RECLAMATION

Managing Water in the West

Windy Gap Firming Project

Geology and Soils Technical Report

U.S. Department of the Interior
Bureau of Reclamation
Great Plains Region

October 2006

Geology and Soils Technical Report

Windy Gap Firming Project

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1.0 INTRODUCTION

The Municipal Subdistrict, Northern Colorado Water Conservancy District, acting by and through the Windy Gap Firming Project Water Activity Enterprise (Subdistrict), the Project proponent, is proposing to improve the firm yield from the existing Windy Gap Project water supply by constructing the Windy Gap Firming Project (WGFP). For more information on the background and purpose of the WGFP, see the Windy Gap Firming Project Purpose and Need Report (ERO Resources 2005a). This technical report was prepared to address the potential environmental effects on geology and soil resources associated with the alternatives described below and will be used in the preparation of the EIS.

2.0 ALTERNATIVES

The Windy Gap Firming Project Alternatives Report (ERO Resources 2005b) identified four action alternatives in addition to the No Action alternative for evaluation in the EIS. All action alternatives include development of 90,000 AF of new storage in either a single reservoir on the East Slope, or a combination of East Slope and West Slope reservoirs. The Subdistrict's Proposed Action is the construction of a 90,000 AF Chimney Hollow Reservoir with prepositioning. The alternatives are—

- Alternative 1 (No Action) – Enlarge Ralph Price Reservoir
- Alternative 2 (Proposed Action) – Chimney Hollow Reservoir (90,000 AF) with prepositioning
- Alternative 3 – Chimney Hollow Reservoir (70,000 AF) and Jasper East Reservoir (20,000 AF)
- Alternative 4 – Chimney Hollow Reservoir (70,000 AF) and Rockwell/Mueller Creek Reservoir (20,000 AF)
- Alternative 5 – Dry Creek Reservoir (60,000 AF) and Rockwell/Mueller Creek Reservoir (30,000 AF)

In addition to the action alternatives, a No Action alternative was identified based on what is reasonably likely to occur if the U.S. Bureau of Reclamation (Reclamation) does not approve a permit to connect new Windy Gap Firming Project facilities to Colorado-Big Thompson (C-BT) facilities. Under this alternative, all Project Participants in the near term would maximize delivery of Windy Gap water according to their demand, Windy Gap water rights, and C BT facility capacity constraints including availability of storage space in Lake Granby, and the Adams Tunnel conveyance constraints. The City of Longmont is the only Participant that currently has an option to develop storage independently for firming Windy Gap water if the WGFP is not implemented. Most Participants indicate that, in the long term, they would seek other storage options, individually or jointly, to firm Windy Gap water because of their need for reliable Windy Gap deliveries and the substantial investment in existing infrastructure.

Detailed descriptions of the components and operation of the alternatives are included in the Windy Gap EIS Alternatives Descriptions Report (Boyle Engineering 2005b).

3.0 STUDY AREAS

The study area for assessing potential effects to geology, paleontology, and soil resources included the projected areas of physical disturbance associated with each alternative. This includes reservoir and dam locations, as well as other permanent and temporary facilities such as pipelines, roads, transmission lines, pump stations, borrow areas for construction materials, and construction staging areas.

3.1. Ralph Price Reservoir Study Area

Ralph Price Reservoir (Button Rock Dam) is located on North St. Vrain Creek, west of the town of Lyons in Boulder County in Sections 17, 18, 19, and 20, T3N, R70W in the Lyons, Colorado USGS Quadrangle (Figure 1) at an elevation of about 6,500 feet. Currently, the reservoir has a storage capacity of about 16,000 AF. The study area for the enlargement of Ralph Price Reservoir includes the potential area of additional inundation surrounding the reservoir including an enlarged dam, new spillway, and possible borrow areas that could provide material for dam enlargement. No new pipelines or other infrastructure is needed. The study area consists mostly of a mixture of ponderosa pine and Douglas-fir forest. North St. Vrain Creek, which flows into the reservoir from the west, is the primary source of water to the reservoir. Other small drainages, including Rattlesnake Gulch from the north and Long Gulch from the south, flow into the reservoir.

3.2. Chimney Hollow Study Area

The Chimney Hollow study area is in Larimer County in Section 33, T5N, R70W and Sections 4, 5, and 9 of T4N, R70W in the Carter Lake Reservoir, Colorado USGS Quadrangle map (Figure 2). The study area includes the Chimney Hollow Valley where the reservoir, dam, pipelines, roads, relocated transmission line, and other disturbances would occur. Chimney Hollow flows into Flatiron Reservoir located at the northeast end of the site and Carter Lake is directly east on the other side of a hogback ridge. Average elevation at the Chimney Hollow Reservoir site is about 5,700 feet.

The study area occurs in a long north-south trending valley between a hogback ridge to the east and foothills to the west. Chimney Hollow is a small intermittent creek that flows through the center of the valley. Several ephemeral to intermittent tributaries drain from the west into the Chimney Hollow. Ponderosa pine forests cover the foothills to the west with mostly native grasslands occurring in openings within the forest. Native and nonnative grasslands cover the valley floor with riparian woodlands and shrublands occurring along the drainages. Native shrublands cover the slopes on the rocky hogback to the east.

3.3. Dry Creek Study Area

The Dry Creek study area is located in Sections 16, 20, 21, and 28 in Larimer County on the Carter Lake Reservoir Colorado USGS Quadrangle map (Figure 3). The study area includes the reservoir, dam, and spillway, as well as pipeline connections to C-BT facilities through Chimney Hollow and across the hogback to Carter Lake, and proposed access roads.

The Dry Creek study area is located in the valley south of Chimney Hollow separated by a gentle saddle. Dry Creek, a tributary to the Little Thompson River, flows south through the center of the valley. Several small, intermittent or ephemeral tributaries from the foothills to the west and the hogback to the east flow into Dry Creek. The forests, shrubland, and grassland vegetation in the Dry Creek study area is similar to the Chimney Hollow study area.

3.4. Jasper East Study Area

The Jasper East study area is located in Grand County in Sections 8, 9, 16, and 17, T2N, R76W, on the Trail Mountain, Colorado Quadrangle, at elevations ranging from about 8,100 feet to 8,200 feet (Figure 4). The study area for the proposed Jasper East Reservoir includes the area encompassing the project facilities including the new reservoir, dam, and spillway, an new pipeline to the existing Windy Gap pipeline, the relocation of the Willow Creek pump station, canal and forebay, and new or realigned roads. Also included are the immediately adjacent lands that would be temporarily affected during construction. The study area consists mainly of flood-irrigated meadows bordered by areas of sagebrush shrublands and stands of lodgepole pine at higher elevations. An intermittent unnamed tributary to Church Creek flows from east to west through the study area. Natural flows in the tributary are supplemented by irrigation return flow and seepage from the Willow Creek Pump Canal and forebay. The property is currently used for livestock grazing and hay production.

3.5. Rockwell/Mueller Creek Study Area

The Rockwell/Mueller Creek study area is located in Grand County in Section 1 of T2N, R77W, and Sections 1 and 12 of T2N, R77 ½W, and an unsurveyed area (Figure 5). The study area for the Rockwell/Mueller Creek Reservoir includes the area encompassing the project facilities, including a pipeline to Windy Gap Reservoir and immediately adjacent lands that would be temporarily affected during construction. Elevations in the study area range from about 8,000 feet to about 8,200 feet. The study area consists mainly of big sagebrush shrublands, with areas of lodgepole pine forest, meadow, and wetland and riparian areas. Two reservoir sizes, a 20,000 AF and a 30,000 AF reservoir, were investigated in the Rockwell/Mueller Creek study areas.

4.0 OBJECTIVES

The purpose of this report is to characterize the affected environment and identify potential environmental effects to geologic, paleontologic, and soil resources associated with the proposed Windy Gap Firming Project alternatives. The information gathered in the technical report will be summarized in the Environmental Impact Statement (EIS) for the proposed project.

5.0 DATA SOURCES

Information on geology, soils, and paleontology was collected from published data sources including U.S. Geologic Service geologic maps, Natural Resources Conservation

Service (NRCS) soil survey reports for Larimer, Boulder, and Grand counties, the NRCS Web Soil Survey, and limited field testing and drilling conducted by Boyle Engineering for the Chimney Hollow Reservoir site and drilling near the Jasper East Reservoir site. Information on geologic resources at the reservoir sites was taken primarily from the Windy Gap Firming Project EIS Alternatives Description Report (Boyle Engineering 2005b). The presence of paleontologic resources was based on literature review and geology.

Potential water quality effects associated with erosion and sedimentation at reservoir sites are addressed in the Water Quality Technical Report (Hydrosphere 2006). Fugitive dust is discussed in the Air Quality and Noise Technical Report (ERO 2006a). Revegetation of disturbed land is discussed in the Vegetation and Wetlands Technical Report (ERO 2006b). Potential effects to stream geomorphology are discussed in the Water Resource Technical Report (ERO and Hydrosphere 2006).

6.0 AFFECTED ENVIRONMENT

6.1. Ralph Price Reservoir

6.1.1. Geologic Setting

Ralph Price Reservoir is located in the Front Range foothills within the Lower Mountain Subsection of the Southern Rocky Mountain physiographic province. The geology of the area is composed of Precambrian-aged granitic rocks of the Silver Plume Granite Formation (Braddock 1988). The granite typically weathers to sand and gravel with some size silts and clays (Woodward Clyde Consultants 1987).

6.1.1.1. Geologic Hazards

No specific geologic hazards were identified in previous geologic feasibility studies for raising the Button Rock Dam (Woodward-Clyde 1987). No faults are mapped near the reservoir (Braddock 1988) or were evident from reconnaissance geotechnical investigations (Woodward-Clyde 1987). Zones of closely spaced joints and some shear zones in the dam foundation area may transmit water and would need to be considered during design (*id.*).

6.1.1.2. Material Sources

Several borrow material sources for use in enlarging the dam have been identified in the vicinity of the reservoir, including a rock quarry located within the reservoir area for rockfill (Woodward-Clyde 1987). Earthfill material could be obtained by removing decomposed granite from borrow sites.

6.1.1.3. Mineral Resources

The Ralph Price Reservoir study area is not currently recognized as a source of mineral or energy resources. The Silver Plume granite may have some use as a coarse aggregate (Streufert and Cappa 1994; Cappa et al. 2000).

6.1.1.4. Paleontologic Resources

Paleontological resources are not known of in this study area. It is unlikely paleontological resources would be recognized in the immediate area because it is composed primarily of igneous rock.

6.1.2. Soil Resources

The NRCS has not surveyed soils at Ralph Price Reservoir. Using information from the Boulder County Soil Survey (NRCS 1975) for lands with similar parent material and geographic position, it is likely the Juget-Rock outcrop soil complex is present on the mountain slopes surrounding Ralph Price Reservoir. The Juget soil series consists of shallow, somewhat excessively drained soils from weathered granite on slopes of 9 to 55 percent. Surface and subsurface soils are very gravely sandy loams over granite bedrock. Runoff is rapid and the erosion hazard is high for this soil.

6.2. Chimney Hollow Reservoir

6.2.1. Geologic Setting

The Chimney Hollow study area is located within the Colorado Front Range near the eastern edge of the southern Rocky Mountain physiographic province (Figure 6). The current geology within the province resulted from processes that began 60 million years ago. The last process to impact the project area was a slow upward lift started about 28 million years ago and resulted in what is identified as the Colorado Piedmont. Subsequently, the area has primarily been subjected to erosional forces resulting in the present landforms. In the study area, the southern Rocky Mountains can be physiographically subdivided (Crosby 1978) into two subsections, the Lower Mountain Subsection and the Hogback Subsection.

The Lower Mountain Subsection is located west of the study area, and includes the western one-third to one-half of the Chimney Hollow study area. It is characterized by mountain peaks, slopes, and valleys that range in elevation from approximately 5,400 to 9,400 feet above sea level.

Geology comprising the Lower Mountain Subsection is characterized by a complex series of Precambrian metasedimentary and metavolcanic rocks intruded by igneous rocks as intrusive stocks, dikes, and sills (Braddock et al. 1988). In the Chimney Hollow study area, the surface of the Precambrian rocks generally dips east beneath Pennsylvanian sedimentary bedrock that generally comprises the Hogback Subsection. Rocks comprising the Hogback Subsection overlie the Precambrian rocks. The Hogback Subsection is characterized by a series of north to south trending ridges and valleys. The ridges consist of tilted sandstone and limestone. The lower slopes and valleys consist of less resistant bedrock, generally siltstone and shale with the lower portions of the slopes covered by a mantle of alluvium or colluvium.

The eastern Hogback Subsection consists of east-dipping sedimentary rocks of the Lower Permian and Upper Pennsylvanian Fountain Formation, Lower Permian Ingleside and Owl Canyon Formations and the Upper Permian-Lower Triassic Lykins Formation. Sedimentary rocks consist primarily of arkosic conglomerate, feldspathic sandstone, siltstone, shale and limestone. The western Subsection includes Proterozoic pegmatite, gneiss and amphibolite, schist and Silver Plume Granite overlain by the Fountain Formation and Quaternary alluvium. The southern portion of the Silver Plume Granite located within the shear zone has been metamorphosed to varying degrees likely as part of the intrusion process.

Several faults are located between approximately ½ to 3 miles west and northwest of the Chimney Hollow study area in the complex series of Precambrian age metamorphic and granite bedrock. These include the Rattlesnake Mountain, Rattlesnake Park, and the Skinner Gulch faults. The Skinner Gulch and Rattlesnake Park faults converge about 3 miles west of the study area with the Bald Mountain Fault that trends eastward and marks the northern boundary of the Moose Mountain Shear Zone. The inferred Blue Mountain Fault, interpreted as an extension of the Rattlesnake Mountain Fault, trends to the southeast and is located south and west of the study area. The fault has an inferred length of about 8 miles with the southern portion of the fault approximately parallel to the Little Thompson River drainage.

Other faults in the project vicinity consist of a pair of unnamed northwest-southeast trending parallel faults located within a few hundred feet of the proposed right dam abutment. These faults offset both Precambrian bedrock and rocks of the Pennsylvanian Fountain Formation. The northernmost fault has a total mapped length of about 6 miles. The western ends of these faults are mapped in the upper reaches of Saddle Notch Gulch, approximately 4 miles west of the proposed dam site. The faults trend eastward beneath the Chimney Hollow valley, in the vicinity of the Flatiron power plant, and terminate in the lower Permian bedrock approximately ¼ mile north of the northern end of Carter Lake Reservoir. East of the Flatiron Powerplant, the fault is semi-parallel to the Carter Lake tunnel, as close as about 500 feet to the tunnel and about 800 feet to the centerline of the east end of the proposed main dam for Chimney Hollow Reservoir. The southernmost fault has been mapped to a length of approximately 1 mile and terminates near the western boundary of Chimney Hollow and about ¼ mile west of the Flatiron Powerplant.

6.2.1.1. Geologic Hazards

Geologic hazards, particularly landslides, were not recognized or identified within the Chimney Hollow study area from early mapping projects (Braddock et al. 1988; Crosby 1978), nor were any observed during the site reconnaissance or field explorations conducted by Boyle Engineering. Faults in the area are not considered active or potentially active (Widmann et al. 2002) and no such geologic hazards were noted in the site reconnaissance and field explorations conducted by Boyle Engineering.

Slickenside materials were observed along bedding planes in the finer grain portion of the bedrock in drill core and in some of the test pits (Boyle 2005b). Similar features were observed in the geologic mapping of the same material types in the excavation of the Carter Lake tunnel and in excavations for the construction of the Flatiron Powerplant. Slickenside materials are known to serve as weakened slip surfaces that sometimes result in material slides or wall failures particularly when the dip of the surface is into an open excavation. Such slides are documented to have occurred in the excavations for the nearby Flatiron Powerplant, as noted in construction photographs in a BOR as-built report.

6.2.1.2. Material Sources

On-site borrow areas for dam construction would be located within the Chimney Hollow Reservoir footprint. The borrow materials required to construct the dam would depend on the final design of the dam (especially the type of rockfill dam) and could include core, shell, filter/drain, riprap and bedding material, and concrete aggregate. The required materials consist of low-permeability materials for the core, aggregate for the filter/drain, and coarse and fine-grained material for the shell. Filter, drain material and bedding material may need to come from offsite sources. A concrete-faced rockfill or asphaltic core rockfill dam are two of the three variations of dam type under consideration. These variations would require some offsite materials. Concrete aggregate for a concrete-faced rockfill dam or bitumen materials for an asphaltic core rockfill dam would, if selected during final design, come from offsite sources.

Two primary borrow sources were identified in the field explorations and sampled for testing. These were the granite along the north-central rim of the reservoir area for use as rockfill in the dam shells, and the fine-grained alluvial/colluvial deposits over the floor and lower slopes of the reservoir area for use as a low permeability material in the core of the dam (Figure 6). These potential borrow sources were explored (drilling, surface geology mapping, and test pit excavations) and representative samples of the materials were collected for testing to further evaluate the suitability of the materials as borrow materials for the dam. The tests completed to characterize and evaluate the samples included geotechnical properties and shear strength tests and aggregate durability tests (Boyle 2005b).

6.2.1.3. Mineral Resources

The Chimney Hollow study area is not currently recognized for its potential for oil and/or natural gas production and metallic mineral resources, or coal bearing rocks. Sand and gravel deposits are not currently recognized in the area (Streufert and Cappa 1994; Cappa et al. 2001). Several quarries are located on the hogback to the east of the reservoir site. The quarries extract sandstones of the Lyons Formation, primarily for decorative building material. The proposed access road corridor southeast of the Chimney Hollow Reservoir would pass through one of these quarries (Keller et al. 2002).

6.2.1.4. Paleontologic Resources

The proposed Chimney Hollow Reservoir site is underlain by metamorphic rocks in the western half and by sandstone rocks of the Fountain, Ingleside, Owl Creek and Lykins Formations in the eastern half. The metamorphic rocks are not known to contain paleontologic resources (no fossils in metamorphosed granitic/amphibolite/schist rocks by definition). Trace fossils of plants and invertebrates have been found in the Fountain and Lykins Formations at locations south of the site near Denver and Castle Rock, but none have been identified in the study area. The proposed access road corridor southeast of the Chimney Hollow Reservoir crosses through the hogback, which is composed primarily of sandstone rocks of the Lyons Formation. Based on a literature review, these rocks are not known to contain paleontologic resources.

6.2.2. Soil Resources

Principal soils in the Chimney Hollow study area (NRCS 1980) from the most common to the least common are described below. Soil map units and distribution are listed in Table 1 and shown on Figure 7.

Kirtley-Purner complex, 5 to 20 percent slopes (Map Unit 58). This complex occurs on strongly sloping (5 to 10 percent) to moderately steep (10 to 25 percent) upland and valley sides within the reservoir footprint. The Kirtley series is a moderately deep, well drained soil formed from weathered sandstone and shale. The surface is loam textured and the subsurface is a heavy loam. The Purner series is a shallow, well drained soil formed from weathered sandstone. The surface horizon and subsoil is composed of a fine sand loam. Runoff is rapid and the erosion hazard is severe in this complex.

Purner-Rock outcrop complex, 10 to 50 percent slopes (Map Unit 86). This complex consists of moderately steep (10 to 25 percent) or steep soils (25 to 50 percent) on upland and ridges and is found along the east shoreline of the study area. The description of the Purner fine sand loam is the same as described for Map Unit 58. The rock outcrop in this unit is primarily in the steep ridges of the hogback above the reservoir. Runoff is rapid and the erosion hazard is severe in this complex.

Ratake-Rock outcrop complex, 25 to 55 percent slopes (Map Unit 87). This complex consists of steep (25 to 50 percent) or very steep (over 50 percent) soils on mountainsides and ridges and encompasses the northwest portion of the reservoir and the proposed pipeline route to the Bald Mountain surge tank. The Ratake series consists of shallow, well drained to somewhat excessively drained soils that formed from weathered granite, schist, or phyllite. The surface soil is a channery loam with increasing rock content with depth. Runoff is rapid and the erosion hazard is severe in this complex.

Wetmore-Boyle-Moen complex, 5 to 40 percent slopes (Map Unit 116). This complex consists of strongly sloping (5 to 10 percent) to steep (25 to 50 percent) soils on the west side of the reservoir. The Wetmore series consists of shallow, well drained soils derived from weathered granite. The surface horizon is a sandy loam and subsurface horizons have a gravely loamy sand texture. The Boyle series is a shallow, well drained soil formed from weathered sandstone. The surface soil is a stony sandy loam with increasing rock content with depth. The Moen series is a moderately deep, well drained soil formed from weathered granite and schist with a surface a loam surface texture and clay loam subsurface texture. Runoff is rapid and the erosion hazard is severe in this complex.

Connerton-Barnum complex, 3 to 9 percent slopes (Map Unit 25). This complex consists of gently sloping (3 to 5 percent) to strongly sloping (5 to 10 percent) soils on terraces and fans. This map unit is located along the Chimney Hollow drainage in the center of the reservoir site. The Connerton series consists of deep, well drained soils that formed in mixed alluvial material with a fine sandy loam surface and loam subsurface. The Barnum series consists of deep, well drained soils formed in alluvium valleys. These soils have a loam textured surface and subsurface. Runoff is medium and the erosion hazard is moderate to severe.

Seven additional map units are present within the Chimney Hollow study area. These map units consist of the same soils series previously described and other soil types with similar parent material, soil textures, depths, and slopes as described for the dominant soil types.

Table 1. Soil Map Units in the Chimney Hollow Reservoir Study Area.

Soil Map Unit Number	Map Unit Name
25	Connerton-Barnum complex, 3 to 9 percent slopes
45	Haplustolls-Rock outcrop, steep
47	Harlan fine sandy loam, 3 to 9 percent slopes
57	Kirtley loam, 3 to 9 percent slopes
58	Kirtley-Purner complex, 5 to 20 percent slopes
83	Pinata-Rock outcrop complex, 15 to 45 percent slopes
86	Purner-Rock outcrop complex, 10 to 50 percent slopes
87	Ratake-Rock outcrop complex, 25 to 55 percent slopes
93	Rock outcrop
112	Trag-Moen complex, 5 to 30 percent slopes
116	Wetmore-Boyle-Moen complex, 5 to 40 percent slopes
117	Wetmore-Boyle-Rock outcrop complex, 5 to 60 percent slopes

Source: NRCS 1980.

6.3. Dry Creek Reservoir

6.3.1. Geologic Setting

The regional and local description of the geologic setting is similar to that described for Chimney Hollow. Geologic reconnaissance or exploration has not been conducted at the Dry Creek site. Based on available published geologic mapping, the western one-half of the dam site is underlain by metasedimentary and metavolcanic rocks (Braddock et al. 1988) (Figure 8). Sedimentary bedrock of the Pennsylvanian Fountain Formation underlies the eastern one-half of the dam site. The sedimentary rocks are described as poorly to moderately well cemented and soft to moderately hard. Little or no alluvium overlays bedrock in the vicinity of the dam site. The bedrock in the lower elevations of the valley and in the vicinity of Dry Creek is generally mantled with colluvial deposits. No explorations have been completed and the nature and quantity of these deposits are unknown.

The northwest-southeast trending Blue Mountain Fault is approximately parallel to portions of the Little Thompson drainage. The Blue Mountain Fault has a length of about 8 miles with the major portion being inferred and concealed beneath younger deposits. A short segment has been mapped approximately 700 feet from the proposed right dam abutment area. The Blue Mountain Fault appears to be an extension of the Rattlesnake Mountain Fault. The fault displaces Early Proterozoic to Pennsylvanian rocks.

Several other faults are located approximately 5 miles northwest of the study area in the complex series of Precambrian age metamorphic and granite bedrock. These include Rattlesnake Park and the Skinner Gulch faults. The Rattlesnake Park and Skinner Gulch faults converge west northwest of the study area with the Bald Mountain Fault trending eastward and marking the northern boundary of the Moose Mountain Shear Zone.

Other faults in the project vicinity consist of a pair of unnamed northwest-southeast trending parallel faults located approximately 5 to 6 miles north of the study area. These faults offset both Precambrian age bedrock and rocks of the Pennsylvanian age Fountain Formation. The northern most fault has a total mapped length of about 6 miles. The southern most fault has been mapped with a length of approximately 1 mile.

The above faults are considered non-active as the Colorado Geological Survey has not classified them as “active” or “potentially active” based on the results of its studies.

The closest fault to the study area that has been classified as potentially active by the Colorado Geological Survey is an unnamed approximate east-west trending fault located approximately 35 miles north of the study area. The fault has a mapped length on the order of 25 miles. The fault has been interpreted as offsetting late Tertiary age sedimentary rock but not having offset Holocene age deposits (Kirkham and Rogers 1981).

6.3.1.1. Geologic Hazards

Published geologic maps that cover the project area (Braddock et al. 1988) were reviewed for the purpose of identifying potential geologic hazards within the project site. Based on review of the available information, no geologic hazards such as landslides or debris flows are believed to be present in the project area. Faults within the study area as previously discussed, including the nearby inferred Blue Mountain Fault, are not considered active or potentially active (Widmann et al. 2002). The potentially active fault located approximately 35 miles north of the study area (see Section 6.3.1 above) is not considered a geologic hazard to this site. Any impact of seismic activity along the fault would be accounted for under seismic characterization of the site for the design of the facilities.

6.3.1.2. Material Sources

Borrow materials typical for construction of a zoned earthen dam include core, shell, filter/drain, riprap and bedding materials, and concrete aggregate. The required materials consist of low-permeability materials for the core, aggregate for the filter/drain, and coarse and fine-grained material for the shell. No site reconnaissance or exploration has been completed at the proposed Dry Creek site to determine if onsite materials would be suitable for dam construction.

Based on available published geologic mapping and exploration at the Chimney Hollow Reservoir site (Braddock 1998), some Holocene age alluvial deposits are located in the lower Dry Creek drainage. Field investigations will be required to determine the nature and quantity of these deposits. Granite bedrock is present within the limits of the proposed reservoir. It is possible that this rock can be quarried to provide a possible aggregate source for portions of construction. This type of construction material could be obtained from offsite commercial sources if needed.

The western portion of the proposed reservoir is underlain by granitic bedrock belonging to the Silver Plume Granite. This unit could be used as a source for riprap and possibly processed for sand and gravel-size material.

Geologic reconnaissance of potential borrow areas along with an exploration program would need to be completed to confirm the characteristics of local material source deposits and to estimate the available quantity. Proposed areas for borrow within and near the Dry Creek site are shown on Figure 8.

6.3.1.3. Mineral Resources

Known oil and/or natural gas production, metallic minerals or coal resources have not been identified in the proposed project area (Streufert and Cappa 1994; Cappa et al. 2001). Numerous quarries are located on the hogback to the east of the reservoir site. The quarries extract sandstones of the Lyons Formation, primarily for decorative building material. The proposed pipeline from the Dry Creek Reservoir to the Carter Lake Reservoir would have to be routed considering the presence of these quarries (Keller et al. 2002).

6.3.1.4. Paleontologic Resources

The proposed Dry Creek Reservoir site is underlain by metamorphic rocks in the western half and by sandstone rocks of the Fountain Formation in the eastern half. These rocks are not known to contain paleontologic resources. The proposed pipeline from the Dry Creek Reservoir to the Carter Lake Reservoir crosses through the hogback, which is composed primarily of sandstone rocks of the Lyons Formation. Based on literature review, the Lyons Formation is not a known paleontologic source material in this area.

6.3.2. Soil Resources

Soils in the Dry Creek study area (NRCS 1980) (Figure 9) are primarily the same map units discussed for the Chimney Hollow study area (Table 2). The dominant soil types within areas of potential inundation or disturbance include Kirtley-Purner complex, 5 to 20 percent slopes (Map Unit 58), which is found on valley side-slopes of the reservoir area, at the spillway, and along much of the pipeline route north to the connection with the Bald Mountain surge tank; the Wetmore-Boyle-Moen complex, 5 to 40 percent slopes (Map Unit 116), which is found along the northwest shoreline of the reservoir; the Ratake-Rock outcrop complex, 25 to 55 percent slopes (Map Unit 87), which is found along the southwestern shoreline and dam site and the upper portion of the pipeline connection to the Bald Mountain surge tank; and the Purner-Rock outcrop complex, 10 to 50 percent slopes (Map Unit 86), which is present along the eastern reservoir shoreline. Additional dominant map units in the Dry Creek study area include—

Haplustolls-Rock outcrop, complex steep (Map Unit 45). This complex consists of strongly sloping (5 to 10 percent) to steep (25 to 50 percent) soils and rock outcrop located on the southeast shoreline of the reservoir. Haplustolls in Map Unit 44 are present along the east side of the hogback ridge where the pipeline connection to Carter Lake would be located. Haplustolls are shallow to deep and have surface and subsurface layers of loam or clay loam with varying amounts of cobbles and stone sized rocks 10 to 24 inches in diameter. Runoff is rapid and the erosion hazard is moderate to severe.

Nunn clay loam, 3 to 5 percent (Map Unit 75). This gently sloping soil is located along a portion of the pipeline route to Carter Lake. These soils are deep, well drained and have a light clay loam surface and clay loam subsurface. Runoff is medium and the water erosion hazard is moderate.

Satanta loam, 3 to 5 percent (Map Unit 96). This soil is located on upland side slopes along the pipeline route to Carter Lake. The Satanta soil is deep, and well drained with a loam surface and heavy loam to clay loam subsurface. Runoff is medium and the erosion hazard is moderate.

Seven other soil map units have been identified within the Dry Creek study area (Table 2). These map units also may be affected by project facilities and consist of the same soils series previously described and other soil types with similar parent material, soil textures, depths, and slopes as described for the dominant soil types.

Table 2. Soil Map Units in Dry Creek Study Area.

Soil Map Unit Number	Map Unit Name
12	Bailer-Rock outcrop complex, 15 to 45 percent slopes
19	Breece coarse sand loam, 3 to 9 percent slopes
25	Connerton-Barnum complex, 3 to 9 percent slopes
45	Haplustolls-Rock outcrop, steep
47	Harlan fine sandy loam, 3 to 9 percent slopes
57	Kirtley loam, 3 to 9 percent slopes
58	Kirtley-Purner complex, 5 to 20 percent slopes
75	Nunn clay loam, 3 to 5 percent
81	Paoli find sandy loam, 0 to 1 percent slopes
83	Pinata-Rock outcrop complex, 15 to 45 percent slopes
87	Ratake-Rock outcrop complex, 25 to 55 percent slopes
93	Rock outcrop
96	Satanta loam, 3 to 5 percent slopes
116	Wetmore-Boyle-Moen complex, 5 to 40 percent slopes
117	Wetmore-Boyle-Rock outcrop complex, 5 to 60 percent slopes

Source: NRCS 1980.

6.4. Jasper East Reservoir

6.4.1. Geologic Setting

Site-specific exploration or reconnaissance has not been conducted for the Jasper East Reservoir site, although reconnaissance of the geology has been conducted by Boyle Engineering (2005a) in the extreme northern and western portions of the study area. The geology summary of the Jasper East study area is based on the review of available sources (USGS well records; Colorado Division of Water Resources well records; Tweto 1979; Izett 1974; Boyle Engineering 2005a; Colorado Geological Survey 2003). The study area is located in the Southern Rocky Mountain physiographic province. The current landforms are the result of faulting, uplift, glaciation, and erosion (Figure 10). The predominant rock unit exposed at the surface in the study area is the Miocene Troublesome Formation, which consists of tuffaceous mudstone and sandstone interlayered with basalt flows, and to a lesser extent, conglomerate composed of granite and volcanic rocks. The Troublesome Formation is reported to range in thickness from about 800 feet to 1,000 feet. Other units exposed at the surface include Tertiary basalt flows, as wells as Quaternary terrace deposits and alluvium consisting of sand and gravel.

A series of northwest trending inferred faults are located near the study area (Izett 1974; Kirkham 1981). The faults have inferred lengths ranging from less than 1 mile up to about 8 miles. The main fault is located a short distance east of the east embankment and trends northwesterly along the approximate toe of Table Mountain. This fault has a mapped length of about 8 miles. The inferred movement along this fault has been interpreted as normal and near vertical with an offset of several hundred feet. The west side of the fault is inferred as being the down-thrown side.

A second unnamed fault branches off the above-described main fault a short distance east of the proposed east embankment and trends north-northeast along the upper west slope of Table Mountain. This fault has offset the basalt bed that caps the east and west portions of Table Mountain. It appears that the western portion of Table Mountain has been down-thrown a distance on the order of several hundred feet relative to east Table Mountain. The fault terminates a short distance north of Table Mountain with an inferred length of about 2 miles with estimated displacement ranging between 400 to 1,500 feet.

Another unnamed fault trends northwesterly through the central portion of the proposed study area terminating a short distance north of the existing Willow Creek Pump Canal forebay dam structure.

Two unnamed inferred faults are located in the western portion of the study area. These faults also trend northwesterly approximately parallel to the Willow Creek drainage. The eastern most of the two faults have offset the basalt beds that form the western boundary of the proposed reservoir. This fault has a mapped length of about 1½ miles with a mapped length of about ¼ mile and the remainder concealed and inferred.

6.4.1.1. Geologic Hazards

Evidence of landslides or instability was not observed nor has been mapped within the project limits. A landslide area is present near the project on the south end of Table Mountain between the upper portions of the mountain and the canal to Lake Granby. The toe of the landslide is located above the canal at about elevation 8,320 feet (Izett 1974). It appears that this feature is located at a sufficient distance east of and away from the proposed project so that the feature is not considered a geologic hazard or would otherwise adversely affect development and operation of the potential Jasper East Reservoir.

Faults previously mapped in the area and, as previously discussed, are not considered active or potentially active (Widmann et al. 2002). Based on this information, it appears that there are no active or potentially active fault hazards in the study area of the Jasper East Reservoir site.

6.4.1.2. Material Sources

Borrow materials typical for construction of a zoned earthen dam include core, shell, filter/drain, riprap and bedding materials, and concrete aggregate. The required materials consist of low-permeability materials for the core, aggregate for the filter/drain, and coarse and fine-grained material for the shell. There is very limited information regarding the availability of impervious core and shell material within the project limits, especially for core material. Based on reconnaissance and exploration data available from adjacent areas of similar geology (Boyle 2005a), it is anticipated that material from overburden deposits and the underlying weathered fine grain bedrock within the reservoir limits would be suitable for shell material. In addition, this source may be suitable for core material. Filter/drain material is available at the existing Willow Creek Gravel Pit located a short distance west of the study area.

Riprap/bedding is anticipated to be available from basalt bedrock located in northwest-southeast trending ridges in the vicinity of the study area. An existing quarry is located near the northern end of the ridge, which forms the west side of the proposed reservoir. The quarry is located near the left abutment of the proposed northwest structure. This ridge is approximately one and one-half mile in length and other potential quarry sites are likely available along the southern portion of the ridge. In addition, a ridge containing basalt is located in the southern portion of the proposed reservoir and is a potential location for a quarry.

Geologic reconnaissance of potential borrow areas along with an exploration program would need to be completed to confirm these assumptions of local material source deposits and to estimate the available quantity. Proposed areas for borrow within and near the Jasper East study area are shown on Figure 10.

6.4.1.3. Mineral Resources

The Jasper East study area is not currently known for its potential for oil and/or natural gas production, metallic mineral resources or coal rocks (Streufert and Cappa 1994; Cappa et al. 2001). Basalt outcrops in the area could be used as a coarse aggregate, and as discussed in Section 6.4.1.2, an existing sand and gravel quarry operation is located on the west side of the proposed reservoir.

6.4.1.4. Paleontologic Resources

The Jasper East study area is located in the Tertiary (Miocene) Troublesome Formation, which is known to contain fossil mammals (Lewis 1969).

6.4.2. Soil Resources

The Jasper Reservoir site, access roads, pipeline route, and relocated Willow Creek Canal overlay 20 different soil map units (NRCS 1983) (Figure 11 and Table 3). Principle soil types in the study area include—

Cimarron loam, 2 to 35 percent (Map Units 12, 13, and 14). This deep, well drained soil is found from gently sloping (5 to 10 percent) fans to steeper mountainsides within the reservoir footprint and along portions of the Willow Creek Pump Canal. These soils formed from shale and alluvium. The surface layer is loam and the subsurface is clay. Surface runoff is slow and the erosion hazard is slight on slopes less than 6 percent. Runoff is rapid and the erosion hazard is severe on slopes steeper than 15 percent.

Youga loam, 6 to 15 percent (Map Unit 94). This is a deep well drained soil found within the reservoir footprint and on the northern dam abutment. This soil has a surface horizon of loam with a subsubsoil of loam and clay loam. Youga loam (Map Unit 93) is found on gentler slopes in the filter borrow area and a portion of the access road. Youga loam (Map Unit 95) is found on steeper slopes of the western dam. Surface runoff is medium and the erosion hazard is moderate.

Leavitt loam, 6 to 50 percent slopes (Map Unit 46 and 47). This soil is a deep well drained, moderately steep (10 to 25 percent) to steep (25 to 50 percent) soil found within the reservoir footprint, in the rock borrow area, and portions of the Willow Creek Pump Canal. This soil is formed in local alluvium from sedimentary rock. The surface layer is loam and the subsurface is clay loam. Surface runoff is slow on slopes less than 15 percent and the erosion hazard is moderate. On steeper slopes the surface runoff is medium and the erosion hazard is high.

Mayoworth clay loam, 6 to 50 percent slopes (Map 52 and 53). This is a moderately deep, well drained soil found on mountainsides within the reservoir footprint and along the Willow Creek Pump Canal route. The surface is a clay loam and the subsurface is clay above shale bedrock. Surface runoff is rapid and the erosion hazard ranges from moderate to high depending on slope.

Waybe clay loam, 10 to 55 percent slopes (Map Unit 90). This is a shallow, well drained soil on strongly sloping (10 to 25 percent) to steep (25 to 50 percent) mountainsides. It is found within the reservoir and dam footprint and access roads. The surface layer is a clay loam and the subsoil is clay over weathered shale. Surface runoff is rapid and the erosion hazard is high.

Remaining soil types found in lesser amounts in the study area mostly have loam and clay loam surface horizons with slopes below 30 percent. Several small areas of rock outcrop (Map Unit 68) are found in scattered locations. Cumulic Cryaquolls (Map Unit 25) are dark wet soils along the drainage that supports wetlands.

Table 3. Soil Map Units in Jasper East Study Area.

Soil Map Unit Number	Map Unit Name
2	Aaberg clay loam, 15 to 30 percent slopes
8	Binco clay loam, 6 to 15 percent slopes
12	Cimarron loam, 2 to 6 percent slopes
13	Cimarron loam, 6 to 15 percent slopes
14	Cimarron loam, 15 to 35 percent slopes
17	Clayburn loam, 15 to 20 percent slopes
25	Cumulic Cryaquolls, nearly level
35	Gateway loam, 15 to 50 percent slopes
38	Harsha loam, 6 to 15 percent slopes
39	Harsha loam, 15 to 50 percent slopes
46	Leavitt loam, 6 to 15 percent slopes
47	Leavitt loam, 15 to 50 percent slopes
52	Mayoworth clay loam, 6 to 15 percent slopes
53	Mayoworth clay loam, 15 to 50 percent slopes
68	Rock outcrop – Cryoborolls complex, extremely steep
90	Waybe clay loam, 10 to 55 percent slopes
92	Woodhall loam, 15 to 50 percent slopes
93	Youga loam, 2 to 6 percent slopes
94	Youga loam, 6 to 15 percent slopes
95	Youga loam, 15 to 45 percent slopes

Source: NRCS 1983.

6.5. Rockwell/Mueller Creek Reservoir

6.5.1. Geologic Setting

No geologic reconnaissance or exploration has been completed at the Rockwell/Mueller Creek Reservoir site. Published data (Shroeder 1995) indicate the Rockwell/Mueller Creek study area is underlain by the Troublesome Formation, except in the narrow valley associated with Rockwell Creek, where limited Quaternary alluvium is present, and in other areas where Pleistocene terrace gravels and landslide deposits are identified (Figure 12). The Troublesome Formation, reported as 1,000 feet thick or more, consists of interbedded siltstone and mudstone or shale, with less abundant arkosic sandstone and conglomerate, and lesser amounts of limestone, ash and tuff and granitic cobbles.

Structurally, the study area is dominated by a north-south trending anticline (Schroeder 1995). The anticline is flanked on the east and west by north-south trending faults that have resulted in a down drop of the sediments between the faults including the study area. The western-most fault, the Coyote Fault, is located approximately ½ mile west of the western limits of the proposed reservoir. The eastern unnamed inferred fault is located approximately 800 feet east of the proposed north dam right abutment and a short distance east and approximately parallel to the south dam (Schroeder 1995). This fault is not considered active or potentially active (Widmann et al. 2002).

6.5.1.1. Geologic Hazards

Upon review of a geology map that includes the proposed project site, landslide derived material is identified as present down stream of the reservoir area. However, it does not appear that massive slides or potential slides that would be hazardous to the development and operation of the proposed dam and reservoir are present within the project area. A landslide has been mapped on the east side of Rockwell Creek several hundred feet downstream of the proposed dam and reservoir location. If active or potentially active in the future, this landslide could impact the Rockwell Creek drainage downstream of the proposed site. Future studies would be required to determine if such an event would have any impact to the operation of the proposed facility and be considered a hazard to the project site. No other geologic hazards or potential hazards were identified in the proposed reservoir area based on information evaluated to date.

An area located south of the proposed reservoir site was identified as a potential borrow area if needed. A portion of this area consists of materials derived as a result of a landslide. This is not considered to be a geologic hazard to the development and operation of the proposed reservoir.

The faults, as previously discussed, are not considered active or potentially active. Based on this information, it is assumed that there is little hazard from seismic activity. Regional seismic activity would be accounted for in final design of the facilities and are not believed to be a significant hazard to the site based on studies for existing dams in the area (Unruh et al. 1996).

6.5.1.2. Material Sources

Borrow materials typical for construction of a zoned earthen dam include core, shell, filter/drain, riprap and bedding materials, and concrete aggregate. The required materials consist of low-permeability materials for the core, aggregate for the filter/drain, and coarse and fine-grained material for the shell. No borrow exploration has been completed. However, based on a review of available literature, fine grain borrow materials for the core and shell zones may be available onsite within the reservoir impoundment from overburden deposits and the underlying highly weathered bedrock. In the event that onsite materials are not suitable for fine grain shell and core material, a potential borrow area less than 1 mile south of the site may provide suitable material (Figure 12).

Based on available geologic mapping, it appears that filter/drain material and riprap material is not available within the study area. This material would probably have to be imported. One possible source for these imported materials is the existing sand and gravel quarry located at or next to the Jasper East Reservoir site as previously discussed.

There is very limited information regarding the availability of core and shell material within the project limit, especially for core material. Geologic reconnaissance of potential borrow areas along with an exploration program would need to be completed to confirm the characteristics of local material source deposits and to estimate the available quantity and need to locate offsite materials. Proposed borrow areas within and near the Jasper East study area are shown on Figure 12.

6.5.1.3. Mineral Resources

The Rockwell/Mueller Creek study area has no currently known potential for oil and/or natural gas production, metallic mineral resources, coal bearing rocks, or sand, gravel or other industrial mineral deposits (Streufert and Cappa 1994, Cappa et al. 2001). The proposed pipeline from the Rockwell/Mueller Creek Reservoir to the Windy Gap Reservoir crosses through areas along the Colorado River with potential sand and gravel deposits.

6.5.1.4. Paleontologic Resources

The Rockwell/Mueller Creek study area is located in the Tertiary-age Troublesome Formation, which is known to contain fossil mammals (Lewis 1969).

6.5.2. Soil Resources

The Rockwell/Mueller Creek Reservoir and dam, pipeline to Windy Gap Reservoir, and relocated county road would cross 18 different soil map units (NRCS 1983) as shown in Figure 13 and listed in Table 4. Several of the same soil map units previously described for the Jasper East study area are also present in the Rockwell/Mueller Creek study area. Cimarron loam, 6 to 15 percent (Map Unit 13) is the dominant soil type in the reservoir and dam footprint. Lesser amounts of Cimarron loam on more gentle (Map Unit 12) and steeper slopes (Map Unit 14) are also present. Mayoworth clay loam (Map Unit 53) is present within the reservoir footprint, the rock borrow area, and along the pipeline. Waybe clay loam (Map Unit 90) is found in the reservoir, dam, and construction staging area. Additional dominant soil map units in the Rockwell/Mueller Creek study area not previously described include—

Aaberg clay loam, 15 to 30 percent slopes (Map Unit 2). This moderately deep, well drained soil is found on mountainsides within the reservoir footprint. The surface soil is a clay loam and the subsoil is clay over soft shale. Surface runoff is rapid and the erosion hazard is high.

Gateway loam, 15 to 50 percent slopes (Map Unit 35). This soil is moderately deep, well drained, and is found on the west side of the reservoir and in the borrow area south of the reservoir. The surface texture is loam and the subsoil is clay over mudstone. Surface runoff is rapid and the erosion hazard is high.

Quander stony loam, 15 to 55 percent slopes (Map Unit 66). This deep, well drained soil is the dominant soil in the borrow area. It has a surface layer of stony loam over very stony sandy clay loam. Surface runoff is rapid and the erosion hazard is high.

The pipeline from Rockwell/Mueller Creek Reservoir to Windy Gap Reservoir crosses several soil map units in addition to those previously described. The pipeline route through the Colorado River floodplain crosses Cumlic-Cryaquolls (Map Unit 25), which are soils formed in alluvium, where the water table is high. Tine gravelly sandy loam, 0 to 3 percent (Map Unit 81) is present in the gently sloping terrace along the pipeline route. This is a deep, well drained soil with a loam surface horizon and very cobbly loam subsoil. Surface runoff is slow and the erosion hazard slight on these gentle slopes.

Other soils in the study area occur in smaller amounts and are primarily loams and sandy loams of widely varying slope ranges.

Table 4. Soil Map Units in Rockwell/Mueller Study Area.

Soil Map Unit Number	Map Unit Name
2	Aaberg clay loam, 15 to 30 percent slopes
8	Binco clay loam, 6 to 15 percent slopes
11	Cebone loam, 15 to 50 percent slopes
12	Cimarron loam, 2 to 6 percent slopes
13	Cimarron loam, 6 to 15 percent slopes
14	Cimarron loam, 15 to 35 percent slopes
25	Cumulic Cryaquolls, nearly level
32	Frisco-Peeler gravelly sandy loams, 6 to 25 percent slopes
35	Gateway loam, 15 to 50 percent slopes
53	Mayoworth clay loam, 15 to 50 percent slopes
66	Quander stony loam, 15 to 55 percent slopes
70	Rogert gravelly sandy loam, 15 to 60 percent slopes
72	Roxal loam, 15 to 50 percent slopes
81	Tine gravelly sandy loam, 0 to 3 percent slopes
83	Tine cobbly sandy loam, 15 to 55 percent slopes
90	Waybe clay loam, 10 to 55 percent slopes
94	Youga loam, 6 to 15 percent slopes
95	Youga loam, 15 to 45 percent slopes

Source: NRCS 1983.

7.0 Environmental Effects

7.1. Methods

Potential effects to geologic, paleontologic, and soil resources were evaluated for each alternative. Possible effects to geologic resource evaluated include geologic hazards that might affect the stability of the dam or other structures, such as faults, the potential for slope failures, or landslides. The potential loss of known mineral resources, such as oil, natural gas, and metallic and non-metallic minerals also were evaluated. The potential for fossil-bearing formations was evaluated for each of the study areas based on the types of rock present or available published data.

Potential effects to soil resource include loss of soil resources or reduced productivity, erosion during construction, shoreline erosion at new reservoirs, reservoir or stream sedimentation, and soil suitability for revegetation of disturbed areas.

Susceptibility to wind and water erosion is primarily a function of soil texture, vegetation cover, and slope. Susceptibility to wind erosion is based on the wind erodibility group for the soil map unit as designated by the NRCS soil survey. The potential for water erosion is based on the erosion hazard classification for each map unit as well as the K factor, which is an indication of the susceptibility of a soil to sheet and rill erosion by water independent of the effects of slope. The K factor is based primarily on percentage of silt, sand, and organic matter and on soil structure and saturated hydraulic conductivity.

Successful revegetation depends in part on the quality of the soils salvaged and replaced. The NRCS established rating for topsoil suitability for each map unit were used to evaluate revegetation potential for temporarily disturbed soils in the study areas. The upper 40 inches of a soil is considered in the determination of topsoil suitability. Soils are rated as good, fair, or poor as potential sources of topsoil. Topsoil ratings are based on the soil properties that affect plant growth; the ease of excavating, loading, and spreading the material; and reclamation of the borrow area. Toxic substances, soil reaction, and properties inferred from soil texture (such as available water capacity and fertility) affect plant growth. The ease of excavating, loading, and spreading is affected by rock fragments, slope, depth to the water table, soil texture, and thickness of suitable material. Reclamation of the borrow area is affected by slope, depth to the water table, rock fragments, depth to bedrock or a cemented pan, and toxic material. The surface layer of most soils is generally preferred for topsoil because of its organic matter content. Organic matter greatly increases the absorption and retention of moisture and nutrients for plant growth.

7.2. Effects Common to All Alternatives

A revegetation and erosion control plan would be developed for all temporary soil disturbances associated with construction activities at any of the potential reservoir sites. The revegetation plan would include site-specific details on the removal, handling, storage, and replacement of soil for revegetation.

7.3. Alternative 1—No Action, Ralph Price Reservoir Enlargement

7.3.1. Geologic Resource Effects

7.3.1.1. Structural Stability

Enlarging Ralph Price Reservoir would require excavation of rock and other material from borrow areas to raise the existing dam approximately 50 feet in elevation. Potential borrow areas include areas within the footprint of the existing reservoir as well as several nearby sites. There are no known geologic hazards associated with raising the dam that would affect the structural stability of construction, but additional studies would need to be conducted during final design to confirm this.

7.3.1.2. Mineral Resources

There are no known oil and/or natural gas production areas, metallic mineral resources, coal bearing formations, or other industrial mineral deposits in the area that would be affected. The Silver Plume granite present in the area may have some use as a coarse aggregate.

7.3.1.3. Paleontologic Resources

No known geologic formations containing potential paleontological resources would be affected by enlarging Ralph Price Reservoir.

7.3.2. Soil Resource Effects

7.3.2.1. Soil Loss and Disturbance

The enlargement of Ralph Price Reservoir would result in a permanent loss of about 72 acres of soil resources from inundation and possible other losses from enlarging the dam and spillway construction. If borrow areas are located within the reservoir footprint there would be no additional loss of soil from extraction of material for dam construction. Although site-specific soil mapping is not available for the area, it is assumed that the majority of the soil loss would occur in the Juget-Rock outcrop complex.

Additional temporary soil disturbance is likely from construction staging and if a borrow site outside of the reservoir footprint is used. The area of temporary disturbance is not known, but is assumed that the Juget-Rock outcrop complex would be a component of the disturbed soils.

7.3.2.2. Soil Erosion

Temporary Erosion. Temporary wind and water erosion of soils is possible during dam and spillway construction and if a borrow area outside the reservoir footprint is used. The Juget-Rock outcrop soil complex has a very low susceptibility to wind erosion when vegetation is removed; thus, wind erosion is expected to be minor. The water erosion hazard is severe because of the steep slopes, although the Juget soil has a low K factor based on soil texture and the high amount of rock.

Shoreline Erosion. Existing shoreline erosion around Ralph Price Reservoir is minimal because the shoreline is fairly stable and has weathered to bedrock. Enlarging the reservoir would inundate soils and increase the potential for shoreline erosion until a new equilibrium is reached. Seasonal fluctuations in water levels of about 14 feet on average and up to 33 feet in wet years also would contribute to shoreline erosion. Based on the condition of the existing shoreline, the granitic bedrock underlying the shallow soils would create a stable non-erosive shoreline over the long term.

Sedimentation. Sedimentation in Ralph Price Reservoir from local sources in the North St. Vrain Creek basin is possible, but would likely be minimal because the majority of the upstream watershed is within National Forest and National Park Service ownership. However, the reservoir would continue to accumulate sediment from stream inflows. Shoreline erosion and areas of soil disturbance from construction also would contribute sediment to the reservoir. Revegetation of temporary disturbances following construction would reduce erosion to natural erosion rates.

7.3.2.3. Revegetation Potential

The amount of area that would require revegetation is unknown, but would likely include construction staging areas near the dam and spillway and possible borrow areas.

The Juget-Rock outcrop complex has poor topsoil suitability because of the depth to bedrock, rock fragments, and steep slopes. Revegetation of disturbed lands may be difficult because of these limitations.

7.4. Alternative 2—Chimney Hollow (90,000 AF) (Proposed Action)

7.4.1. Geologic Resource Effects

7.4.1.1. Structural Stability

Filling the Chimney Hollow Reservoir would result in wetting of the reservoir slopes. Wave action and wetting and draining of soils on the perimeter reservoir slopes resulting from raising and lowering water levels could result in creep movement or sloughing of near surface materials into the reservoir. Such occurrences are considered normal and acceptable in the operation of reservoirs and in the terrain and environments such as these reservoirs. There are no indications of potential slides, slope failures or debris flows that would adversely affect the integrity or safety of the dam based on available information. The perimeter soil erosion and sloughing of shallow, near surface materials will contribute to the sediment load accumulated in the reservoir.

None of the faults previously mapped in the area are considered active or potentially active (Widmann et al. 2002) and thus, there is little to no hazard from seismic activity restricted to known fault zones. However, the faults would need additional investigation to determine their characteristics and affect on the facility construction.

7.4.1.2. Mineral Resources

There are no known oil and/or natural gas production areas, metallic mineral resources, coal bearing formations, or sand, gravel or other industrial mineral deposits in the area that would be affected by construction of Chimney Hollow Reservoir and facilities. The construction road access corridor through the hogback on the southeast side of the reservoir would cross a sandstone quarry, which could affect quarry operation.

7.4.1.3. Paleontologic Resources

No currently known geologic formations containing potential paleontological resources would be affected by construction of Chimney Hollow Reservoir and facilities.

7.4.2. Soil Resource Effects

7.4.2.1. Soil Loss and Disturbance

Construction of Chimney Hollow Reservoir and facilities would result in a permanent loss of about 794 acres of soil resources. Affected soils would either be inundated by the new reservoir or buried or removed for dam, spillway and road construction. Proposed borrow areas are located within the reservoir footprint so there would be no additional loss of soil from extraction of material for dam construction. There would also be a small loss of soil resources associated with construction of the foundation for new transmission line towers. The majority of the lost soil resources would be to the Kirtley-Purner soil complex (48 percent) and the Purner-Rock outcrop complex (19 percent).

Construction of the pipeline connection to the Bald Mountain surge tank, as well as inlet/outlet pipelines below the dam, and construction staging areas would temporarily affect soil resources on about 130 acres.

7.4.2.2. Soil Erosion

Temporary Erosion. Temporary wind and water erosion of soils is possible during excavation of material for dam construction, installation of pipelines, road construction, relocation of the transmission line, and other facilities until disturbed areas can be revegetated. The Kirtley, Purner, and Ratake soils series common at planned areas of soil disturbance have moderate susceptibility to wind erosion when vegetation is removed. These same soils series are subject to severe water erosion hazard, particularly where the slopes are steep due to rapid runoff and the texture of the surface soil. An increase in soil erosion is likely during construction, but implementation of an erosion control plan and revegetation would reduce soil loss.

Shoreline Erosion. Shoreline erosion on Chimney Hollow Reservoir is possible from wave action and fluctuating water levels. Chimney Hollow Reservoir would remain close to full throughout the year under most conditions with fluctuations in reservoir elevation of less than 2 feet. Erosion of shoreline soils, particularly during the first several years following reservoir construction, is likely until the shoreline stabilizes. The Purner-Rock outcrop soil complex dominates the east side of the reservoir site. The Purner soil has a moderate erosion potential, but the steep slopes increase the potential for erosion on the shoreline and prevailing winds would generate wave action on the east side of the reservoir. Soil map units on the west side of the reservoir have a lower K factor, but areas with steeper slopes have greater susceptibility to erosion. The finer textured soils of the Kirtley-Purner complex at the north end of the reservoir have a moderate K factor and gentle slopes. This is the only portion of the reservoir that may develop beach areas with areas of sand or mudflats.

Sedimentation. Sedimentation in Chimney Hollow Reservoir from local sources within the basin is expected to be minimal. The relatively undisturbed Chimney Hollow watershed is about 3,000 acres. All of the Chimney Hollow drainage would be inundated by the new reservoir; therefore, the only local source of inflow would be from ephemeral tributary drainages to the east and west. Shoreline erosion and areas of soil disturbance from construction also would contribute sediment to the reservoir. Revegetation of temporary disturbances would reduce erosion from these sites to natural erosion rates. Development of recreation facilities by Larimer County Parks and Open Lands Department would generate minor sources of sedimentation from a parking area and trails.

7.4.2.3. Revegetation Potential

Reclamation of about 130 acres of temporarily disturbed soils to facilitate vegetation establishment would be needed for construction staging areas, along pipelines, and other areas of construction disturbance. NRCS topsoil suitability ratings for temporarily disturbed soils in the study area indicate that soils have primarily fair to poor suitability for use as topsoil (Table 5). The Kirtley-Purney complex, which makes up most of the disturbed soils, has fair topsoil suitability and is limited because the soil material is less than 20 inches thick over bedrock. The poorly rated soils are composed primarily of the Ratake-Rock outcrop complex and are limited because of steep slope, shallow soils, and the amount of rock in the soil. Topsoil from areas of temporary disturbance would be salvaged where possible to aid in revegetation following construction, but there would be a loss in productivity from soils that are stripped, stored, and reapplied. Revegetation of areas with poor topsoil quality may require the addition of soil amendments to improve conditions for revegetation and vegetation establishment would likely take longer.

Table 5. Topsoil suitability rating for temporarily disturbed soils at the 90,000 AF Chimney Hollow Reservoir.

Good	Fair	Poor
0.4 acre	67 acres	62 acres

7.5. Alternative 3—Chimney Hollow Reservoir (70,000 AF) and Jasper East Reservoir (20,000 AF)

7.5.1. Geologic Resource Effects

7.5.1.1. Chimney Hollow Reservoir

The effects to geologic resources for a smaller 70,000 AF Chimney Hollow Reservoir would be similar to those described for Alternative 2.

7.5.1.2. Jasper East Reservoir

Structural Stability. A landslide area on the south end of Table Mountain would have little to no effect on Jasper East Reservoir. Filling of the reservoir would result in wetting of the reservoir slopes. This wetting, in conjunction with wave action and seepage induced by raising and lowering the reservoir level, could result in minor instability around the reservoir rim. It is anticipated that this would be limited to surface erosion and related shallow slope movement. These processes do not pose a threat to the safety of the dam, but they would contribute sediment to the reservoir.

Available information indicates that there is little to no hazard to the reservoir structure from faulting. However, the faults within the project limits and study area would need investigation to determine their characteristics and potential impact to structures and facilities.

Mineral Resources. There would be no affect to known oil and/or natural gas production areas, metallic mineral resources, or coal bearing formations in the area from construction of Chimney Hollow or Jasper East Reservoir. The existing aggregate source near Jasper East Reservoir would be used for reservoir construction.

Paleontologic Resources. Excavations in the Troublesome Formation could expose mammal fossils, which may require monitoring and salvaging during construction as discussed in Section 9.

7.5.2. Soil Resource Effects

7.5.2.1. Chimney Hollow Reservoir

Soil Loss and Disturbance. Construction of a 70,000 AF Chimney Hollow Reservoir and facilities would have less effect to soil resources than the larger sized reservoir in Alternative 2. This alternative would result in a permanent loss of about 671 acres of soil resources. The majority of the lost soil resources would be to the Kirtley-Purner soil complex (54 percent) and the Purner-Rock outcrop complex (15 percent).

Construction of the pipeline connection to the Bald Mountain surge tank, as well as inlet/outlet pipelines below the dam, construction staging areas, and 23 acres of borrow area outside of the reservoir footprint, would temporarily affect soil resources on about 149 acres.

Temporary Erosion. The potential for temporary wind and water erosion of soils would be the same as discussed for Alternative 2 because similar soil types would be disturbed.

Shoreline Erosion. Shoreline erosion at Chimney Hollow Reservoir from wave action and fluctuating water levels would be similar to the 90,000 AF reservoir in the Proposed Action. However, a wider range in reservoir water surface level fluctuations of about 15 feet on average and up to 28 feet in wet years could increase the potential for shoreline erosion.

Sedimentation. The potential for sedimentation in Chimney Hollow Reservoir from local sources within the basin would be similar to Alternative 2, although there would be a slightly larger area of temporary soils disturbance from a borrow area outside the reservoir footprint that could contribute additional sediment until revegetated.

Revegetation Potential. Approximately 149 acres of soils would be temporarily disturbed during construction. NRCS topsoil suitability ratings for temporarily disturbed soils in the study area indicate about an even distribution of soils with fair to poor suitability for topsoil (Table 6). Similar to Alternative 2, the soils rated with fair topsoil suitability are limited because the soil material is less than 20 inches thick over bedrock and the poorly rated soils are limited because of steep slope, shallow soils, and the amount of rock in the soil.

Table 6. Topsoil suitability for temporarily disturbed soils at the 70,000 AF Chimney Hollow Reservoir.

Good	Fair	Poor
0.4 acre	76 acres	73 acres

7.5.2.2. Jasper East Reservoir

Soil Loss and Disturbance. Construction of Jasper East Reservoir and facilities would result in a permanent loss of about 491 acres of soil resources. Affected soils include those inundated by the new reservoir or buried or removed for dam, spillway and road construction and soils affected by relocation of the Willow Creek Canal, pump station, and forebay. Soil loss is spread over 20 different map units. Some of the larger map units affected include Cimarron loam (34 percent), Leavitt loam (13 percent), Youga loam (10 percent), and Mayworth clay loam (9 percent).

Temporary disturbance from construction staging areas, borrow sites, the relocation of the Willow Creek pipeline, and road construction would affect soil resources on about 125 acres.

Temporary Erosion. Disturbance of soils during construction would result in a temporary increase in wind and water erosion. Dominant soil types representing about 55 percent of the area expected to be disturbed, include Cimarron loam, Youga loam, and Mayworth clay loam, which have a low potential for wind erosion. Remaining soils have a moderate potential for wind erosion when exposed. The potential for water erosion is high for most of the areas of expected disturbance, although areas with gentle slopes including Youga loam and Mayworth loam have moderate ratings for water erosion.

Shoreline Erosion. Wave action and wide fluctuations in Jasper Reservoir water levels would result in shoreline erosion. Because water levels in Jasper East Reservoir would fluctuate about 59 feet on average and as much as 72 feet during wet years, there would be continuing inundation and exposure of the shoreline. Shoreline soils are primarily clay loam and clays that would contribute fine textured suspended sediment. Weathered shale parent material below the soil would also be subject to shoreline erosion.

Sedimentation. Potential local sources of sedimentation to Jasper East Reservoir in addition to shoreline erosion are limited within the 957-acre watershed that the reservoir is located. Surrounding lands are undeveloped range land with natural levels of erosion. Relocation of County Road 40 below the reservoir dams would eliminate road-generated erosion and sediment. Revegetation of the Willow Creek pipeline would reduce erosion to natural erosion rates. If recreation facilities are developed, this could generate minor sources of sedimentation from a parking area and trails.

Revegetation Potential. Reclamation of about 125 acres of temporarily disturbed soils to facilitate vegetation establishment would be needed for construction staging areas along the Willow Creek pipeline and pipeline connection to the existing Windy Gap pipeline and roadside disturbance associated with relocation of County Road 40. NRCS topsoil suitability ratings for temporarily disturbed soils in the study area indicate that the majority of soils have a poor suitability for topsoil (Table 7). A number of the temporarily disturbed soils including Cimarron, Mayoworth, and Waybe soils series have poor topsoil properties because of a high clay content. Steep slopes for some soils and the amount of rock fragments also reduce topsoil suitability. The Youga loam soils series has fair topsoil suitability, with limitations because of the amount of rock fragments or the steepness of the slope.

Table 7. Topsoil suitability for temporarily disturbed soils at the at Jasper East Reservoir.

Good	Fair	Poor
0 acre	32 acres	93 acres

7.6. Alternative 4—Chimney Hollow Reservoir (70,000 AF) and Rockwell Mueller Creek Reservoir (20,000 AF)

7.6.1. Geologic Resource Effects

7.6.1.1. Chimney Hollow Reservoir

Potential effects to geologic resources at Chimney Hollow Reservoir would be the same as described for Alternative 3.

7.6.1.2. Rockwell/Mueller Creek Reservoir

Structural Stability. A landslide has been mapped several hundred feet on the east side of Rockwell Creek. If active or potentially active in the future, this landside could impact the downstream drainage of Rockwell Creek. Future studies would be required to evaluate this potential hazard.

Filling of the reservoir would result in wetting of the reservoir slopes. Wave action and wetting and draining of soils on the perimeter reservoir slopes resulting from raising and lowering water levels could result in creep movement or sloughing of near surface materials into the reservoir. Such occurrences are considered normal and acceptable in the operation of reservoirs and in the terrain and environments such as these reservoirs. There are no indications of potential slides, slope failures or debris flows that would adversely affect the integrity or safety of the dam based on available information. The perimeter soil erosion and sloughing of shallow, near surface materials will contribute to the sediment load accumulated in the reservoir.

Available information indicates that there is little to no hazard from faulting. However, the faults within the project limits and study area would need further investigation to determine their characteristics and impact on facilities or structures.

Mineral Resources. There would be no affect to known oil and/or natural gas production areas, metallic mineral resources, coal bearing formations, or other industrial mineral deposits in the area. The pipeline across the Colorado River would include excavation in potential sand and gravel deposits that are often found in alluvial floodplain.

Paleontologic Resources. Excavations in the Troublesome Formation could expose mammal fossils, which may require monitoring and salvaging during construction as discussed in Section 9.

7.6.2. Soil Resource Effects

7.6.2.1. Chimney Hollow Reservoir

Potential effects to soil resources at Chimney Hollow Reservoir would be the same as described for Alternative 3.

7.6.2.2. Rockwell/Mueller Creek Reservoir

Soil Loss and Disturbance. Construction of Rockwell/Mueller Creek Reservoir and facilities would result in a permanent loss of about 315 acres of soil resources. Affected soils include those inundated by the new reservoir or buried or removed for dam, spillway, and road construction and soils affected by construction of the pipeline to

Windy Gap Reservoir. Primary soil types affected include Cimarron loam (54 percent), Mayoworth clay loam (18 percent), and Aaberg clay loam (16 percent).

Temporary disturbance from construction staging areas, an offsite borrow area, and the pipeline to Windy Gap Reservoir would affect soil resources on about 155 acres.

Temporary Soil Erosion. Wind erosion susceptibility from temporarily disturbed lands varies from low to high for the various soils that would be exposed during construction. Low to moderate wind erodibility would occur from exposure of Gateway loam, Quander cobbly loam, and Cimarron loam. Exposures of Rogert gravelly sandy loam, Tine gravelly sandy loam, and Waybe clay loam have a higher potential for wind erosion. The potential for water erosion is high for most of the areas of expected disturbance because of steep slopes. The water erosion hazard is slight on gentle slopes where the pipeline to Windy Gap crosses the Tine and the Cumulic Cryaquoll soil map units near the Colorado River. The Youga loam soil type along the pipeline route has a moderate water erosion hazard.

Shoreline Erosion. Similar to Jasper East Reservoir, substantial fluctuations in reservoir levels would result in erosion of the shoreline. Water levels in Rockwell/Mueller Reservoir could fluctuate 80 feet on average and as much as 102 feet during wet years. Shoreline soils are primarily clay loam and clays that would contribute fine textured suspended sediment. Weathered shale parent material below the soil also would be subject to shoreline erosion.

Sedimentation. Potential local sources of sedimentation to Rockwell/Mueller Creek Reservoir in addition to shoreline erosion are limited within the 1,358-acre watershed within which the reservoir is located. Lands within the watershed west of the reservoir are primarily undeveloped forest land, but include scattered homes and gravel access roads. Erosion from upstream land development is likely to be minor because of the buffer areas of native forest vegetation. If recreation facilities are developed, this could generate minor sources of sedimentation from a parking area and trails.

Revegetation Potential. Reclamation of about 155 acres of temporarily disturbed soils to facilitate vegetation establishment would be needed for construction staging areas, along the pipeline to Windy Gap Reservoir, and for the offsite borrow area. NRCS topsoil suitability ratings for temporarily disturbed soils in the study area indicate that the majority of soils have a poor suitability for topsoil (Table 8). Poor topsoil suitability is due to the amount of clay in the Cimarron, Mayoworth, and Gateway loam soil series, and a combination of shallow depth and/or rock fragment limitations in most of the other soils. The Clayburn loam and Youga loam along the pipeline route have fair topsoil suitability, but with limitations because of the amount of rock fragments.

Table 8. Topsoil suitability for temporarily disturbed soils at the at 20,000 AF Rockwell/Mueller Creek Reservoir.

Good	Fair	Poor
0 acre	13 acres	142 acres

7.7. Alternative 5—Dry Creek Reservoir (60,000 AF) and Rockwell/Mueller Creek Reservoir (30,000 AF)

7.7.1. Geologic Resource Effects

7.7.1.1. Dry Creek Reservoir

Structural Stability. Filling of the reservoir would result in wetting of the reservoir slopes. This wetting, in conjunction with wave action and seepage induced by raising and lowering the reservoir level, could result in minor instability around the reservoir rim. It is anticipated that this would be limited to surface erosion and related shallow slope movement. These processes do not pose a threat to the safety of the dam, but they would contribute sediment to the reservoir.

Available information indicates that there is minimal hazard from seismic activity. However, the faults within the project limits and study area would need further investigation to determine their characteristics and impact on facilities or structures.

Mineral Resources. There would be no effect to known oil and/or natural gas production areas, metallic mineral resources, coal bearing formations, sand, gravel or other industrial mineral deposits in the area. The pipeline to Carter Lake would cross a sandstone quarry.

Paleontologic Resources. No known geologic formations containing potential paleontological resources are recognized that would be affected by reservoir and facility construction.

7.7.1.2. Rockwell/Mueller Creek Reservoir

Potential effects to geologic resources for a 30,000 AF Rockwell/Mueller Creek Reservoir would be similar to Alternative 4.

7.7.2. Soil Resource Effects

7.7.2.1. Dry Creek Reservoir

Soil Loss and Disturbance. Construction of Dry Creek Reservoir and facilities would result in a permanent loss of about 633 acres of soil resources. Affected soils include those inundated by the new reservoir or buried or removed for dam, spillway and access roads along the pipeline from the north and from the east over the hogback. The majority of the lost soil resources would be to the Kirtley-Purner soil complex (31 percent), the Wetmore-Boyle-Moen complex (20 percent), and the Ratake-Rock outcrop complex (19 percent).

Temporary disturbance from construction staging areas, along access roads, and the pipeline connection to the Bald Mountain surge tank, and from the dam to Carter Lake would affect soil resources on about 158 acres.

Temporary Soil Erosion. The majority of soils subject to wind erosion from temporary disturbances have a moderate susceptibility for erosion along the pipeline to Carter Lake, the pipeline to the Bald Mountain surge tank, and construction staging areas. The Paoli fine sandy loam, Pinata-Rock outcrop, and Conerton-Barnum complex found along pipeline routes and staging areas are more susceptible to wind erosion when disturbed. The potential for water erosion is generally severe because of the steep slopes, although erosion hazard is moderate on gentle slopes in the Connerton-Barnum and Nunn Clay loam soils found along pipeline routes.

Shoreline Erosion. Dry Creek Reservoir would fluctuate about 9 feet on average, but as much as 17 feet in wet years. Shoreline soils subject to erosion from wave action and fluctuating reservoir levels include principally the Purner-Rock outcrop complex on the west side of the reservoir and the Wetmore-Boyle-Moen complex on the west side of the reservoir. Both these soils have severe erosion hazard because of slope, but both have low K factor values, which indicates low susceptibility to sheet and rill erosion when slope is less. The shallow Purner soils overlay sandstone, which would result in a fairly stable shoreline. The granitic bedrock underlying the Wetmore-Boyle-Moen complex would have a very weather resistant shoreline following erosion of surface soil. The finer textured soils of the Kirtley-Purner complex at the north end of the reservoir have a moderate K factor, and gentle slopes. This is the only portion of the reservoir that may develop beach areas with areas of sand or mudflats depending on which soil type is present.

Sedimentation. Sedimentation in Dry Creek Reservoir from local sources within the basin other than shoreline erosion is expected to be minimal. The relatively undisturbed Dry Creek watershed is about 2,500 acres. All of the Dry Creek drainage above the dam would be inundated by the new reservoir so the only local source of inflow would be from ephemeral tributary drainages to the east and west. Sediment input from these tributaries would be at natural erosion rates. Revegetation of temporary disturbances would reduce erosion from these sites to natural erosion rates over the long-term. If recreation facilities are developed, this could generate minor sources of sedimentation from a parking area and trails.

Revegetation Potential. Reclamation of about 158 acres of temporarily disturbed soils to facilitate vegetation establishment would be needed for construction staging areas, along pipelines, and other areas of construction disturbance. NRCS topsoil suitability ratings for temporarily disturbed soils in the study area indicate that soils have primarily fair to poor suitability for use as topsoil (Table 9). The Connerton-Barnum soils along the pipeline route to the north have good topsoil characteristics for revegetation. The Kirtley-Purney complex, which makes up a majority of the soils rated as fair topsoil suitability, are limited because the soil material is less than 20 inches thick over bedrock. The Ratake-Rock outcrop complex is poorly rated for topsoil use because of steep slopes, shallow soils, and the amount of rock in the soil. The Nunn clay loam and Pinata-Rock Outcrop are too clayey for topsoil use. Revegetation of areas with poor topsoil quality may require the addition of soil amendments to improve conditions for revegetation and vegetation establishment would likely take longer.

Table 9. Topsoil suitability for temporarily disturbed soils at the Dry Creek Reservoir.

Good	Fair	Poor
13 acres	71 acres	74 acres

7.7.2.2. Rockwell/Mueller Creek Reservoir

Soil Loss and Disturbance. Construction of a 30,000 AF Rockwell/Mueller Creek Reservoir and facilities would have a greater effect to soil resources than the smaller sized reservoir in Alternative 4. This alternative would result in a permanent loss of about 393 acres of soil resources from inundation and dam, spillway, and road construction. The same primary soil types would be affected as the 20,000 AF reservoir.

Temporary soil disturbances would affect 161 acres from construction staging areas, pipelines, and roads.

Temporary Soil Erosion. The potential for temporary wind and water erosion of soils would be the same as discussed for Alternative 4 because similar soil types would be disturbed.

Shoreline Erosion. Shoreline erosion on a 30,000 AF Rockwell/Mueller Creek Reservoir from wave action and fluctuating water levels would be similar to Alternative 4. The reservoir would fluctuate about 70 feet on average and up to 100 feet in wet years. Large fluctuations in water levels expose more of the reservoir to wind action and increase the potential for erosion.

Sedimentation. The potential for sedimentation in Rockwell/Mueller Creek Reservoir from local sources within the basin would be similar to Alternative 4. Lands within the watershed west of the reservoir are primarily undeveloped forest land, but include scattered homes and gravel access roads. Erosion from upstream land development is likely to be minor because of the buffer areas of native forest vegetation. If recreation facilities are developed, this could generate minor sources of sedimentation from a parking area and trails.

Revegetation Potential. Reclamation of about 161 acres of temporarily disturbed soils to facilitate vegetation establishment would be needed for construction staging areas, along pipelines, borrow areas and other areas of construction disturbance. NRCS topsoil suitability ratings for temporarily disturbed soils in the study area indicate about 148 acres have poor suitability for topsoil, 13 acres are rated fair, and 0 acres are rated as good (Table 10). Similar to Alternative 4, the soils rated as fair topsoil suitability are limited because amount of rock fragments and the poorly rated soils are limited because of clay content, shallow soils, and the amount of rock in the soil. Revegetation of areas with poor topsoil quality may require the addition of soil amendments to improve conditions for revegetation and vegetation establishment would likely take longer.

Table 10. Topsoil suitability for temporarily disturbed soils at the 30,000 AF Rockwell/Mueller Creek Reservoir.

Good	Fair	Poor
0 acre	13 acres	148 acres

8.0 CUMULATIVE EFFECTS

Cumulative effects are those resulting from the incremental effect of an alternative when added to other past, present, and reasonably foreseeable future actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a time period.

Several reasonably foreseeable actions are anticipated to occur in the future regardless of the implementation of any of the WGFP action alternatives or the No Action alternative. Reasonably foreseeable actions were divided into water-based actions that affect portions of the Colorado River where Windy Gap diversions would occur and land-based actions that include ground disturbances or other activities near potential WGFP facilities.

No reasonably foreseeable actions that would incrementally add to the disturbance to geologic and soil resources and increase the potential for localized erosion were identified at the potential reservoir sites. No cumulative effects are expected from water-based reasonably foreseeable actions.

9.0 BEST MANAGEMENT PRACTICES

Additional investigations and measures should be applied during final design and construction for all of the alternatives to minimize effects to geologic and soil resources. Measures include—

- Further evaluate potential geologic hazards prior to final design, including all applicable guidelines and codes from applicable local, state, or federal agencies.
- Develop an erosion control plan as part of the required Stormwater NPDES permit to reduce the potential for erosion from disturbed areas or capture sediments on site.
- Integrate the erosion control plan with the revegetation plan.
- Salvage topsoil from areas of temporary disturbance where possible to aid in revegetation following construction.
- Clearly define construction limits to minimize soil disturbance.

If the Jasper East or Rockwell/Mueller Creek reservoir sites are constructed, a mitigation plan for paleontologic resources should be implemented. These resources consist of fossil mammals known to occur in the Troublesome Formation, which forms the underlying bedrock in the area of the two reservoir sites. Mitigation should be completed by a qualified vertebrate paleontologist. The mitigation plan could have the following components:

- A preliminary survey and surface salvage prior to construction.
- Monitoring and salvage during excavation.
- Preparation, including screen washing to recover small specimens (if applicable), and specimen preparation to a point of stabilization and identification.
- Identification, cataloging, curation, and storage.
- Reporting and documentation.

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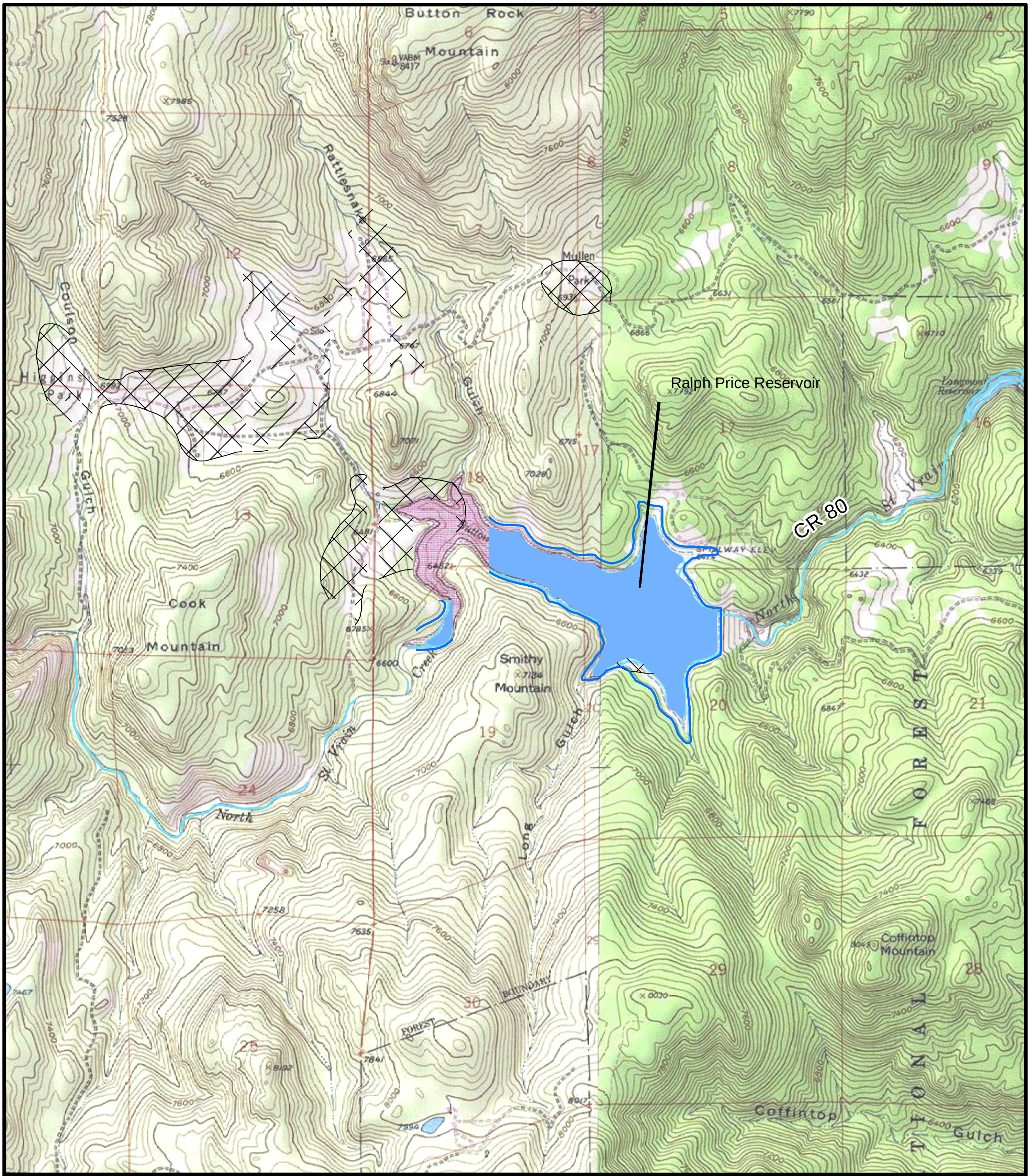
FIGURES



Ralph Price Reservoir Enlargement

Potential Borrow Areas

ERO

ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

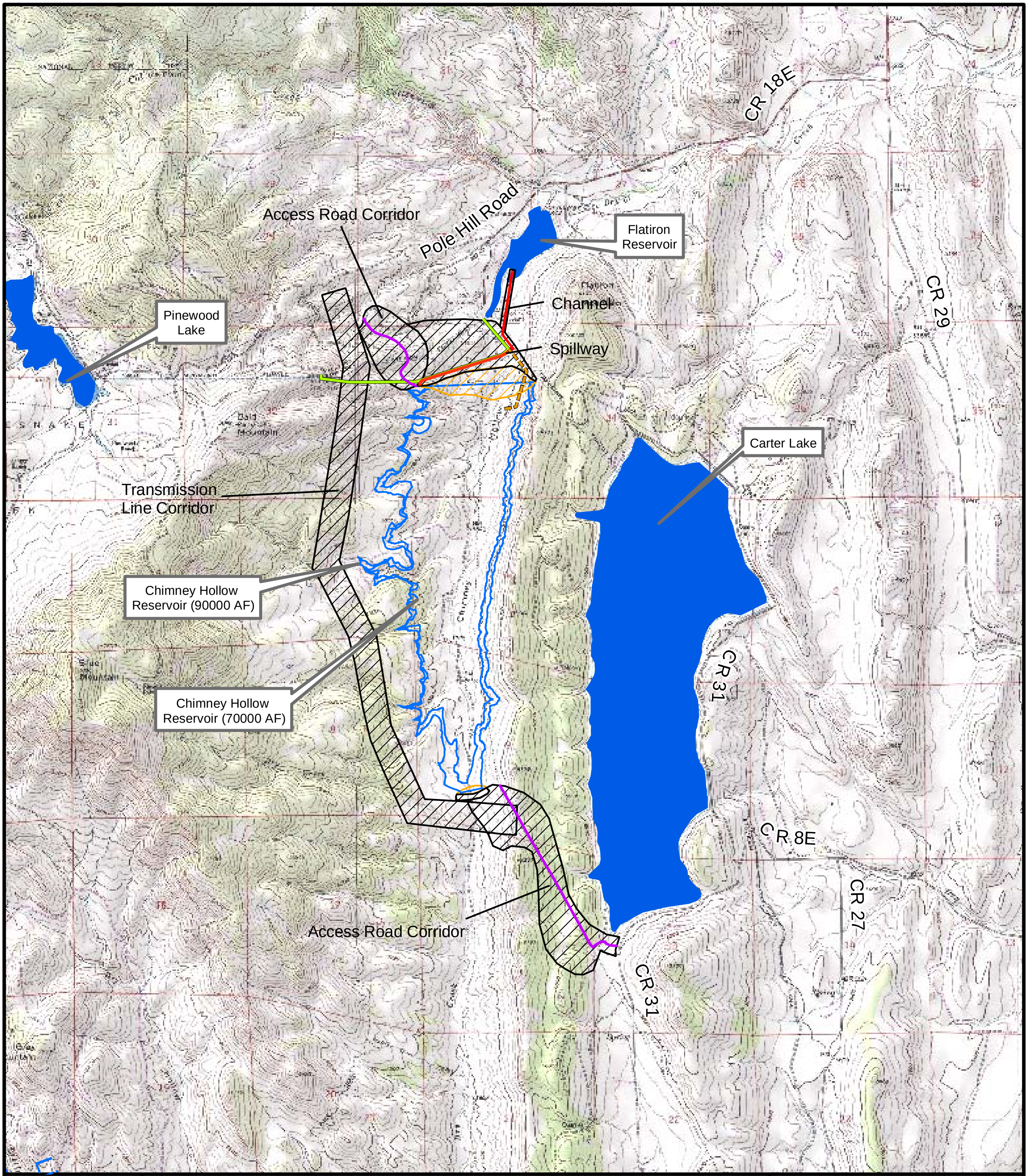
0 1,300 2,600 Feet

1 Inch = 2600 Feet

N

Figure 1
Ralph Price Reservoir Study Area

Prepared for: Windy Gap Firming Project
File: Ralph_Price_Reservoir_Study_Area.mxd
Date: March 2006



ERO

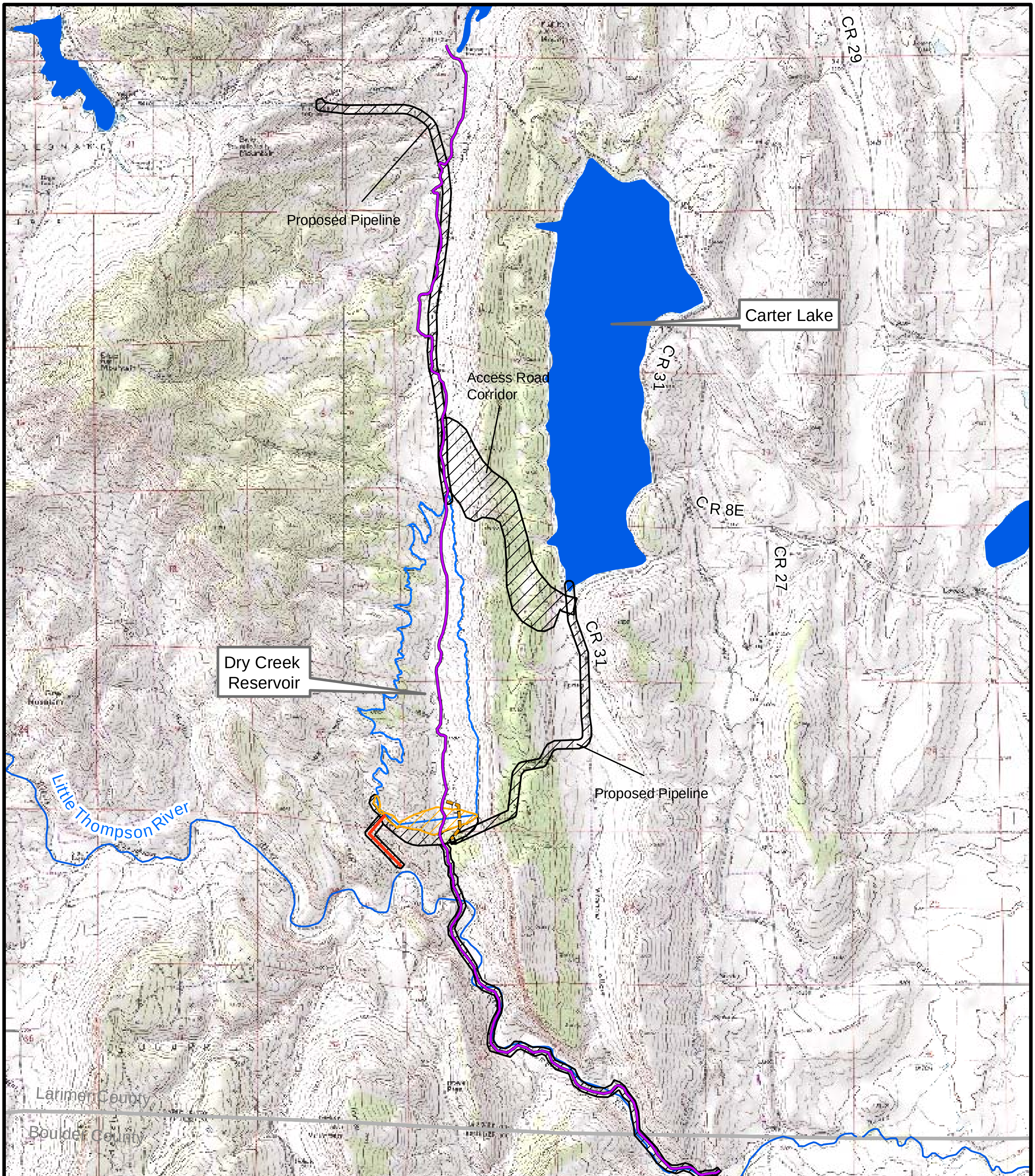
ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

New or Improved Access Road
Inlet - Outlet
Spillway/Channel
Pipeline
Potential Area of Disturbance
Reservoir
Dam

0 2,000 4,000 Feet
1 Inch = 4,000 Feet
N

Figure 2
Chimney Hollow Study Area

Prepared for: Windy Gap Firming Project
File: Chimney_Hollow_Wildlife_Study_Area.mxd
Date: March 2006



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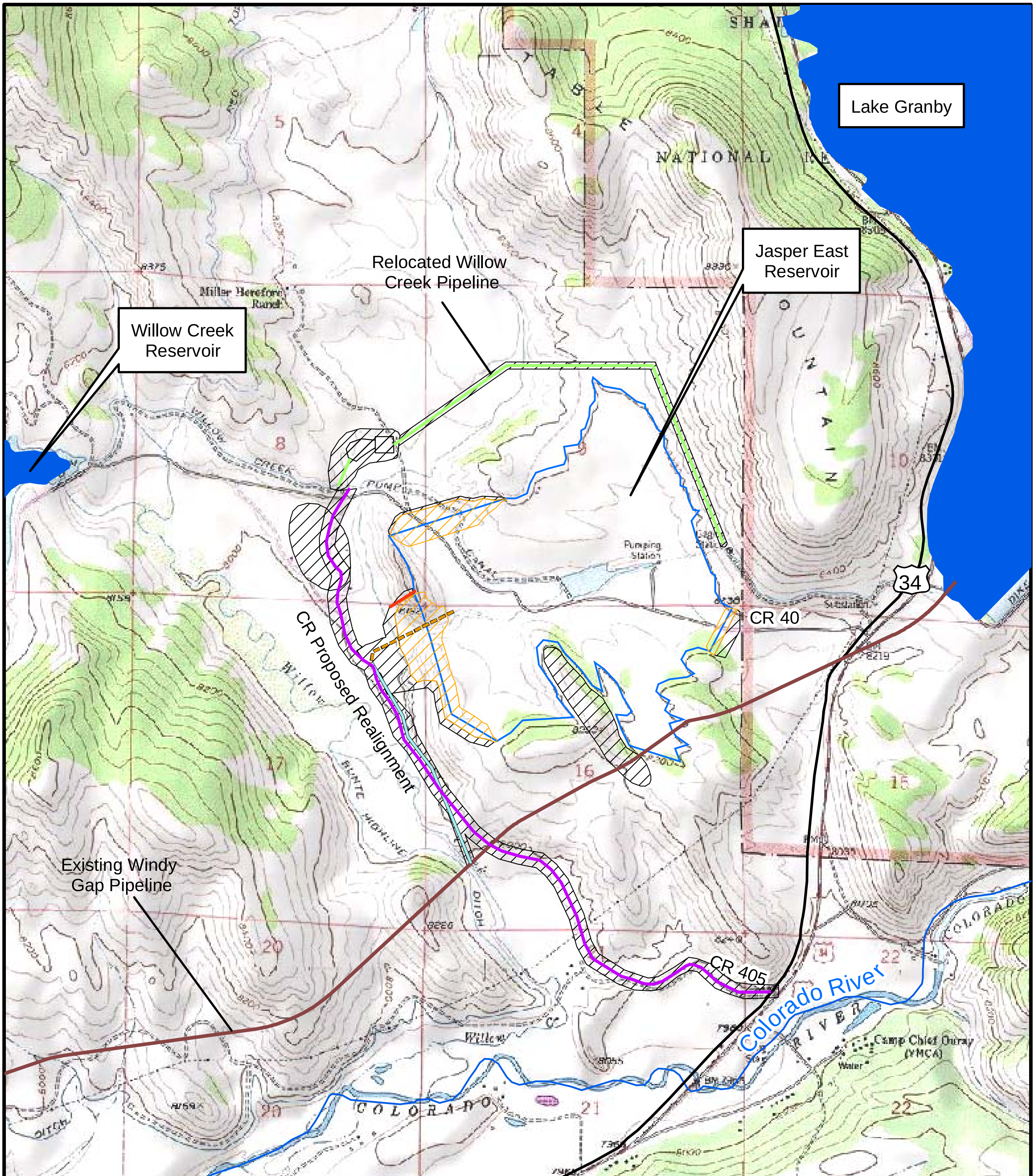
Fax: 830-1199

New or Improved Access Road
Inlet - Outlet
Spillway
Potential Area of Disturbance
Reservoir
Dam
County Boundary

0 2,300 4,600 Feet
1 Inch = 4,600 Feet
N

Figure 3
Dry Creek Study Area

Prepared for: Windy Gap Firming Project
File: Dry_Creek_Wildlife_Study_Area.mxd
Date: March 2006



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New or Improved Access Road
New Pipeline
Inlet - Outlet
Spillway
Potential Area of Disturbance
Reservoir
Dam

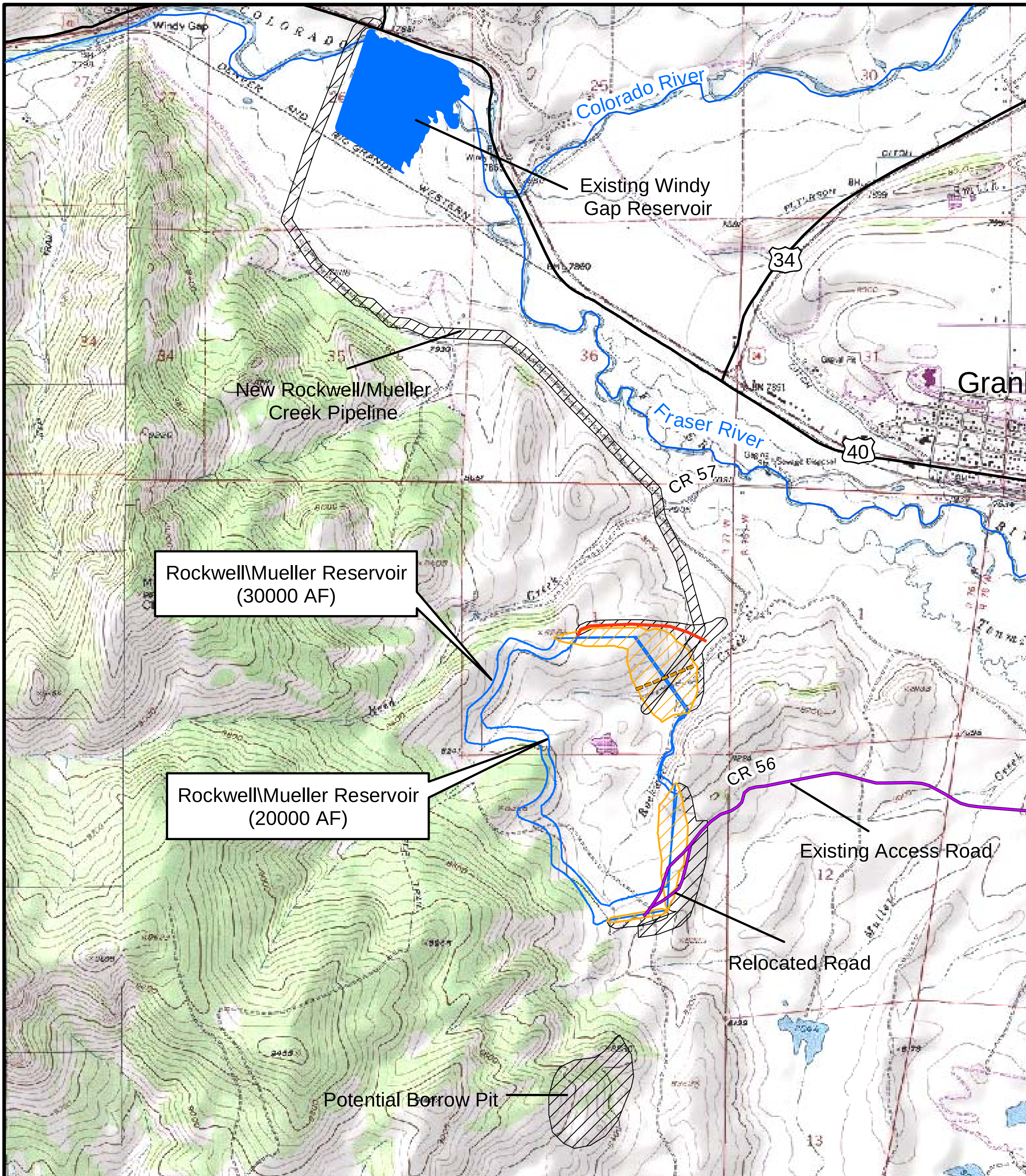
0 1,100 2,200 Feet

1 Inch = 2,200 Feet

N

Figure 4
Jasper East Study Area

Prepared for: Windy Gap Firming Project
File: Jasper_East_Wildlife_Study_Area.mxd
Date: March 2006



ERO

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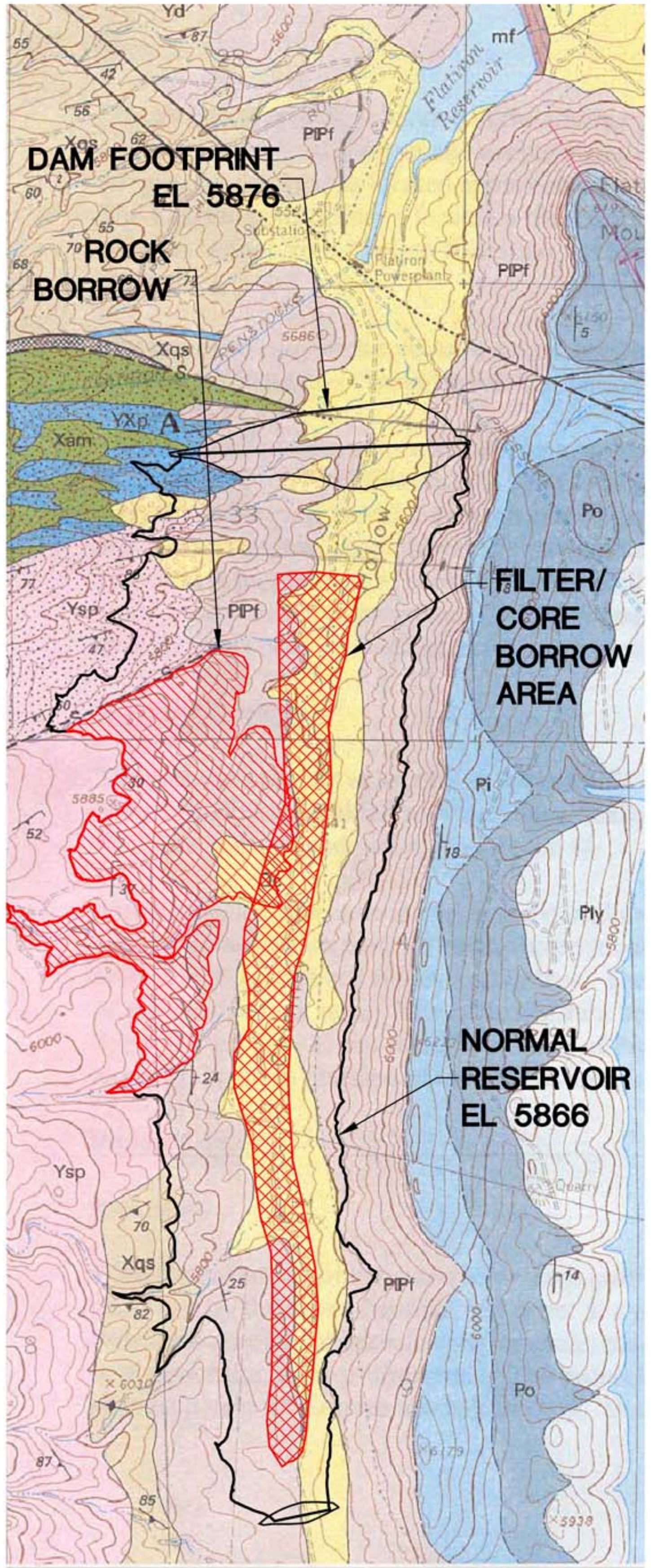
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

New or Improved Access Road
Inlet - Outlet
Spillway
Potential Area of Disturbance
Reservoir
Dam

0 1,300 2,600 Feet
1 Inch = 2,600 Feet
N

Figure 5
Rockwell/Mueller Creek Study Area

Prepared for: Windy Gap Firming Project
File: Rockwell_Wildlife_Study_Area.mxd
Date: March 2006

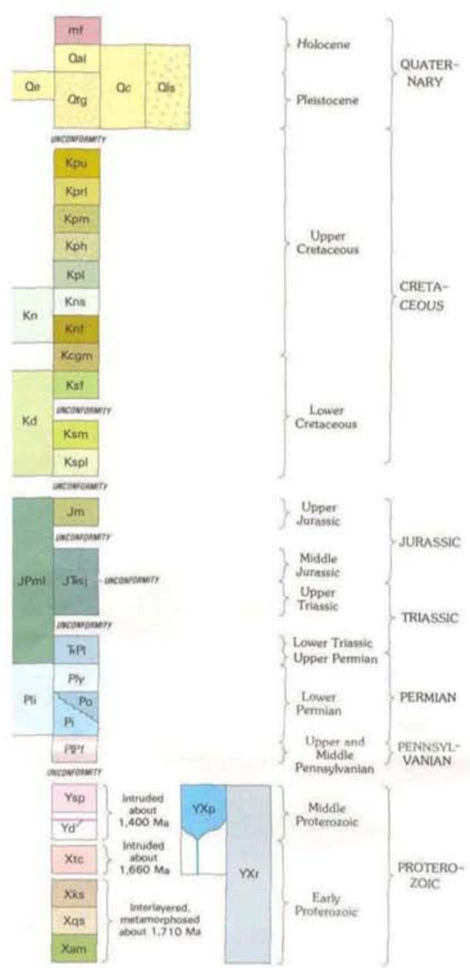


GEOLOGY MAP

0 2000 4000
SCALE IN FEET

"GEOLOGIC MAP OF THE CARTER LAKE RESERVIOR QUADRANGLE, BOULDER AND LARIMER COUNTIES, COLORADO", MAP GQ–1628, U.S. GEOLOGICAL SURVEY, 1988.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

[All radiometric ages quoted here have been recalculated using the IUGS decay constants (Steiger and Jäger, 1977)]

mf — **Manmade fill (Holocene)**—Rock- and earth-fill dams

Qal — **Alluvium (Holocene)**—Light-brownish-gray, silty or sandy gravel and pale-brown, clayey gravel

Qe — **Eolian deposits (upper Pleistocene)**—Pale-brown, massive, calcareous, clayey or sandy silt

Qtg — **Gravel deposits on benches, terraces, and pediments (Pleistocene)**—Reddish-brown or white, poorly sorted and poorly to well-stratified gravel. Clasts derived mostly from Precambrian rocks but also from nearby sedimentary rocks. Most clasts are weathered. Calcium carbonate cement may be locally abundant

Qc — **Colluvium and alluvium (Quaternary)**—Poorly sorted silt, clay, sand, gravel, and boulders. Deposits formed by sheet wash, debris flows, and concentrated surface flow in intermittent streams. Commonly mixed with talus

Qls — **Landslide deposits (Quaternary)**—Slumps and earthflows composed of clay, silt, sand, boulders as large as 10 ft in diameter, and large rock falls. Also includes small block-glide landslides, having poorly defined boundaries and internal structures, in which displaced geologic units are not identifiable

Pierre Shale (Upper Cretaceous)—Lithologic units and ammonite zones were mapped by Scott and Cobban (1965). Formation has been subdivided into the following members adapted from Scott and Cobban (1965):

Kpu — **Upper shale member**—Gray, concretionary, silty shale. Thickness about 2,800 ft (865 m), but top of unit does not crop out in quadrangle. *Baculites jenseni* ammonite zone at base

Kprl — **Richard, Larimer, and Rocky Ridge Sandstone Members and intervening unnamed shale units**—Richard Sandstone Member consists of pale-brown, clayey, micaceous siltstone and sandstone. Larimer Sandstone Member is hard to soft, yellowish-brown sandstone that contains fossiliferous, calcareous concretions. Rocky Ridge Sandstone Member is light-brown, fine- to medium-grained glauconitic sandstone that contains brown, calcareous concretions. Thickness of unit is about 260 ft (79 m). Upper half of *Baculites reesidei* ammonite zone included in basal part

Kpm — **Middle shale member**—Claystone and sandy siltstone containing thin bentonite beds. Unit includes Terry Sandstone Member (not mapped) near middle. Upper part of *Baculites scotti* ammonite zone included in basal part. About 715 ft (218 m) thick

Kph — **Hygiene Sandstone Member**—Two layers of hard, glauconitic, gray sandstone separated by concretionary siltstone comprise upper one-third of member; combined thickness about 300 ft (91 m). Middle part of member consists of about 400 ft (122 m) of medium-gray siltstone. Friable, gray, concretionary sandstone about 200 ft (61 m) thick forms basal part of member. Total thickness of member is about 900 ft (274 m). Top of *Baculites perplexus* ammonite zone is at base

Kpl — **Lower shale member**—Consists of Mitten Black Shale Member, Sharon Springs Member, and Gammon Ferruginous Member, all mostly dark-olive-gray shale and sandy shale containing limestone and ironstone concretions. Bentonite beds common in lower part. Thickness about 1,900 ft (589 m)

Kn — **Niobrara Formation (Upper Cretaceous)**—Total thickness about 315 ft (96 m). Shown as formation only on cross sections. Consists of two members:

Kns — **Smoky Hill Shale Member**—Very fissile, calcareous shale; dark gray on fresh surfaces, weathers to light-gray plates; distinctive yellowish-brown-weathering micrite about 15 ft (5 m) thick at top; layers having abundant *Pseudoperna congesta* common near middle; lower 50 ft (15 m) commonly less calcareous and not fissile

Knf — **Fort Hays Limestone Member**—Light-gray, thick-bedded micrite about 15 ft (5 m) thick; *Inoceramus* and *Pseudoperna congesta* abundant

Kcgm — **Carlile Shale, Greenhorn Limestone, Graneros Shale (Upper Cretaceous), and Mowry Shale (Lower Cretaceous)**—Total thickness 410–500 ft (125–152 m). Units not mapped separately due to poor exposures

Carlile Shale—Olive-gray, silty claystone and sandy siltstone; about 75 ft (23 m) thick

Greenhorn Limestone—Interlayered, dark-gray limestone and olive-gray, calcareous, silty claystone and siltstone; about 260 ft (80 m) thick

Graneros Shale—Dark-gray to grayish-black siltstone and claystone; about 160 ft (49 m) thick

Mowry Shale—Siliceous, white-weathering shale as much as 10 ft (3 m) thick

Kd — **Dakota Group (Lower Cretaceous)**—Shown as group only in cross sections. Subdivisions of the group are those defined by Waagé (1955)

South Platte Formation

Ksf — **First sandstone member**—Gray to light-brown, well-sorted, fine- to medium-grained sandstone 0–30 ft (9 m) thick

Ksm — **Middle shale member**—Dark-gray, carbonaceous shale containing thin bentonite beds and thin, gray siltstone and sandstone beds; about 190 ft (58 m) thick

Kspl — **Plainview Sandstone Member of the South Platte Formation and Lytle Formation, undivided**—Total thickness about 145 ft (44 m)

Plainview Sandstone Member—Gray to light-brown, thinly bedded, fine-grained carbonaceous sandstone. About 25 ft (8 m) thick

Lytle Formation—Gray to light-brown, coarse-grained to conglomeratic sandstone and blocky-weathering, varicolored, noncarbonaceous mudstone. About 120 ft (36 m) thick

JPml — **Morrison (Upper Jurassic), Sundance (Middle Jurassic), Jelm (Upper Triassic), and Lykins (Lower Triassic and Upper Permian) Formations undivided**—Shown in cross sections only

Jm — **Morrison Formation (Upper Jurassic)**—Green, red, yellow, and white, blocky-weathering claystone and siltstone interbedded with gray micrite and gray, fine- to medium-grained sandstone; about 310 ft (94 m) thick

JŦsj — **Sundance Formation (Middle Jurassic) and Jelm Formation (Upper Triassic)**—Sundance and Jelm Formations (Pipiringos and O'Sullivan, 1976) have a combined thickness ranging from 100 ft (30 m), in the southern part of the quadrangle, to 153 ft (47 m), in the northern part of the quadrangle. Pine Butte Member of the Sundance consists of about 5 ft (1.5 m) of massive to flat-bedded, fine-grained, gray to white sandstone, which conformably overlies the Canyon Springs Sandstone Member of the Sundance. Canyon Springs consists of about 15 ft (4.6 m) of pink, orange-pink, or reddish-brown, fine- to medium-grained, crossbedded, calcareous sandstone. It unconformably overlies the Red Draw Member of Jelm Formation. Unconformity is marked by conspicuous chert pebbles. The Red Draw Member of Jelm consists of orange-pink or reddish-brown, fine-grained, crossbedded, calcareous sandstone, which unconformably overlies the Lykins Formation. Red Draw is about 140 ft (43 m) thick in the northern part of the area and thins to about 75 ft (23 m) in the southern part

ŦPl — **Lykins Formation (Lower Triassic and Upper Permian)**—Dominantly red and reddish-brown siltstone and fine-grained sandstone containing several thin carbonate beds. Total thickness about 505 ft (154 m). Members defined by Broin (1957) could not be mapped because of poor exposure. The Park Creek Limestone Member, about 1 ft (0.3 m) of red, massive limestone, is about 175 ft (53 m) above the base of formation. The Forelle Limestone Member, which is about 30 ft (9 m) thick, is about 100 ft (30 m) above the base. It is a light-to dark-gray, laminated rock varying from limestone to dolomite, which contains stromatolite structures. The Falcon Tongue of the Minnekahta Limestone Member, which is about 1–2 ft (0.3–0.6 m) thick, is about 55 ft (17 m) above the base. It is dark-gray, sandy, laminated dolomite or dolomitic limestone

Pli — **Lyons Sandstone, Owl Canyon and Ingleside Formations (Lower Permian)**—Shown in cross sections only

Ply — **Lyons Sandstone (Lower Permian)**—Orange to pink to pinkish-gray, fine- to medium-grained, well-sorted, quartzose sandstone. Commonly well cemented with quartz. Characterized by large-scale dune crossbedding; about 50 ft (15 m) thick

Po — **Owl Canyon Formation (Lower Permian)**—Red siltstone and fine-grained, red, ripple-laminated sandstone; intertongues with Ingleside Formation and not present south of Carter Lake Reservoir. At north edge of quadrangle, formation is about 200 ft (61 m) thick

Pi — **Ingleside Formation (Lower Permian)**—Pink to light-red, fine-grained quartzose sandstone. Commonly well cemented with quartz or calcite. Varies from thinly bedded, in southern part of quadrangle, to very thick bedded in northern part of quadrangle. Thickness ranges from about 200 ft (61 m), in southern part of quadrangle, to about 70 ft (21 m) in northern part of quadrangle

PPf — **Fountain Formation (Lower Permian and Upper and Middle Pennsylvanian)**—Reddish-brown to purplish-gray, arkosic conglomerate; medium- to coarse-grained, feldspathic sandstone; dark-reddish-brown siltstone and shale; and minor thin limestone. About 1,100 ft (335 m) thick

Ysp — **Silver Plume Granite (Middle Proterozoic)**—Equigranular muscovite-biotite granite containing aligned, subhedral microcline phenocrysts. Occurs as generally discordant bodies

Yd — **Mafic dikes (Middle Proterozoic)**—Black to dark- or light-gray, fine- to medium-grained rocks of basaltic or andesitic composition, which form a north- to northwest-trending dike swarm throughout much of the northern Front Range. Plagioclase forms phenocrysts in most dikes. Mineralogy and texture vary both regionally and locally, and variations are due to primary magmatic factors, such as bulk composition and rate of cooling, and also to metamorphism, which has affected the dikes to varying degrees.

Because of crosscutting relations at various places in the northern Front Range, the dike swarm is believed to be intermediate in age between Silver Plume Granite and Sherman Granite.

The only dike mapped is in the northwest corner of the quadrangle, and it is fine-grained, blastophitic, hornblende-biotite diorite

Xtc — **Trondhjemite of Thompson Canyon (Early Proterozoic)**—Light-gray, fine-grained, porphyritic rock composed of sodic plagioclase, quartz, microcline, and biotite

METASEDIMENTARY AND METAVOLCANIC ROCKS (EARLY PROTEROZOIC)

Schist units (Xks, Xqs) are metasedimentary rocks; amphibolite (Xam) is probably metavolcanic. Whole-rock Rb-Sr age of the time of regional metamorphism is 1,713±30 Ma (Peterman and others,1968). The age of deposition cannot be much older, because Sm-Nd isotopic analyses are consistent with a model age of 1,800 Ma for the formation of continental crust in Colorado (DePaolo, 1981)

Xks — **Knotted mica schist**—Biotite schist that, in this area, is migmatitic and contains abundant sillimanite

Xqs — **Quartzofeldspathic mica schist**—In the northwest corner of the quadrangle, this unit consists of fine-grained muscovite-chlorite phyllite interbedded with quartzofeldspathic metasandstone. Both rock types contain biotite and albite. Along west edge of quadrangle, unit consists of migmatitic biotite schist interlayered with quartzofeldspathic metasandstone

Xam — **Hornblende gneiss and amphibolite**—Weakly to strongly layered hornblende-plagioclase gneiss locally interlayered with massive amphibolite. Contains thin layers and pods of white to light-green calc-silicate gneiss

YXr — **Proterozoic rocks, undifferentiated**—Cross sections only

Contact—Approximately located. Vertical or showing dip or overturned dip. Contacts of Pennsylvanian through Cretaceous formations are solid where exposed, dashed where unexposed, dotted where concealed

Head scarp of block-glide landslide of Quaternary age—Approximately located. Glide mass is stippled. Displaced stratigraphic units shown within glide mass

Fault or fracture zone—Showing dip. Dashed where approximately located; dotted where concealed; queried where inferred. R, apparent upthrown side of supposed reverse fault

Subsurface fault—Shown where intersecting the base of the Niobrara Formation

Shear zone—Overprinted on other map units. Rock within zone is protomylonite

Fold—Showing approximate trace of axial surface, and bearing and plunge of hinge lines where known. Dashed where inferred; dotted where concealed. Form of folds, which may change along trace, shown by following symbols

Anticline

Syncline

Axial surfaces of monocline or structural terrace.—Short arrows show position of steep limb. Axial surfaces commonly occur in pairs

Strike and dip of beds—No dip values given where orientation is approximate

Inclined

Vertical

Strike and dip of foliations—May be combined with lineation symbols. Approximate orientation shown by symbol without dip value

Schistosity—Relict bedding and compositional layering are parallel to schistosity

Inclined

Vertical

Crenulations cleavage—Circled number indicates fold episode in which cleavage was formed

Inclined

Primary flow foliation in intrusive igneous rocks

Inclined

Mylonitic foliation

Inclined

Bearing and plunge of lineations—May be combined with foliation symbols

Small folds, crenulations, boudinage, or aligned minerals

Structure contour—Drawn on the base of the Niobrara Formation; contour interval 50 ft. Modified from Lavington (1961)

Well—Drilled for oil and gas

Gravel quarry

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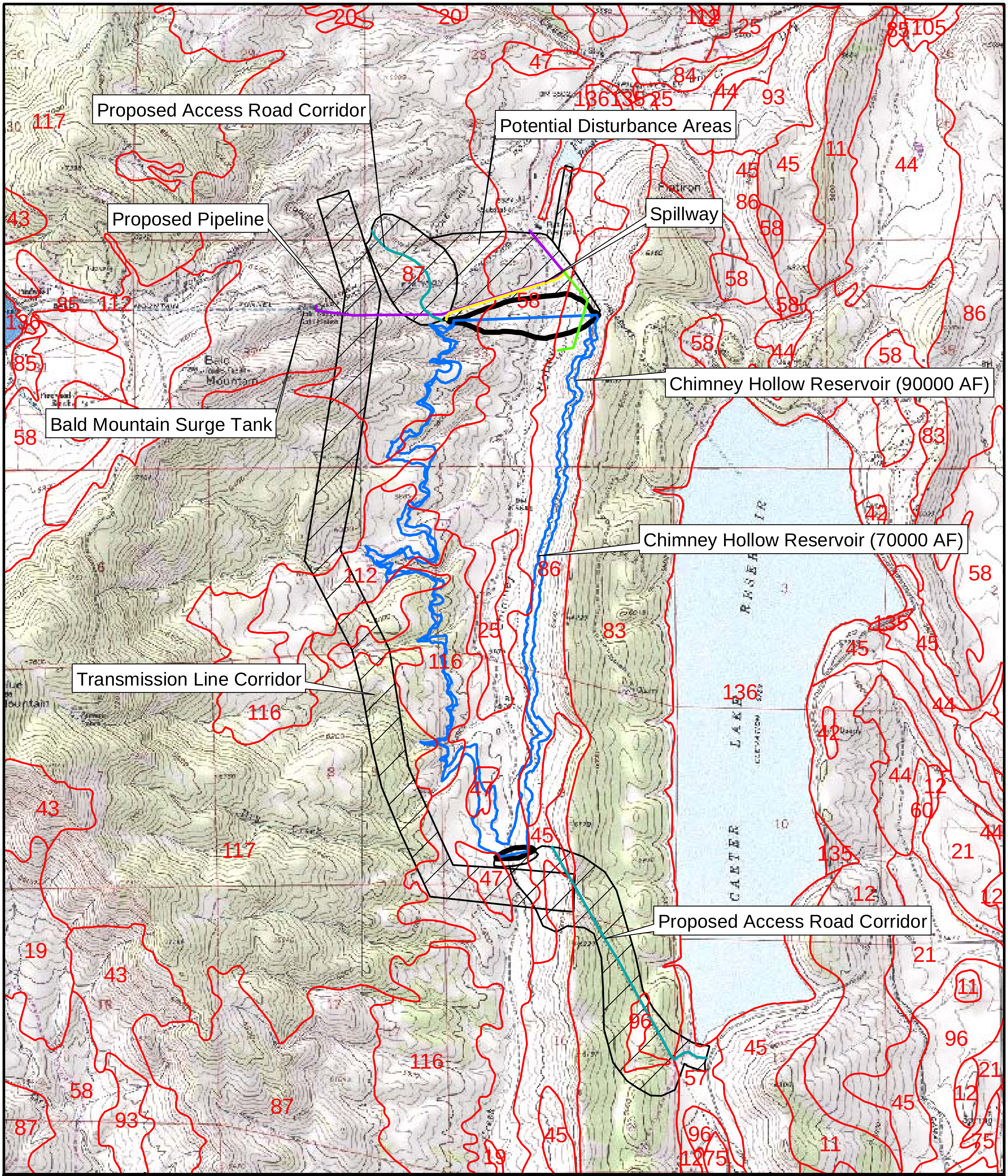
N.C.W.C.D.

WINDY GAP FIRMING PROJECT
CHIMNEY HOLLOW DAM AND RESERVOIR

SITE GEOLOGY MAP

FIGURE

6



ERO

ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

Soils Data

Soil Map Units

Structures

Access Road

Inlet - Outlet

Spillway

Chimney Hollow Pipeline

Chimney Hollow Reservoir

Chimney Hollow Dam

Potential Disturbance Area

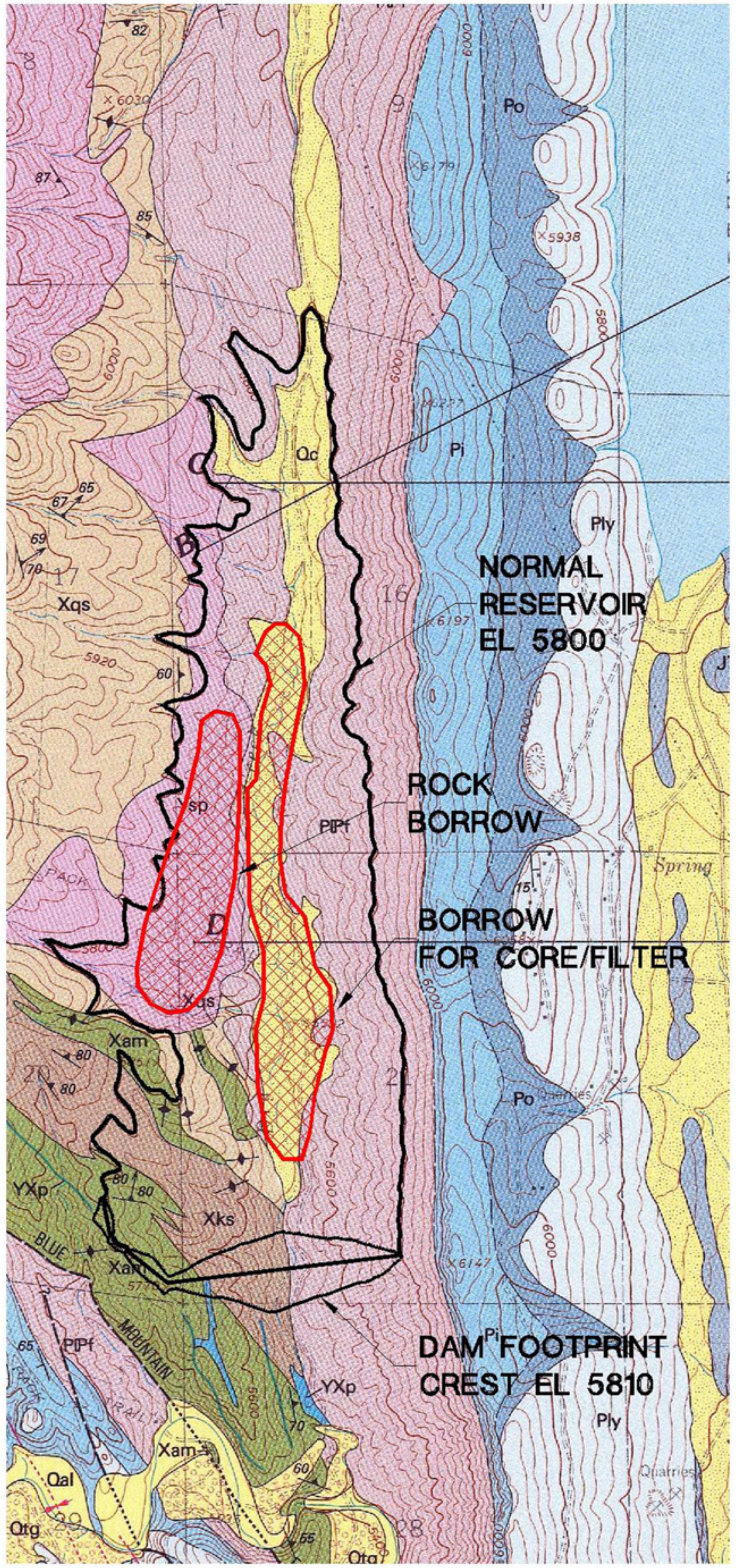
0 1,500 3,000 Feet

1 Inch = 3000 Feet

N

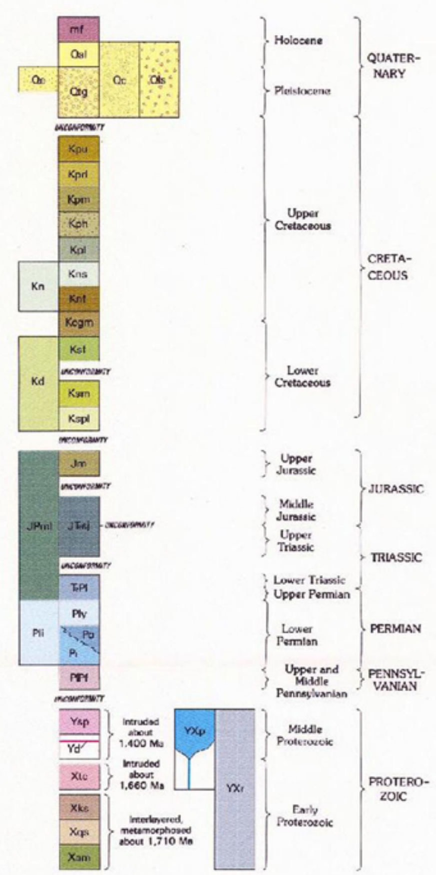
Figure 7
Chimney Hollow Reservoir Soils

Prepared for: Windy Gap Firming Project
File: W/Chimney_Hollow_Soils.mxd
Date: May 2006



"GEOLOGIC MAP OF THE CARTER LAKE QUADRANGLE, LARIMER COUNTY, COLORADO", MAP GQ-1628, U.S. GEOLOGICAL SURVEY, 1988.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

[All radiometric ages quoted here have been recalculated using the IUGS decay constants (Steiger and Jäger, 1977)]

mf **Manmade fill (Holocene)**—Rock- and earth-fill dams

Qal **Alluvium (Holocene)**—Light-brownish-gray, silty or sandy gravel and pale-brown, clayey gravel

Qe **Eolian deposits (upper Pleistocene)**—Pale-brown, massive, calcareous, clayey or sandy silt

Qtg **Gravel deposits on benches, terraces, and pediments (Pleistocene)**—Reddish-brown or white, poorly sorted and poorly to well-stratified gravel. Clasts derived mostly from Precambrian rocks but also from nearby sedimentary rocks. Most clasts are weathered. Calcium carbonate cement may be locally abundant

Qc **Colluvium and alluvium (Quaternary)**—Poorly sorted silt, clay, sand, gravel, and boulders. Deposits formed by sheet wash, debris flows, and concentrated surface flow in intermittent streams. Commonly mixed with talus

Qls **Landslide deposits (Quaternary)**—Slumps and earthflows composed of clay, silt, sand, boulders as large as 10 ft in diameter, and large rock falls. Also includes small block-glide landslides, having poorly defined boundaries and internal structures, in which displaced geologic units are not identifiable

Pierre Shale (Upper Cretaceous)—Lithologic units and ammonite zones were mapped by Scott and Cobban (1965). Formation has been subdivided into the following members adapted from Scott and Cobban (1965):

Kpu **Upper shale member**—Gray, concretionary, silty shale. Thickness about 2,800 ft (865 m), but top of unit does not crop out in quadrangle. *Baculites jenseni* ammonite zone at base

Kprl **Richard, Larimer, and Rocky Ridge Sandstone Members and intervening unnamed shale units**—Richard Sandstone Member consists of pale-brown, clayey, micaceous siltstone and sandstone. Larimer Sandstone Member is hard to soft, yellowish-brown sandstone that contains fossiliferous, calcareous concretions. Rocky Ridge Sandstone Member is light-brown, fine- to medium-grained glauconitic sandstone that contains brown, calcareous concretions. Thickness of unit is about 260 ft (79 m). Upper half of *Baculites reesidei* ammonite zone included in basal part

Kpm **Middle shale member**—Claystone and sandy siltstone containing thin bentonite beds. Unit includes Terry Sandstone Member (not mapped) near middle. Upper part of *Baculites scotti* ammonite zone included in basal part. About 715 ft (218 m) thick

Kph **Hygiene Sandstone Member**—Two layers of hard, glauconitic, gray sandstone separated by concretionary siltstone comprise upper one-third of member; combined thickness about 300 ft (91 m). Middle part of member consists of about 400 ft (122 m) of medium-gray siltstone. Friable, gray, concretionary sandstone about 200 ft (61 m) thick forms basal part of member. Total thickness of member is about 900 ft (274 m). Top of *Baculites perplexus* ammonite zone is at base

Kpl **Lower shale member**—Consists of Mitten Black Shale Member, Sharon Springs Member, and Gammon Ferruginous Member, all mostly dark-olive-gray shale and sandy shale containing limestone and ironstone concretions. Bentonite beds common in lower part. Thickness about 1,900 ft (589 m)

Kn **Niobrara Formation (Upper Cretaceous)**—Total thickness about 315 ft (96 m). Shown as formation only on cross sections. Consists of two members:

Kns **Smoky Hill Shale Member**—Very fissile, calcareous shale; dark gray on fresh surfaces, weathers to light-gray plates; distinctive yellowish-brown-weathering micrite about 15 ft (5 m) thick at top; layers having abundant *Pseudoperna congesta* common near middle; lower 50 ft (15 m) commonly less calcareous and not fissile

Knf **Fort Hays Limestone Member**—Light-gray, thick-bedded micrite about 15 ft (5 m) thick; *Inoceramus* and *Pseudoperna congesta* abundant

Kcgm **Carlile Shale, Greenhorn Limestone, Graneros Shale (Upper Cretaceous), and Mowry Shale (Lower Cretaceous)**—Total thickness 410–500 ft (125–152 m). Units not mapped separately due to poor exposures

Carlile Shale—Olive-gray, silty claystone and sandy siltstone; about 75 ft (23 m) thick

Greenhorn Limestone—Interlayered, dark-gray limestone and olive-gray, calcareous, silty claystone and siltstone; about 260 ft (80 m) thick

Graneros Shale—Dark-gray to grayish-black siltstone and claystone; about 160 ft (49 m) thick

Mowry Shale—Siliceous, white-weathering shale as much as 10 ft (3 m) thick

Kd **Dakota Group (Lower Cretaceous)**—Shown as group only in cross sections. Subdivisions of the group are those defined by Waagé (1955)

South Platte Formation

Ksf **First sandstone member**—Gray to light-brown, well-sorted, fine- to medium-grained sandstone 0–30 ft (9 m) thick

Ksm **Middle shale member**—Dark-gray, carbonaceous shale containing thin bentonite beds and thin, gray siltstone and sandstone beds; about 190 ft (58 m) thick

Kspl **Plainview Sandstone Member of the South Platte Formation and Lytle Formation, undivided**—Total thickness about 145 ft (44 m)

Plainview Sandstone Member—Gray to light-brown, thinly bedded, fine-grained carbonaceous sandstone. About 25 ft (8 m) thick

Lytle Formation—Gray to light-brown, coarse-grained to conglomeratic sandstone and blocky-weathering, varicolored, noncarbonaceous mudstone. About 120 ft (36 m) thick

JPml **Morrison (Upper Jurassic), Sundance (Middle Jurassic), Jelm (Upper Triassic), and Lykins (Lower Triassic and Upper Permian) Formations undivided**—Shown in cross sections only

Jm **Morrison Formation (Upper Jurassic)**—Green, red, yellow, and white, blocky-weathering claystone and siltstone interbedded with gray micrite and gray, fine- to medium-grained sandstone; about 310 ft (94 m) thick

JTRsj **Sundance Formation (Middle Jurassic) and Jelm Formation (Upper Triassic)**—Sundance and Jelm Formations (Pipiringos and O'Sullivan, 1976) have a combined thickness ranging from 100 ft (30 m), in the southern part of the quadrangle, to 153 ft (47 m), in the northern part of the quadrangle. Pine Butte Member of the Sundance consists of about 5 ft (1.5 m) of massive to flat-bedded, fine-grained, gray to white sandstone, which conformably overlies the Canyon Springs Sandstone Member of the Sundance. Canyon Springs consists of about 15 ft (4.6 m) of pink, orange-pink, or reddish-brown, fine- to medium-grained, crossbedded, calcareous sandstone. It unconformably overlies the Red Draw Member of Jelm Formation. Unconformity is marked by conspicuous chert pebbles. The Red Draw Member of Jelm consists of orange-pink or reddish-brown, fine-grained, crossbedded, calcareous sandstone, which unconformably overlies the Lykins Formation. Red Draw is about 140 ft (43 m) thick in the northern part of the area and thins to about 75 ft (23 m) in the southern part

TRPl **Lykins Formation (Lower Triassic and Upper Permian)**—Dominantly red and reddish-brown siltstone and fine-grained sandstone containing several thin carbonate beds. Total thickness about 505 ft (154 m). Members defined by Broin (1957) could not be mapped because of poor exposure. The Park Creek Limestone Member, about 1 ft (0.3 m) of red, massive limestone, is about 175 ft (53 m) above the base of formation. The Forelle Limestone Member, which is about 30 ft (9 m) thick, is about 100 ft (30 m) above the base. It is a light-to dark-gray, laminated rock varying from limestone to dolomite, which contains stromatolite structures. The Falcon Tongue of the Minnekahta Limestone Member, which is about 1–2 ft (0.3–0.6 m) thick, is about 55 ft (17 m) above the base. It is dark-gray, sandy, laminated dolomite or dolomitic limestone

Pli **Lyons Sandstone, Owl Canyon and Ingleside Formations (Lower Permian)**—Shown in cross sections only

Ply **Lyons Sandstone (Lower Permian)**—Orange to pink to pinkish-gray, fine- to medium-grained, well-sorted, quartzose sandstone. Commonly well cemented with quartz. Characterized by large-scale dune crossbedding; about 50 ft (15 m) thick

Po **Owl Canyon Formation (Lower Permian)**—Red siltstone and fine-grained, red, ripple-laminated sandstone; intertongues with Ingleside Formation and not present south of Carter Lake Reservoir. At north edge of quadrangle, formation is about 200 ft (61 m) thick

Pi **Ingleside Formation (Lower Permian)**—Pink to light-red, fine-grained quartzose sandstone. Commonly well cemented with quartz or calcite. Varies from thinly bedded, in southern part of quadrangle, to very thick bedded in northern part of quadrangle. Thickness ranges from about 200 ft (61 m), in southern part of quadrangle, to about 70 ft (21 m) in northern part of quadrangle

PIPf **Fountain Formation (Lower Permian and Upper and Middle Pennsylvanian)**—Reddish-brown to purplish-gray, arkosic conglomerate; medium- to coarse-grained, feldspathic sandstone; dark-reddish-brown siltstone and shale; and minor thin limestone. About 1,100 ft (335 m) thick

Ysp **Silver Plume Granite (Middle Proterozoic)**—Equigranular muscovite-biotite granite containing aligned, subhedral microcline phenocrysts. Occurs as generally discordant bodies

Yd **Mafic dikes (Middle Proterozoic)**—Black to dark- or light-gray, fine- to medium-grained rocks of basaltic or andesitic composition, which form a north- to northwest-trending dike swarm throughout much of the northern Front Range. Plagioclase forms phenocrysts in most dikes. Mineralogy and texture vary both regionally and locally, and variations are due to primary magmatic factors, such as bulk composition and rate of cooling, and also to metamorphism, which has affected the dikes to varying degrees.

Because of crosscutting relations at various places in the northern Front Range, the dike swarm is believed to be intermediate in age between Silver Plume Granite and Sherman Granite.

The only dike mapped is in the northwest corner of the quadrangle, and it is fine-grained, blastophitic, hornblende-biotite diorite

YXp **Pegmatite (Middle and Early Proterozoic)**—Coarse to very coarse grained. Both Middle and Early Proterozoic pegmatites occur, but they could not be distinguished unequivocally by field examination. Many discordant pegmatites probably are related to emplacement of the Silver Plume Granite. Concordant pegmatites, probably mostly Early Proterozoic, commonly form phacoliths. Early Proterozoic pegmatites may be related to emplacement of the Boulder Creek Granodiorite or may be migmatitic

Xtc **Trondhjemite of Thompson Canyon (Early Proterozoic)**—Light-gray, fine-grained, porphyritic rock composed of sodic plagioclase, quartz, microcline, and biotite

METASEDIMENTARY AND METAVOLCANIC ROCKS (EARLY PROTEROZOIC)

Schist units (Xks, Xqs) are metasedimentary rocks; amphibolite (Xam) is probably metavolcanic. Whole-rock Rb-Sr age of the time of regional metamorphism is 1,713±30 Ma (Peterman and others, 1968). The age of deposition cannot be much older, because Sm-Nd isotopic analyses are consistent with a model age of 1,800 Ma for the formation of continental crust in Colorado (DePaolo, 1981)

Xks **Knotted mica schist**—Biotite schist that, in this area, is migmatitic and contains abundant sillimanite

Xqs **Quartzofeldspathic mica schist**—In the northwest corner of the quadrangle, this unit consists of fine-grained muscovite-chlorite phyllite interbedded with quartzofeldspathic metasandstone. Both rock types contain biotite and albite. Along west edge of quadrangle, unit consists of migmatitic biotite schist interlayered with quartzofeldspathic metasandstone

Xam **Hornblende gneiss and amphibolite**—Weakly to strongly layered hornblende-plagioclase gneiss locally interlayered with massive amphibolite. Contains thin layers and pods of white to light-green calc-silicate gneiss

YXr **Proterozoic rocks, undifferentiated**—Cross sections only

Contact—Approximately located. Vertical or showing dip or overturned dip. Contacts of Pennsylvanian through Cretaceous formations are solid where exposed, dashed where unexposed, dotted where concealed

Head scarp of block-glide landslide of Quaternary age—Approximately located. Glide mass is stippled. Displaced stratigraphic units shown within glide mass

Fault or fracture zone—Showing dip. Dashed where approximately located; dotted where concealed; queried where inferred. R, apparent upthrown side of supposed reverse fault

Subsurface fault—Shown where intersecting the base of the Niobrara Formation

Shear zone—Overprinted on other map units. Rock within zone is protomylonite

Fold—Showing approximate trace of axial surface, and bearing and plunge of hinge lines where known. Dashed where inferred; dotted where concealed. Form of folds, which may change along trace, shown by following symbols

Anticline

Syncline

Axial surfaces of monocline or structural terrace.—Short arrows show position of steep limb. Axial surfaces commonly occur in pairs

Strike and dip of beds—No dip values given where orientation is approximate

Inclined

Vertical

Strike and dip of foliations—May be combined with lineation symbols. Approximate orientation shown by symbol without dip value

Schistosity—Relict bedding and compositional layering are parallel to schistosity

Inclined

Vertical

Crenulations cleavage—Circled number indicates fold episode in which cleavage was formed

Inclined

Primary flow foliation in intrusive igneous rocks

Inclined

Mylonitic foliation

Inclined

Bearing and plunge of lineations—May be combined with foliation symbols

Small folds, crenulations, boudinage, or aligned minerals

Structure contour—Drawn on the base of the Niobrara Formation; contour interval 50 ft. Modified from Lavington (1961)

Well—Drilled for oil and gas

Gravel quarry

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GEOLOGY MAP

0 2000 4000
SCALE IN FEET

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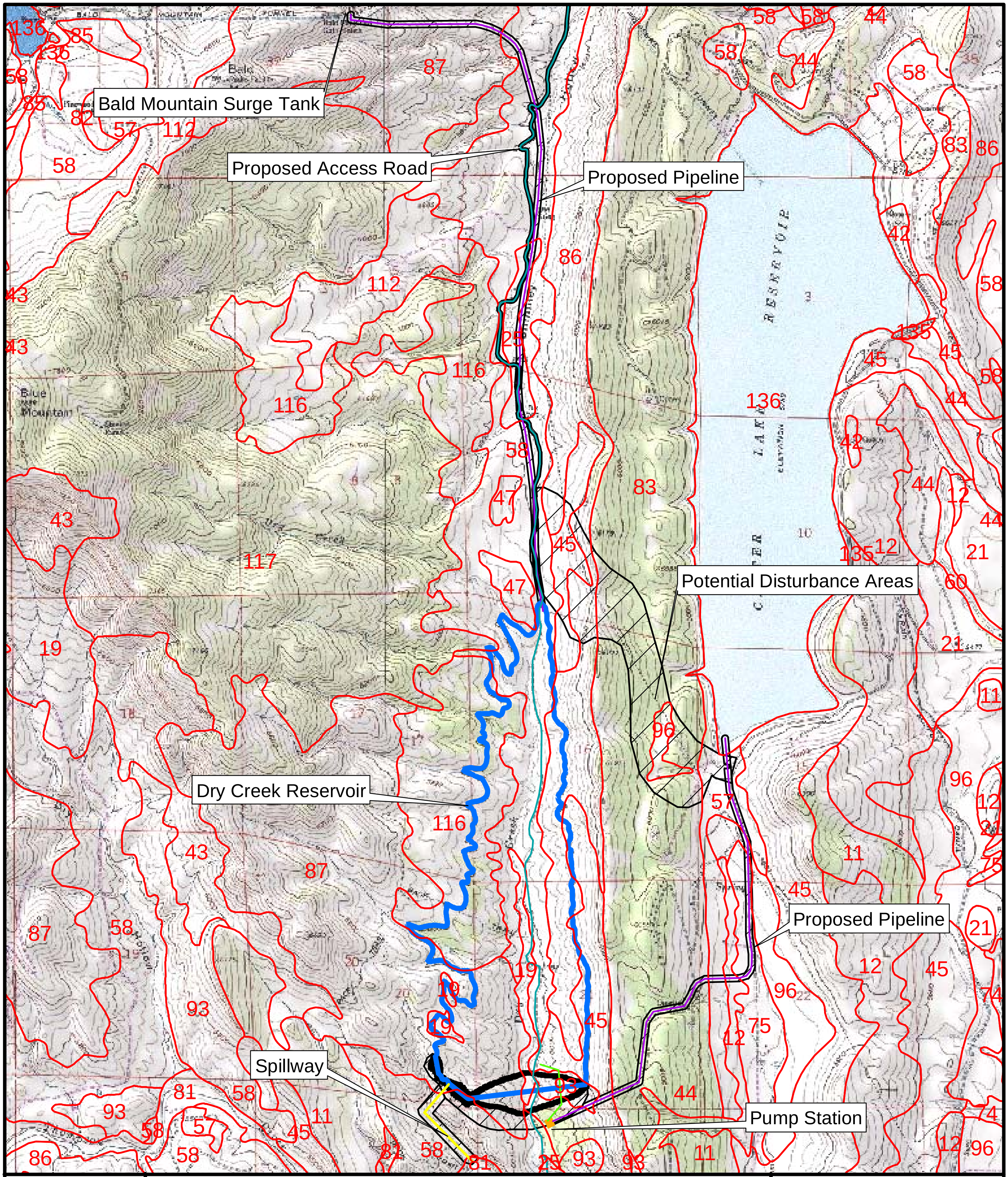
WINDY GAP FIRMING PROJECT
DRY CREEK DAM AND RESERVOIR

SITE GEOLOGY MAP

FIGURE
8



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Soils Data

Soil Map Units

Structures

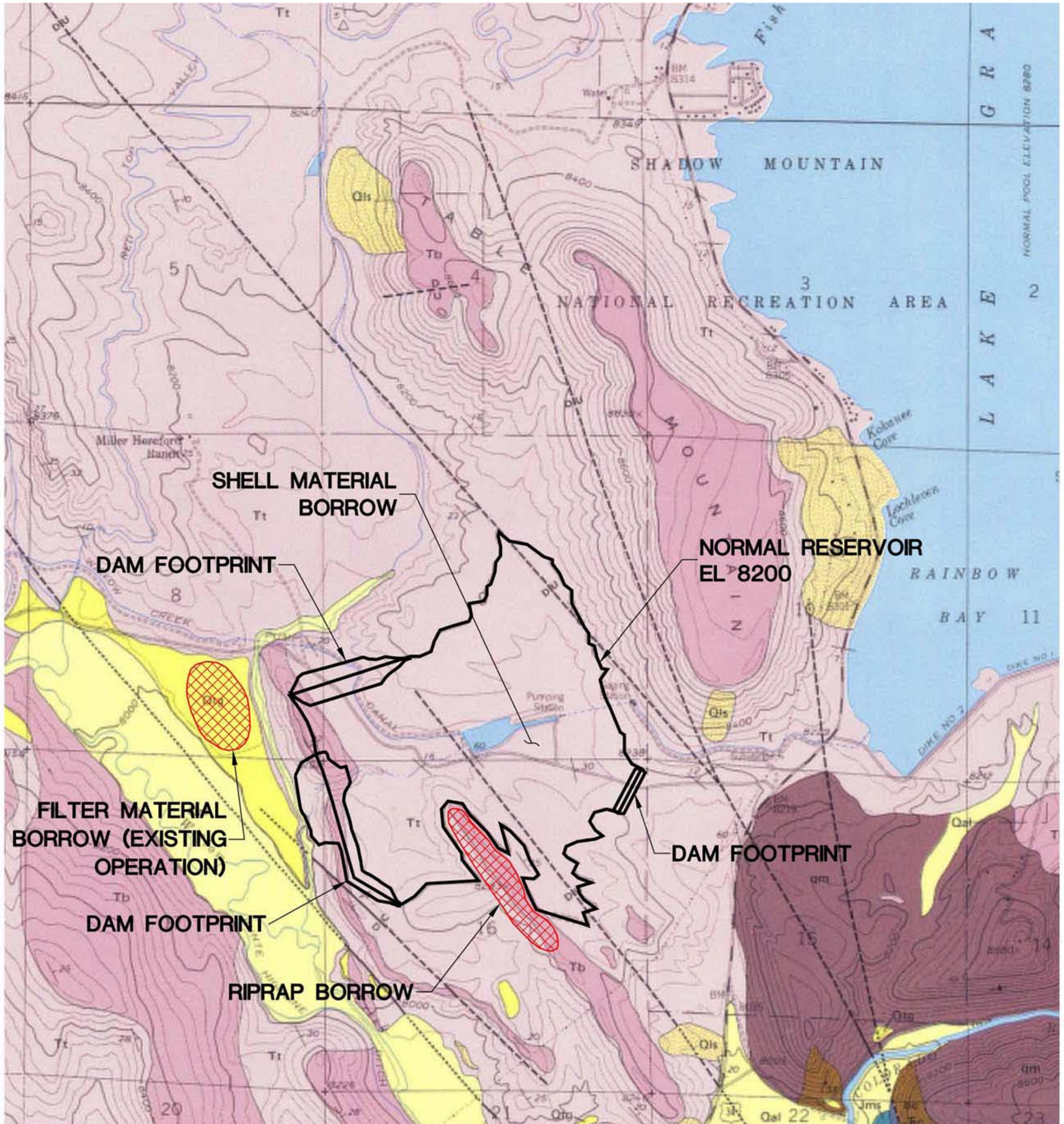
Access Road
Inlet - Outlet
Spillway

Dry Creek Pipeline
Dry Creek Reservoir
Dry Creek Dam
Potential Disturbance Area

0 1,500 3,000 Feet
1 Inch = 3000 Feet
N

Figure 9
Dry Creek Reservoir Soils

Prepared for: Windy Gap Firming Project
File: W/Dry_Creek_Soils.mxd
Date: May 2006



"GEOLOGIC MAP OF THE TRAIL MOUNTAIN QUADRANGLE, GRAND COUNTY, COLORADO", MAP GQ-1763, U.S. GEOLOGICAL SURVEY, 1995.

0 2000 4000

SCALE IN FEET

GEOLOGY MAP

DESCRIPTION OF MAP UNITS

Qal	ALLUVIUM (HOLOCENE) – Gravel, sand, silt, and clay along modern rivers
Qls	LANDSLIDE DEPOSITS (HOLOCENE)
Qc	COLLUVIUM (HOLOCENE)
Qtg	TERRACE DEPOSITS (PLEISTOCENE) – Sand and gravel as much as 25 feet thick along main rivers and streams
Qt	TILL (PLEISTOCENE) – Poorly sorted sandy till containing large erratics of granitic and gneissic Precambrian rocks
Qp	PEDIMENT DEPOSITS (PLEISTOCENE) – Poorly sorted sand and gravel
Tbc	BOULDER CONGLOMERATE OF GRAVEL MOUNTAIN (PLIOCENE?) – Poorly sorted unconsolidated deposits that characteristically contain well-rounded boulders of pink granitic Precambrian rock as much as 14 feet in diameter; as mapped may include some till and lag deposits
Tt	TROUBLESOME FORMATION (MIOCENE) – Gray tuffaceous mudstone and sandstone; several interlayered basalt flows (Tb); locally contains conglomerate composed of Precambrian rocks and middle Tertiary volcanic rocks; thickness not well known but probably 500-1,000 feet thick. Fossil mammals reported by Lovering (1930, p. 74) include *Parahippus, Merycus, Procamelus,* and *Blastomeryx.* Fossil rodent remains were found by Peter Robinson of the University of Colorado in the SW¼ sec. 33, T. 3 N., R. 76 W., and identified by him as a *Gregorymys*-like pocket gopher of probable early Miocene age. Zircons separated from tuff in lower part of formation in the NW¼SW¼ sec. 18, T. 2N., R. 76W. have a fission-track age of about 23 million years (C. W. Naeser, written commun., 1973)
Tb	BASALT FLOWS (MIOCENE) – Dark-gray to black lavas; some flows contain conspicuous clinopyroxene phenocrysts as much as 10 mm long; a few flows contain small altered olivine phenocrysts; all flows have normal remanent magnetization; whole rock K-Ar age determination on basalt flow in the NW¼ SW¼ SE¼ sec. 7, T. 2N., R. 76W. is 25.9 ± 0.4 m.y. (J. D. Obradovich, written commun., 1973)
Tib	BASALT DIKES AND PLUGS (MIOCENE) – Dark-gray to black dense rock that has normal remanent magnetization
Tim	LAMPROPHYRIC INTRUSIVE ROCK (MIOCENE) – Dark-brown; contains abundant biotite
Tr	RHYOLITE INTRUSIVE (MIOCENE) – Light-reddish-brown laminated and intricately folded lithoidal rock; locally has pitchstone chill border
Trf	RHYOLITE FLOWS (MIOCENE) – Light-reddish-brown laminated intricately folded lithoidal rock; zircon crystals separated from this rock have a fission-track age of about 25.5 ± 2.4 million years (C. W. Naeser, written commun., 1973)
Tli	LATITE INTRUSIVE (MIOCENE) – Dark-brown to dark-gray aphanitic rock; locally brecciated
Tl	LATITE PORPHYRY OF TRAIL MOUNTAIN (MIOCENE) – Gray to brown rock containing andesine phenocrysts as much as 30 mm long and a few small biotite, sanidine, and clinopyroxene phenocrysts. Zircons from this rock have a fission-track age of about 27.6 ± 2.9 million years (C. W. Naeser, written commun., 1973)
Tlbr	LATITE PORPHYRY BRECCIA (MIOCENE) – Brown to reddish-brown monolithologic flow breccia; locally grades into the latite porphyry of Trail Mountain
Tm	MIDDLE PARK FORMATION (PALEOCENE) – Varicolored in shades of gray, brown, purple, and green; considerable volcanic pebbles and cobbles; complexly interbedded micaceous siltstone, sandstone, and conglomerate; dominantly arkosic; pebbles, boulders, and cobbles consist of Precambrian granitic rock, gneiss, and pegmatite along with andesite and felsite porphyry; local carbonaceous and impure coal beds and thin discontinuous limestone beds near base; local volcanic breccia and conglomerate beds; only lower part exposed in quadrangle, but in nearby areas formation is more than 6,000 feet thick
Kmw	Windy Gap Volcanic Member (Upper Cretaceous?) – Medium-gray to dark-gray and purplish-gray andesite and trachyandesite porphyry breccia; locally contains well-bedded volcanic siltstone, sandstone, and conglomerate beds in upper part; poorly sorted and poorly stratified in lower and middle parts of unit; locally contains a few Precambrian rock fragments near base of units; about 300 feet thick
Kp (p, s)	PIERRE SHALE (UPPER CRETACEOUS) – Upper part is interbedded silty shale and sandstone, some sandstone beds as much as 100 feet thick; lower part is dark-gray to black shale about 1,500 feet thick; total thickness of formation not determined owing to faulting and poor exposures. p, prominent sandstone bed; s, prominent sandstone beds probably equivalent to the Hygiene Sandstone Member
Kn	NIOBRARA FORMATION (UPPER CRETACEOUS) – Light- to dark-gray subfissile calcareous shale; only middle part of formation exposed in quadrangle; *Inoceramus* and *Ostrea congesta* fragments found at outcrops
Kb	BENTON SHALE (UPPER AND LOWER CRETACEOUS) – Only lower part inferred in map area; elsewhere in region the formation is calcareous shale about 250 feet thick underlain by medium- to dark-gray shale about 150 feet thick. Topmost beds are fossiliferous recrystallized limestone about 20 feet thick underlain by very fine grained sandstone about 30 feet thick; contain fossils of Juana Lopez age
Kd	DAKOTA SANDSTONE (LOWER CRETACEOUS) – Light-gray to light-brown very fine grained to fine-grained ripple-marked thin- to very thick bedded even-bedded sandstone; locally conglomeratic; a few trails and borings of soft-bodied organisms in upper part; light-gray to light-brown lenticular conglomeratic sandstone and chert pebble conglomerate in lower part; about 250 feet thick
Jms	MORRISON AND SUNDANCE FORMATIONS (UPPER JURASSIC) – Green, greenish-gray, and grayish-red structureless silty claystone intercalated with light-gray siltstone and sandstone; locally calcareous; a few thin discontinuous dense limestone beds; very fine grained sandstone and laminated siltstone probably equivalent of Canyon Springs Sandstone Member of Sundance Formation near base. Morrison Formation about 300 feet thick; Sundance Formation about 60 feet thick
Trc	CHUGWATER FORMATION (TRIASSIC) – Reddish-brown mudstone and sandstone, micaceous; laminated to thin-bedded; contains lenticular limestone 1-3 feet thick in lower part; thickness not established
q	QUARTZ MONZONITE OF STILLWATER CREEK (PRECAMBRIAN) – Gray medium-grained weakly foliated intrusive rock; mainly contains quartz, microcline, sodic plagioclase, biotite, and muscovite; contains some pegmatite; locally has dark micaceous clots
qm	QUARTZ MONZONITE (PRECAMBRIAN) – Pink to red fine- to medium-grained weakly foliated intrusive rock; generally contains quartz, microcline, and sodic plagioclase and a few percent of biotite and muscovite; includes some pegmatite, aplite, and gneiss
bc	BOULDER CREEK GRANODIORITE (PRECAMBRIAN) – Gray medium-grained intrusive rock that contains scattered feldspar phenocrysts; locally grades into quartz diorite; commonly foliated; includes some pegmatite
gn	GNEISS (PRECAMBRIAN) – Gray fine- to medium-grained irregularly banded and contorted rock consisting of mica, quartz, and plagioclase; locally migmatized; includes some pegmatite

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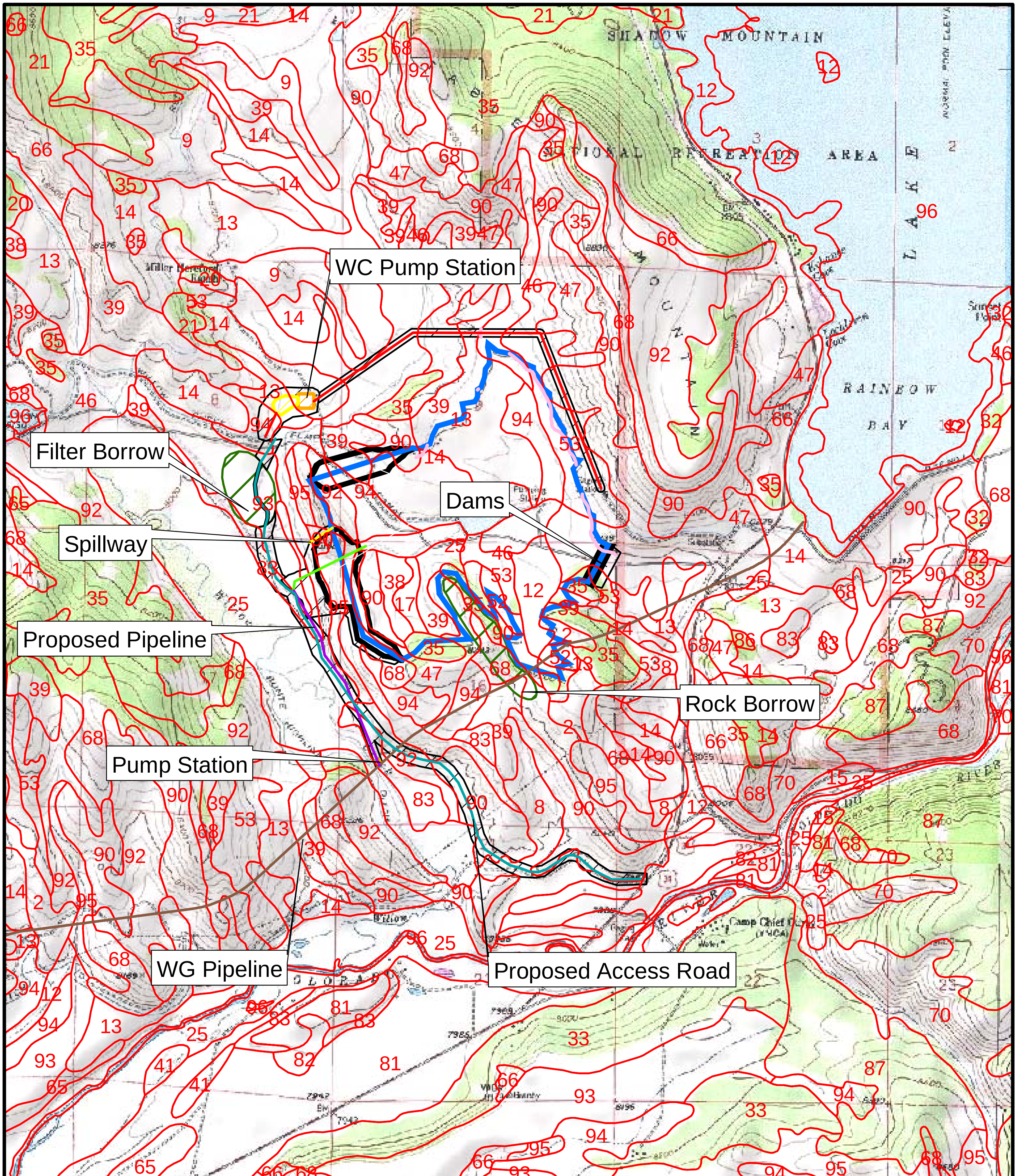
WINDY GAP FIRMING PROJECT
JASPER EAST DAM AND RESERVOIR

SITE GEOLOGY MAP

FIGURE

10



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Soils Data

Soil Map Units

Structures

Access Road
Inlet - Outlet
Spillway
Jasper East Pipeline

WC Pipeline
Existing Windy Gap Pipeline
Jasper East Reservoir
Potential Disturbance Area
Dam
Borrow Area

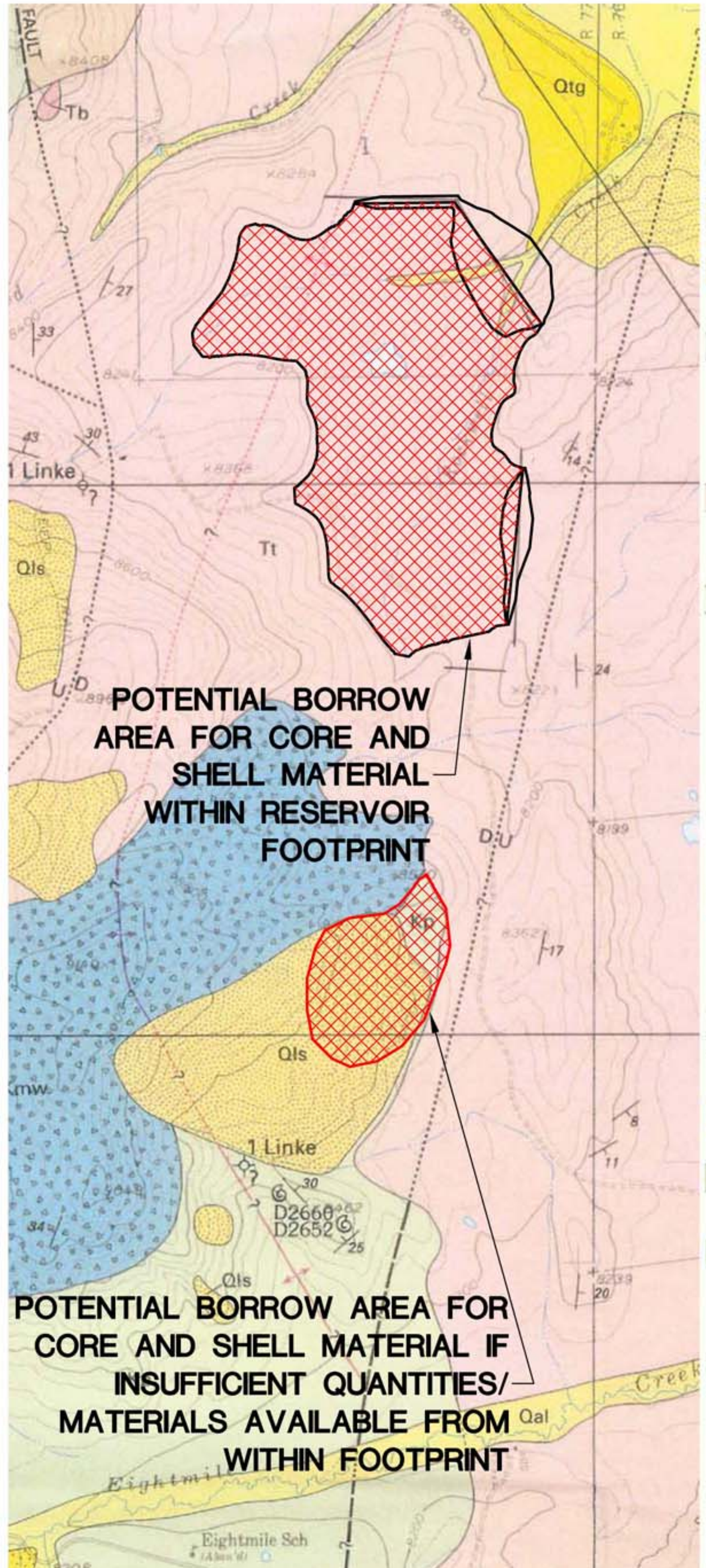
0 1,250 2,500 Feet

1 Inch = 2500 Feet

N

Figure 11
Jasper East Reservoir Soils

Prepared for: Windy Gap Firming Project
File: W/Jaspereast_Soils.mxd
Date: May 2006



DESCRIPTION OF MAP UNITS

Qal — **Alluvium (Holocene and late Pleistocene)**—Varies from boulder gravel to carbonaceous silt and clay; along present streams and as small alluvial fans. Late Pleistocene deposits are mostly of Pinedale age but may include a few deposits of Bull Lake age (Meierding, 1977). Thickness as much as 100 ft

Qc — **Colluvium (Holocene and late Pleistocene)**—Pervasive mantle of locally derived, poorly sorted, unstratified, weathered material ranging in size from blocks to clay; mapped only where identity of underlying map units is uncertain. Thickness as much as 10 ft or more

Qls — **Landslide deposits (Holocene and late Pleistocene)**—Jumbled material commonly composed of Troublesome Formation, Pierre Shale, or Morrison Formation and respective superjacent units. Thickness as much as tens of feet

Qtg — **Terrace gravel (late and middle Pleistocene)**—Boulder gravel to sand; forms benches above major streams; locally capped by silt, probably loess, as much as 3 ft thick. Bull Lake and pre-Bull Lake in age, but may include a few small deposits of Pinedale age (Meierding, 1977). Thickness as much as 80 ft

Tt — **Troublesome Formation (Miocene and Oligocene)**—Pale shades of pink, tan, gray, green, and white interbedded siltstone and mudstone, less abundant arkosic sandstone and conglomerate, and sparse limestone and altered crystal-vitric ash and tuff; generally poorly consolidated. Includes atypical deposits containing abundant pink, granitic cobbles and boulders along the western parts of outcrop in the west-central and southwestern parts of the quadrangle. Interlayered with basalt in north half of quadrangle. Fossil mammals from three sites south of the town of Granby indicate a late Oligocene age (Kron, 1988). Thickness as much as 1,000 ft or more

Tb — **Basalt (Miocene and Oligocene)**—Dark-gray to black basalt, weathers brown to reddish brown; single and multiple flows interlayered with Troublesome Formation; scoriaceous and brecciated near top and bottom of individual flows. Thickness variable, but aggregate flows locally as much as a few hundred feet thick

Middle Park Formation (Paleocene and Upper Cretaceous?)

TKm — **Upper part (Paleocene and Upper Cretaceous?)**—Interbedded, light- to medium-brown, tan, or gray, volcanic and (or) arkosic sandstone and siltstone; volcanic and (or) granitic pebble to boulder conglomerate; and red, green, and brown mudstone. Includes the Windy Gap Volcanic Member at the base, but in this quadrangle the contact between the member and the main body of the formation is not exposed. A complete thickness of the Middle Park Formation is not exposed in the quadrangle, but in the adjacent Hot Sulphur Springs 15-minute quadrangle (Izett, 1968) the formation has a maximum thickness of 6,600 ft

Tma, *dark-greenish-gray to dark-brown dirty arkosic conglomerate, grit, and sandstones rich in fragments of porphyritic andesite; intercalated with dark micaceous volcanic mudstones; locally contains impure coal beds near base; shown only in Breccia Spoon syncline*

Tmm, *breccia of Marietta Creek; medium- to dark-purplish-gray breccia composed of porphyritic andesite and trachyandesite; intercalated with volcanic siltstone, sandstone, and conglomerate; occurs only in Breccia Spoon syncline*

Kmw — **Windy Gap Volcanic Member (Upper Cretaceous?)**—Brown or greenish-brown to gray to purple, massive volcanic breccia; interbedded volcanic conglomerate and sandstone; and rare, probable flows of latite to trachyte porphyry. A detailed description is given by Izett (1968). The member, named by Izett and others (1963) for extensive exposures adjacent to the Colorado River near Windy Gap at the west edge of the quadrangle, averages 600 ft thick in the type area; the regional thickness is 0–1,100 ft (Izett, 1968)

Kp — **Pierre Shale (Upper Cretaceous)**—Medium- to dark-gray shale, weathers olive. Thickness 4,000(?) ft

—s— **Sandstone bed**—Several beds of resistant, light-olive to tan sandstone mapped in northwest part of quadrangle. Correlates, at least in part, with the Hygiene Member (Izett, 1974). Some as much as 40 ft thick. Dashed where approximately located

Kn — **Niobrara Formation (Upper Cretaceous)**—Light-gray- to white-weathering, platy, calcareous shale; weathers buff near top; thin, light-gray to tan, bivalve-rich biomicrite beds near middle; several feet of light-gray to white micritic limestone at base. Total thickness about 400–500 ft

Kb — **Benton Shale (Upper Cretaceous)**—Mostly black shale. Top marked by medium-gray to brownish-gray, thin-bedded, crystalline limestone underlain by light-gray to tan quartz sandstone, together several feet thick. Shale interbedded with thin, resistant layers of light-gray to light-tan quartz sandstone near base. Total thickness about 450 ft

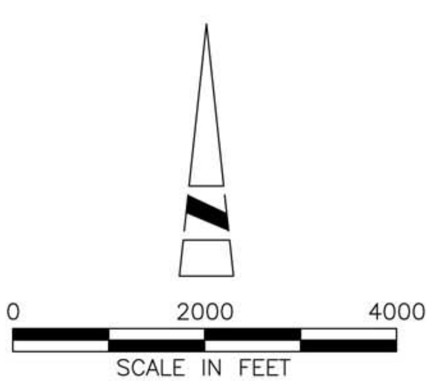
Kd — **Dakota Sandstone (Upper Cretaceous)**—Light-tan to light-gray, medium- to thin-bedded, fine-grained quartz sandstone in upper part; thick- to medium-bedded chert-pebble conglomerate and quartz sandstone in lower part; sparse trails and burrows of soft-bodied organisms in upper part; locally, uppermost part interlayered with black shale of the overlying Benton Shale; uppermost contact is gradational. Thin black shale beds also locally present at base of upper part. Total thickness about 225–350 ft

Jmsc — **Morrison Formation (Upper Jurassic) and Canyon Springs Sandstone Member of the Sundance Formation (Middle Jurassic), undivided**—Gray, green, and red mudstone and shale; lesser amounts of tan to white sandstone and siltstone; and minor light-gray to white micritic limestone of Morrison Formation underlain by light-tan to white, fine-grained quartz sandstone of the Canyon Springs Sandstone Member of the Sundance Formation which displays some large-scale crossbedding and may be separated from the Morrison Formation by a disconformity. Morrison Formation about 300 ft thick; Canyon Springs Sandstone Member of the Sundance Formation 60 ft or less thick

Ysp — **Silver Plume Granite (Middle Proterozoic)**—Pink to gray, fine-grained massive, granular, muscovite-bearing biotite granite (monzogranite)

"GEOLOGIC MAP OF THE GRANBY QUADRANGLE, GRAND COUNTY, COLORADO", MAP GQ-1763, U.S. GEOLOGICAL SURVEY, 1995.

GEOLOGY MAP



NOTES:

1. SOUTHERN CORE AND SHELL BORROW AREA TO BE UTILIZED ONLY IF INSUFFICIENT QUANTITIES/MATERIALS ARE AVAILABLE FROM WITHIN THE RESERVOIR FOOTPRINT.
2. THE ASSUMED SOURCE FOR FILTER/DRAIN MATERIAL, RIPRAP, AND BEDDING MATERIAL IS THE EXISTING BASALT RIPRAP QUARRY AND SAND AND GRAVEL QUARRY LOCATED NEAR THE JASPER EAST SITE.

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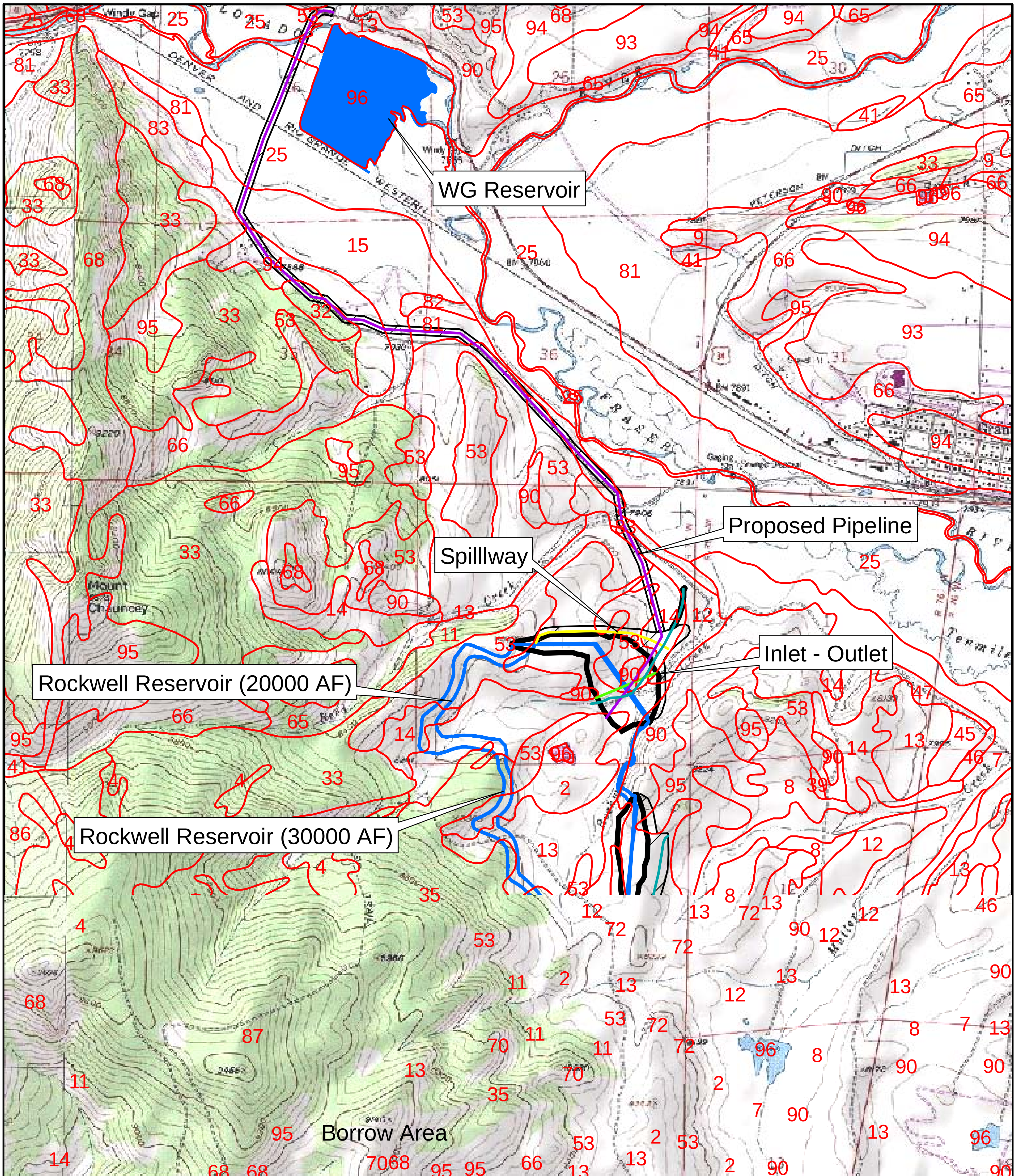
WINDY GAP FIRMING PROJECT
ROCKWELL CREEK DAM AND RESERVOIR

SITE GEOLOGY MAP

FIGURE

12

DWG: Z:_DENVER PROJECTS\N50\106\09 - Project Management\CAD\DESIGN\ROCKWELL\FIGURE 3.dwg USER: mrau
DATE: Apr 11, 2005 3:02pm XREFS: IMAGES: b40105a8.jpg DESCRIPTION.jpg ROCKWELL_CRK_GEOL.jpg



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Rockwell Pipeline
Existing Windy Gap Pipeline
Rockwell/Mueller Cree Reservoir
Dam
Potential Disturbance Area

0 1,250 2,500 Feet

1 Inch = 2500 Feet

N

Figure 13
Rockwell/Mueller Creek Reservoir Soils

Prepared for: Windy Gap Firming Project
File: W/Rockwell_Soils.mxd
Date:May 2006