Geotechnical Investigation Report

Rocky Mountain National Park Fall River Entrance

Estes Park, Colorado

Yeh Project No.: 220-348

September 15, 2021

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Geotechnical and Pavement Investigation Report

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1. PURPOSE AND SCOPE OF STUDY

This report presents the results of our geotechnical investigation for the proposed improvements to the Fall River Entrance at Rocky Mountain National Park near Estes Park, Colorado as shown in Figures 1 and 2. The purpose of this study was to evaluate geotechnical characteristics of the on-site soils and provide geotechnical recommendations for foundation design, pavement design, retaining walls, and on-site wastewater treatment system (OWTS) design.

The investigation consisted of exploratory test pits and test hole drilling to investigate subsurface conditions. Test pit and test hole drilling was observed, and percolation tests performed, by a representative of Yeh and Associates. Samples obtained during the field exploration were examined by the project personnel and representative samples were subjected to laboratory testing to evaluate the engineering characteristics of materials encountered. This report summarizes our field investigation, the results of our analyses, and our conclusions and recommendations based on the proposed construction, site reconnaissance, subsurface investigation, and results of the laboratory testing. Services were performed in general accordance with our proposal to Anderson Hallas Architects dated September 18, 2020.

2. Proposed Construction

The Fall River Entrance Station reconstruction proposes three (3) new kiosk buildings, a new administration building with employee break area, addition of a “fast pass” and employee entrance, reconstruction of the exit lane with a pull-off for map returns, construction of employee parking, widening of the approach lanes, reconfiguration of the vehicle turnaround west of the entrance. The proposed buildings are single story.

In addition to the entrance station improvements, water distribution and sanity sewer collection system upgrades are proposed within the complex of the buildings, in and around the Bighorn Ranger Station and extending southeast of the entrance station where a new onside wastewater treatment system (OWTS) will be constructed.

3. Geological Setting and Site Conditions

3.1 Site Conditions

The site is located at the Fall River Entrance to Rocky Mountain National Park on United States Highway 34, approximately four miles west of downtown Estes Park, Colorado. The entry kiosks are on the generally flat ledge of US 34. The OWTS area is down a slope on the south side of US 34, and the Big Horn Ranger Station and adjacent buildings are upslope of US 34 on the north side. Vegetation includes native trees, shrubs, wildflowers, and grasses. Scattered patches of snow were visible in shade slopes under tree cover.

3.2 Geologic Setting

Based on the 1990 USGS Geologic Map of Rocky Mountain National Park and Vicinity, Colorado, most of the project area is mapped as Till of Bull Lake age (Qb; upper Pleistocene age). This glacial till deposit consists of subangular to subrounded boulders, cobbles, and gravel in a silty sand matrix.

Alluvium of Holocene and upper Pleistocene age (Qa) forms is present just southwest of the main project area. These deposits consist of gravel, sand, and silt along streams and in valley fans. The regional bedrock is Silver Plume Granite (Ysp) of middle Proterozoic age. The Silver Plume Granite is typically shades of gray, orange, pink, red, or purple and contains tabular microcline phenocrysts in an equigranular matrix. Outcrops in this area are often irregular shaped masses.

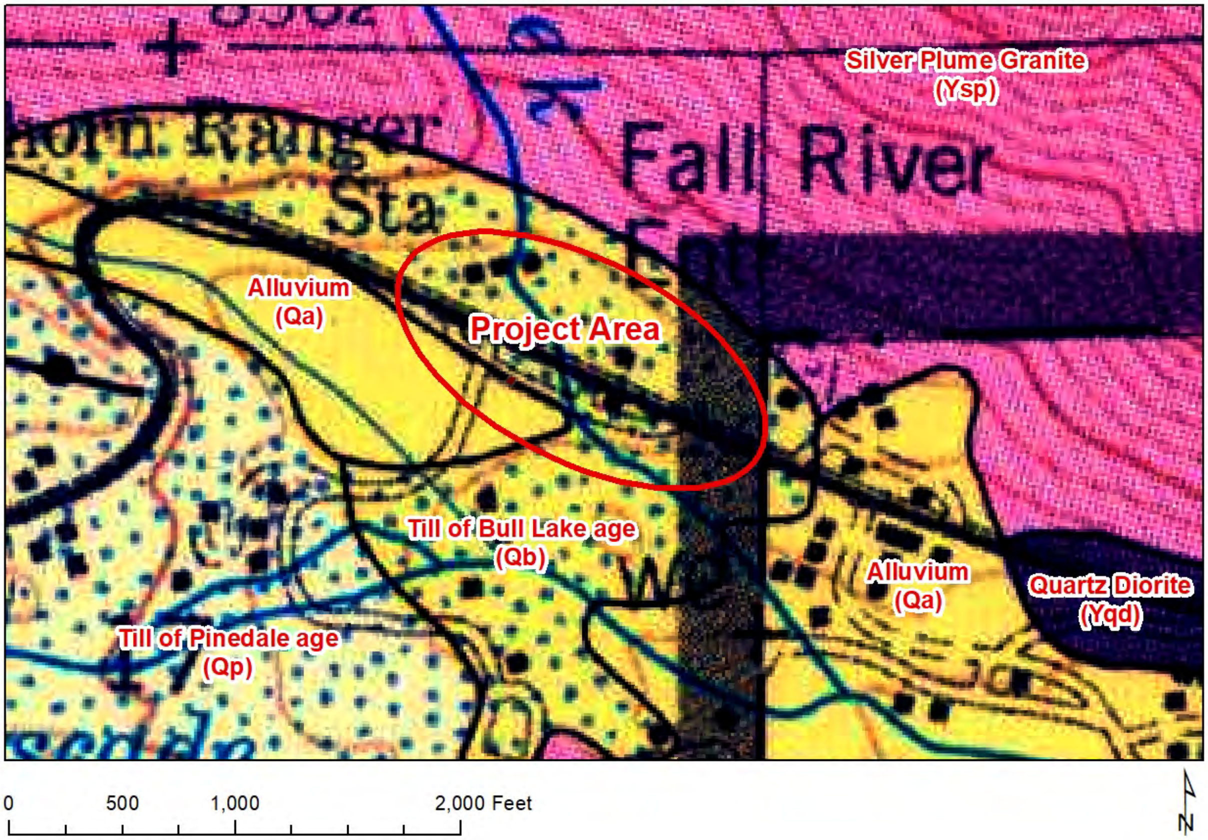


Figure 1. Geology of the Fall River Entrance area.

4. SITE INVESTIGATION

4.1 Subsurface Investigation

Seven borings were drilled on December 1 and 4, 2020. Boring locations were staked in the field the week prior to drilling to complete utility locates. Borings were placed based on locations provided by the client. Three test pits and two percolation test holes were dug on December 22, 2020. Photographs documenting the field investigation and site conditions are presented in Appendix A.

Borings were advanced using a CME 75 truck-mounted drill rig with 4-inch solid stem, continuous flight auger to predetermined depths. At selected intervals, a modified California sampler with a 2-inch interior diameter (ID) and 2.5 inch outside diameter (OD), or a standard split spoon sampler with a 1⅜-inch ID and 2-inch OD were used to record blow counts and obtain samples. The sampler was seated at the bottom of the boring, then advanced by an automatic hydraulic hammer equivalent to 140 pounds falling 30 inches. The number of blows (blow count) required to drive the sampler 12 inches or a fraction thereof, constitutes the N-value. The N-value, when properly evaluated, is an index of the consistency or relative density of the material tested. Bulk samples of drill cuttings were also obtained. Boring logs and legend are presented in Appendix B.

Test pits were dug using a small track-mounted excavator. The original plan was to dig two test pits to approximately eight feet in depth. Due to encountering four-inch diameter clay pipes and an approximately two-foot-thick layer of filter sand in the first two test pits, it was decided to dig a third pit in between and slightly south, near the edge of the slope. Two pits were dug to approximately eight feet and one was dug to approximately four feet.

Figure 2. Approximate boring locations

Figure 3. Approximate boring and test pit locations from the original OWTS investigation.

Figure 4. Approximate boring and test pit locations from the second OWTS investigation.

4.2 Subsurface Conditions

In general, the subsoils encountered in the borings consisted of silty sand with variable amounts of gravel. The two northwest structure borings, YA-NW-1 and YA-NW-2 encountered coarser material. Beneath several feet of local silty sand fill material, YA-NW-1 encountered gravel and cobbles below five feet depth, and auger refusal on a boulder at 22 feet. A second attempt 10 feet east of the original also encountered gravel and cobbles but successfully reached 30 feet depth.

Test pit YA-OWTS-TP-2 was dug to approximately four feet deep, and test pits YA-OWTS-TP-1 and 3 were dug to approximately eight feet deep. The subsurface material encountered in the test pits generally encountered approximately two feet of brown silty sand fill with gravel, cobbles, and boulders; six inches of gray gravel fill; two feet of gray coarse sand fill (existing filter material); another six inches of gray gravel fill; followed by reddish brown silty sand with gravel (possibly native material). Four-inch diameter red clay pipes were encountered at approximately two and a half to four feet deep, and a second pipe at approximately six and a half feet deep in YA-OWTS-TP-1. Based on our initial percolation testing, the native silty sand would likely be classified as sandy loam – Type 2 soils, in accordance with the Larimer County guidance documents.

Based on the initial findings of Test Pits YA-OWTS-TP-1 and YA-OWTS-TP-2, an alternative location for the OWTS was investigated. The alternate site investigation consisted of excavating two additional test pits and 3 borings for percolation testing. A profile boring was drilled with a Geoprobe drill rig with a 4-inch diameter solid-stem auger by Drilling Engineers of Ft. Collins. This profile boring terminated at 9 feet in depth and encountered a layer of topsoil over brown silty sand with gravel, encountering cobbles and boulders at approximately 3 feet and 7 feet depth. Hollow-stem auger was used to drill the percolcation borings. Hollow-stem auger and excavator refusal was reached at approximately 3 to 5 feet below the existing grades at the alternate OWTS location.

4.3 Percolation Testing

At the initial OWTS site, two percolation holes were drilled with a two-man power auger with an eight-inch diameter bit on December 22, 2020. Several locations were attempted but hit auger refusal within one foot of ground surface. A third percolation hole was attempted in the existing filter sand but due to lack of cohesive material the walls collapsed upon removal of the auger. Holes were prepared and tested in general accordance with Larimer County regulations. Approximately two inches of fine (pea) gravel was placed in the bottom of the holes, and water was added to presoak the material at least 12 inches over the top of the gravel. The holes were covered with traffic cones (for safety, and to hold in warmth/prevent freezing of the water) overnight and tested on December 23, 2020.

Perc holes were approximately two and a half feet deep, drilled downslope of the OWTS area surface, to penetrate the desired material as encountered in the test pits.

Water remained in both holes the next day, B1 (east) had water just covering the gravel, B1 (west) had sloughed so gravel was covered with wet mud and was ~ 2 ft deep from surface. Water was added to the holes prior to testing to approximately 1.2 feet below surface (B1) and 0.8 feet below surface (B2) at the beginning of testing. B1 consistently drained at a rate 25 minutes per inch. The percolation rate of B2 varied between readings from zero to one-fifth of a foot per half-hour, with an average over the four-hour test period of 80 minutes per inch.

A second OWTS location was investigated and tested in late June, 2021. Two test pits encountered silty sand with gravel but the excavator could not advance the two test pits beyond 4.3 and 5 feet depth because of boulders. Three percolation holes were drilled with 8-inch diameter auger to 3 feet depth. Several holes were attempted but hit refusal on boulders and various depths above the approximate target of 6 feet depth. Holes were prepared and tested in general accordance with Larimer County regulations. The three holes drained at rates of 49 minutes per inch, 58 minutes per inch, and 113 minutes per inch with an average of 73 minutes per inch. Based on the United Soil Classification System, soils encountered generally classify as silty sand with gravel. Based on our initial percolation testing and USDA soil textures the native soil would likely be classified as sandy clay loam – Type 3A soils, in accordance with the Larimer County guidance documents.

4.4 Laboratory Testing

Four samples from were classified by Yeh's Denver lab as silty sand (SM) according to the Unified Soil Classification System (USCS) and three (3) of the four (4) were classified as A-1-b (0) and one (1) as A-2-4 according to the American Association of State Highway and Transportation Officials (AASHTO).

The bulk samples from the two pavement design borings (YA-P1 and YA-P2) were combined. The combined bulk sample were tested for classification in accordance with AASHTO M45 and for R-value in accordance with AASHTO M190 (ASTM D-2844). The resulting classifications of the soils sampled from depths from 1 to 6 feet were A-1-b(0) (AASHTO) and SM (USCS) with a resulting R-value of 59.

4.5 Groundwater

Groundwater was encountered in boring YA-K1 at 10 feet. Groundwater encountered in YA-NW-1 and YA-NW-2, at 13 feet and 22 feet, respectively, is likely to be perched based on the relative elevation difference between these borings and YA-K1.

5. Foundation Design Recommendations

The site appears suitable for the proposed construction based on geotechnical conditions encountered in the borings. Considering the proposed Kiosks and Administration buildings are single story structures, spread footing foundations founded 3 feet below grade on 1 foot of engineered fill are recommended.

Design and construction details for the foundation options are given below for these options based on Allowable Stress Design (ASD) criteria.

5.1 Shallow Foundations

The recommended foundation for the proposed Kiosks and Administration building is a series of concrete strip footings supporting a slab-on-grade. Based on the subsurface conditions encountered, the strip footings may bear upon in-place loose to medium dense silty sand fill or medium dense silty sand with cobbles and boulder. The natural subgrade soils should be scarified, moisture conditioned and compacted to a minimum depth of 12 inches.

The footings may be designed for a maximum allowable bearing pressure of 3,000 psf. The recommended minimum widths of column and wall footings are 24 inches. The design bearing pressure may be increased for transient loads such as wind or seismic by 1/3 or as allowable by local building code. The footings should be placed a minimum of 36 inches below finished grade for frost protection.

Areas of loose soils may be encountered at foundation bearing depth after excavation is completed for footings. When such conditions exist beneath planned footing areas, the subgrade soils should be compacted prior to placement of the foundation system. In addition, large cobbles or boulder-sized materials may be encountered beneath footing areas. Such conditions could create point loads on the bottom of footings, increasing the potential for differential foundation movement. If cobbles or boulders are encountered in the footing excavations, they should be removed and replaced with engineered fill, placed, and compacted as discussed in the Earthwork section.

Total movement of the footings and slab resulting from structural loads and soil conditions is estimated to be less than 1 inch. Differential movement should be about ½ to ¾ of the total movement, provided infiltration of water from any source is minimized. As additional movement of the foundation and slab may occur should water infiltrate the soils, proper drainage around the building must be provided in final design and construction.

Foundations and slabs should be reinforced as necessary to reduce the potential for distress caused by differential foundation movement.

The exterior footings should be placed a minimum of 3 feet below finished grade for frost protection. Interior footings should bear a minimum of 12 inches below finished grade. Finished grade is the lowest adjacent grade for perimeter footings and floor level for interior footings.

Footings should be proportioned to reduce differential foundation movement. Proportioning on the basis of equal total movement is recommended; however, proportioning to relative constant dead load pressure will also reduce differential movement between adjacent footings. Total movement is estimated to be on the order of 1 inch or less. Differential movement should be on the order of ½ to ¾ of the estimated total movement. Additional foundation movements could occur if water from any source infiltrates the foundation soils; therefore, proper drainage should be provided in the final design and during construction. Footings and foundations should be reinforced as necessary to reduce the potential for distress caused by differential foundation movement. A perimeter foundation drain is not required for shallow foundations with slab-on-grade construction.

Foundation excavations and placement of engineered fill should be observed by the geotechnical engineer. If the soil conditions encountered differ significantly from those presented in this report, supplemental recommendations will be required.

5.2 Floor Slab Design and Construction

The floor slab should be supported on engineered fill by scarifying, moisture conditioning and compacting the subgrade sandy soil to a minimum depth of 12 inches. If non-granular material is encountered below the slab, twelve inches of the material should be removed and replaced with granular, non-plastic fill. Some differential movement of a slab-on-grade floor system is possible should the subgrade soils become elevated in moisture content. To reduce potential slab movements, the subgrade soils and imported fill should be prepared as outlined in Section 8.1 of this report.

For structural design of concrete slabs-on-grade, a modulus of subgrade reaction of 200 pci may be used for floors supported on 12 inches of engineered on site sandy soils fill or non-expansive, imported fill meeting the specifications of Section 8.1 Earthwork.

Additional floor slab design and construction recommendations are as follows:

1. Positive separations and/or isolation joints should be provided between slabs and all foundations, columns, or utility lines to allow independent movement.
2. Control joints should be provided in slabs to control the location and extent of cracking.
3. Interior trench backfill placed beneath slabs should be properly placed and compacted.
4. In areas subjected to normal loading, a minimum 4-inch layer of sand, clean graded gravel or aggregate base course should be placed beneath interior slabs. For heavy loading, reevaluation of slab and/or base course thickness may be required.
5. If moisture-sensitive floor coverings are used on interior slabs, consideration should be given to the use of barriers to minimize potential vapor rise through the slab.
6. Floor slabs should not be constructed on frozen subgrade.
7. Other design and construction considerations, as outlined in Section 302.1 R of the "ACI Design Manual", are recommended.

5.4 Exterior Concrete Flat Work Design and Construction

Some of the on-site soils, whether in-place or used in fills, may have susceptibility to frost heave. Covering of the native soils and/or introduction of moisture from irrigation or concentrated precipitation may increase the moisture content of the soils and result in frost heave. Therefore, movement may occur in exterior concrete slabs, which can result in off-sets, tilting and cracking. The movement and cracking may affect the appearance and performance of the slabs and can affect slab compliance with ADA requirements. There are several mitigation measures to improve slab appearance and performance; however, these options are not solely related to the geotechnical aspects, so input from the design team is suggested. In areas where movement is to be mitigated, we believe these options can be considered for best performance.

1. The upper 12 inches of the native silty sandy subgrade soils and/or topsoil could be removed and replaced with granular non-plastic fill with less than 10 percent fines by weight. CDOT Class 6 aggregate base or Class 1 Structure backfill generally meet this requirement.

2. At entrances to the building, the exterior slab may be structurally tied to the building foundation. This detail would reduce offsets between the exterior slab and the building interior; however, the movement may be translated to other portions of the exterior slab. The structural engineer should also include uplift loads from the exterior slab in designing the foundation.

3. Moisture is one of the key elements; therefore, elimination of irrigation around the exterior slabs, directing roof discharges away from these slabs and preventing snow accumulation adjacent to the slabs can reduce the potential for movement. Additionally, slopes should be graded to slope away from the building for a minimum of 10 feet.

4. Use of plants that do not require irrigation and will help absorb the moisture beneath the exterior slab without creating large root masses, which could cause slab movement, may also reduce potential movement.

6. Box Culvert and Wingwalls

A concrete box culvert is proposed just west of the Kiosks, replacing an existing 36" CMP culvert. We anticipate this box could be as large as a 6-foot wide single cell box with a height of 7 feet. The culvert was estimated to be 100 feet in length. In Boring YA-K1, loose to medium dense silty sand and silty sand with gravel (fill and native) were encountered from the roadway surface to a depth of about 30 feet. Groundwater was encountered at 10 feet below the road surface.

A second culvert is proposed between borings NW-1 and NW-2. These borings also encountered loose to dense silty sands and gravels with groundwater at 13 and 22 feet below grades.

Both culverts are not anticipated to be classified as CDOT major structures and will be designed based on the CDOT M Standards for concrete box structures. For our recommendations we estimated the culverts will be 4 to 8 feet wide, and no longer than 100 feet.

We recommend the following soil parameters be used for design of the box culverts:

Table 1. Box Culvert Soil Parameters

Material	Friction Angle, φ (degrees)	Cohesion, c (psf)	Moist Unit Weight, γ_m (pcf)
Silty Sand	32	0	125
Class 1 Structure Backfill	34	-	135

The boxes should be constructed on scarified and compacted native subgrade, however groundwater is relatively shallow in this area and may be encountered in the excavation. If soft or wet soils are encountered at the base of the excavation, they should be removed to the extent practical and replaced with coarse, washed rock (ie 3" minus-sized) and 6" of Class 1 Structure Backfill or Class 6 Aggregate Base. A separator geotextile (Mirafi FW300 or similar) should be placed between the washed rock layer and the structure backfill to prevent the migration of the structure backfill into the rock.

The estimated settlement of a 6-foot wide by 100-foot long culvert at these locations is about 1-2 inches, and for a 48" culvert, we estimate the settlement will be less than 1 inch, of which about half will occur as the CBC and approach fills are built.

Because box culverts are constrained from horizontal movement, they should be designed for at-rest earth pressure K_0. The at-rest lateral earth pressure coefficient K_0 is dependent on the material used to backfill the RCBC. If the CBC is backfilled with Class 1 structural backfill a K_0 of 0.44 is applicable. If the excavation is backfilled with flow fill, a K_0 of 0.3 is appropriate. Where wingwalls are no longer constrained due to length, and expansion joints, the recommendations for roadway retaining walls in Section 7 would apply.

7. Roadway Retaining Walls

Two potential retaining walls supporting the roadway were identified during preliminary design. The walls height, length, and type (MSE, CIP Concrete Cantilever, Rockery, etc.) have not been determined. The following preliminary general retaining wall recommendations will be updated when the wall geometry is further developed.

1. Passive earth pressure resistance is not anticipated for the retaining walls due to the magnitude of deformation necessary to mobilize the resistance.
2. If walls can move (i.e., rotate at the top of the wall) and mobilize shear strength of the retained soils, the walls can be designed for the active earth pressure condition in the backfill. The required horizontal wall movement is typically around 0.1 to 0.2 percent of the wall height for a granular backfill as listed in AASHTO (2020) table C3.11.1-1.
3. If wall movement is restricted, then the at-rest earth pressure condition should be assumed for the backfill. For the on-site soils, an at-rest lateral earth pressure coefficient (k_0) of 0.5 may be used.
4. Walls should be backfilled with cohesion less material with meeting the following gradation:

Sieve Size	Percent Passing by Mass (AASHTO T27 & AASHTO T11)
4-inch	100
No 40	0-60
No. 200	0 -15

5. The ultimate bearing capacity is dependent on the wall footing width and depth below ground. For preliminary design, the ultimate bearing resistance can be taken as 10,000 psf. A bearing resistance of 0.55 should be applied for gravity walls.
6. The resistance factor for sliding can be taken as tan (2/3 Φ) or 0.42.
7. The external stability analysis for the retaining walls (bearing capacity, global stability, sliding and eccentricity) will be conducted once wall plan and profiles are available.
8. Walls should be designed and constructed with drains at a maximum spacing of 10 feet to prevent hydrostatic pressures. Wall drain details, ie pipe size and drainage material are dependent on the type of wall to be constructed. Drain details can be provided when wall design nears 60 percent.

9. Prior to placement of the wall foundations or leveling pads, the natural subgrade soils should be scarified, moisture conditioned and compacted to a minimum depth of 8 inches.

8. LATERAL EARTH PRESSURES

Cohesionless soils, such as an imported granular fill, or the on-site silty sand and gravel with less than 15 percent fines may be used for backfilling the foundations and retaining structures. Lateral earth pressures can be calculated using the equivalent fluid pressures below for cohesionless soils above any free water surface. The values below assume no surcharge load or inclined backfill at the top of the wall.

For soils above any free water surface, recommended equivalent fluid pressures for unrestrained foundation elements are:

- Active:
  Cohesionless soil backfill (on-site sand) ....38 psf/ft
  Undisturbed soil...36 psf/ft
  Compacted granular backfill... 34 psf/ft
  On-site bedrock materials .... not recommended for use

- Passive:
  Cohesionless soil backfill (on-site sand) ....350 psf/ft

  - Coefficient of base friction..0.38*

  *The coefficient of base friction should be reduced to 0.30 when used in conjunction with passive pressure.

For a sloped backfill above the wall, AASHTO equations 3.11.5.3-1 and 3.11.5.3-2 may be used to calculate the lateral earth pressure coefficient Ka. The corresponding equivalent fluid pressure is equal to Ka times the unit weight of the soil.

Where the design includes restrained elements, the following equivalent fluid pressures are recommended:

- At rest:
  Cohesionless soil backfill (on-site sand) ....60 psf/ft
  Undisturbed soil...55 psf/ft
  Compacted granular backfill..52 psf/ft
  On-site bedrock materials .... not recommended for use

The lateral earth pressures herein do not include any factor of safety and are not applicable for submerged soils/hydrostatic loading. Additional recommendations may be necessary if submerged conditions are to be included in the design. Compaction of each lift of fill adjacent to walls should be accomplished with hand-operated tampers or other lightweight compactors. Over compaction may cause excessive lateral earth pressures, which could result in wall movement.

A representative of the geotechnical engineer should observe and test structural material used for construction.

9. SITE GRADING CONSIDERATIONS

9.1 Excavation and Trench Construction

Excavations into the on-site soils will encounter a variety of conditions. All excavations must comply with the applicable local, State, and Federal safety regulations, and particularly with the excavation standards of the Occupational Safety and Health Administration (OSHA). Construction site safety, including excavation safety, is the sole responsibility of the Contractor as part of its overall responsibility for the means, methods, and sequencing of construction operations. Please note that an OSHA-qualified “competent person” must make the actual determination of soil type and allowable sloping in the field.

9.2 Earthwork

Based on the preliminary plans provided at the time of this report, it is likely that cuts and fills up to 5 feet should be anticipated to achieve foundation grades. Earth retention may be required for construction of below-grade areas. Based on our investigation, excavations for the proposed construction would likely encounter variable amounts of silt, sand, gravel, cobbles, and boulders. We believe the excavations can be accomplished using conventional, heavy-duty excavation equipment. If encountered, large boulders or bedrock may require larger equipment for removal.

We recommend topsoil, vegetation and organic materials be removed from the site or used to revegetate landscaped areas after completion of grading operations. All exposed surfaces should be free of mounds and depressions, which could prevent uniform compaction.

Engineered fill should have no more than 15 percent passing the No. 200 sieve. On-site material may be suitable for engineered fill below structures.

All exposed areas which will receive fill, once properly cleared, should be scarified to a minimum depth of 8 inches, conditioned to near optimum moisture content, and compacted.

Fill should be placed and compacted in horizontal lifts not exceeding 8 inches loose measurement, using equipment and procedures that will produce a uniform fill with the recommended moisture contents and densities throughout the lift. Recommended compaction criteria for engineered fill is 95 percent of the maximum dry density as determined by ASTM D698, at a moisture content within 2 percent of optimum for granular soils and 0 to 2 percent above optimum for low plasticity clay soils. Placement and compaction of structural fill should be observed and tested by a representative of the geotechnical engineer.

Roadway grading should conform to CDOT Standard Specifications for Road and Bridge Construction. Cut slopes in the native soils and bedrock may be constructed at a maximum of 2H:1V. It should be noted that while these soils are considered stable at 2:1 slopes, they can be difficult to vegetate and as result, highly susceptible to surface erosion.

Surface water should be directed away from the crest of slopes. The slopes should be protected from erosion by re-vegetation or other means.

10. Surface Drainage

Surface drainage is crucial to the performance of foundations and flatwork. We recommend the ground surface surrounding the building be sloped to drain away from the structure. We recommend a slope of at least 6 inches in the first 10 feet for landscape areas and a minimum slope of 0.5 percent for paved areas. Backfill around foundations should be moisture conditioned and compacted at 95 percent maximum density of standard Proctor value and at +/- 2 percent optimum moisture content. Roof downspouts and drains should discharge beyond the backfill area. We recommend irrigated landscaping be a minimum of 5 feet away from building walls and foundations.

11. Concrete and Corrosivity

Water-soluble sulfate, pH, water soluble chloride, and soil resistivity tests were performed on a sample from Boring K-1 to evaluate the potential attack on a concrete and buried metal at the site. The concentration of water-soluble sulfates measured in samples obtained from the exploratory boring was to 0.001 percent. This concentration of water-soluble sulfates represents a Class 0 degree of sulfate attack on concrete exposed to these geologic materials. The degree of attack is based on a range of Class 0 (negligible) to Class 3 (very severe) as described in the American Concrete Institute (ACI)

Standard 201.2R, “Guide to Durable Concrete” and as presented in the CDOT Section 601, Structural Concrete, of the Standard Specifications for Road and Bridge Construction, 2019 edition.

The sample tested indicated a pH value of 7.2 (slightly basic). This value is near neutral and should represent a negligible degree of acid attack on concrete and metal exposed to these materials. The water-soluble chloride concentration was 0.0017 percent, indicating a low degree of corrosiveness. Electrical resistivity measured value of 7576 ohm-cm. The laboratory soil resistivity value indicates these soils are moderately corrosive when subjected to ambient stray currents.

Where corrosion may be an issue the services of a qualified corrosion engineer should be retained.

12. SEISMICITY

Based upon the nature of the subsurface materials, a Site Class D, should be used for the design of the risk category II structure for the proposed project (IBC-2018, site coordinates: 40.403391° N, -105.596327° W). The project site is located in a seismic area with a mapped maximum short period (Ss) and 1-second period (S1) ground motion of 0.215 g and 0.064 g, respectively. The site coefficient Fa for the same period is 1.6.

The site is low risk for seismic-related or induced hazards including liquefaction, spreading, settlement and slope stability.

13. PAVEMENT RECOMMENDATIONS

Improvements have been proposed to the Rocky Mountain National Park Fall River Road Entrance Station in conjunction with the proposed new kiosks and administration building.

13.1 Traffic Loading

Twenty-year, 18-kip design Equivalent Single Axle Loads (ESALs) were used based on CDOT traffic volumes from their traffic station 101407, located on SH 34, North off SH 36, Deer Ridge. Complete calculations for flexible pavement are shown in Appendix D. CDOT’s 2019 AADT of 2,700 agrees with the AADT provided for the Fall River Entrance Station counts. However, CDOT’s data includes trucks. The 50 trucks per day count were assumed to be mostly recreation vehicles such as motor homes and campers. Using a 1.28% 20-year traffic increase factor, the design 18 k ESAL’s is 150,510, for a 2-lane roadway.

13.2 Resilient Modulus (MR) of Subgrade Design

Based on laboratory test results, we estimated an R-value of 59 for the A-1-b soils in the project area. From this estimated R-value, the resilient modulus was calculated using equations from the NCHRP Study No. 172 used in AASHTO 1993 Pavement Design Guide. The resulting resilient modulus was 17,692 psi. A pavement design Excel spreadsheet generally following the AASHTO 1993 Pavement Design Manual and was used to determine the pavement thickness designs. Other structural design coefficients used were found in the Federal Highway Administration (FHWA) Federal Lands Highway (FLH) Project Development and Design Manual (PDDM).

13.3 Asphalt Pavement Thickness Recommendations

A composite pavement design using a combination of asphalt concrete (HMA) and Class 6 Aggregate Base Course (ABC) and a full depth asphalt alternative are presented below. The parameters for the preliminary pavement design are shown below in Table 1.

Table 2 – Pavement Design Parameters

Hot Mix Asphalt (HMA) Composite Designs			
Initial Serviceability	4.5	Reliability Level, %	80
Terminal Serviceability	2.5	Overall Standard Deviation	0.49
Construction Stage	1	20 Year Design ESALs	150,510
Str. Layer Coeff. – HMA	0.44	Str. Layer Coeff. – ABC	0.12

The pavement alternatives provided consist of full-depth hot mix asphalt (HMA) option, a hot mix asphalt over aggregate base course (ABC) option and a Portland Cement Concrete (PCCP) option. The results of the equivalent pavement thickness designs are shown in Appendix D and summarized below in Table 2.

Table 3– Recommended Pavement Sections

Section	Pavement Type	Design Life (years)	Thickness (inches)
Fall River Road Entrance Station Rocky Mountain National Park	Full Depth HMA	20	5 HMA
	HMA + ABC	20	4 HMA + 4 ABC
	PCCP	30	8 PCCP + 4 ABC

13.4 Hot Mix Asphalt Type and Binder Recommendations

Using the Long-Term Pavement Performance program LTPPBIND, the recommended binder to provide 98% reliability against low temperature cracking and rutting for Estes Park, Colorado is PG 58-28. Estes Park is approximately two miles south of the project site and is at approximately the same elevation as this project. We recommend that this project use an SX(75) gyratory mix with PG 58-28 for the top mat. The lower mat can be either SX(75) or S(75).

We recommend that the asphalt mix meet Grading SX (75) or S(75) criteria in accordance with the current FHWA PDDM Specifications. The SuperPave Gyratory Revolutions (Ndes) for the asphalt mix should be 75. A performance graded binder meeting the requirements of PG 58-28 is recommended for the SX(75) mix. The PG 58-28 is not a polymer modified asphalt. This binder provides 98 percent reliability against rutting and 98 percent reliability against low temperature thermal cracking to accommodate slow moving and stop and go traffic.

Regardless of the pavement chosen, the asphalt mix for asphalt pavement should be placed in 2-to-3-inch lifts.

Aggregates for hot plant mix bituminous pavement should be of uniform quality, composed of clean, hard, durable particles of crushed stone, gravel, or slag. Excess of fine material should be wasted before crushing.

13.5 Portland Cement Concrete Pavement

If a concrete pavement is chosen, we recommend following the FHWA Central Federal Lands Division Project Development and Design Manual (PDDM). The concrete option recommended for high volume stop and go traffic is an 8-inch concrete pavement. The pavement should contain 1.25-inch diameter dowel bars at one foot spacing in the transverse joints and #5 tie bars with 30 inch spacing in the longitudinal joints. The concrete pavement should be placed on a properly prepared, graded and compacted subgrade consisting of the in-place soils and four (4) inches aggregate base course meeting the requirements for ABC Class 6.

To simplify the specifications for the concrete pavement we recommend that the concrete pavement be constructed in conformance with Colorado Department of Transportation Specifications and that the pavement conform to CDOT M-Standard M-412.

13.6 Pavement Subgrade Preparation

To provide stability for new pavement, we recommend the upper 8 to 12 inches of native soils should be scarified and recompacted to 95 percent of maximum density for standard Proctor at a moisture content +/- 2 percent of optimum.

For all layers, drainage needs to be addressed during construction to prevent ponding of water and provide for ease of construction. The pavement subgrade and each layer of ABC should be proof rolled with a heavily loaded pneumatic-tire vehicle. Areas which deform more than 0.5 inch under heavy wheel loads should be removed, replaced if necessary and reworked to achieve a stable subgrade prior to paving. We recommend that proof rolling, and compaction tests be performed under the direct supervision of a representative of the geotechnical engineer.

14. LIMITATIONS

This study was conducted in accordance with generally accepted geotechnical engineering practices in this area for use by the client for design purposes. The conclusions and

recommendations submitted in this report are based upon the data obtained from exploratory borings, field reconnaissance and anticipated construction. The nature and extent of subsurface variations across the site may not become evident until excavation is performed. If during construction, conditions appear to be different from those described herein; this office should be advised at once so reevaluation of the recommendations may be made. We recommend on-site observation of excavations by a representative of the geotechnical engineer.

The scope of services for this project did not include, specifically or by implication, any environmental or biological (e.g., mold, fungi, and bacteria) assessment of the site or identification or prevention of pollutants, or conditions or biological conditions. If the owner is concerned about the potential for such contamination, conditions or pollution, other studies should be undertaken and a professional in that field should be consulted.

This report was prepared in substantial accordance with the generally accepted standards of practice for geotechnical engineering as exist in the site area at the time of our investigation. No warranties, express or implied, are intended or made.

15. References

AASHTO, 1993 Pavement Design Manual

Braddock, W.A., and Cole, J.C., Geologic Map of Rocky Mountain National Park and Vicinity, Colorado. United States Geological Survey Map I-1973, Sheet 1, 1990.

Federal Highway Administration Project Development and Design Manual, 2018.

International Building Code, 2018 accessed at:https://codes.iccsafe.org/content/IBC2018/chapter-18-soils-and-foundations.

Larimer County On-Site Wastewater Treatment System Regulations:

https://www.larimer.org/sites/default/files/uploads/2017/lcdhe-owts-rules-2016.pdf

APPENDICES

Appendix A	Field Investigation Site Photographs
Appendix B	Field Exploration BORING LOGS and LEGEND
Appendix C	Laboratory Test Results
Appendix D	Pavement Design Calculations

Appendix A

FIELD INVESTIGATION SITE PHOTOGRAPHS

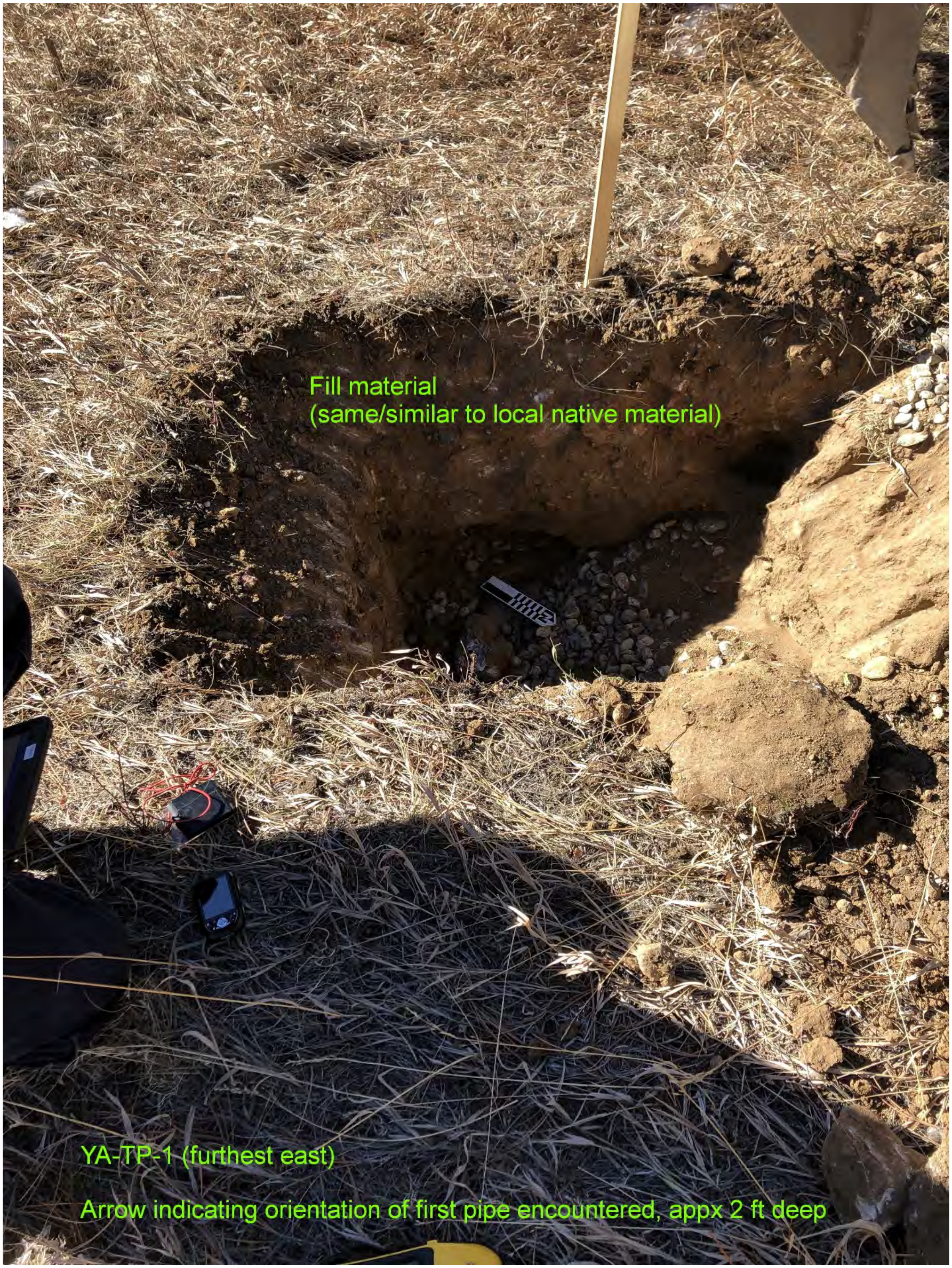


Figure A 1. Annotated image of test pit YA-TP-1 at original OWTS location.

Figure A 2. Annotated image of test pit YA-TP-2 at original OWTS location.

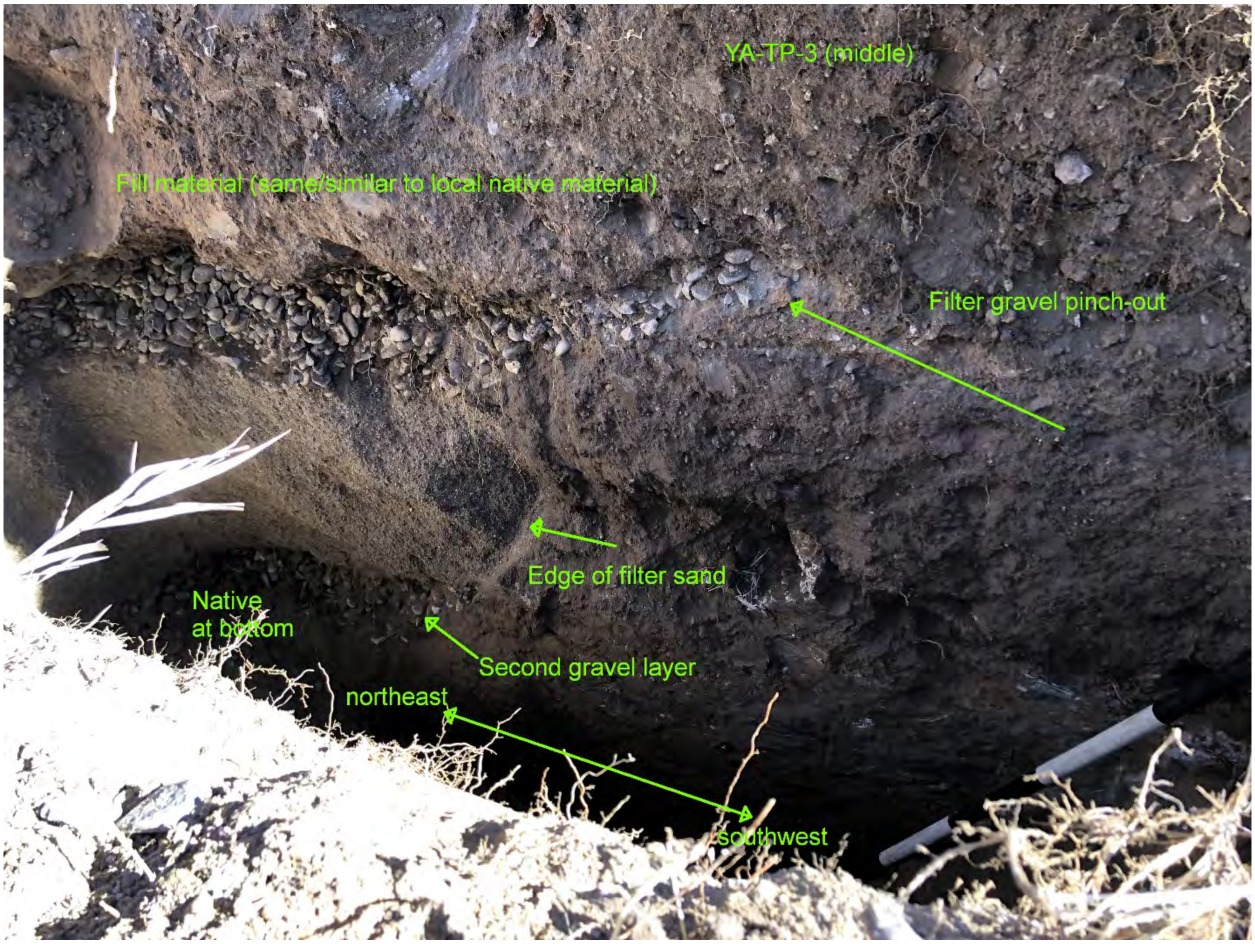


Figure A 3. Annotated image of test pit YA-TP-3 at original test pit location.

Figure A 4. Test pit YA-TP-1 at final OWTS location.

Figure A 5. Test pit YA-TP-2 at final OWTS location.

Figure A 6. Drilling boring YA-NW-1.

Figure A 7. Drilling boring YA-K1.

Appendix B

FIELD EXPLORATION BORING LOGS AND LEGEND

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	*Project:* ROMO Rall River Entrance *Project Number:* 220-348

Legend for Symbols Used on Borehole Logs

Sample Types

- Bulk Sample of auger/odex cuttings
- Modified California Sampler (2.5 inch OD, 2.0 inch ID)
- Standard Penetration Test (ASTM D1586)

Drilling Methods

- SOLID-STEM AUGER (4" OD)
- TEST PIT - EXCAVATOR

Lithology Symbols (see Boring Logs for complete descriptions)

- Asphalt
- Boulders and cobbles
- Fill with Sand as major soil
- Poorly-graded Gravelly Sand
- Poorly-graded Sandy Gravel
- USCS Clayey Sand
- USCS Silty Sand
- Cobbles and gravel
- Topsoil

Lab Test Standards

Moisture Content	ASTM D2216
Dry Density	ASTM D7263
Sand/Fines Content	ASTM D421, ASTM C136, ASTM D1140
Atterberg Limits	ASTM D4318
AASHTO Class.	AASHTO M145, ASTM D3282
USCS Class.	ASTM D2487

(Fines = % Passing #200 Sieve
Sand = % Passing #4 Sieve, but not passing #200 Sieve)

Other Lab Test Abbreviations

pH	Soil pH (AASHTO T289-91)
S	Water-Soluble Sulfate Content (AASHTO T290-91, ASTM D4327)
Chl	Water-Soluble Chloride Content (AASHTO T291-91, ASTM D4327)
S/C	Swell/Collapse (ASTM D4546)
UCCS	Unconfined Compressive Strength (Soil - ASTM D2166, Rock - ASTM D7012)
R-Value	Resistance R-Value (ASTM D2844)
DS (C)	Direct Shear cohesion (ASTM D3080)
DS (phi)	Direct Shear friction angle (ASTM D3080)
Re	Electrical Resistivity (AASHTO T288-91)
PtL	Point Load Strength Index (ASTM D5731)

Notes

1. Visual classifications are in general accordance with ASTM D2488, "Standard Practice for Description and Identification of Soils (Visual-Manual Procedures)".
2. "Penetration Resistance" on the Boring Logs refers to the uncorrected N value for SPT samples only, as per ASTM D1586. For samples obtained with a Modified California (MC) sampler, drive depth is 12 inches, and "Penetration Resistance" refers to the sum of all blows. Where blow counts were > 50 for the 3rd increment (SPT) or 2nd increment (MC), "Penetration Resistance" combines the last and 2nd-to-last blows and lengths; for other increments with > 50 blows, the blows for the last increment are reported.
3. The Modified California sampler used to obtain samples is a 2.5-inch OD, 2.0-inch ID (1.95-inch ID with liners), split-barrel sampler with internal liners, as per ASTM D3550. Sampler is driven with a 140-pound hammer, dropped 30 inches per blow.
4. "ER" for the hammer is the Reported Calibrated Energy Transfer Ratio for that specific hammer, as provided by the drilling company.

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	*Project Name:* ROMO Rall River Entrance	
	Project Number: 220-348 *Boring No.:* **YA-K1**	

Boring Began: 12/1/2020 | **Total Depth: 30.5 ft** | Weather Notes: Cloudy and cold

Boring Completed: 12/4/2020 | Ground Elevation: | Inclination from Horiz.: Vertical

Drilling Method(s): Solid-Stem Auger (4" OD) | Coordinates:

Driller: Drilling Engineers | Location: Fall River Road Access RMNP | Night Work: ☐

Drill Rig: CME 75 Truck

Hammer: Automatic (hydraulic), ER: % | Logged By: R. Desterhouse

Final By: R. Desterhouse

Groundwater Levels:			
Symbol	∇		
Depth	10.0 ft	-	-
Date	12/1/20	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
	0						**0.0 - 0.3 ft. ASPHALT** (4 inches).									
							0.3 - 0.7 ft. BASE (4 inches) **(Fill)**.									
							0.7 - 5.0 ft. Silty SAND (SM) (Fill), dark gray brown to dark gray, moist to damp.									
				17-39	56											
				21-50:2"	71:8"											pH=7.2 S=<0.001% Chl=0.0017% Re=7576ohm·cm
	5						**5.0 - 10.0 ft. Silty SAND (SM)**, brown, moist to wet, medium dense to loose, gravel. Cobbles and boulders at 6 ft.									
				2-5	7			13.7		11.0	67.0	22.0	NV	NP	A-1-b (0) SM	
	∇10						**10.0 - 30.5 ft. Silty SAND with gravel (SM)**, brown, wet, medium dense to dense.									
	15			10-4	14											
	20			10-10-6	16											
	25			10-6	16											
	30			18-21-18	39											

Bottom of Hole at 30.5 ft.

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

Project Name: ROMO Rall River Entrance

Project Number: 220-348 *Boring No.:* **YA-NW1**

Boring Began: 12/1/2020
Boring Completed: 12/4/2020
Drilling Method(s): Solid-Stem Auger (4" OD)
Driller: Drilling Engineers
Drill Rig: CME 75 Truck
Hammer: Automatic (hydraulic), ER: %

Total Depth: 29.5 ft
Ground Elevation:
Coordinates:
Location: Fall River Road Access RMNP

Logged By: R. Desterhouse
Final By: R. Desterhouse

Weather Notes: Cloudy and cold
Inclination from Horiz.: Vertical

Night Work: ☐

Groundwater Levels:			
Symbol	▽		
Depth	13.0 ft	-	-
Date	12/1/20	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
	0.0 - 0.3						**0.0 - 0.3 ft. ASPHALT** (3 inches).									
	0.3 - 5.0						**0.3 - 5.0 ft. Silty SAND with gravel (SM) (Fill)**, brown, dry to damp, medium dense.									
	5			5-11	16											
	5.0 - 13.0						**5.0 - 13.0 ft. Poorly graded GRAVEL with sand (GP)**, orange-brown, moist, dense, rust staining, cobbles.									
	10			21-22	43											
	13.0 - 18.0 (▽)						**13.0 - 18.0 ft. Clayey SAND with gravel (SC)**, brown, wet, medium dense, cobbles.									
	15			4-24	28			10.3	124.5	12.0	62.0	26.0	28	10	A-2-4 (0) SC	
	18.0 - 29.5						**18.0 - 29.5 ft. Poorly graded GRAVEL with sand (GP)**, brown, wet, very dense, some clayey layers.									
	20			28-50:5"	78:11"											
							Refusal on boulder at 22 ft, moved boring 10 ft east to continue.									
	25			17-38	55											
	29.5			50:6"	50:6"											

Bottom of Hole at 29.5 ft.

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	Project Name: ROMO Rall River Entrance	PAGE 1 of 1
	Project Number: 220-348	Boring No.: **YA-NW2**

Boring Began: 12/1/2020
Boring Completed: 12/4/2020
Drilling Method(s): Solid-Stem Auger (4" OD)
Driller: Drilling Engineers
Drill Rig: CME 75 Truck
Hammer: Automatic (hydraulic), ER: %

Total Depth: 30.4 ft
Ground Elevation:
Coordinates:
Location: Fall River Road Access RMNP
Logged By: R. Desterhouse
Final By: R. Desterhouse

Weather Notes: Cloudy and cold
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels: Not Observed			
Symbol	∇		
Depth	22.0 ft	-	-
Date	12/4/20	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
							0.0 - 5.0 ft. Silty SAND with gravel (SM) (Fill), brown to yellowish brown, moist, loose, rootlets.									
	5			5-6	11											
							5.0 - 13.0 ft. Silty SAND (SM), with variable amounts of gravel, brown to yellowish brown, moist, dense, rootlets, rust staining, some cobbles.									
	10			18-27	45			4.9	132.6	2.0	64.0	34.0	NV	NP	A-2-4 (0) SM	
							13.0 - 17.0 ft. Poorly graded GRAVEL with sand (GP), gray - brown to brown, moist, dense, rust staining.									
	15			12-47	59											
							17.0 - 30.4 ft. Silty SAND with gravel (SM), yellowish brown to light brown, dry to wet, medium dense to very dense, cobbles, some clay layers.									
	20			14-18	32											
	∇															
	25			8-22	30											
	30			39-39-50:5"	89:11"											

Bottom of Hole at 30.4 ft.

Boring Began: 12/22/2020
Boring Completed: 12/22/2020
Drilling Method(s): Test Pit - excavator
Driller: Len's Excavating
Drill Rig:
Hammer: , ER: %

Total Depth: 8.0 ft
Ground Elevation:
Coordinates:
Location: Original OWTS Location

Logged By: M. Boyd
Final By: M. Boyd

Weather Notes: Sunny, cool
Inclination from Horiz.: Vertical

Night Work: ☐

Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
							0.0 - 2.0 ft. Silty SAND with gravel (SM) (Fill), brown, moist, cobbles and boulders.							
							2.0 - 2.5 ft. Gravel (Fill), gray, dry, 4" clay pipe.							
							2.5 - 6.0 ft. Silty SAND (SM) (Fill), gray, dry.							
	5													
							6.0 - 6.5 ft. Gravel (Fill), gray, dry, 4" clay pipe.							
							6.5 - 8.0 ft. Silty SAND (SM) with gravel, brown, dry to moist, may be native material or locally sourced fill.							

Bottom of Hole at 8.0 ft.

Project Name:	ROMO Rall River Entrance	PAGE 1 of 1
Project Number: 220-348	Boring No.: **YA-OWTS-TP-2**	

Boring Began: 12/22/2020
Boring Completed: 12/22/2020
Drilling Method(s): Test Pit - excavator
Driller: Len's Excavating
Drill Rig:
Hammer: , ER: %

Total Depth: 4.0 ft
Ground Elevation:
Coordinates:
Location: Original OWTS Location
Logged By: M. Boyd
Final By: M. Boyd

Weather Notes: Sunny, cool
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels:			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
							0.0 - 3.0 ft. Silty SAND with gravel (SM) (Fill), brown, moist, cobbles and boulders.							
							3.0 - 4.0 ft. gravel (Fill), gray, dry, 4" clay pipe.							

Bottom of Hole at 4.0 ft.

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	Project Name: ROMO Rall River Entrance	PAGE 1 of 1
	Project Number: 220-348	Boring No.: **YA-OWTS-TP-3**

Boring Began: 12/22/2020
Boring Completed: 12/22/2020
Drilling Method(s): Test Pit - excavator
Driller: Len's Excavating
Drill Rig:
Hammer: , ER: %

Total Depth: 8.0 ft
Ground Elevation:
Coordinates:
Location: Original OWTS Location

Logged By: M. Boyd
Final By: M. Boyd

Weather Notes: Sunny, cool
Inclination from Horiz.: Vertical

Night Work: ☐

Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
							0.0 - 2.0 ft. Silty SAND with gravel (SM) (Fill), brown, moist, cobbles and boulders.							
							2.0 - 2.5 ft. Gravel (Fill), gray, dry.							
							2.5 - 4.5 ft. Silty SAND (SM) (Fill), gray, dry.							
	5						**4.5 - 5.0 ft. Gravel (Fill)**, gray, dry.							
							5.0 - 8.0 ft. Silty SAND with gravel (SM), reddish brown, moist.							

Bottom of Hole at 8.0 ft.

BORING LOG 2019 - SPT CDOT STYLE 220-348 ROMO 2019 LIBRARY.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 9/15/21

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	Project Name: ROMO Rall River Entrance	PAGE 1 of 1
	Project Number: 220-348	Boring No.: **YA-P1**

Boring Began: 12/1/2020
Boring Completed: 12/1/2020
Drilling Method(s): Solid-Stem Auger (4" OD)
Driller: Drilling Engineers
Drill Rig: CME 75 Truck
Hammer: Automatic (hydraulic), ER: %

Total Depth: 10.0 ft
Ground Elevation:
Coordinates:
Location: Fall River Road Access RMNP

Logged By: R. Desterhouse
Final By: R. Desterhouse

Weather Notes: Cloudy and cold
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
							0.0 - 0.5 ft. ASPHALT (5.5 inches).							
							0.5 - 1.0 ft. BASE (5 inches) **(Fill)**.							
				5-7	12		**1.0 - 3.0 ft. Silty SAND (SM) (Fill)**, brown, moist, loose, some gravel.							
	5			5-9	14		**3.0 - 7.0 ft. Silty SAND (SM)**, brown, moist, medium dense, gravel and rootlets.							
	10			36-48	84		**7.0 - 10.0 ft. Poorly graded SAND with gravel (SP)**, brown, moist, very dense. Cobbles and boulders at 8 ft.							

Bottom of Hole at 10.0 ft.

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	*Project Name:* ROMO Rall River Entrance	*PAGE 1 of 1*
	Project Number: 220-348	*Boring No.:* **YA-P2**

Boring Began: 12/1/2020
Boring Completed: 12/1/2020
Drilling Method(s): Solid-Stem Auger (4" OD)
Driller: Drilling Engineers
Drill Rig: CME 75 Truck
Hammer: Automatic (hydraulic), ER: %

Total Depth: 10.0 ft
Ground Elevation:
Coordinates:
Location: Fall River Road Access RMNP
Logged By: R. Desterhouse
Final By: R. Desterhouse

Weather Notes: Cloudy and cold
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
							0.0 - 10.0 ft. Silty SAND with gravel (SM), brown and dark brown, moist, medium dense to dense, gravel, cobbles.							
				50:4"	50:4"									
	5			8-9	17									
	10			13-15	28									
							Bottom of Hole at 10.0 ft.							

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	Project Name: ROMO Rall River Entrance	PAGE 1 of 1
	Project Number: 220-348	Boring No.: **YA-PH-1 (profile)**

Boring Began: 6/25/2021
Boring Completed: 6/25/2021
Drilling Method(s): Solid-Stem Auger (4" OD)
Driller: Drilling Engineers
Drill Rig: Geoprobe
Hammer: , ER: %

Total Depth: 9.0 ft
Ground Elevation:
Coordinates:
Location: Final OWTS Location
Logged By: S. Maloney
Final By: M. Boyd

Weather Notes: Partly cloudy
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
							0.0 - 0.7 ft. TOPSOIL.							
							0.7 - 9.0 ft. Silty SAND with gravel (SM), brown, moist.							
							Cobbles and boulders at 3 ft.							
	5													
							Cobbles and boulders at 7 ft.							

Bottom of Hole at 9.0 ft.

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	Project Name: ROMO Rall River Entrance	
	Project Number: 220-348	Boring No.: **YA-TP-1**

Boring Began: 6/30/2021
Boring Completed: 6/30/2021
Drilling Method(s): Test Pit - excavator
Driller: Len's Excavating
Drill Rig:
Hammer: , ER: %

Total Depth: 5.0 ft
Ground Elevation:
Coordinates:
Location: Final OWTS Location

Logged By: S. Maloney
Final By: M. Boyd

Weather Notes: Clear
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
							0.0 - 0.7 ft. TOPSOIL.							
							0.7 - 2.0 ft. Silty SAND with gravel (SM), brown, moist.							
							2.0 - 5.0 ft. Silty SAND with gravel (SM), abundant cobbles and boulders.							
	5													

Bottom of Hole at 5.0 ft.

Test pit terminated at 5 ft due to boulders

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

Project Name:	ROMO Rall River Entrance	PAGE 1 of 1
Project Number: 220-348	Boring No.: **YA-TP-2**	

Boring Began: 6/30/2021
Boring Completed: 6/30/2021
Drilling Method(s): Test Pit - excavator
Driller: Len's Excavating
Drill Rig:
Hammer: , ER: %

Total Depth: 4.3 ft
Ground Elevation:
Coordinates:
Location: Final OWTS Location

Logged By: S. Maloney
Final By: M. Boyd

Weather Notes: Clear
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
							0.0 - 0.7 ft. TOPSOIL.									
							0.7 - 4.3 ft. Silty SAND with gravel (SM), brown, moist, cobbles and boulders.	8.9		15.0	57.3	27.7	NV	NP	A-2-4 (0) SM	
								7.6		24.6	52.3	23.1	NV	NP	A-1-b (0) SM	

Bottom of Hole at 4.3 ft.

Test pit terminated at 4.25 ft due to boulders

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	Project Name: ROMO Rall River Entrance	PAGE 1 of 1
	Project Number: 220-348	Boring No.: **YA-W1**

Boring Began: 12/1/2020
Boring Completed: 12/1/2020
Drilling Method(s): Solid-Stem Auger (4" OD)
Driller: Drilling Engineers
Drill Rig: CME 75 Truck
Hammer: Automatic (hydraulic), ER: %

Total Depth: 20.0 ft
Ground Elevation:
Coordinates:
Location: Fall River Road Access RMNP
Logged By: R. Desterhouse
Final By: R. Desterhouse

Weather Notes: Cloudy and cold
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
	0.0						**0.0 - 18.0 ft. Silty SAND with gravel (SM)**, brown, moist, loose to medium dense.									
	5			6-6	12											
							Cobbles and boulders at 6 to 9 ft.									
	10			10-22	32			3.4		41.0	45.0	14.0	NV	NP	A-1-b (0) SM	
							Cobbles and boulders at 11 to 13 ft.									
	15			7-8	15											
							Cobbles and boulders at 16 ft.									
	18.0						**18.0 - 20.0 ft. Poorly graded GRAVEL with sand (GP)**, light brown, dry, very dense.									
	20			20-48	68											

Bottom of Hole at 20.0 ft.

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	*Project Name:* ROMO Rall River Entrance	*PAGE* *1 of 1*
	Project Number: 220-348	*Boring No.:* **YA-W2**

Boring Began: 12/1/2020 | **Total Depth: 19.8 ft** | Weather Notes: Cloudy and cold

Boring Completed: 12/1/2020 | Ground Elevation: | Inclination from Horiz.: Vertical

Drilling Method(s): Solid-Stem Auger (4" OD) | Coordinates:

Driller: Drilling Engineers | Location: Fall River Road Access RMNP | Night Work: ☐

Drill Rig: CME 75 Truck

Hammer: Automatic (hydraulic), ER: % | Logged By: R. Desterhouse

Final By: R. Desterhouse

Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
	0						**0.0 - 12.0 ft. Silty SAND with gravel (SM)**, brown, moist to damp, medium dense, rust staining, gravels.									
	5			10-15	25			4.3	135.9	34.0	49.0	17.0	NV	NP	A-1-b (0) SM	
	10			6-8	14											
	12						**12.0 - 16.0 ft. Poorly graded GRAVEL with sand (GP)**, brown, damp, dense, some cobbles.									
	15			22-28	50											
	16						**16.0 - 19.8 ft. Silty SAND with gravel (SM)**, brown, moist, very dense, some cobbles.									
				27-50:4"	77:10"											

Bottom of Hole at 19.8 ft.

Appendix C

LABORATORY TEST RESULTS

Summary of Laboratory Test Results

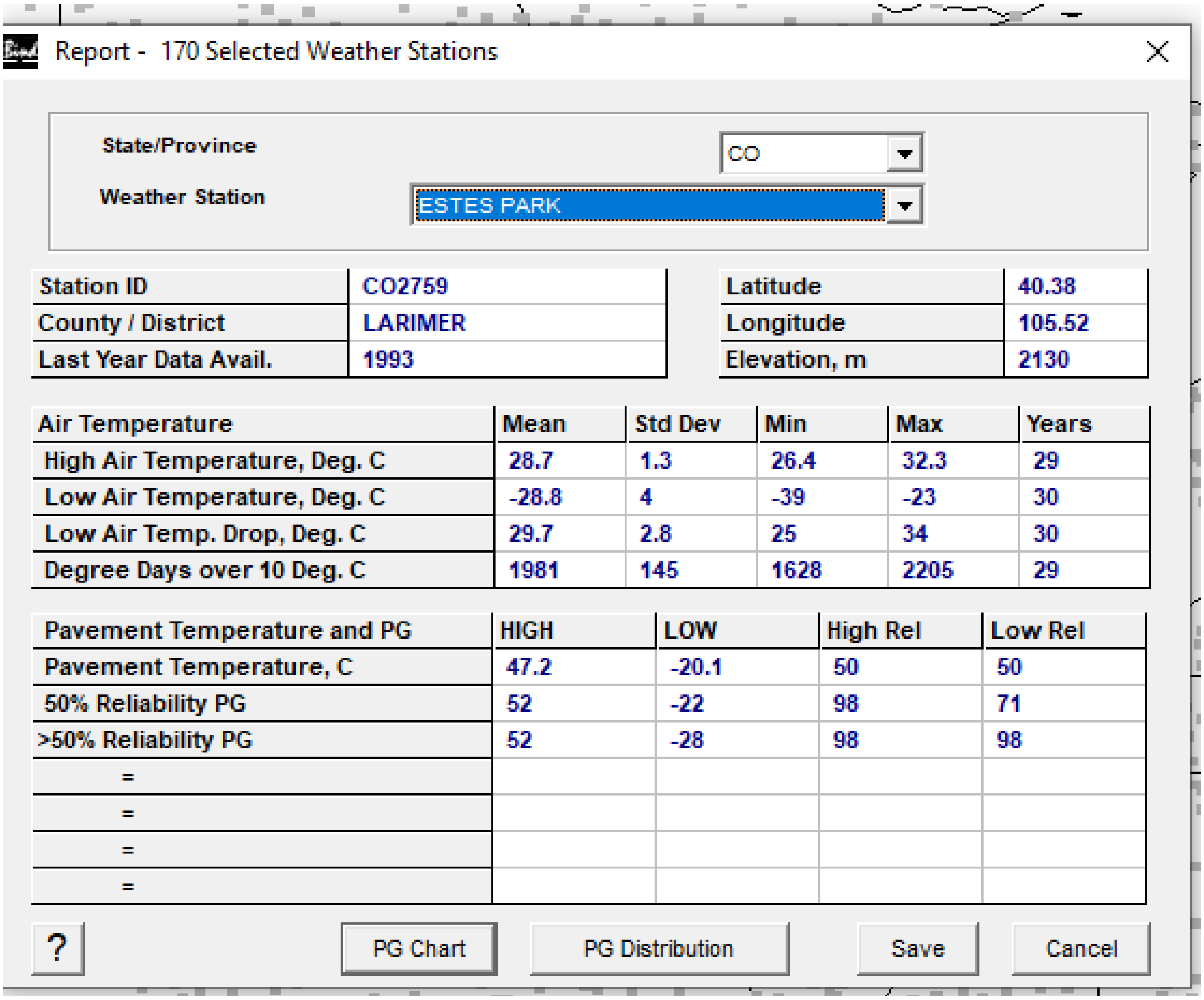
Project No: 220-348 Project Name: ROMO Rall River Entrance Date: 09-15-2021

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength ()	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
YA-K1	4.0	MC									7.2	<0.001	0.0017	7576					
YA-K1	9.0	MC	13.7		11.0	67.0	22.0	NV	NP	NP								A-1-b (0)	SM
YA-NW1	14.0	MC	10.3	124.5	12.0	62.0	26.0	28	18	10								A-2-4 (0)	SC
YA-NW2	9.0	MC	4.9	132.6	2.0	64.0	34.0	NV	NP	NP								A-2-4 (0)	SM
YA-OWTS-B1	1.0	BULK	4		15.0	62.0	23.0	NV	NP	NP								A-1-b (0)	SM
YA-P1+P2	0	BULK	5.3		11.0	67.0	22.0	NV	NP	NP							59	A-1-b (0)	SM
YA-TP-2	2.0	BULK	8.9		15.0	57.3	27.7	NV	NP	NP								A-2-4 (0)	SM
YA-TP-2	4.0	BULK	7.6		24.6	52.3	23.1	NV	NP	NP								A-1-b (0)	SM
YA-W1	9.0	MC	3.4		41.0	45.0	14.0	NV	NP	NP								A-1-b (0)	SM
YA-W2	4.0	MC	4.3	135.9	34.0	49.0	17.0	NV	NP	NP								A-1-b (0)	SM

Appendix D

PAVEMENT DESIGN CALCULATIONS

Asphalt Binder Recommendation



Report - 170 Selected Weather Stations

State/Province: CO

Weather Station: ESTES PARK

Station ID	CO2759
County / District	LARIMER
Last Year Data Avail.	1993

Latitude	40.38
Longitude	105.52
Elevation, m	2130

Air Temperature	Mean	Std Dev	Min	Max	Years
High Air Temperature, Deg. C	28.7	1.3	26.4	32.3	29
Low Air Temperature, Deg. C	-28.8	4	-39	-23	30
Low Air Temp. Drop, Deg. C	29.7	2.8	25	34	30
Degree Days over 10 Deg. C	1981	145	1628	2205	29

Pavement Temperature and PG	HIGH	LOW	High Rel	Low Rel
Pavement Temperature, C	47.2	-20.1	50	50
50% Reliability PG	52	-22	98	71
>50% Reliability PG	52	-28	98	98
=				
=				
=				
=				

? PG Chart PG Distribution Save Cancel

The recommended asphalt binder is PG 58-28.

The recommended binder above is PG 52-28, which is not available locally, but PG 58-28 is readily available. PG 58-28 meets the low temperature requirements and exceeds the high temperature requirements.

Traffic Loading for Pavement Design

Stations | AADT | Future Traffic | ESAL

Found **5** Short Duration stations and **0** Continuous Count stations. Click the magnifying glass icon in front of a station to see count data below.

Projection Year: 2042

Export to Excel

	Station ID	Route	Start	End	AADT	Year	Single Trucks	Combined Trucks	% Trucks	DHV	Projected AADT	Projected Single Trucks	Projected Combined Trucks
	101406	034A	51.307	53.758	4,500	2019	60	9	1.5	16	6,260	83	13
	101407	034A	53.758	57.686	2,700	2019	50	8	2.2	15	3,569	66	11
	101408	034A	57.686	59.18	2,800	2019	40	8	1.8	15	3,380	48	10
	101409	034A	59.18	60.965	5,500	2019	70	6	1.4	16	7,018	89	8
	101410	034A	60.965	61.943	4,000	2019	50	10	1.6	15	5,426	68	14

Year 2042 Volumes

Stations | AADT | Future Traffic | ESAL

Found **5** Short Duration stations and **0** Continuous Count stations. Click the magnifying glass icon in front of a station to see count data below.

Build Year: 2022 Design Life (yrs): 20 Lanes: 2 Rigid pavement:

Export to Excel

	Route	Start	End	Length	AADT	Year	20 Year Factor	Single Trucks	Combined Trucks	Projected AADT	Projected Single Trucks	Projected Combined Trucks	18 Kip ESALs
	034A	51.307	53.758	2.451	4,500	2019	1.34	60	9	6,260	83	13	203,309
	034A	53.758	57.686	3.926	2,700	2019	1.28	50	8	3,569	66	11	150,510
	034A	57.686	59.18	1.549	2,800	2019	1.18	40	8	3,380	48	10	131,666
	034A	59.18	60.965	1.765	5,500	2019	1.24	70	6	7,018	89	8	203,665
	034A	60.965	61.943	0.985	4,000	2019	1.31	50	10	5,426	68	14	184,927

20-Year ESAL Values - Two Lane

Stations | AADT | Future Traffic | ESAL

Found **5** Short Duration stations and **0** Continuous Count stations. Click the magnifying glass icon in front of a station to see count data below.

Build Year: 2022 Design Life (yrs): 20 Lanes: 1 Rigid pavement:

Export to Excel

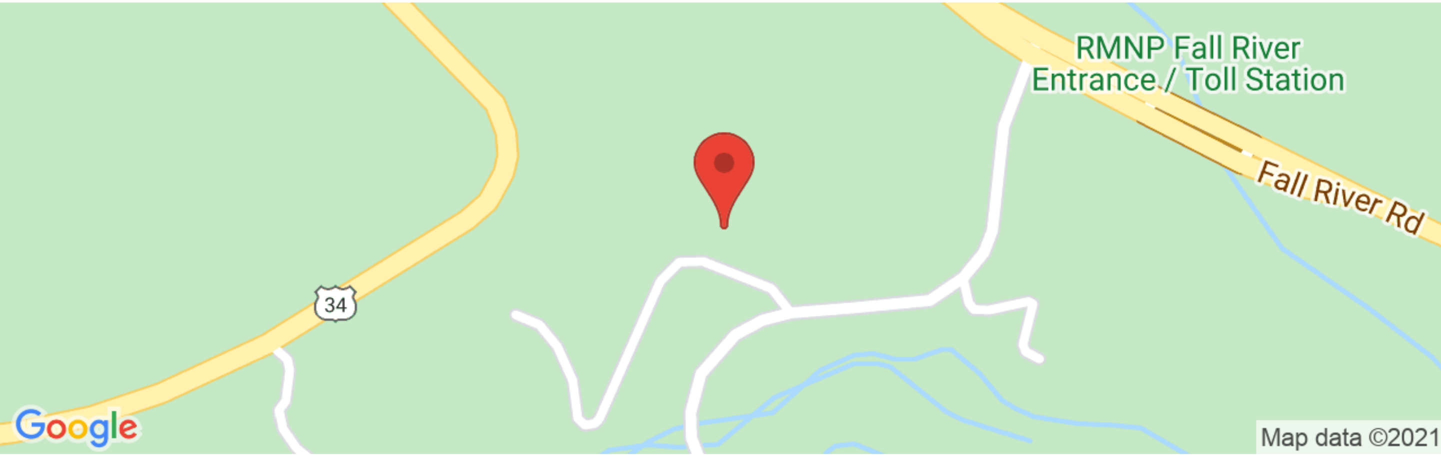
	Route	Start	End	Length	AADT	Year	20 Year Factor	Single Trucks	Combined Trucks	Projected AADT	Projected Single Trucks	Projected Combined Trucks	18 Kip ESALs
	034A	51.307	53.758	2.451	4,500	2019	1.34	60	9	6,260	83	13	338,848
	034A	53.758	57.686	3.926	2,700	2019	1.28	50	8	3,569	66	11	250,851
	034A	57.686	59.18	1.549	2,800	2019	1.18	40	8	3,380	48	10	219,443
	034A	59.18	60.965	1.765	5,500	2019	1.24	70	6	7,018	89	8	339,442
	034A	60.965	61.943	0.985	4,000	2019	1.31	50	10	5,426	68	14	308,211

20-Year ESAL Values – One Lane

AASHTO 1993 Flexible Pavement Design

R-value	SN	W18	log(W18)	ZR	So	po	pt	Dpsi	Mr	log(W18	difference	Daily ESAL'	Design Life	Reliablility
60.0	1.76	219000	5.340	-0.67	0.49	4.2	2.5	1.7	17671.55	5.340	0.000	30.0	20	75
59.0	2.03	148920	5.173	-0.84	0.44	4.5	2.5	2	10565.67	5.172	0.001	20.4	20	80
5.0	2.87	70080	4.846	-1.04	0.44	4.5	2.5	2	3025	4.755	0.090	9.6	20	85
32.9	1.40	73000	4.863	-1.28	0.44	4.5	2.5	2	19261.68	4.651	0.212	10.0	20	90
5.0	2.66	109500	5.039	-1.28	0.44	4.5	2.5	2	3775	4.658	0.381	15.0	20	90
5.0	2.77	146000	5.164	-1.28	0.44	4.5	2.5	2	3775	4.774	0.391	20.0	20	90

Latitude, Longitude: 40.403391, -105.596327



Date	2/2/2021, 1:41:14 PM
Design Code Reference Document	IBC-2015
Risk Category	II
Site Class	D - Stiff Soil

Type	Value	Description
S_S	0.215	MCE_R ground motion. (for 0.2 second period)
S_1	0.064	MCE_R ground motion. (for 1.0s period)
S_{MS}	0.344	Site-modified spectral acceleration value
S_{M1}	0.154	Site-modified spectral acceleration value
S_{DS}	0.229	Numeric seismic design value at 0.2 second SA
S_{D1}	0.103	Numeric seismic design value at 1.0 second SA

Type	Value	Description
SDC	B	Seismic design category
F_a	1.6	Site amplification factor at 0.2 second
F_v	2.4	Site amplification factor at 1.0 second
PGA	0.113	MCE_G peak ground acceleration
F_{PGA}	1.573	Site amplification factor at PGA
PGA_M	0.178	Site modified peak ground acceleration
T_L	4	Long-period transition period in seconds
SsRT	0.215	Probabilistic risk-targeted ground motion. (0.2 second)
SsUH	0.237	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration
SsD	1.5	Factored deterministic acceleration value. (0.2 second)
S1RT	0.064	Probabilistic risk-targeted ground motion. (1.0 second)
S1UH	0.071	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration.
S1D	0.6	Factored deterministic acceleration value. (1.0 second)
PGAd	0.6	Factored deterministic acceleration value. (Peak Ground Acceleration)
C_{RS}	0.909	Mapped value of the risk coefficient at short periods
C_{R1}	0.905	Mapped value of the risk coefficient at a period of 1 s