

**Subsurface Exploration Program
Geotechnical Recommendations
Parachute Comfort Inn
Northeast Corner of 3rd Street and Railroad Avenue
Parachute, Colorado**

Prepared for:

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GROUND

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PURPOSE AND SCOPE OF STUDY

This report presents the results of a subsurface exploration program performed by GROUND Engineering Consultants, Inc., (GROUND) to develop geotechnical and pavement section recommendations for design and construction of the proposed Comfort Inn to be located near the northeast corner of the intersection of 3rd Street and Railroad Avenue in Parachute, Colorado. Our study was conducted in general accordance with GROUND's Proposal No. 1001-0007 dated January 5, 2010. Any prospective buyer or future ownership must be made aware of and must agree to the terms, conditions, and liability limitations outlined in that proposal.

A field exploration program was conducted to obtain information on subsurface conditions. Material samples obtained during the subsurface exploration were tested in the laboratory to provide data on the classification and engineering characteristics of the on-site soils. The field exploration and laboratory testing are summarized herein.

This report has been prepared to summarize the data obtained and to present our conclusions and recommendations based on the proposed construction and the subsurface conditions encountered. Design parameters and a discussion of geotechnical engineering considerations related to the construction of the proposed development are included.

PROPOSED CONSTRUCTION

We understand that the proposed Comfort Inn will include a three-story, 30,000 square foot structure constructed on a 1.8-acre undeveloped lot. Additionally, we anticipate private parking and drive areas are planned for construction. We assume that underground utility lines may be installed to service the new building. The general site layout is depicted in Figure 1 following the text. We understand that no below-grade (basement) level is planned at this time.

No grading plans were available for review at the time of preparation of this report. However, the existing grades in the area of the proposed addition appeared mostly flat. Therefore, we anticipate material cuts and fills of less than 3 feet, to achieve the final grades. Deeper excavations and backfills will also be needed to install utilities and perform remedial earthworks where recommended.

If the proposed construction differs significantly from that described above, GROUND should be notified to re-evaluate the recommendations contained herein.

SITE CONDITIONS

The site is located in the town of Parachute, Colorado and is northeast of the intersection of Third Street and Railroad Avenue. The site was undeveloped at the time of our visit. Small businesses bordered the site to the north and east and residential housing bordered the site to the south and west. The site was bound on all sides by paved public streets.

The site was covered by approximately 8 to 18 inches of snow at the time of our site visit, though it appeared to be mostly flat. There was about 1 to 2 feet of elevation difference across the length of the site, possibly from past grading. The direction of drainage was not visible at the time of our visit due to the snow cover. Previous site photographs (courtesy of Google Earth) indicate that the site may have served as a construction staging area.

SUBSURFACE EXPLORATION

The subsurface exploration for the project was conducted on January 14, 2010. A total of eight (8) test holes were drilled with a truck-mounted, continuous flight, power auger rig to evaluate subsurface conditions, including depths to groundwater and bedrock, where encountered, as well as to retrieve samples for laboratory testing and analysis. Of these, four (4) test holes were drilled within or near the proposed building footprint and were advanced to depths of approximately 23 to 40 feet below existing grades. The four (4) remaining test holes were advanced within the areas proposed for private paved areas to depths of approximately 5 feet below existing grades. A GROUND engineer directed subsurface exploration, logged the test holes in the field and prepared the samples for transport to our laboratory.

Relatively undisturbed samples of the subsurface materials were taken with a 2-inch I.D. "California" -type liner sampler. The sampler was driven into the substrata with blows from a 140-pound hammer falling 30 inches. This procedure is similar to the Standard Penetration Test described by ASTM Method D1586. Penetration resistance values (blows per distance driven, typically 12 inches), when properly evaluated, indicate the

relative density or consistency of soils and bedrock. Depths at which the samples were taken and associated penetration resistance values are shown on the test hole logs.

The approximate locations of the test holes are shown in Figure 1. Logs of the exploratory test holes are presented in Figures 2 and 3. Explanatory notes and a legend are provided in Figure 4.

LABORATORY TESTING

Samples retrieved from our test holes were examined and visually classified in the laboratory by the project engineer. Laboratory testing of soil samples obtained from the subject site included standard property tests, such as natural moisture contents, dry unit weights, grain size analyses, and Atterberg limits. Swell-consolidation, water-soluble sulfate, and corrosivity tests were performed on selected samples, as well. Resilient modulus testing was also performed on a composite, bulk sample as well. Laboratory tests were performed in general accordance with applicable ASTM and AASHTO protocols.

Data from the laboratory-testing program are summarized on Tables 1 and 2.

SUBSURFACE CONDITIONS

The subsurface conditions encountered in the test holes at the time of our subsurface exploration generally consisted of silts and clays that extended to depths of approximately 20 to 21 feet below existing grades. These materials were underlain by interbedded sandstone, claystone, siltstone and shale bedrock extending to depths explored.

Although not encountered in the test holes at the time of our subsurface exploration program, photographic documentation of construction activities on-site (courtesy of Google Earth) suggest that man-made fill may exist on-site. The exact extents, limits, and composition of any man-made fill were not determined as part of the scope of work addressed by this study, and should be expected to exist at varying depths and locations across the site.

Clays and Silts typically classified as sandy clays and sandy silts. These materials were dry to moist, fine to coarse grained, low to moderately plastic, stiff to very stiff to hard, and brown in color.

Claystone/Sandstone/Siltstone/Shale Bedrock was interbedded, dry to moist, fine grained, low to highly plastic, medium hard to hard, and gray to gray-brown to purple-gray-brown to blue-green-gray to dark gray in color.

Groundwater was not encountered in the test holes at depths of up to approximately 40 feet below existing grades at the time of our subsurface exploration. Groundwater levels can be expected to fluctuate, however, in response to annual and longer-term cycles of precipitation, irrigation, surface drainage, land use, and the development of transient, perched water conditions.

Swell-Consolidation Testing indicated low to moderate potentials for movements in the on-site overburden clays. Measured swells ranged up to 2.2 percent upon wetting against a 1,000-pound per square foot (psf) surcharge load. A consolidation of 1.6 percent was measured upon wetting against a 1,000-psf surcharge load (See Table 1).

GEOTECHNICAL CONSIDERATIONS FOR DESIGN

The soils underlying the site exhibited low to moderate potentials for swells and similar consolidation potential that can contribute to post-construction movements. Given the soil conditions encountered, we estimate likely post-construction movements for conventional shallow foundations placed directly on the site soils of about 2 inches. This value was obtained by assuming an average swell of one percent and a depth of wetting of 15 feet. Although there is risk involved where structures are placed directly on these types of soils, with appropriate geotechnical and civil design, properly implemented during construction, the proposed development is feasible with regard to the on-site materials.

In order to reduce the potential for post-construction movements in the native materials, we recommend that prior to building foundation construction, a portion of the overburden materials be excavated and replaced as properly moisture conditioned and compacted fill. This will require the removal and replacement of approximately 3 feet of existing

materials below the spread footings and approximately 6.5 feet of existing materials below the floor slabs.

BUILDING FOUNDATIONS

The design and construction criteria presented below should be observed for a spread footing foundation system. The construction details should be considered when preparing project documents. The precautions and recommendations provided below will not prevent movement of the footings if the underlying materials are wetted or subjected to alternate wetting and drying cycles. However, the recommended measures will tend to make the movement more uniform, and reduce resultant damage if such movement occurs.

In general, the native site soils are suitable for placement as properly compacted fill beneath the new building. The fill material should be placed in accordance with the recommendations in the *Project Earthwork* section of this report.

- 1) Footings should bear on an overexcavated and properly constructed fill prism of at least 3 feet beneath the lowest footing bearing elevation. The existing soils should be removed to a depth of at least 3 feet beneath the lowest footing bearing elevation to accommodate construction of the fill section, in addition to scarification and re-compaction of the underlying 8 to 12 inches of material. It should be noted that a stable platform should be constructed prior to the placement of this fill prism.

In general, the native site soils are suitable for placement as properly compacted fill beneath the new building. The fill material should be placed in accordance with the recommendations in the *Project Earthwork* section of this report.

The overexcavation and replacement should extend the full-recommended depth at least 5 feet laterally beyond the exterior limits of the building. GROUND recommends that this distance be increased at areas such as main entrances to reduce the possible movements of the flatwork in these high traffic areas. (Also refer to the *Exterior Flatwork* section of this report).

- 2) The Contractor should take care to construct a fill section of uniform depth and composition to reduce differential post-construction foundation movements. A

differential fill beneath the footings will tend to increase differential settlements. (Please refer to the *Project Earthwork* section of this report for more information regarding post-construction fill settlement).

- 3) Footings bearing on the fill prism as describe above may be designed for an allowable soil bearing pressure (Q) of 2,500 psf under drained conditions. This value may be increased by $\frac{1}{3}$ for transient loads such as wind or seismic loading.

Footings should be designed to impose a minimum dead load of 800 psf. The minimum dead load does not need to be maintained during transient loading.

Based on this allowable bearing capacity, we anticipate vertical post-construction movements of approximately 1 inch. For other estimated settlements, allowable bearing pressure values can be obtained from Figure 5.

The recommended allowable bearing pressure was based on an assumption of drained conditions. If foundation materials are subjected to an increase in moisture content, the effective bearing capacity will be reduced and larger post-construction movements than those estimated above will result.

- 3) Footing excavation bottoms may expose loose, organic or otherwise deleterious materials, including debris. Firm materials may be disturbed by the excavation process. All such unsuitable materials should be excavated and replaced with properly compacted fill.
- 4) In order to reduce differential settlements between footings or along continuous footings, footing loads should be as uniform as possible. Differentially loaded footings will settle differentially. Similarly, differential fill thicknesses beneath footings will result in increased differential settlements.
- 5) Spread footings should have a minimum footing lateral dimension of 16 or more inches for linear strip footings and a minimum lateral dimension of 24 of more inches for isolated pad footings. Actual footing dimensions, however, should be determined by the Structural Engineer, based on the design loads.

- 6) Footings should be provided with adequate soil cover above their bearing elevation for frost protection. Footings should be placed at a bearing elevation 3.5 or more feet below the lowest adjacent exterior finish grades.
- 7) Continuous foundation walls should be reinforced top and bottom to span an unsupported length of at least 10 feet.
- 8) The lateral resistance of spread footings will be developed as sliding resistance of the footing bottoms on the foundation materials. Sliding friction at the bottom of footings may be taken as 0.28 times the vertical dead load. Passive pressure may be computed on the basis of an equivalent fluid unit weight of 300 pcf, up to a maximum of 3,000 psf. The upper foot of embedment should not be relied upon for passive resistance, however.
- 9) Compacted fill placed against the sides of the footings should be compacted in accordance with the recommendations in the *Project Earthwork* section of this report.
- 10) Foundation soils may be disturbed or deform excessively under the wheel loads of heavy construction vehicles as the excavations approach footing levels. Construction equipment should be as light as possible to limit development of this condition. The use of track-mounted vehicles is recommended since they exert lower contact pressures. The movement of vehicles over proposed foundation areas should be restricted.
- 11) All footing areas should be compacted with a vibratory plate compactor prior to placement of concrete.

A Geotechnical Engineer should be retained to observe and test the footing bearing areas prior to placement of reinforcing steel or concrete.

FLOOR SYSTEMS

Slab-on-grade construction should be used only if the Owner understands and accepts the risk of post-construction slab movements. If slab-on-grade floors are constructed in accordance with the recommendations provided in this report, we estimate that potential post-construction slab movements may be approximately 1 inch.

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- 1) The floor system should bear on an overexcavated and properly constructed fill prism of at least 6.5 feet in thickness beneath the slab on grade. The existing soils should be removed to a depth of at least 6.5 feet beneath slab bearing elevations to accommodate the construction of the fill section, in addition to the scarification and re-compaction of the underlying 8 to 12 inches of material. The removal and replacement of the fill materials should extend at least 5 feet laterally beyond the proposed new building.
- 2) In general, the native site soils are suitable for placement as properly compacted fill beneath the new building. The fill material should be placed in accordance with the recommendations in the *Project Earthwork* section of this report.
- 3) The Geotechnical Engineer should also be retained to observe the prepared surface on which the floor slab will be cast, prior to placement of steel reinforcement.
- 4) Exposed loose, soft or otherwise unsuitable materials should be excavated and replaced with properly compacted fill, placed in accordance with the recommendations in the *Project Earthwork* section of this report.
- 5) The slab should be separated from all bearing walls and columns with slip joints, which allow unrestrained vertical movement. Joints should be observed periodically, particularly during the first several years after construction. Slab movement can cause previously free-slipping joints to bind. Measures should be taken to assure that slab isolation is maintained in order to reduce the likelihood of damage to walls and other interior improvements, including door frames, plumbing fixtures, etc.
- 6) Interior partitions resting on floor slabs should be provided with slip joints so that if the slabs move, the movement cannot be transmitted to the upper structure. This detail is also important for wallboards and doorframes. A slip joint, which will allow at least 2 inches of vertical movement, is recommended. If slip joints are placed at the tops of walls, in the event that the floor slabs move, it is likely that the wall will show signs of distress, especially where the floors meet the exterior wall.

- 7) Concrete slabs-on-grade should be placed on properly prepared subgrade. They should also be constructed and cured according to applicable standards and be provided with properly designed and constructed control joints. The design and construction of such joints should account for cracking as a result of shrinkage, tension, and loading; curling; as well as proposed slab use. Joint layout based on the slab design may require more frequent, additional, or deeper joints, and should also be based on the ultimate use and configuration of the slabs. Areas where slabs consist of interior corners or curves (at column blockouts or around corners) or where slabs have high length to width ratios, high degree of slopes, thickness transitions, high traffic loads, or other unique features should be carefully considered. The improper placement or construction of control joints will increase the potential for slab cracking. ACI, AASHTO, and other industry groups provide many guidelines for proper design and construction of concrete slabs on grade and the associated jointing.
- 8) Floor slabs should be adequately reinforced. Recommendations based on structural considerations for slab thickness, jointing, and steel reinforcement in floor slabs should be developed by the Structural Engineer.
- 9) GROUND recommends that the Client/Project Team review the American Concrete Institute's (ACI) Sections 301/302/360 for additional guidance and recommendations regarding slab on grade design and construction.
- 10) All plumbing lines should be carefully tested before operation. Where plumbing lines enter through the floor, a positive bond break should be provided. Flexible connections allowing 2 or more inches of vertical movement should be provided for slab-bearing mechanical equipment.
- 11) Moisture can be introduced into a slab subgrade during construction and additional moisture will be released from the slab concrete as it cures. GROUND recommends placement of a properly compacted layer of free-draining gravel, 4 or more inches in thickness, beneath the slabs. This layer will help distribute floor slab loadings, ease construction, reduce capillary moisture rise and aid in drainage. The free-draining gravel should contain less than 5 percent material passing the No. 200 Sieve, more than 50 percent retained on the No. 4 Sieve, and a maximum particle size of 2 inches.

The capillary break and the drainage space provided by the gravel layer also may reduce the potential for excessive water vapor fluxes from the slab after construction as mix water is released from the concrete. A vapor barrier beneath a building floor slab can be beneficial with regard to reducing exterior moisture moving into the building additions, but can retard downward drainage of construction moisture. Uneven moisture release can result in slab curling. Elevated vapor fluxes can be detrimental to the adhesion and performance of many floor coverings and may exceed various flooring manufacturers' usage criteria.

Therefore, in light of the several, potentially conflicting effects of the use vapor-barriers, the Owner and the Architect and/or Flooring Contractor should weigh the performance of the slab and appropriate flooring products in light of the intended building use, etc., during the floor system design process and the selection of flooring materials. Use of a plastic vapor-barrier membrane may be appropriate for some buildings and not for others.

Slab movements are directly related to the increases in moisture contents to the underlying soils after construction is completed. The precautions and recommendations itemized above will not prevent the movement of floor slabs if the underlying materials are subjected to excessive moisture. However, these steps will reduce the damage if such movement occurs.

PROJECT EARTHWORK

General Considerations We anticipate material cuts of less than 3 feet will be required to achieve final grades. Deeper excavations and backfills will be needed to install utilities and perform remedial earthworks as recommended in this report. Site grading should be planned carefully to provide positive surface drainage away from the buildings, pavements, utility alignments, and flatwork. Surface diversion features should be provided around paved areas to prevent surface runoff from flowing across the paved surfaces. Site grading should be performed as early as possible in the construction sequence to allow settlement of fills and surcharged ground to be realized to the greatest extent prior to building construction.

Prior to earthwork construction, existing structures, vegetation and other deleterious materials should be removed and disposed of off-site. Relic underground utilities should be abandoned in accordance with applicable regulations, removed as necessary, and properly capped.

Topsoils present on-site should not be incorporated into ordinary fills. Instead, topsoils should be stockpiled during initial grading operations for placement in areas to be landscaped or for other approved uses.

Use of On-Site Materials as Fill The native overburden clays, that are free of organic materials, construction debris, large cobbles and other deleterious materials (if encountered) are suitable, in general, for placement as fill. Cobbles and non-expansive rock fragments larger than 6 inches in maximum dimension should not be incorporated into project fills.

Although areas of previously placed fill soils were not encountered in the test holes, fills may be present across the site and may not be suitable for replacement as backfill. If fill materials are encountered, the Geotechnical Engineer should be retained during site excavations, to observe the excavated fill materials and provide recommendations for its suitability for reuse.

Imported Fill Materials If it is necessary to import material to the site, the imported soils should be free of organic material, and other deleterious materials. Imported material should have less than 70 percent passing the No. 200 Sieve and should have a plasticity index of less than 15 or otherwise approved by the Geotechnical Engineer. All materials proposed for import should be tested and approved prior to transport to the site, based on their intended use, however.

Fill Platform Preparation Prior to filling, the top 8 to 12 inches of in-place materials on which fill soils will be placed should be scarified, moisture conditioned and properly compacted in accordance with the recommendations below to provide a uniform base for fill placement.

If surfaces to receive fill expose loose, wet, soft or otherwise deleterious material, additional material should be excavated, or other measures taken, to establish a firm

platform for filling. The surfaces to receive fill must be effectively stable prior to placement of fill.

Fill Placement Fill materials should be thoroughly mixed to achieve a uniform moisture content, placed in uniform lifts not exceeding 8 inches in loose thickness, and properly compacted. Soils that classify as GP, GW, GM, GC, SP, SW, SM, or SC in accordance with the USCS classification system (granular materials) should be compacted to 95 or more percent of the maximum Proctor dry density at moisture contents within 2 percent of optimum moisture content as determined by ASTM D1557, the “modified Proctor.” Soils that classify as ML, MH, CL or CH should be compacted to 95 percent of the maximum Proctor density at moisture contents from 1 percent below to 3 percent above the optimum moisture content as determined by ASTM D698, the “standard Proctor.”

No fill materials should be placed, worked, rolled while they are frozen, thawing, or during poor/inclement weather conditions.

Compaction areas should be kept separate, and no lift should be covered by another until relative compaction and moisture content within the recommended ranges are obtained.

Use of Squeegee Relatively uniformly graded fine gravel or coarse sand, i.e., “squeegee,” or similar materials commonly are proposed for backfilling foundation excavations, portions of utility trenches and other areas where employing compaction equipment is difficult. In general, GROUND does not recommend this procedure for the following reasons:

Although commonly considered “self compacting,” uniformly graded granular materials require densification after placement, typically by vibration. The equipment to densify these materials is not available on many job-sites.

Even when properly densified, uniformly graded granular materials are permeable and allow water to reach and collect in the lower portions of the excavations backfilled with those materials. This leads to wetting of the underlying soils and resultant potential loss of bearing support as well as increased local heave or settlement.

GROUND recommends that wherever possible, excavations be backfilled with approved, on-site soils placed as properly compacted fill. Where this is not feasible, use of “Controlled Low Strength Material” (CLSM), i.e., a lean, sand-cement slurry (“flowable fill”) or a similar material for backfilling should be considered.

Where “squeegee” or similar materials are proposed for use by the Contractor, the design team should be notified by means of a Request for Information (RFI), so that the proposed use can be considered on a case-by-case basis. Where “squeegee” meets the project requirements for pipe bedding material, however, it is acceptable for that use.

Quality Assurance A Geotechnical Engineer should be retained to observe project excavations prior to placement of fill. The Geotechnical Engineer also should observe earthwork operations and test the soils. The Geotechnical Engineer should provide a written declaration stating that the project site, including the building pad area, was filled with acceptable materials and was placed in general accordance with the requirements outlined in this report or otherwise specified for the project.

It should be noted that in the later stages of projects, multiple sub-contractors commonly are installing or adjusting/replacing components of the project simultaneously. These can include utility laterals, electrical boxes, sidewalk access ramps, lighting fixtures and other components. In order to facilitate proper observation and testing of the associated earthworks, GROUND recommends that the Contractor verify that his sub-contractors mobilize the necessary equipment and personnel to moisture-condition and compact disturbed or excavated soils effectively. The Contractor also should coordinate with his sub-contractors to ensure that these local earthwork operations are observed with sufficient frequency, and the soils tested, by the Geotechnical Engineer.

Settlements Settlements will occur in filled ground, typically on the order of 1 to 2 percent of the fill depth. For a 5-foot fill, this corresponds to settlement of approximately 1 inch, without imposition of foundation loads. If fill placement is performed properly and is tightly controlled, in GROUND’s experience the majority of that settlement will take place during earthwork construction. The remaining potential settlements likely will take several months or longer, to be realized.

Cut and Filled Slopes Permanent site slopes supported by on-site soils up to 5 feet in height may be constructed no steeper than 3:1 (horizontal : vertical). Minor raveling or

surficial sloughing should be anticipated on slopes cut at this angle until vegetation is well re-established. Surface drainage should be designed to direct water away from slope faces.

EXCAVATION CONSIDERATIONS

Test holes for subsurface exploration were advanced to the depths indicated on the test hole logs by means of truck-mounted, continuous flight auger equipment. We anticipate no unusual excavation difficulties, in general, for the proposed construction in these materials with conventional, heavy-duty excavating equipment in good working condition.

Groundwater was not encountered during subsurface exploration within depths of up to approximately 40 feet below existing grades. Based on the likely depths of earthworking and construction, groundwater is not anticipated to be a significant factor for shallow earthworks during construction of this project, although elevated moisture contents in the soils in the lower portions of project excavations should be anticipated by the Contractor. Dewatering may be needed in some utility and similar excavations. If seepage or groundwater is encountered in shallow project excavations, the Geotechnical Engineer should evaluate the conditions and provide additional recommendations, as appropriate.

We recommend that temporary, un-shored excavation slopes up to 7 feet in height be cut no steeper than 1½ :1 (horizontal : vertical) in the native and fill soils in the absence of seepage. Stockpiling of materials should not be permitted closer to the tops of temporary slopes than 5 feet or a distance equal to the depth of the excavation, whichever is greater.

Should site constraints prohibit the use of the recommended slope angles, then temporary shoring should be used. Actual shoring system(s) should be designed for the Contractor by a registered engineer.

Good surface drainage should be provided around temporary excavation slopes to direct surface runoff away from the slope faces. A properly designed drainage swale should be provided at the top of the excavations. In no case should water be allowed to pond at

the site. Slopes should also be protected against erosion. Erosion along the slopes will result in sloughing and could lead to a slope failure.

Excavations in which personnel will be working must comply with all OSHA Standards and Regulations. The Contractor's "responsible person" should evaluate the soil exposed in the excavations as part of the Contractor's safety procedures. GROUND has provided the information above solely as a service to the Client and is not assuming responsibility for construction site safety or the Contractor's activities.

UTILITY INSTALLATION

Recommendations regarding utility trench excavation are provided in the *Excavation Considerations* section of this report. We anticipate that on-site soils excavated from trenches will be suitable, in general, for use as trench backfill (see the *Project Earthwork* section of this report for more information). Backfill soils should be free of vegetation, debris and other deleterious materials. Cobbles coarser than 6 inches in maximum dimension should not be incorporated into trench backfills.

Trench backfill materials should be conditioned to a uniform moisture content, placed in uniform lifts not exceeding 8 inches in loose thickness, and properly compacted in accordance with the recommendations in the *Project Earthwork* section of this report. Bedding should be brought up uniformly on both sides of the pipe to reduce differential loadings.

Some settlement of trench backfill materials should be anticipated, even where materials are placed and compacted correctly. To reduce these settlements, the Contractor should take adequate measures to achieve adequate compaction in the utility trench backfills, particularly in the lower portions of the excavations and around manholes, valve risers and other vertical pipeline elements where greater settlements commonly are observed. However, the need to compact to the lowest portion of the backfill must be balanced against the need to protect the pipe from damage during backfilling. Some thickness of backfill may need to be placed at compaction levels lower than recommended above to avoid damaging the pipe. Likewise, construction conditions may preclude density testing at specified frequencies in the lower portions of a trench.

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Because of these limitations, we recommend the use of “controlled low strength material” (CLSM), i.e., a lean, sand-cement slurry, “flowable fill,” or similar material in lieu of compacted soil backfill for areas with low tolerances for surface settlements. Placement of CLSM in the lower portion of the trench and around risers, etc., likely will yield a superior backfill and provide protection for the pipe, although at an increased cost. Other means, e.g., use of smaller compaction equipment, also may be effective for achieving adequate compaction in these areas.

Pipe bedding materials, placement and compaction should meet the specifications of the pipe manufacturer and applicable municipal standards. The Contractor should not anticipate that significant quantities of materials excavated on-site will be suitable for use where relatively free-draining bedding materials are called for. Materials proposed for use as pipe bedding should be tested for suitability prior to use. Imported materials should be tested and approved by the Geotechnical Engineer prior to transport to the site.

We assume that surface drainage will direct water away from trench alignments. Nevertheless, we recommend that, non-woven filter fabric (e.g., Mirafi[®] 140N, or the equivalent) should be placed around the granular bedding materials to reduce migration of fines into the bedding which can result in severe, local settlements. Where this protection is not provided, settlements can develop/continue several months or years after completion of the project.

Development of site grading plans should consider the subsurface transfer of water in utility trenches and the pipe bedding. Sandy pipe bedding materials can function as efficient conduits for re-distribution of natural and applied waters in the subsurface. Cut-off walls in utility trenches or other water-stopping measures should be implemented to reduce the rates and volumes of water transmitted along utility alignments and toward buildings, pavements and other structures where excessive wetting of the underlying soils will be damaging. Incorporation of water cut-offs and/or outlet mechanisms for saturated bedding materials into development plans could be beneficial to the project. These measures also will reduce the risk of loss of fine-grained backfill soils into the bedding material with resultant surface settlement.

EXTERIOR FLATWORK

Proper design, drainage, construction and maintenance of the areas between individual buildings and parking/driveway areas are critical to the satisfactory performance of the project. Sidewalks, entranceway slabs and roofs, fountains, raised planters and other highly visible improvements commonly are installed within these zones, and distress in or near these improvements is common. Commonly, proper soil preparation in these areas receives little attention during overlot construction because they fall between the building and pavement areas which typically are built with heavy equipment. Subsequent landscaping and hardscape installation often is performed by multiple sub-contractors with light or hand equipment, and necessary over-excavation and soil processing is not performed. Consequently, subgrade soil conditions commonly deviate significantly from recommended ranges. Therefore, GROUND recommends that the Contractor take particular care with regard to proper subgrade preparation in the immediate building exteriors.

Similar to slab-on-grade floors, exterior flatwork and other hardscaping placed on the generally granular soils encountered at the site will experience post-construction movements as soil moisture contents increase after construction. Local settlements in the native soils as well as in filled and backfilled areas should be anticipated. Distress to rigid hardscaping likely will result. The following measures will help to reduce damages to these improvements.

GROUND recommends that shortly before installation, the subgrade soils beneath project sidewalks, paved entryways and patios, masonry planters and short, decorative walls, and other hardscaping be excavated and/or scarified to a depth of 12 or more inches. The excavated soil should be replaced as properly moisture-conditioned and compacted fill as outlined in the *Project Earthwork* section of this report, in order to reduce the magnitude of potential movements. Greater depths of moisture-density conditioning of the subgrade soils beyond the above minimum will improve hardscape performance.

Prior to placement of flatwork, a proof roll should be performed to identify areas which exhibit instability and deflection. The deleterious soils in these areas should be removed and replaced with properly compacted fill. The Contractor should take care to achieve and maintain compaction behind curbs to reduce differential sidewalk settlements.

Flatwork should be provided with effective control joints and spaced no more than 10 feet apart, both ways. Narrow flatwork, such as sidewalks, likely will require more closely spaced joints.

In no case should exterior flatwork extend to under any portion of the building where there is less than 2 inches of clearance between the flatwork and any element of the building. Exterior flatwork in contact with brick, rock facades, or any other element of the building can cause damage to the structure if the flatwork experiences movements.

As recommended in the *Project Earthwork* and *Surface Drainage* sections of this report, positive surface drainage away from all pavements and flatwork should be included in project design. Proper drainage also should be maintained after completion of the project, and re-established as necessary.

Concrete Scaling Climatic conditions in the project area including relatively low humidity, large temperature changes and repeated freeze – thaw cycles, make it likely that project sidewalks and other exterior concrete will experience surficial scaling or spalling. The likelihood of concrete scaling can be increased by poor workmanship during construction, such as ‘over-finishing’ the surfaces. In addition, the use of de-icing salts on exterior concrete flatwork, particularly during the first winter after construction, will increase the likelihood of scaling. Even use of de-icing salts on nearby roadways, from where vehicle traffic can transfer them to newly placed concrete, can be sufficient to induce scaling. Typical quality control / quality assurance tests that are performed during construction for concrete strength, air content, etc., do not provide information with regard to the properties and conditions that give rise to scaling.

We understand that some municipalities require removal and replacement of concrete that exhibits scaling, even if the material was within specification and placed correctly. The contractor should be aware of the local requirements and be prepared to take measures to reduce the potential for scaling and/or replace concrete that scales.

In GROUND’s experience the measures below can be beneficial for reducing the likelihood of concrete scaling. It must be understood, however, that because of the other factors involved, including weather conditions and workmanship, surface damage to concrete can develop, even where all of these measures were followed. The mix design criteria should be coordinated with other project requirements including the

criteria for sulfate resistance presented in the *Water-Soluble Sulfates* section of this report.

- 1) Maintaining a maximum water/cement ratio of 0.45 by weight for exterior concrete mixes.
- 2) Include Type F fly ash in exterior concrete mixes as 20 percent of the cementitious material.
- 3) Specify a minimum, 28-day, compressive strength of 4,500 psi for all exterior concrete.
- 4) Include 'fibermesh' in the concrete mix may be beneficial for reducing surficial scaling.
- 5) Cure the concrete effectively at uniform temperature and humidity. This commonly will require fogging, blanketing and/or tenting, depending on the weather conditions. As long as 3 to 4 weeks of curing may be required, and possibly more.
- 6) Avoid placement of concrete during cold weather so that it is exposed to freeze-thaw cycling before it is fully cured.
- 7) Avoid the use of de-icing salts on given reaches of flatwork through the first winter after construction.

We understand that commonly it may not be practical to implement some of these measures for reducing scaling due to safety considerations, project scheduling, etc. In such cases, additional costs for flatwork maintenance or reconstruction should be incorporated into project budgets.

Frost and Ice Nearly all soils other than relatively coarse, clean, granular materials are susceptible to loss of density if allowed to become saturated and exposed to freezing temperatures and repeated freeze – thaw cycling. The formation of ice in the underlying soils can result in heaving of pavements, flatwork and other hardscaping ("ice-jacking") in sustained cold weather up to 2 inches or more. This heaving can develop relatively rapidly. A portion of this movement typically is recovered when the soils thaw, but due to

loss of soil density, some degree of displacement will remain. This can result even where the subgrade soils were prepared properly.

Where hardscape movements are a design concern, e.g., at doorways, replacement of the subgrade soils with 3 or more feet of clean, coarse sand or gravel should be considered or supporting the element on foundations similar to the building and spanning over a void. This area should be properly drained to reduce additional collection of water. Detailed recommendations in this regard can be provided upon request. It should be noted that where such open graded granular soils are placed, water can infiltrate and accumulate in the subsurface relatively easily, which can lead to increased settlement or heave from factors unrelated to ice formation. The relative risks from these soil conditions should be taken into consideration where frost heave is a concern. GROUND will be available to discuss these concerns upon request.

Where soils supporting foundations or on which foundation will be placed are exposed to these conditions during construction – commonly due to water ponding in foundation excavations – bearing capacity typically is reduced and/or settlements increased due to the loss of density in the supporting soils. After periods of freezing conditions, the Contractor should re-work areas affected by the formation of ice to re-establish adequate bearing support.

WATER-SOLUBLE SULFATES

The concentration of water-soluble sulfates measured in a sample obtained from the test holes was approximately 0.01 percent by weight (see Table 2). Such concentrations of water-soluble sulfates represent a negligible degree of sulfate attack on concrete exposed to these materials. Degrees of attack are based on the scale of 'negligible,' 'moderate,' 'severe' and 'very severe' as described in the "Design and Control of Concrete Mixtures," published by the Portland Cement Association.

Based on these data GROUND, makes no recommendation for use of a special, sulfate-resistant cement in project concrete.

In addition, the water-soluble sulfate value represents Class 0 in accordance with the Colorado Department of Transportation revised Sections 601 and 701 (dated November 5, 2009). We recommend that specific recommendations for Class 0 be followed.

SOIL CORROSIVITY

The degree of risk for corrosion of metals in soils commonly is considered to be in two categories: corrosion in undisturbed soils and corrosion in disturbed soils. The potential for corrosion in undisturbed soil is generally low, regardless of soil types and conditions, because it is limited by the amount of oxygen that is available to create an electrolytic cell. In disturbed soils, the potential for corrosion typically is higher, but is strongly affected by soil conditions for a variety of reasons, primarily soil chemistry.

A corrosivity analysis was performed to provide a general assessment of the potential for corrosion of ferrous metals installed in contact with earth materials at the site, based on the conditions existing at the time of GROUND's evaluation. Soil chemistry and physical property data including pH, oxidation-reduction (redox) potential, sulfides, and moisture content were obtained. Test results are summarized on Table 2.

Soil Resistivity: In order to assess the "worst case" for mitigation planning, samples of materials retrieved from the test holes were tested for resistivity in the laboratory, after being saturated with water, rather than in the field. Resistivity also varies inversely with temperature. Therefore, the laboratory measurements were made at a controlled temperature.

A measurement of electrical resistivity indicated a value of approximately 8,611 ohm-cm. The following table presents the relationship between soil resistivity and a qualitative corrosivity rating¹:

Corrosivity Ratings Based on Soil Resistivity

Soil Resistivity (ohm-cm)	Corrosivity Rating
>20,000	Essentially non-corrosive
10,000 – 20,000	Mildly corrosive
5,000 – 10,000	Moderately corrosive
3,000 – 5,000	Corrosive
1,000 – 3,000	Highly corrosive
<1,000	Extremely corrosive

¹ ASM International, 2003, *Corrosion: Fundamentals, Testing and Protection*, ASM Handbook, Volume 13A.

pH: According to the American Water Works Association² (AWWA), where pH is less than 4.0, soil acts as an electrolyte; the pH range of about 6.5 to 7.5 indicates soil conditions that are optimum for sulfate reduction. In the pH range above 8.5, soils are generally high in dissolved salts, yielding a low soil resistivity. Testing indicated a pH value of approximately 7.5.

Reduction-Oxidation testing indicated negative a red-ox potential of -32 milivolts. Low potentials typically create a more corrosive environment.

Sulfide Reactivity testing indicated “positive” results in the soils tested. The presence of sulfides in the alignment soils suggests a more corrosive environment.

Corrosivity Assessment The AWWA also has developed a point system scale used to assess corrosivity more quantitatively and predict the need for pipe protection. The scale is intended for protection of ductile iron pipe but is valuable for project steel selection. Where the soil characteristics yield 10 or more points, protective measures for ductile iron pipe are recommended. The AWWA scale is presented below. The soil characteristics refer to the conditions at and above pipe installation depth.

Table A.3 Soil-test Evaluation³

<u>Soil Characteristic / Value</u>	<u>Points</u>
Resistivity	
<1,500 ohm-cm	10
1,500 to 1,800 ohm-cm	8
1,800 to 2,100 ohm-cm	5
2,100 to 2,500 ohm-cm	2
2,500 to 3,000 ohm-cm	1
>3,000 ohm-cm	0
pH	
0 to 2.0	5
2.0 to 4.0	3
4.0 to 6.5	0
6.5 to 7.5	0 *
7.5 to 8.5	0
>8.5	3

² American Water Works Association ANSI/AWWA C105/A21.5-05 Standard

³ American Water Works Association ANSI/AWWA C105/A21.5-05 Standard

**Parachute Comfort Inn
Northeast Corner of 3rd Street and Railroad Avenue
Parachute, Colorado**

Redox Potential	
< 0 (negative values)	5
0 to +50 mV	4
+50 to +100 mV	3½
> +100 mV	0
 Sulfide Content	
Positive	3½
Trace	2
Negative	0
 Moisture	
Poor drainage, continuously wet	2
Fair drainage, generally moist	1
Good drainage, generally dry	0

* If sulfides are present and low or negative redox-potential results (< 50 mV) are obtained, add three points for this range.

We anticipate that drainage at the site after construction will be good. Based on the values obtained for the soil parameters, the overburden soils appear to comprise a highly corrosive environment for metals.

Corrosive conditions can be addressed by use of materials not vulnerable to corrosion, heavier gauge materials with longer design lives, polyethylene encasement, or cathodic protection systems. If additional information or recommendations are needed regarding soil corrosivity, GROUND recommends contacting the American Water Works Association or a Corrosion Engineer. It should be noted, however, that changes to the site conditions during construction, such as the import of other soils, or the intended or unintended introduction of off-site water, may alter corrosion potentials significantly.

SURFACE DRAINAGE

The following drainage precautions should be observed during construction and maintained at all times after the building has been completed. If the drainage measures below are not implemented effectively, the movement estimates provided in this report could be exceeded.

- 1) Wetting or drying of the foundation excavations and underslab areas should be avoided during and after construction as well as throughout the life of the building. Permitting increases/variations in moisture to the supporting soils may

result in a decrease in bearing capacity and an increase in settlement, heave, and/or differential movement.

- 2) Positive surface drainage measures should be provided and maintained to reduce water infiltration into foundation soils. The ground surface surrounding the exterior of the building should be sloped to drain away from the foundation in all directions. We recommend a minimum slope of 12 inches in the first 10 feet in the areas not covered with pavement or concrete slabs, or a minimum 3 percent in the first 10 feet in areas where hardscaping or pavements cover that area adjacent to the building. (It may be necessary to incorporate ramps or other measures into project design to implement this recommendation while complying with access requirements.) In no case should water be allowed to pond near or adjacent to foundation elements. Ponding will lead to infiltration and increased post-construction building movements.

Drainage measures also should be included in project design to direct water away from sidewalks and other hardscaping as well as utility trench alignments which are likely to be adversely affected by moisture-volume changes in the underlying soils or flow of infiltrating water. Regular maintenance of site drainage should be undertaken throughout the design-life of the project.

In GROUND's experience, it is common during construction that in areas of partially completed paving or hardscaping, bare soil behind curbs and gutters, and utility trenches, water is allowed to pond after rain or snow-melt events. Wetting of the subgrade can result in loss of subgrade support and increased settlements or heave. By the time final grading has been completed, significant volumes of water can already have entered the subgrade, leading to subsequent distress and failures. The Contractor should maintain effective site drainage throughout construction so that water is directed into appropriate drainage structures.

- 3) The ground surface near foundation elements should be able to convey water away readily. Ground coverings that direct water downward rather than away from the buildings should not be used near the foundations or other improvements sensitive to post-construction soil movements. Cobbles or other materials that tend to act as baffles and restrict surface flow should not be used.

Correspondingly, near other project improvements such as hardscaping, where the ground surface does not convey water away readily additional post-construction movements and distress should be anticipated.

- 4) Roof downspouts and drains should discharge well beyond the perimeters of the structure foundations, or be provided with positive (effective) conveyance off-site for collected waters. Downspouts should not discharge into the building underdrain system, if utilized.

Although the use of gutters for the proposed development is unknown to us, our experience indicates that most buildings in mountainous areas are not provided with roof drains and gutters. We understand that the main reason for not including such systems is the potential damage that may result from snow and ice accumulation. Therefore, after snowmelt and heavy rains, significant amounts of water discharging from the roof can be introduced into surface and subsurface soils near foundation elements (foundation footings, foundation walls, etc.). Introduction of water into building foundation systems and backfill soils may cause damage to structures due to increased lateral loads and reduction of soil bearing capacity. In addition, introduction of water will cause settlement of foundation backfill and related distress to exterior flatwork, and other components of the residence such as deck foundations, that are supported within the foundation backfill zone.

There are various alternate provisions such as roof heating systems and snow guards that can be incorporated into a roof design to properly drain water discharging from the roof away from the residence. The Project Design Team should consider incorporating such systems in order to control roof water discharge and direct it well beyond the perimeters of the structures foundation elements.

- 5) Landscaping which requires watering should be located 10 or more feet from building perimeters. Irrigation sprinkler heads should be deployed so that applied water is not introduced into foundation soils. Landscape irrigation should be limited to the minimum quantities necessary to sustain healthy plant growth.

Use of drip irrigation systems can be beneficial for reducing over-spray beyond planters. Drip irrigation can also be beneficial for reducing the amounts of water

introduced to building foundation soils, but only if the total volumes of applied water are controlled with regard to limiting that introduction. Controlling rates of moisture increase beneath the foundations and floors should take higher priority than minimizing landscape plant losses.

Where plantings are desired within 5 feet of the building, GROUND recommends that the plants be placed in water-tight planters, constructed either in-ground or above-grade, to reduce moisture infiltration in the surrounding subgrade soils. Planters should be provided with positive drainage and landscape underdrains.

- 6) We do not recommend the use of plastic membranes to cover the ground surface near the building without careful consideration of other components of project drainage. Plastic membranes can be beneficial to directing surface waters away from the building and toward drainage structures. However, they effectively preclude evaporation or transpiration of shallow soil moisture. Therefore, soil moisture tends to increase beneath a continuous membrane. Where plastic membranes are used, additional shallow, subsurface drains should be installed. If such drains are not installed, the risk of post-construction movements will be increased. Perforated “weed barrier” membranes, which allow ready evaporation from the underlying soils may be used.
- 7) Detention ponds commonly are incorporated into drainage design. When a detention ponds fills, the rate of release of the water is controlled and water is retained in the pond for a period of time. Where in-ground storm sewers direct surface water to the pond, the granular pipe bedding also can direct shallow groundwater or infiltrating surface water toward the pond. Thus, detention ponds can become locations of enhanced and concentrated infiltration into the subsurface, leading to wetting of foundation soils in the vicinity with consequent heave or settlement. Therefore, unless the pond is clearly down-gradient from the proposed buildings and other structures that would be adversely affected by wetting of the subgrade soils, including off-site improvements, GROUND recommends that the detention pond should be provided with an effective, low permeability liner.

SUBSURFACE MOISTURE INFILTRATION AND DRAINAGE

Common practice for the combination of soil and foundation system proposed for this project includes the installation of perimeter underdrains. As a component of project civil design, properly functioning, subsurface drain systems (underdrains) can be beneficial for collecting and discharging saturated subsurface waters. Underdrains will not collect water infiltrating under unsaturated (vadose) conditions, or moving via capillarity, however. In addition, if not properly constructed and maintained, underdrains can transfer water into foundation soils, rather than remove it. This will tend to induce settlement of the subsurface soils, and may result in structure/floor slab distress. Underdrains can, however, provide an added level of protection against relatively severe post-construction movements by draining saturated conditions near individual structures should they arise, and limiting the volume of wetted soil.

The site soils are relatively stable with regard to moisture content – volume relationships at their existing moisture contents. Other than the anticipated, post-placement settlement of fills, vertical post-construction soil movements will result primarily from the introduction of water into the soils underlying the proposed structure, hardscaping and pavements. Based on the site surface and subsurface conditions encountered in this study, we do not anticipate a rise in the local water table sufficient to cause adverse wetting of the soils supporting shallow foundations. Therefore, wetting of the soils likely will result from infiltrating surface waters (precipitation, irrigation, etc.), flow along constructed pathways such as bedding in utility pipe trenches. Project design should incorporate measures to prevent water from wetting the project soils. Surface drainage gradients, pavements, flatwork, piping, drainage structures, etc., should be maintained during and after construction to prevent infiltration.

It is the responsibility of the design team and Ownership as well as the construction and maintenance Contractor(s) within their respective disciplines and in accordance with their familiarity with the site conditions to evaluate the possible sources of water that could affect the project area and provide design and/or construction measures that address the conditions so that moisture is directed away from the foundations and supporting materials prior to being allowed to infiltrate the subsurface, both during and after construction. Wetting or drying of the foundation excavations and underslab areas should be avoided during and after construction as well as throughout the life of the

building. Permitting increases/variations in moisture to the supporting soils may result in a decrease in bearing capacity and an increase in total and/or differential movements.

If an underdrain is incorporated into project design, the underdrain system should consist of perforated PVC drain pipe at least 4 inches in diameter, free-draining gravel, and filter fabric. The free-draining gravel should contain less than 5 percent passing the No. 200 Sieve and more than 50 percent retained on the No. 4 Sieve, and have a maximum particle size of 2 inches. Each drain pipe should be surrounded on the sides and top with 6 or more inches of free-draining gravel. The gravel surrounding the drain pipe and/or the pipe itself should be wrapped with filter fabric to reduce the migration of fines into the drain system. A typical cross-sectional detail of an underdrain can be provided upon request. The actual design/layout, outlets, and location should be designed by the Civil Engineer. Furthermore, the information provided above should not be utilized by the Contractor to “field-construct” a perimeter underdrain system.

PAVEMENT SECTIONS

A pavement section is a layered system designed to distribute concentrated traffic loads to the subgrade. Performance of the pavement structure is directly related to the physical properties of the subgrade soils and traffic loadings. Because the project pavements will be privately maintained, pavement section alternatives for the project parking and driveways were developed in general accordance with the guidelines and procedures of the American Association of State Highway and Transportation Officials (AASHTO) and the Colorado Department of Transportation (CDOT) and local pavement construction practice.

The recommendations provided below are for private paved surfaces, such as parking lots and driveways. Providing pavement section recommendations for public improvements, such as widening Railroad Avenue, is beyond our scope of services. These services can be provided under a separate scope of work upon request.

Subgrade Materials Based on the results of our field and laboratory studies, subgrade materials in the proposed pavement areas consisted predominantly of soils that generally classify as clays and silts. These materials were classified typically as A-4 and A-6 soils in accordance with the AASHTO classification system, with Group Index values ranging from 1 to 9.

Resilient Modulus (M_R) testing (AASHTO T-307) was performed on a representative composite sample of the subgrade materials encountered at the site. A modulus of resilience of 3301 psi, obtained at 2 percent above the optimum moisture content, was taken as characteristic of the subgrade soils. It is important to note that significant decreases in soil support as quantified by the resilient modulus have been observed as the moisture content increases above the optimum. Therefore, pavements that are not properly drained may experience a loss of the soil support and subsequent reduction in pavement life.

Design Traffic Specific traffic loadings were not available at the time of this report preparation. Therefore, an equivalent 18-kip daily load application (EDLA) value of 5 was assumed for the design of the pavement structure for automobile parking stall areas. An EDLA of 10 was assumed for general parking areas and project driveways. The EDLA values of 5 and 10 were converted to equivalent 18-kip single axle load (ESAL) values of 36,500 and 73,000, respectively, for a 20-year design life. An EDLA of 50, corresponding to an ESAL value of 365,000, was assumed for trash collection zones, drive through lanes and other areas subject to heavier traffic including large trucks. If design traffic loadings differ significantly from these assumed values, GROUND should be notified to re-evaluate the pavement recommendations below.

Pavement Design The soil resilient modulus and the design ESAL values were used to determine the required design structural number for the private project pavements. The required structural number was then used to develop recommended pavement sections. Pavement designs were based on the DARWin™ computer program that solves the 1993 AASHTO pavement design equation. Pavement design parameters and calculations are summarized in Appendix A. A Reliability Level of 75 percent was utilized for design of the private pavement sections. Structural coefficients of 0.40 and 0.12 were used for hot bituminous asphalt and high quality aggregate base course, respectively. The minimum pavement sections recommended by GROUND are tabulated below. We recommend that primary delivery truck routes serving the facility, the loading/unloading zone, drive-through lane, and trash collection area, as well as other pavement areas subjected to high turning stresses or heavy truck traffic be provided with rigid pavements consisting of 6 or more inches of Portland cement concrete.

Recommended Minimum Pavement Sections

Pavement	Minimum Full Depth Asphalt (Inches HBA)	Minimum Composite Section (Inches HBA / inches ABC)
Automobile-Only Parking	6.0	4.0 / 8.0
Drive-Lanes and General Parking	7.0	4.5 / 9.0
High Turning Stresses & Heavy Traffic	6.0 inches of Portland Cement Concrete	

Pavement Materials Asphalt pavement should consist of a bituminous plant mix composed of a mixture of aggregate and bituminous material. Asphalt mixture(s) should meet the requirements of a job-mix formula established by a qualified engineer.

Concrete pavements should consist of a plant mix composed of a mixture of aggregate, portland cement and appropriate admixtures meeting the requirements of a job-mix formula established by a qualified engineer as well as applicable municipal design requirements. Concrete should have a minimum modulus of rupture of third point loading of 650 psi. Normally, concrete with a 28-day compressive strength of 4,500 psi should develop this modulus of rupture value. The concrete should be air-entrained with approximately 6 percent air and should have a minimum cement content of 6 sacks per cubic yard. Maximum allowable slump should be 4 inches. These concrete mix design criteria should be coordinated with other project requirements including the criteria for sulfate resistance presented in the *Water-Soluble Sulfates* section of this report.

Concrete Scaling Surficial scaling or spalling of concrete pavements likely will develop at some point. The climate, workmanship and weather conditions after concrete placement all can contribute to the development of scaling. GROUND suggests the following measures to reduce the potential for scaling of pavement concrete. Pavement concrete should meet the requirements of CDOT Class P concrete. (The mix design criteria should be coordinated with other project requirements including the criteria for sulfate resistance presented in the *Water-Soluble Sulfates* section of this report.) Additional recommendations regarding temperature, humidity, cold weather placement, and use of de-icing salts are presented in the *Exterior Flatwork* section of this report.

Note that even use of de-icing salts on nearby roadways, from where vehicle traffic can transfer them to newly placed concrete, can be sufficient to induce scaling.

It must be understood, however, that because of the other factors involved, including weather conditions and workmanship, surface damage to concrete pavements can develop, even where all of these measures were implemented. Typical quality control / quality assurance tests that are performed during construction for concrete strength, air content, etc., do not provide information with regard to the properties and conditions that give rise to scaling.

We understand that some municipalities require removal and replacement of concrete that exhibits scaling, even if the material was within specification and placed correctly. The contractor should be aware of the local requirements and be prepared to take measures to reduce the potential for scaling and/or replace concrete that scales.

The concrete pavement should contain effective sawed or formed joints. In areas of repeated turning stresses we recommend that the concrete pavement joints be fully tied and doweled. We suggest that civil design consider joint layout in accordance with CDOT's M Standards. Standard plans for placement of ties and dowels, etc., (CDOT M Standards) for concrete pavements can be found at the CDOT website: <http://www.dot.state.co.us/DesignSupport/>.

If composite flexible sections are placed, the aggregate base material should meet the criteria of CDOT Class 6 aggregate base course. Base course should be placed in uniform lifts not exceeding 8 inches in loose thickness and compacted to at least 95 percent of the maximum dry density a uniform moisture contents within 3 percent of the optimum as determined by ASTM D1557 / AASHTO T-180, the "modified Proctor."

Subgrade Preparation Shortly before placement of pavement, including aggregate base, the exposed subgrade soils should be excavated and/or scarified to a depth of at least 12 inches, mixed to achieve a uniform moisture content and then re-compacted in accordance with the recommendations provided in the *Project Earthwork* section of this report. Subgrade preparation should extend the full width of the pavement from back-of-curb to back-of-curb. Greater depths (i.e. 24 inches) of moisture-density conditioning of the subgrade soils beyond the above minimum will improve pavement performance, particularly for the soils encountered at the project site.

The contractor should be prepared either to dry the subgrade materials or moisten them, as needed, prior to compaction. It may be difficult for the contractor to achieve and maintain compaction in some on-site soils encountered without careful control of water contents. Likewise, some site soils likely will “pump” or deflect during compaction if moisture levels are not carefully controlled. The contractor should be prepared to process and compact such soils to establish a stable platform for paving, including use of chemical stabilization, if necessary.

Immediately prior to paving, the subgrade should be proof rolled with a heavily loaded, pneumatic tired vehicle. Areas that show excessive deflection during proof rolling should be excavated and replaced and/or stabilized. Areas allowed to pond prior to paving will require significant re-working prior to proof-rolling. Passing a proof roll is an additional requirement, beyond placement and compaction of the subgrade soils in accordance with the recommendations in this report. Some soils that are compacted in accordance with the recommendations herein may not be stable under a proof roll, particularly at moisture contents in the upper portion of the acceptable range.

Additional Recommendations The collection and diversion of surface drainage away from paved areas is extremely important to satisfactory performance of the pavements. The subsurface and surface drainage systems should be carefully designed to ensure removal of the water from paved areas and subgrade soils. Allowing surface waters to pond on pavements will cause premature pavement deterioration. Where topography, site constraints or other factors limit or preclude adequate surface drainage, pavements should be provided with edge drains to reduce loss of subgrade support. The long-term performance of the pavement also can be improved greatly by proper backfilling and compaction behind curbs, gutters, and sidewalks so that ponding is not permitted and water infiltration is reduced.

Landscape irrigation in planters adjacent to pavements and in “island” planters within paved areas should be carefully controlled or differential heave and/or rutting of the nearby pavements will result. Drip irrigation systems are recommended for such planters to reduce over-spray and water infiltration beyond the planters. Enclosing the soil in the planters with plastic liners and providing them with positive drainage also will reduce differential moisture increases in the surrounding subgrade soils. ‘Xeriscape’-type landscaping is beneficial in this regard. If this is not possible, we recommend edge

drains where the profile/slopes are less than 1 percent. In our experience, infiltration from planters adjacent to pavements is a principal source of moisture increase beneath those pavements. This wetting of the subgrade soils from infiltrating irrigation commonly leads to loss of subgrade support for the pavement with resultant accelerating distress, loss of pavement life and increased maintenance costs. This is particularly the case in the later stages of project construction after landscaping has been emplaced but heave construction has not ended. Heavy vehicle traffic over wetted subgrade commonly results in rutting and pushing of flexible pavements, and cracking of rigid pavements. Where the subgrade soils are expansive, wetting also typically results in increased pavement heave. In relatively flat areas where design drainage gradients necessarily are small, subgrade settlement or heave can obstruct proper drainage and yield increased infiltration, exaggerated distress, etc. (These considerations apply to project flatwork as well.)

Also, GROUND's experience indicates that longitudinal cracking is common in asphalt-pavements generally parallel to the interface between the asphalt and concrete structures such as curbs, gutters or drain pans. Distress of this type is likely to occur even where the subgrade has been prepared properly and the asphalt has been compacted properly.

As noted above, the standard care of practice in pavement design describes the recommended flexible pavement section as a "20-year" design pavement; however, most pavements will not remain in satisfactory condition without routine, preventive maintenance and rehabilitation procedures performed throughout the life of the pavement. Preventive pavement treatments are surface rehabilitation and operations applied to improve or extend the functional life of a pavement. These treatments preserve, rather than improve, the structural capacity of the pavement structure. In the event the existing pavement is not structurally sound, the preventive maintenance will have no long-lasting effect. Therefore, a routine maintenance program to seal cracks, repair distressed areas, and perform thin overlays throughout the life of the pavement is recommended.

A crack sealing and fog seal/chip seal program should be performed on the pavements every 3 to 4 years. After approximately 8 to 10 years, patching, additional crack sealing, and asphalt overlay may be required. Prior to future overlays, it is important that all

transverse and longitudinal cracks be sealed with a flexible, rubberized crack sealant in order to reduce the potential for propagation of the crack through the overlay. Traffic volumes that exceed the values utilized by this report will likely necessitate the need of pavement maintenance practices on a schedule of shorter timeframe than that stated above. "The greatest benefit of preventive maintenance is achieved by placing the treatments on sound pavements that have little or no distress".

The estimated traffic loadings do not include excess loading conditions imposed by heavy construction vehicles. Consequently, heavily loaded concrete, lumber, and building material trucks can have a detrimental effect on the pavement. GROUND recommends that an effective program of regular maintenance be developed and implemented to seal cracks, repair distressed areas, and perform thin overlays throughout the life of the pavements.

CLOSURE

Geotechnical Review The poor performance of many foundations and pavements has been directly attributed to inadequate geotechnical review and earthwork quality control. Therefore, a Geotechnical Engineer should be retained to review project plans and specifications to evaluate whether they comply with the intent of the recommendations in this report. The author of this report and/or the reviewing engineer should be contacted directly to provide this review. The review should be reported in writing.

Project earthwork construction operations should be observed by the Geotechnical Engineer. All excavations should be observed by the Geotechnical Engineer prior to placement of fill or backfill soils, installation of shoring, or foundation construction. Placement of fill/backfill soils should be observed by the Geotechnical Engineer, and the soils tested.

The geotechnical recommendations presented in this report are contingent upon observation and testing of project earthworks by representatives of GROUND. If another geotechnical consultant is selected to provide construction observation and quality control, then that consultant must assume all responsibility for the geotechnical aspects of the project by concurring in writing with the recommendations in this report, or by providing alternative recommendations.

Limitations This report has been prepared for Quality Inn and Suites, as it pertains to design and construction of the proposed Parachute Comfort Inn, as described herein. It may not contain sufficient information for other parties or other purposes. In addition, GROUND has assumed that project construction will commence by Fall 2011. Changes in project plans or schedule should be brought to the attention of the Geotechnical Engineer, in order that the geotechnical recommendations may be re-evaluated and, as necessary, modified.

The geotechnical conclusions and recommendations in this report relied upon subsurface exploration at a limited number of exploration points, as shown in Figure 1. Subsurface conditions were interpolated between and extrapolated beyond these locations. It is not possible to guarantee the subsurface conditions are as indicated in this report. Actual conditions exposed during construction should be anticipated to differ, somewhat, from those encountered during site exploration. If during construction, surface, soil, bedrock, or groundwater conditions appear to be at variance with those described herein, the Geotechnical Engineer should be advised at once, so that re-evaluation of the recommendations may be made in a timely manner. In addition, a Contractor who relies upon this report for development of his scope of work or cost estimates may consider the geotechnical information in this report to be inadequate for his purposes or find the geotechnical conditions described herein to be at variance with his experience in the greater project area. In such cases, the Contractor should obtain the additional geotechnical information that he considers necessary to develop his workscope and cost estimates with sufficient precision. This includes depths to groundwater, etc.

Contractors should review all available project information prior to providing construction/service bids. Findings were dependent on the limited amount of direct evidence obtained at the time of this geotechnical evaluation. Our recommendations were developed for the site conditions as described above.

Any prospective buyer or future ownership must be made aware of and must agree to the terms, conditions, and liability limitations outlined in GROUND's proposal for this project.

The materials present on-site are stable at their natural moisture content, but may shrink, swell, or lose bearing capacity with changes in moisture content. It is the

responsibility of the design team (the architect(s), civil engineer(s), landscape architect(s), structural engineer(s), and ownership) as well as the construction and maintenance contractor(s) to ensure that moisture is not allowed to infiltrate the underlying soils.

Performance of the proposed structure, pavements and the other related improvements will depend on implementation of the recommendations in this report and on proper maintenance after construction is completed. Because water is the principal cause of volume change in soils and rock, the design, construction, and maintenance of the improvements must eliminate changes in moisture content of the site soils/bedrock. Structural movements will most likely occur following project completion and should therefore be expected by the Owner.

The recommendations and criteria provided in this report were based on the data presented herein, and our experience in the general project area with similar structures, and our engineering judgment with regard to the applicability of the data and methods of forecasting future performance. A variety of engineering parameters were considered as indicators of potential future soil movements. Our recommendations were based on our judgment of “likely movement potentials,” (i.e., the amount of movement likely to be realized if site drainage is effective, estimated to a reasonable degree of engineering certainty) as well as our assumptions about the Owner’s willingness to accept geotechnical risk. “Maximum possible” movement estimates necessarily will be larger than those presented herein. They also have a lower likelihood of being realized in our opinion, and generally require more expensive measures to address. We encourage the Owner or prospective future owners, upon receipt of this report, however, to discuss these risks and the geotechnical alternatives with us.

Engineering consulting and design practice necessarily involves weighing the risks inherent in a given design approach against the construction and maintenance costs associated with reducing those risks. The Owner (and subsequent prospective future owners) must, therefore, understand the risks and remedial approaches presented in this report (and the risk-cost trade-offs addressed by the Civil Engineer and Structural Engineer) in order to direct his Design Team to the portion of the Higher Cost / Lower Risk – Lower Cost / Higher Risk spectrum in which this project should be designed. If the Owner or a prospective future owner does not understand these risks, it is critical

Parachute Comfort Inn
Northeast Corner of 3rd Street and Railroad Avenue
Parachute, Colorado

that he request additional information or clarification so that his expectations reasonably can be met.

This report was prepared in accordance with generally accepted soil and foundation engineering practice in the Garfield County, area at the date of preparation. GROUND makes no other warranties, either expressed or implied, as to the professional data, opinions or recommendations contained herein.

GROUND appreciates the opportunity to complete this portion of the project and welcomes the opportunity to provide the Owner with a cost proposal for construction observation and materials testing prior to construction commencement.

Sincerely,

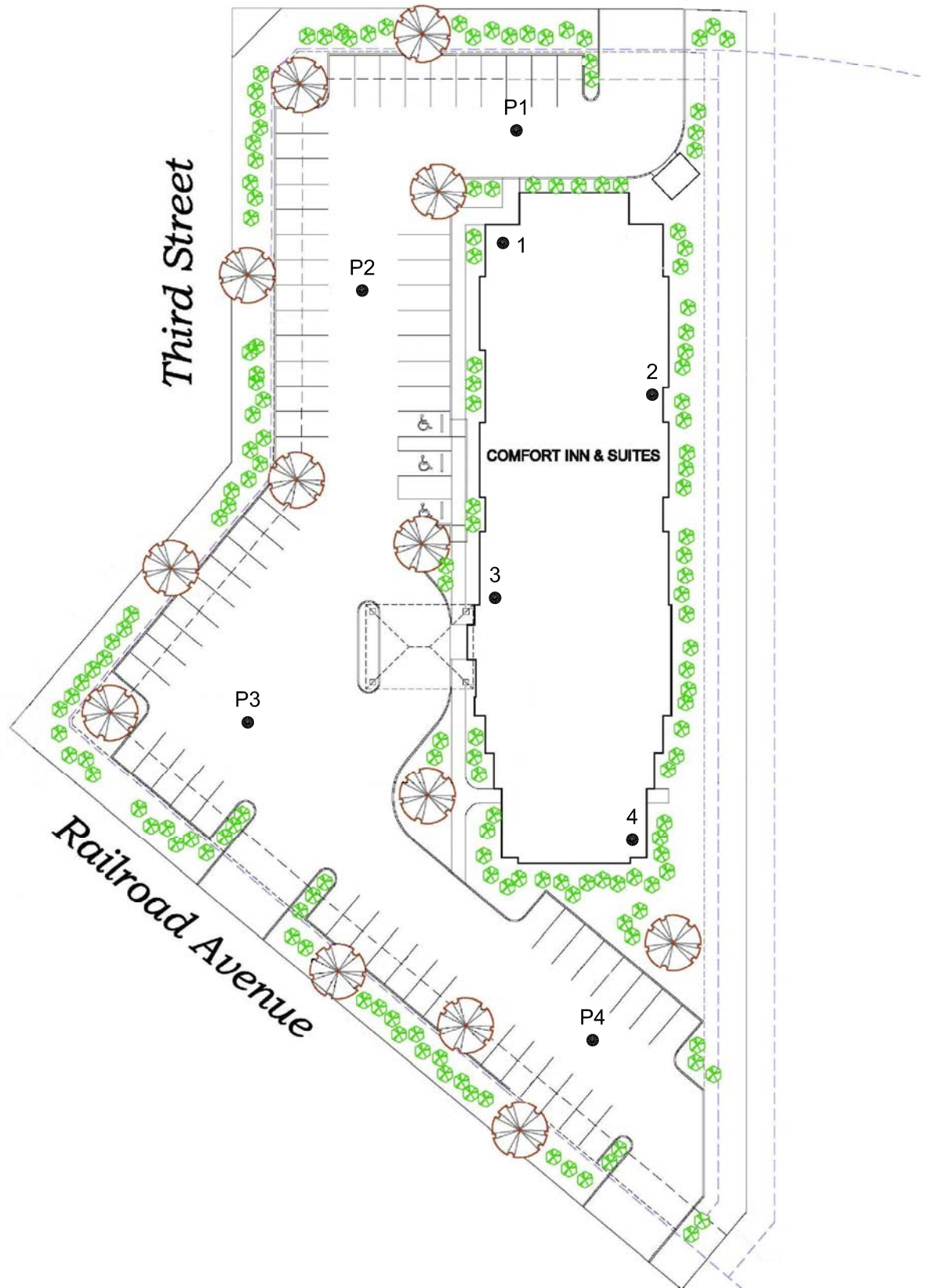
GROUND Engineering Consultants, Inc.

Donald Van Devener, P.E.



Reviewed by Michael K. Wariner, P.E.

Green Street



Third Street

P1

P2

1

2

COMFORT INN & SUITES

3

P3

4

Railroad Avenue

P4

1

● Indicates test hole number and approximate location.



(Not to Scale)

GROUND

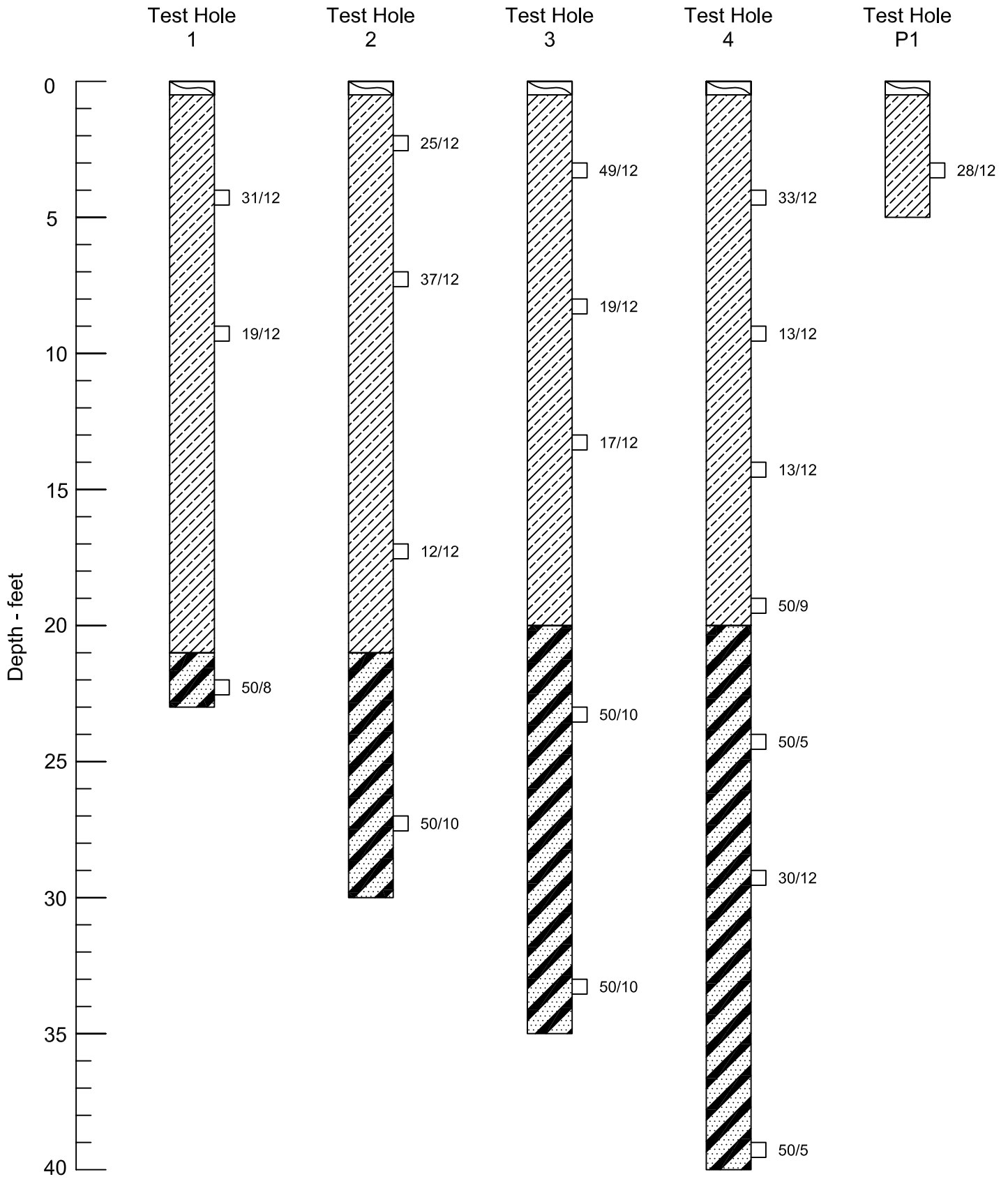
ENGINEERING CONSULTANTS

LOCATION OF TEST HOLES

JOB NO.: 10-6000

FIGURE: 1

CADFILE NAME: 6000SITE.DWG



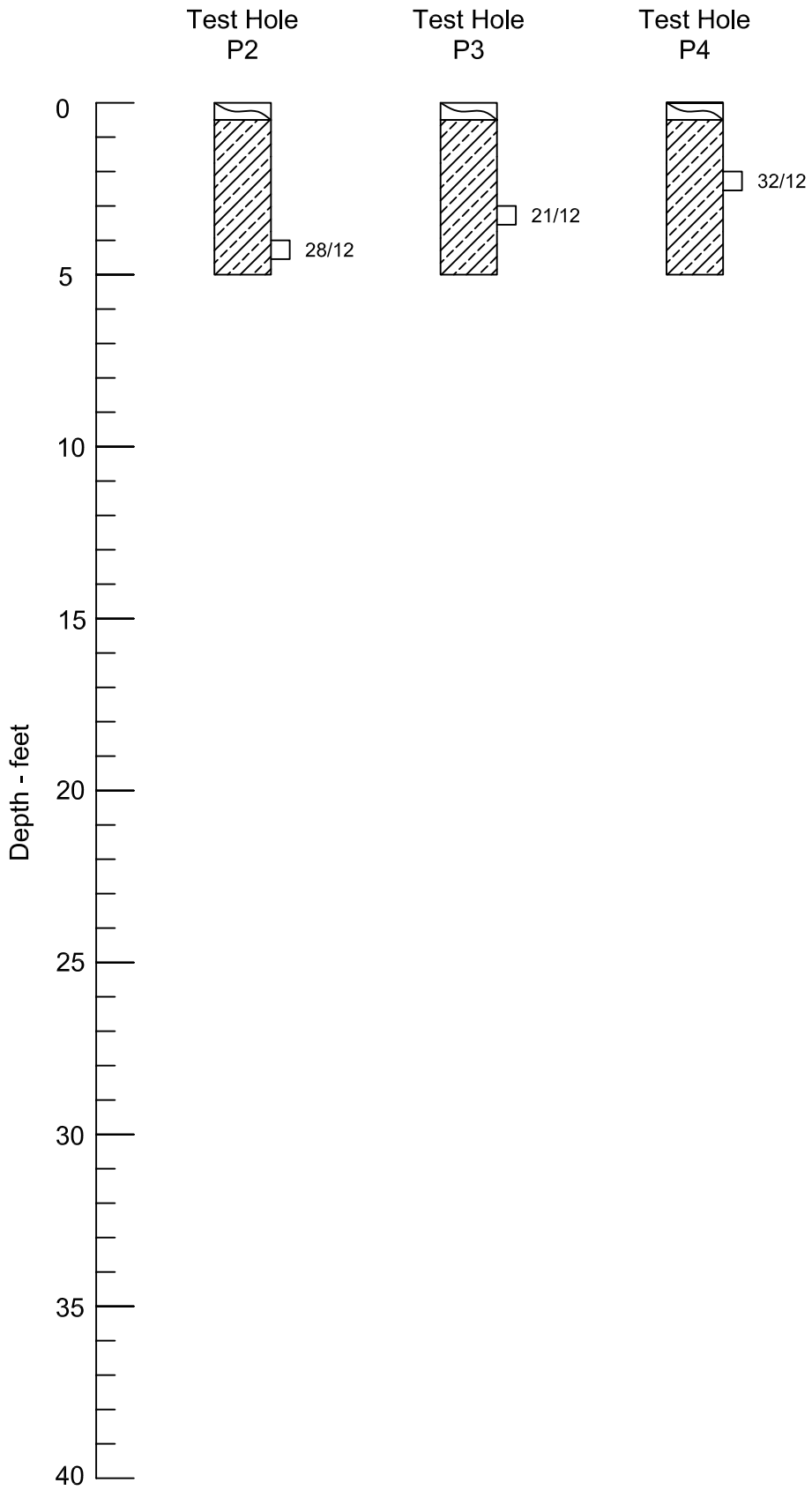
GROUND
ENGINEERING CONSULTANTS

LOGS OF TEST HOLES

JOB NO.: 10-6000

FIGURE: 2

CADFILE NAME: 6000LOG01.DWG



GROUND
ENGINEERING CONSULTANTS

LOGS OF TEST HOLES

JOB NO.: 10-6000

FIGURE: 3

CADFILE NAME: 6000LOG02.DWG

LEGEND:



Topsoil



Clay and Silt: Typically classified as clays and silts. They were dry to moist, fine to coarse, low to moderately plastic, stiff to very stiff to hard, and brown in color



Claystone/Sandstone/Siltstone/Shale Bedrock: Interbedded, dry to moist, low to highly plastic, medium hard to hard, and gray to gray-brown to purple-gray-brown to blue-green-gray to dark gray in color.



Drive sample, 2-inch I.D. California liner sample

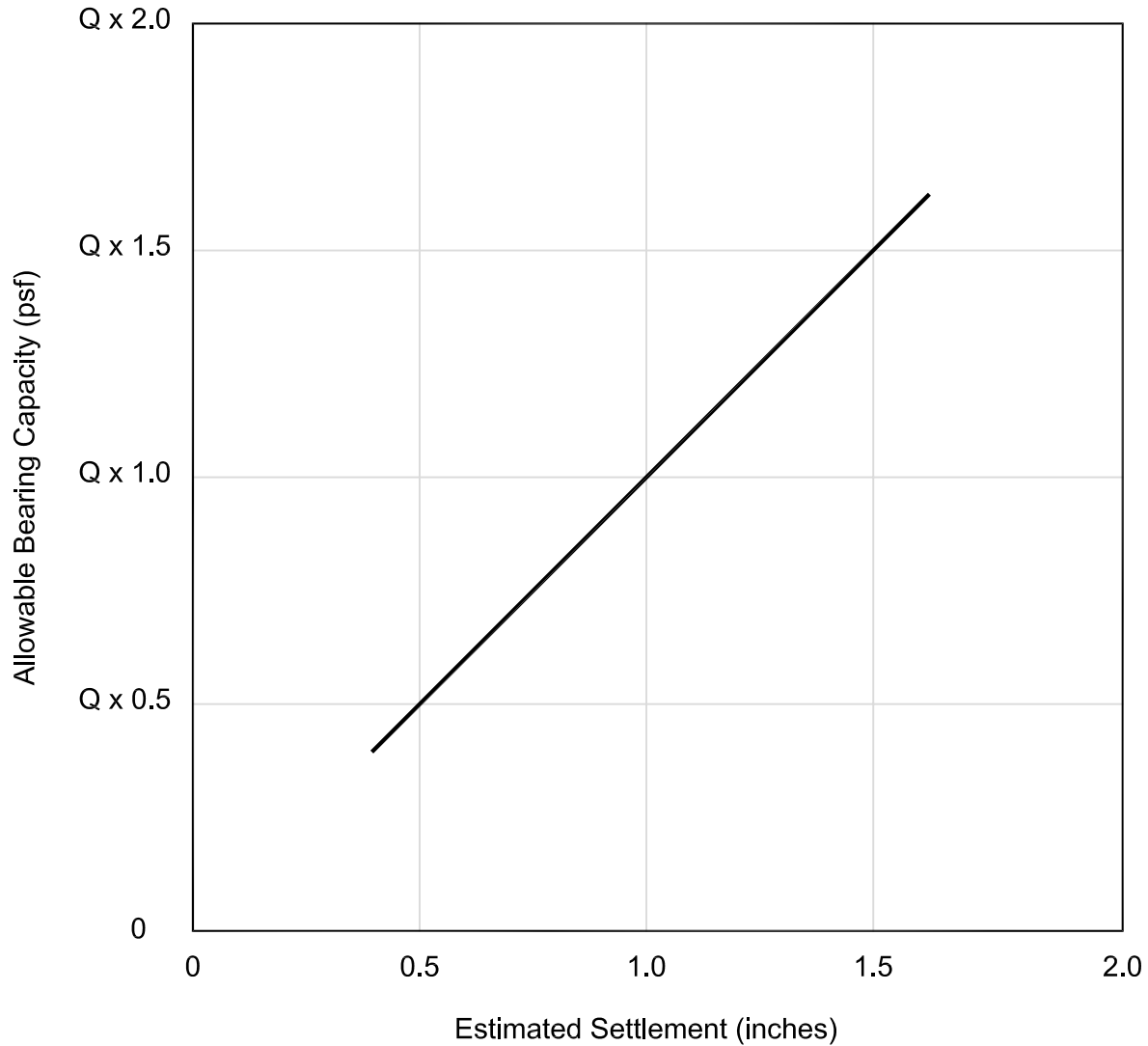
23/12 Drive sample blow count, indicates 23 blows of a 140-pound hammer falling 30 inches were required to drive the sampler 12 inches.

NOTES:

- 1) Test holes were drilled on 01/14/10 with 4-inch diameter continuous flight power augers.
- 2) Locations of the test holes were measured approximately by pacing from features shown on the site plan provided.
- 3) Elevations of the test holes were not measured and the logs of the test holes are drawn to depth.
- 4) The test hole locations and elevations should be considered accurate only to the degree implied by the method used.
- 5) The lines between materials shown on the test hole logs represent the approximate boundaries between material types and the transitions may be gradual.
- 6) Groundwater was not encountered during drilling. Groundwater levels can fluctuate seasonally and in response to landscape irrigation.

The material descriptions on this legend are for general classification purposes only. See the full text of this report for descriptions of the site materials and related recommendations.

GROUND ENGINEERING CONSULTANTS	
LEGEND AND NOTES	
JOB NO.: 10-6000	FIGURE: 4
CADFILE NAME: 6000LEG.DWG	



$Q = 2,500 \text{ psf}$

Note: Design should be controlled by settlement. Estimated settlement values indicated above are based on drained conditions. If foundation materials become wet, the allowable bearing capacity will be reduced and result in larger estimated settlement. This relationship is based on footing widths of 1 to 4 feet. If the footing width is to be greater than 4 feet, we should be notified to reevaluate these recommendations.

GROUND ENGINEERING CONSULTANTS	
BEARING CAPACITY CHART	
JOB NO.: 10-6000	FIGURE: 5
CADFILE NAME: 6000BRCP.DWG	

GROUND

ENGINEERING CONSULTANTS

TABLE 1

SUMMARY OF LABORATORY TEST RESULTS

Sample Location		Natural Moisture Content (%)	Natural Dry Density (pcf)	Percent Passing No. 200 Sieve	Atterberg Limits		Percent Swell (1000 psf Surcharge)	USCS Classification	AASHTO Classification (GI)	Soil or Bedrock Type
Test Hole No.	Depth (feet)				Liquid Limit (%)	Plasticity Index (%)				
1	4	8.2	123.1	80	32	16	2.2	(CL)s	A-6(11)	CLAY with sand
1	9	10.6	124.1	78	29	12		(CL)s	A-6(7)	CLAY with sand
2	7	9.4	121.6	82	28	13	1.0	(CL)s	A-6(9)	CLAY with sand
2	17	23.9	96.1	76	27	3		(ML)s	A-4(1)	SILT with sand
3	3	7.9	118.5	88	29	13		CL	A-6(10)	CLAY
3	13	11.6	121.0	83	31	14	-1.6	(CL)s	A-6(10)	CLAY with sand
4	9	11.9	119.5	88	29	12		CL	A-6(9)	CLAY
4	24	9.2	SD	21	31	7		SM	A-2-4(0)	SANDSTONE Bedrock
P1	3	6.5	109.8	77	23	9		(CL)s	A-4(4)	CLAY with sand
P4	2	7.9	122.8	77	29	12		(CL)s	A-6(7)	CLAY with sand

SD = Sample Disturbed; Negative swell value indicates consolidation

Job No. 10-6000

GROUND

ENGINEERING CONSULTANTS

TABLE 2
SUMMARY OF LABORATORY TEST RESULTS

Sample Location		Water Soluble Sulfates (%)	pH	Redox Potential (mV)	Sulfides Content	Resistivity (ohm-cm)	USCS Classification	Soil or Bedrock Type
Test Hole No.	Depth (feet)							
3	3	0.01	7.5	-32	Positive	8,611	CL	CLAY

Job No. 10-6000

Appendix A

PAVEMENT SECTION CALCULATIONS

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Network Administrator

Flexible Structural Design Module

Parachute Comfort Inn

Parachute, Colorado

10-6000

Automobile Only Parking - Composite

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	36,500
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	75 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	3,301 psi
Stage Construction	1
Calculated Design Structural Number	2.40 in

Specified Layer Design

<u>Layer</u>	<u>Material Description</u>	<u>Struct Coef. (Ai)</u>	<u>Drain Coef. (Mi)</u>	<u>Thickness (Di)(in)</u>	<u>Width (ft)</u>	<u>Calculated SN (in)</u>
1	Asphalt	0.4	1	4	-	1.60
2	Roadbase	0.12	1	8	-	0.96
Total	-	-	-	12.00	-	2.56

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

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Computer Software Product
Network Administrator

Flexible Structural Design Module

Parachute Comfort Inn
Parachute, Colorado
10-6000
Automobile Only Parking - Full Depth Asphalt

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	36,500
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	75 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	3,301 psi
Stage Construction	1
Calculated Design Structural Number	2.40 in

Specified Layer Design

<u>Layer</u>	<u>Material Description</u>	<u>Struct Coef. (Ai)</u>	<u>Drain Coef. (Mi)</u>	<u>Thickness (Di)(in)</u>	<u>Width (ft)</u>	<u>Calculated SN (in)</u>
1	Asphalt only	0.4	1	6	-	2.40
Total	-	-	-	6.00	-	2.40

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
Network Administrator

Flexible Structural Design Module

Parachute Comfort Inn
Parachute, Colorado
10-6000
Drive Lanes and General Parking - Composite

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	73,000
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	75 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	3,301 psi
Stage Construction	1
Calculated Design Structural Number	2.67 in

Specified Layer Design

<u>Layer</u>	<u>Material Description</u>	Struct Coef. <u>(Ai)</u>	Drain Coef. <u>(Mi)</u>	Thickness <u>(Di)(in)</u>	Width <u>(ft)</u>	Calculated <u>SN (in)</u>
1	Asphalt	0.4	1	4.5	-	1.80
2	Roadbase	0.12	1	9	-	1.08
Total	-	-	-	13.50	-	2.88

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
Network Administrator

Flexible Structural Design Module

Parachute Comfort Inn
Parachute, Colorado
10-6000
Drive Lanes and General Parking - Full depth Asphalt

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	73,000
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	75 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	3,301 psi
Stage Construction	1
Calculated Design Structural Number	2.67 in

Specified Layer Design

<u>Layer</u>	<u>Material Description</u>	<u>Struct Coef. (Ai)</u>	<u>Drain Coef. (Mi)</u>	<u>Thickness (Di)(in)</u>	<u>Width (ft)</u>	<u>Calculated SN (in)</u>
1	Asphalt	0.4	1	7	-	2.80
Total	-	-	-	7.00	-	2.80

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Network Administrator

Rigid Structural Design Module

Parachute Comfort Inn
Parachute, Colorado
10-6000
Heavy Traffic - Concrete

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	365,000
Initial Serviceability	4.5
Terminal Serviceability	2
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	3,600,000 psi
Mean Effective k-value	180 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.34
Load Transfer Coefficient, J	3.6
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	5.74 in