered in the Denver Formation and Pleistocene-age surficial deposits in the Denver Basin attest to the potential for these deposits to contain scientifically significant fossil remains within the study area for the 6th Avenue and Wadsworth Boulevard Interchange EA. The differing paleontological sensitivity of these units is indicative of differing fossil abundances, types and ages of fossils, and the typical quality of fossil preservation (see Table 2).

7.4 Field Survey

No fossils or exposures of fossiliferous Denver Formation bedrock were observed within the study area. The surface of the study area is entirely vegetated or covered with existing roadway, residential, and commercial construction (figures 3 and 5). It is possible that exposures of bedrock occur along the banks of Lakewood Gulch within the study area (figures 4 and 6). However, the presence of such exposures was impossible to ascertain due to thick vegetation obscuring the sides of the stream banks and ice cover.

At the time of this analysis, no details were available regarding the depth and lateral extent of ground disturbance resulting from excavations for the proposed interchange improvements. However, potential adverse impacts to scientifically significant paleontological resources are possible wherever high sensitivity bedrock Denver Formation and low sensitivity sediments of Pleistocene-age Verdos Alluvium or Pleistocene-age loess are disturbed. Additionally, fossiliferous Denver Formation underlies the entire project area at an unknown depth. Lindvall (1978) reported the depth of the top of the Denver Formation at six locations approximately 1-2 miles from the study area as 100 feet, 23 feet, 7 feet, 39 feet, 40 feet, and 11 feet. Thus, the thickness of surficial sediments in the vicinity of the area is highly variable. Nevertheless, the fact that high sensitivity Denver Formation is mapped at the surface just to the southwest of the study area (see Figure 2, Tkda) suggests that it is not deeply buried within the study area, and could be impacted by construction excavations associated with the proposed interchange improvements.

Figure 3. View looking north along Wadsworth Boulevard from 2nd Avenue.

Figure 4. View looking northeast at a southern tributary of Lakewood Gulch north of 6th Avenue towards Wadsworth Boulevard.

Figure 5. View looking east northeast at the 6th Avenue and Wadsworth Boulevard Interchange.

Figure 6. View looking southwest at a southern tributary of Lakewood Gulch on the south side of 6th Avenue west of Wadsworth Boulevard.

8.0 RECOMMENDATIONS

1) Based on the results of this study, immediate paleontological clearance for the surface of the study area is recommended.

2) When the project design plans are finalized, the CDOT Staff Paleontologist should examine them and determine the extent of impact to bedrock Denver Formation, and the scope of paleontological monitoring, if any, which is required.

3) If any sub-surface bones or other potential fossils are found anywhere within the study area during construction, the CDOT Staff Paleontologist should be notified immediately to assess their significance and make further mitigation recommendations.

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