GEOTECHNICAL ENGINEERING REPORT
88TH AVENUE AT CATALINA APARTMENTS
PRV REPLACEMENT
THORNTON, COLORADO

Prepared For:

City of Thornton
Thornton, Colorado

COLORADO LICENSED PROFESSIONAL ENGINEER
THOMAS C. KETTLER, JR.
48726
1-13-20

January 13, 2020
Olsson Project No. 019-2365

olsson

January 13, 2020

City of Thornton
Attn: Mr. Matt Eberly
9500 Civic Center Drive
Thornton, CO 80229

Re: Geotechnical Engineering Report
88th Avenue at Catalina Apartments PRV Replacement
Thornton, Colorado
Olsson Project No. 019-2365

Dear Mr. Eberly,

Olsson has completed the geotechnical engineering report for the above referenced project. The enclosed report summarizes our understanding of the project, presents the findings of the borings and laboratory tests, discusses the observed subsurface conditions and, based on those conditions, provides geotechnical engineering recommendations for this project.

We appreciate the opportunity to provide our geotechnical engineering services for this project. If you have any questions or need further assistance, please contact us at your convenience.

Respectfully submitted,
Olsson, Inc.

Sean Parks

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A. PROJECT UNDERSTANDING

A.1. GEOTECHNICAL SCOPE

This geotechnical engineering report presents the results of the subsurface exploration completed for a proposed pressure reducing valve (PRV) station in Thornton, Colorado. Two (2) borings were drilled to an approximate depth of 20 feet below ground surface (bgs). The purpose of this exploration was to evaluate the subsurface conditions and, based on the encountered conditions, provide geotechnical design recommendations for the proposed PRV station associated with the project. Approximate locations of the borings are shown on the Boring Location Plan in *Appendix A*, and boring logs are provided in *Appendix B*.

A.2. SITE INFORMATION

The project site is located northwest of the intersection of East 88th Avenue and Colorado Boulevard in Thornton, Colorado (Figure A.1). The site generally slopes downward to the south and east and was covered by grass with several trees located within the project limits at the time of our exploration. From our review of readily available historical aerial images obtained from Google Earth dating back to 1994, the site has remained unchanged.

Figure A.1: Site Location

A.3. PROJECT INFORMATION

We understand the proposed project consists of installing a prefabricated PRV station supported on a cast-in-place slab and associated utility lines to replace an existing station. We estimate the base of the slab will be approximately 8 feet below grade.

The geotechnical recommendations presented herein are based on the available project information, proposed project location, and the subsurface conditions described in this report. If any of the noted information is incorrect, please inform ***Olsson*** so that we may amend the recommendations presented in this report if appropriate.

B. EXPLORATORY AND TEST PROCEDURES

B.1. FIELD EXPLORATION

Two (2) borings were drilled to a depth of approximately 20 feet bgs. The borings were drilled with a truck-mounted drilling rig using solid-stem, continuous flight augers. The locations of the borings were selected based on the proposed site plan, located using a hand-held GPS device, and adjusted in the field based on positions of underground utilities. The boring locations should be considered accurate only to the degree implied by the methods used to obtain them. Approximate final locations of the borings are shown on the Boring Location Plan in *Appendix A.* The boring logs are provided in *Appendix B*.

Soil samples were obtained at selected intervals in the borings using either a standard split spoon sampler during the Standard Penetration Tests (SPT; “SS” on the boring logs) or a ring lined barrel sampler (“MC” on the borings logs). The standard split spoon sampler was driven in three 6-inch intervals and the ring lined barrel sampler was driven in two 6-inch intervals into the substrata with blows from a 140-pound automatic hammer free-falling 30 inches. Penetration resistance (blow counts) was recorded for each 6-inch drive. Penetration resistance of the final 12 inches is defined as the SPT “N” values for the SS sampler. The blow counts and SPT “N” values are shown on the boring logs at the respective depths the samples were taken. The blow counts shown for the MC sampler are not equivalent to the blow counts obtained from the SS sampler.

An ***Olsson*** field engineer prepared field logs of the material encountered in each boring during the drilling operation. The field logs include the engineer’s and driller’s interpretation of the conditions between samples and approximate elevations of each stratum change. The boring logs presented in *Appendix B* have been modified to represent the project engineer’s interpretation of the field logs based on visual classification and laboratory tests of the samples.

B.2. LABORATORY TESTING

The samples obtained from the borings were sealed and returned to the laboratory for testing and classification. All recovered soil samples were visually classified using the Unified Soil Classification System (USCS). The moisture contents of all samples were measured in the laboratory. In addition, Atterberg limits, grain size distribution, in-situ density, and percent passing the number 200 sieve tests were performed on selected samples. One-dimensional swell/consolidation tests were performed on two (2) selected ring lined barrel samples to evaluate the tendency of the materials to expand with moisture changes and consolidate/settle with loading changes. The laboratory test results are presented on the respective boring logs, and in the laboratory test result graphs in *Appendix C*.

B.3. SOIL CORROSIVITY

Laboratory testing was also performed on one (1) composite soil sample to determine pH, water-soluble sulfate, water-soluble chloride, and electrical resistivity to evaluate the corrosivity of the material. The results are presented in *Appendix C* and summarized in the following table.

Table B.1: Soil Corrosion Series Test Results

Test/Sample Location	Water Soluble Sulfate (% by mass)	Water Soluble Chloride (mg/L)	pH	Soil resistivity (ohms-cm)
Composite sample from B-1 MC-1 @ 1-2', B-1 MC-6 @ 19-19.9', B-2 MC-2 @ 3,5-4,5', and B-2 MC-6 @ 19-20'	0	177	6.65	653

The resistivity values indicate that the soils are very corrosive to buried metal objects. No specific cement type is required per ACI 201.2R, based on sulfate levels less than 0.1 percent by mass. An experienced designer should review these results and evaluate corrosivity in developing the design for this project.

C. SUBSURFACE CONDITIONS

C.1. SOIL STRATIGRAPHY

Specific conditions at each boring location are shown on the boring logs in *Appendix B*. The logs represent subsurface conditions at each specific boring location. Stratification boundaries shown on the boring logs represent the approximate depth of changes in soil types. The changes are more gradual in-situ. The boring logs do not reflect variations that may occur between borings or across the project site. The nature and extent of such variations may not become evident until construction.

Surficial materials consisted of approximately 6 inches of root zone material in boring B-1 and approximately 6 inches of asphalt in boring B-2.

The subsurface conditions encountered in the borings below the surficial materials generally consisted of firm to very stiff lean or fat clay fill with varying amounts of sand to depths ranging from approximately 4.5 feet to 6 feet overlying firm to stiff sandy clay or sandy silty clay to depth ranging from 6 feet to 9 feet underlain by silty clayey sands to depths of approximately 15 feet to 18 feet. Claystone was encountered below the silty clayey sands and extended to the base of the borings.

C.2. GROUNDWATER OBSERVATION

Water level observations were recorded at the boring locations during drilling and immediately upon completion of drilling. Although groundwater was not observed in the borings, a cave-in was observed in boring B-1 at an approximate depth of 18 feet bgs. Soil cave-ins within bore holes are typically indications of saturated conditions and nearby groundwater tables. The observed depths to groundwater and cave-in in the borings are shown in the respective boring logs and summarized in *Table C.1.*

Table C.1: Groundwater Level Observation

Boring No.	During Drilling (bgs, ft)	Immediately After Drilling (bgs, ft)
B-1	NE	18*
B-2	NE	NE

NE = Not Encountered, * = Cave-in

Variations and uncertainties exist with relatively short-term water levels observed and recorded during this exploration. Water levels can and should be anticipated to vary between boring locations as well as with time within specific borings. Water also tends to be present near the soil and bedrock interface and can flow through joints in the bedrock. Groundwater levels may be expected to fluctuate with the seasons, precipitation, site grading, drainage and adjacent land use. Long term monitoring with piezometers generally provides a more representative indication of the potential range of groundwater conditions.

D. GEOTECHNICAL CONSIDERATIONS

The on-site tested lean clay and fat clay fill soils were determined to have potentially significant expansion potential based on the laboratory one dimensional swell/consolidation test. The test results are presented in the table below:

Table D.1: Summary of expansion potential based on one-dimensional consolidation/swell tests

Test/Sample Location	Material	In-situ moisture (%)	In-situ dry density (pcf)	Inundation Pressure (psf)	Percentage swell (%)	Swell pressure (psf)
B-1 MC-1 (1-2’)	Lean clay	27.6	90.9	500	1.2	1,800
B-2 MC-2 (3.5-4.5’)	Fat clay	7.3	114.3	200	6.3	14,600

While the on-site fill soils exhibited marginal to high swell potential, the PRV is anticipated to bearing on sand soils that typically have minimal swell potential. We recommend overexcavating below the base of the PRV foundation as per *Section F.1* and replacing the excavated soils with a uniform granular bedding as per *Section E.2*.

E. SITE PREPARATION

E.1. GENERAL SITE AND SUBGRADE PREPARATION

As part of installing the PRV and appurtenances, sections of the existing roadway, sidewalks, and gutter may need to be removed and reconstructed. Demolition of these items should include the removal of any remaining flatwork, pavement, and undocumented fill from the construction area. After removal and excavation, the area should be thoroughly cleared of loose soil before backfilling with well compacted structural fill. The concrete and asphalt debris from the demolition should be carefully stockpiled and separated from the structural fill.

All topsoil, vegetation, major root systems, organic soils, and any loose, soft, or otherwise unsuitable or deleterious material should be stripped and removed from the entire construction area. These materials should be carefully separated to avoid incorporation into structural fill.

Site clearing, grubbing, and stripping should be completed during periods of dry weather. Operating heavy equipment on the site during periods of wet weather could result in excessive pumping and rutting of the subgrade soils.

After grubbing, stripping, demolition, and any required excavations, but prior to site grading and placement of structures, pavements, or fill in areas below design grade, the exposed subgrade should be prepared by scarifying, moisture conditioning and recompacting the upper 12 inches of exposed surface within the compaction and moisture limits as recommended in *Section E.2*.

We recommend that an ***Olsson*** representative be on-site to observe and document uniform and stable subgrade conditions prior to placing new structural fill, structures, or pavement.

E.2. STRUCTURAL FILL

All structural fill soils should be free of debris, organics, unsuitable materials, and particles larger than 3 inches. The on-site sandy silty clay and silty clayey sand appear suitable for reuse as structural fill. The on-site fill soils appear variable should not be reused as structural fill due to their higher expansion potential. Imported fill materials, if required, should consist of non-cohesive well graded sand and gravel soils, or cohesive, low plasticity, non-expansive soil with a liquid limit less than 45 and a plasticity index less than 25. Samples of all imported structural fill soils should be submitted to ***Olsson*** for review prior to use on the site.

New fill should be placed in maximum loose lift thicknesses of 8 inches and compacted as recommended in Table E.1. The lift thicknesses should be limited to 4 inches when compacting in small areas requiring hand-operated equipment such as vibrating plate compactors, walk behind trench rollers, or jumping jacks.

An ***Olsson*** representative should regularly observe and monitor the excavation and grading operations and perform field density tests to document that moisture and compaction requirements are being achieved.

Table E.1: Fill Placement Guidelines

Areas of Fill Placement	Material	Minimum Compaction Recommendation	Moisture Content (% of Optimum)
General subgrade preparation, overexcavation backfill, and trench backfill	On site excavated or imported cohesionless soils, or low plasticity predominantly sandy soils	95% Standard (ASTM D698) or Modified (ASTM D1557) Proctor*	-2 to +2 percent
	On site excavated or imported low plasticity, cohesive predominantly clay soils	95% Standard Proctor (ASTM D698)	+1 to +3 percent
Below PRV vault foundation and pavements	Non-cohesive granular fills (CDOT Class 6 material)	95% Standard (ASTM D698) or Modified (ASTM D1557) Proctor*	Necessary Moisture Content to reach compaction
Utility trench	Granular bedding	95% Standard (ASTM D698) or Modified (ASTM D1557) Proctor*	Necessary Moisture Content to reach compaction

*Modified Proctor (ASTM D1557) is required for cohesionless soils below pavement areas and Standard Proctor (ASTM D698) is required for cohesionless soils outside of pavement areas.

The moisture content for the structural fill at the time of compaction should generally be maintained between the ranges specified above. More stringent moisture limits may be necessary with certain soils and some adjustments to moisture contents may be necessary to achieve compaction in accordance with project specifications.

E.3. DRAINAGE CONSIDERATIONS

Water should not be allowed to collect at the ground surfaces near areas of new structures or pavement, either during or after construction. Provisions should be made to quickly remove accumulating seepage water or storm water runoff from excavations. Undercut or excavated areas should be sloped toward one corner to allow rainwater or surface runoff to be quickly collected and gravity drained or pumped from construction areas. Subgrade soils that are exposed to precipitation or runoff should be evaluated by ***Olsson*** prior to the placement of new fill, reinforcing steel, or concrete to determine if corrective action is required.

To minimize concerns related to improper or inadequate drainage away from cohesive backfill materials used in utility trenches, we recommend the following:

- Site grading should provide for efficient drainage of rainfall or surface runoff away from new structures or pavement.
- Roof run-off should be collected and discharged directly to the storm sewer system or directed to a location with positive and rapid drainage away from new structures or pavements.

E.4. TEMPORARY SLOPES AND EXCAVATIONS

Construction site safety is the responsibility of the general contractor. The contractor is also be solely responsible for the means, methods, techniques, sequencing, and operations during construction. ***Olsson*** is providing the following information solely as a service to our client. Under no circumstances should ***Olsson***'s provision of the following information be construed to mean that we are assuming responsibility for construction site safety or the contractor's activities. Such responsibility is not implied and should not be inferred.

The contractor should be aware that slope height, slope inclination, and excavation depths (including utility trench excavations) should in no case exceed those specified in local, state, or federal safety regulation; e.g., *OSHA Health and Safety Standards for Excavations, 29 CFR Part 1926,* or successor regulations. Such regulations are strictly enforced and, if not followed, the owner, contractor, or earthwork or utility subcontractor could be liable for substantial penalties.

For mass grading, temporary slopes exceeding 5H:1V should be properly benched prior to placement of new fill to reduce the potential for slippage between existing slopes and fills. Benches should be wide enough to accommodate compaction and earth moving equipment, and to allow placement of horizontal lifts of fill. As an alternative to flatter and benched temporary slopes, vertical excavations can be temporarily shored. The contractor should be responsible for the design of temporary shoring in accordance with applicable regulatory requirements.

Permanent fill and cut slopes at the site should not exceed 3H:1V. Where steeper slopes are planned, additional analysis should be performed once grading plans have been developed.

If excavations, including utility trenches, are extended to depths of more than 20 feet, OSHA requires that the side slopes of such excavations be designed by a professional engineer registered in the state where construction is occurring.

E.5. UTILITIES

We recommend the subgrade supporting the utility pipes should be prepared as recommended in *Section E.1*. If fat clay is encountered at the utility pipe invert elevation, at least 12 inches of the fat clay should be overexcavated and replaced with lean clay structural fill as recommended in *Section E.2*. Granular pipe bedding is acceptable and should be placed over the structural fill and be compacted per *Section E.2*. The remaining trench should be backfilled using the soils originally removed from the trench excavations as long as these soils meet the structural fill requirements and have a compatible gradation with the granular bedding material such that structural fill does not migrate into the granular bedding, causing unexpected settlement. If the gradation of the structural fill is not compatible, we recommend a separating fabric be installed between the granular bedding material and the structural fill. The trenches should be backfilled with properly compacted structural fill placed in accordance with *Section E.2* of this report. In places where proper compaction of the backfill cannot be achieved, the utility trenches should be backfilled with flowable fill or controlled low-strength materials (CLSM) and the material should completely surround the utility line.

Water should be prevented from entering utility trenches before and during construction. While in service, the utility designer should consider the potential impact of groundwater on the utilities depending on its depth. Excavations should not remain open if rain is anticipated. Excavations should be backfilled as soon as possible with approved structural fill to reduce the potential for moisture infiltration or sidewall sloughing.

E.6. CONSTRUCTION EQUIPMENT MOBILITY

The on-site clay soils are susceptible to degradation and softening under construction equipment traffic, especially when exposed to high moisture levels. Excessive pumping and rutting may occur during construction operations, especially under repeated traffic loads or during periods of wet weather. Depending on weather events and the severity of the degradation, temporary stabilization techniques may be required.

Some general guidelines for reducing equipment mobility problems and addressing potential soft and wet surface soils are as follows:

- Optimize surface water drainage at the site during construction.
- Whenever possible, wait for dry weather conditions to prevail, and do not operate construction equipment on the site during wet conditions. Ruts caused by construction vehicle traffic will accelerate subgrade disturbance. Disc or scarify wet surface soils during periods of favorable weather to accelerate drying. Temporarily recompact loose subgrade soils if rain is forecast to promote site drainage and reduce moisture infiltration.
- Use construction equipment that is well suited for the intended job under the existing site conditions. Heavy rubber-tired equipment typically requires better site conditions than lightly loaded track-mounted equipment.

It may be necessary to take steps to aggressively improve equipment mobility if construction must proceed during unfavorable conditions.

F. STRUCTURES

F.1. CAST-IN-PLACE MAT FOUNDATION DESIGN

We understand that the proposed PRV station will be a prefabricated vault supported on a cast-in-place mat foundation. To provide uniform support, we recommend at least 12 inches of the soils below the slab foundation be overexcavated and replaced with compacted granular fill (CDOT Class 6 material, or equivalent). The excavation should extend at least 3 feet beyond the structure edges. The granular fill should be placed in 8-inch loose lifts and compacted per *Section E.2*. Prior to placement of the granular fill, the exposed subgrade should be prepared as in *Section E.1*.

Mat foundations supported on the recommended and approved materials discussed above can be designed and proportioned using a unit subgrade modulus "*k*" value of 200 pci. Soil modulus is not a fundamental property of soil and depends on many factors including foundation size and shape, depth of embedment of the foundation, or location of the soil under the foundation (edge or center). The recommended unit subgrade modulus is based on a 1-foot square area and should be adjusted to account for actual size of the mat using the following relationship:

$$k_{BL}(pci) = k_{BB}.\left(\frac{1 + 0.5\left(\frac{B}{L}\right)}{1.5}\right)$$

Where: *B* = width of the foundation
L = length of the foundation
$k_{BB}(pci) = subgrade\ modulus\ of\ a\ square\ foundation\ of\ width\ B = k.\left(\frac{1}{B}\right)$

Design of mat foundations can be an iterative process. Once deflection and bearing pressures beneath the mat have been developed, this information should be provided to ***Olsson*** for our review and, as necessary, to adjust the modulus value provided.

A value of 0.50 can be used as coefficient of friction between the granular fill (CDOT Class 6) and the foundation concrete for design against sliding.

Foundation excavations and fill placement should be observed and tested by ***Olsson***. The final subgrade should be observed and evaluated by an ***Olsson*** representative before placing the foundation. After foundation subgrades have been observed and evaluated by an ***Olsson*** representative, concrete should be placed as soon as possible to avoid subjecting the exposed soils to drying, wetting, or freezing conditions. If foundation bearing conditions degrade, ***Olsson*** should be contacted to reevaluate the foundation bearing materials.

F.2. LATERAL EARTH PRESSURES/VAULT WALL DESIGN

The vault walls should be designed utilizing the lateral earth pressures provided in this section. The parameters below are based on the understanding that the surrounding soils will be similar in composition to the on-site soils encountered during this exploration.

The at-rest condition assumes no wall rotation or deflection and would be applicable for walls which are rigidly restrained at the top, such as basement walls. Walls that are not restrained at the top and are free to deflect or rotate slightly may be designed for active earth pressure conditions. The passive earth pressure condition should be used to evaluate the resistance of soil to lateral loads. The table below presents recommended values of earth pressure coefficients and equivalent fluid densities. The drained condition values provided assume that positive drainage is present to prevent hydrostatic forces from developing behind the wall.

Table F.1: Earth Pressure Parameters

Condition	Earth Pressure Coefficient		Equivalent Fluid Density	
			Drained Condition	Undrained Condition
Active (K_a)	Low plasticity, clayey soils	0.36	47 pcf	87 pcf
	Granular backfill material	0.31	39 pcf	82 pcf
At Rest (K_0)	Low plasticity, clayey soils	0.53	69 pcf	99 pcf
	Granular backfill material	0.47	59 pcf	92 pcf
Passive (K_p)	Low plasticity, clayey soils	2.77	360 pcf	249 pcf
	Granular backfill material	3.25	406 pcf	266 pcf

These design recommendations are based on the following assumptions:

- For active earth pressure, the wall must rotate outward about its base with top lateral movements 0.002 Z to 0.004 Z (granular) or 0.010 Z to 0.020 Z (clays), where Z is wall height. This is necessary to allow the active condition to develop.
- For passive earth pressure, the wall must rotate inward about its base with top lateral movements 0.020 Z to 0.060 Z (granular) or 0.020 Z to 0.040 Z (clays), where Z is wall height. This is necessary to allow the passive condition to develop.
- Drained condition requires the walls have a permanent drainage system behind the wall that will prevent hydrostatic pressure from developing. Moisture collected in the drain system should be collected in a sump pit and pumped away from the structure or daylight to a location that will gravity drain. If permanent drainage is not provided, undrained condition and hydrostatic pressures should be used for design.
- The soil parameters provided above assume the surrounding soil is level with the top of the wall. If a sloping backfill is utilized, the parameters will need to be reevaluated. In addition to the slope of the backfill, the walls should be designed

to resist surcharge loads, including nearby shallow foundations or other concentrated load components and traffic loads. Passive pressures are typically lower if the ground surface slopes downward away from the face of the wall.

- Backfill soils placed within the height of the retained wall should consist of well compacted selected granular soils or low-plasticity non-expansive cohesive soils. On-site overburden soils placed within the height of the retained wall consisting of non-expansive clayey soils should be tested to verify these soils exhibit low plasticity and can achieve a minimum friction angle of 28 degrees and a unit weight of 120 pcf. Backfilled granular materials should have a minimum friction angle of 32 degrees and a unit weight of 125 pcf. For the granular values to be valid, the granular backfill must extend out from the base of the wall at an angle of at least 45 and 60 degrees from vertical for the active and passive cases, respectively.
- Passive resistance against horizontal movement within the frost zone of 3 feet should be ignored.
- Heavy equipment and other concentrated load components are not included. If heavy construction equipment is anticipated, the walls should be designed to resist surcharge loads, including any construction equipment load or traffic loads.
- Factor of safety is not included. The designer should use appropriate factor of safety for design.
- To calculate the resistance to sliding on CDOT Class 6 material, a coefficient of friction value of 0.50 should be used for the cast-in-place slab.

To intercept infiltrating surface water behind the vault walls, we recommend a perimeter drain be installed at or slightly below the foundation level. The drain line should be sloped to provide positive gravity drainage to a reliable discharge, a collection chamber, or a sump from where the collected water can be pumped away. The drain line should be surrounded by free-draining granular material graded to prevent the intrusion of fines, or an alternative free-draining granular material encapsulated with suitable filter fabric. A minimum 2-foot wide section of free-draining granular fill should be used for backfill above the drain line and adjacent to the wall should extend to within 2 feet of final grade. The granular backfill should be capped with compacted cohesive fill to minimize infiltration of surface water into the drain system.

G. PAVEMENTS

G.1. PAVEMENT SUBGRADE PREPARATION

If pavement outside of the PRV vault and utility installation area needs restoration, this pavement should be supported on at least 1 foot of structural fill by overexcavating and replacing the onsite soil with properly moisture conditioned and compacted structural fill per *Section E.2*. Prior to placing the structural fill in the overexcavated area, the exposed subgrade should be prepared per *Section E.1*. We recommend that the subgrade preparation and overexcavation extend a minimum of 2-feet outside the roadway surface where applicable to provide edge support. Due to the undocumented fill, the procedures recommended above may not eliminate all future subgrade volume change and resultant movement for the pavement, so some post construction movement may occur.

It is important that the subgrade support be relatively uniform, with no abrupt changes in the degree of support. Non-uniform pavement support can occur at the transition from cut to fill areas, as a result of varying soil moisture contents or soil types, or where improperly placed utility backfill has been placed across or through areas to be paved. Improper subgrade preparation such as inadequate vegetation removal, failure to identify soft or unstable areas, and inadequate or improper compaction can also produce non-uniform subgrade support.

Olsson should be present during subgrade preparation to observe, document, and test compaction of the materials at the time of placement. As recommended for all prepared soil subgrades, heavy, repetitive construction traffic should be controlled, especially during periods of wet weather, to minimize disturbance. Unstable or unsuitable soils revealed by proofrolling should be reworked to provide a stable subgrade or removed and replaced with structural fill.

G.2. PAVEMENT DESIGN

Per the direction of the City of Thornton, the asphalt concrete (AC) pavement should be patched with 6 inches of AC or the thickness of the existing AC plus 1-inch, whichever is greater, after the PRV vault and utilities are installed. During our investigation, an existing AC thickness of approximately 6 inches was encountered, so the AC patch is anticipated to be 7 inches; however, the existing AC thickness may vary across the project site, which may require a greater patch thickness. The AC patch should also extend a minimum of 9 inches outside the utility cut. In addition, the aggregate base (compacted CDOT Class 6 material) below the AC patch should be installed per *Section E.2* to the same depth as the existing aggregate base.

The pavement section indicated above represents a typical minimum thickness assuming routine maintenance. Routine maintenance typically consists of periodic seal coats and possibly one intermediate mill in addition to regular crack maintenance. The performance of pavements will be dependent upon several factors, including subgrade conditions at the time of paving, rainwater runoff, and traffic.

Rainwater runoff should not be allowed to seep below pavements from adjacent areas. The thickness of the aggregate base (compacted Class 6 material) should be uniform and the pavement subgrade should be graded to provide positive drainage of the granular base section. The granular section should be graded to adjacent storm sewer inlets and provisions should be made to provide drainage from the granular section into the storm sewer. Pavement surfaces should be sloped approximately 1/4 inch per foot to provide rapid surface drainage. Proper drainage below the surface layer helps prevent softening of the subgrade and has a significant impact on pavement performance.

H. SIDEWALKS/CONCRETE FLATWORK

If sidewalks and concrete flatwork outside of the PRV vault and utility installation area need restoration, this flatwork should be supported on at least 1 foot of structural fill by overexcavating and replacing the onsite soil with properly moisture conditioned and compacted structural fill per *Section E.2*. Prior to placing the structural fill in the overexcavated area, the exposed subgrade should be prepared per *Section E.1*. Due to the undocumented fill, this overexcavation and replacement may not eliminate all future subgrade volume change and resultant movement, so some post construction movement may occur.

If soft areas are identified during the subgrade preparation or if the subgrade soils have been exposed to adverse weather conditions, frost, excessive construction traffic, standing water, or similar conditions, ***Olsson*** should be consulted to determine if corrective action is necessary. It is important that the subgrade support be relatively uniform, with no abrupt changes in the degree of support. Improper subgrade preparation such as inadequate vegetation removal, failure to identify soft or unstable areas, and inadequate or improper compaction can also produce non-uniform subgrade support.

I. LIMITATIONS

The conclusions and recommendations presented in this report are based on the information available regarding the proposed construction, the results obtained from our soil test borings and sampling procedures, the results of the laboratory testing program, and our experience with similar projects. The soil test borings represent a very small statistical sampling of subsurface soils and it is possible that conditions may be encountered during construction that are substantially different from those indicated by the soil test borings. In these instances, adjustments to design and construction may be necessary. This geotechnical report is based on the site plan and information provided to ***Olsson*** and our understanding of the project as noted in this report. Changes in the location or design of new structures and/or pavements could significantly affect the conclusions and recommendations presented in this geotechnical report. ***Olsson*** should be contacted in the event of such changes to determine if the recommendations of this report remain appropriate for the revised site design.

This report was prepared under the direction and supervision of a Professional Engineer registered in the State of Colorado with the firm of ***Olsson***. The conclusions and recommendations contained herein are based on generally accepted professional geotechnical engineering practices at the time of this report within this geographic area. No other warranty is expressed, intended or made. This report has been prepared for the exclusive use of **City of Thornton** and their authorized representatives for specific application to the proposed project.

88th and Catalina Apartments

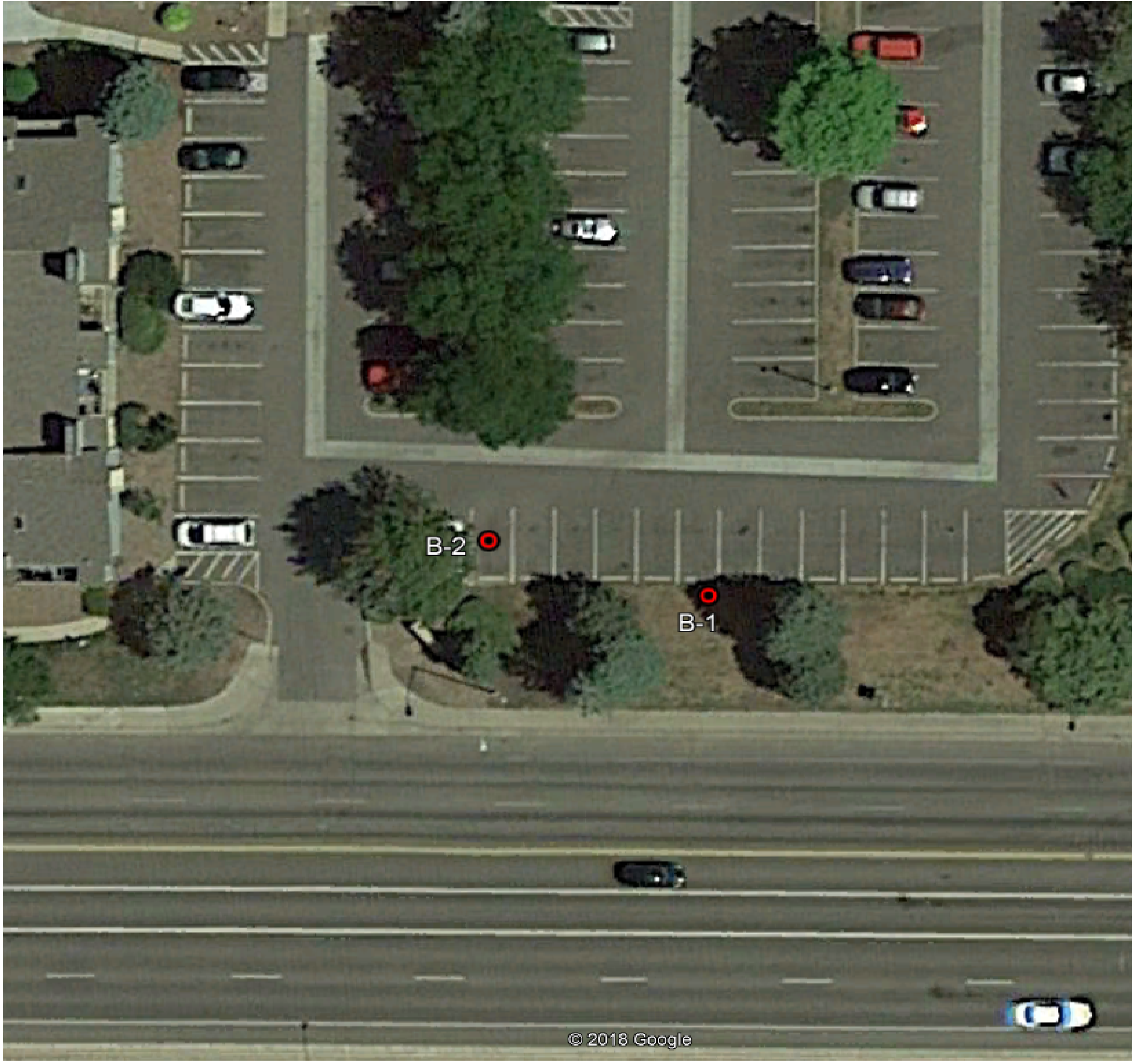
Thornton, Colorado 2020

January 13, 2020

Olsson Project No. 019-2365

APPENDIX A

Boring Location Plan



Boring	Depth	Approximate Coordinates	
B-1	20	39° 51' 22.11" N	104° 56' 28.26" W
B-2	20	39° 51' 22.24" N	104° 56' 28.88" W

Boring Location Plan

Scale: nts
Project: 019-2365
Approved by: SDR
Date: 12/5/19

88th & Catalina Apartments
Thornton, CO

APPENDIX B

Symbols and Nomenclature, Boring Logs

SYMBOLS AND NOMENCLATURE

DRILLING NOTES

DRILLING AND SAMPLING SYMBOLS

SS:	Split-Spoon Sample (1.375” ID, 2.0” OD)	HSA:	Hollow Stem Auger	NE:	Not Encountered
U:	Thin-Walled Tube Sample (3.0” OD)	CFA:	Continuous Flight Auger	NP:	Not Performed
CS:	Continuous Sample	HA:	Hand Auger	NA:	Not Applicable
BS:	Bulk Sample	CPT:	Cone Penetration Test	% Rec:	Percent of Recovery
MC:	Modified California Sampler	WB:	Wash Bore	WD:	While Drilling
GB:	Grab Sample	FT:	Fish Tail Bit	IAD:	Immediately After Drilling
SPT:	Standard Penetration Test Blows per 6.0”	RB:	Rock Bit	AD:	After Drilling
				CI:	Cave-In

DRILLING PROCEDURES

Soil samples designated as “U” samples on the boring logs were obtained in using Thin-Walled Tube Sampling techniques. Soil samples designated as “SS” samples were obtained during Penetration Test using a Split-Spoon Barrel sampler. The standard penetration resistance ‘N’ value is the number of blows of a 140 pound hammer falling 30 inches to drive the Split-Spoon sampler one foot. Soil samples designated as “MC” were obtained in using Thick-Walled, Ring-Lined, Split-Barrel Drive sampling techniques. Recovered samples were sealed in containers, labeled, and protected for transportation to the laboratory for testing.

WATER LEVEL MEASUREMENTS

Water levels indicated on the boring logs are levels measured in the borings at the times indicated. In relatively high permeable materials, the indicated levels may reflect the location of groundwater. In low permeability soils, the accurate determination of groundwater levels is not possible with only short-term observations.

SOIL PROPERTIES & DESCRIPTIONS

Descriptions of the soils encountered in the soil test borings were prepared using Visual-Manual Procedures for Descriptions and Identification of Soils.

PARTICLE SIZE

Boulders	12 in. +	Coarse Sand	4.75mm-2.0mm	Silt	0.075mm-0.005mm
Cobbles	12 in.-3 in.	Medium Sand	2.0mm-0.425mm	Clay	<0.005mm
Gravel	3 in.-4.75mm	Fine Sand	0.425mm-0.075mm		

COHESIVE SOILS

Consistency	Unconfined Compressive Strength (Qu) (tsf)
Very Soft	<0.25
Soft	0.25 – 0.5
Firm	0.5 – 1.0
Stiff	1.0 – 2.0
Very Stiff	2.0 – 4.0
Hard	> 4.0

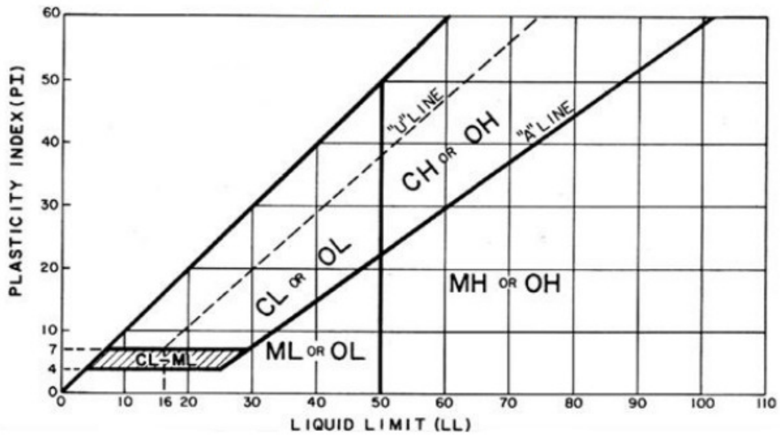
COHESIONLESS SOILS

Relative Density	‘N’ Value
Very Loose	0 – 3
Loose	4 – 9
Medium Dense	10 – 29
Dense	30 – 49
Very Dense	≥ 50

COMPONENT %

Description	Percent (%)
Trace	<5
Few	5 - 10
Little	15 - 25
Some	30 - 45
Mostly	50 - 100

PLASTICITY CHART



ROCK QUALITY DESIGNATION (RQD)

Description	RQD (%)
Very Poor	0 – 25
Poor	25 – 50
Fair	50 – 75
Good	75 – 90
Excellent	90 – 100

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SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS		TYPICAL DESCRIPTIONS
			GRAPH	LETTER	
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)	●	GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
			○	GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)	◫	GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
			▨	GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)	⁘	SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
			░	SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)	▥	SM	SILTY SANDS, SAND - SILT MIXTURES
			▨	SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50	▥	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
			▨	CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			☰	OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50	▥	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
			▨	CH	INORGANIC CLAYS OF HIGH PLASTICITY
			≋	OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS			⁂	PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

BOREHOLE REPORT NO. B-1

Sheet 1 of 1

PROJECT NAME **88th and Catalina Apartments**	CLIENT **City of Thornton**
PROJECT NUMBER **019-2365**	LOCATION **Thornton, CO**

⧓ Modified California Sampler

☒ Split Spoon

APPROX. SURFACE ELEV. (ft): 5114

ELEVATION (ft)	MATERIAL DESCRIPTION	DEPTH (ft)	SAMPLE TYPE NUMBER	CLASSIFICATION (USCS)	BLOWS/6" N-VALUE	UNC. STR. (tsf)	MOISTURE (%)	DRY DENSITY (pcf)	LL/PI (%)	ADDITIONAL DATA/ REMARKS
		0								
	ROOT ZONE *0.5'* *grass root zone, lean clay with sand, brown, moist*									
	FILL *lean clay with sand, with some interbedded gravel, stiff, brown with orange brown staining, very moist*		MC 1		4-5		27.6	90.9		
5110	*grades to firm, moist* *4.5'*		MC 2	CL	3-4		22.0		42/22	P-200 = 70.6%
	SANDY CLAY *firm, light brown, moist* *6.0'*	5								
	SILTY CLAYEY SAND *fine to coarse grained with gravel, dense, light brown, moist to dry*		SS 3		15-19-22 N=41		2.7			
5105	*grades to medium dense, with some cobbles*	10	SS 4		19-15-12 N=27		0.6			
5100	*grades to dense*	15	SS 5		24-20-14 N=34		2.9			
	Driller's Note: Cave-in to 18 feet immediately following drilling completion *18.0'*									
5095	***CLAYSTONE*** *highly weathered, gray to dark brown, moist* *19.9'*		MC 6		24-50/5"		16.8			

BASE OF BORING AT 19.9 FEET

WATER LEVEL OBSERVATIONS	
WD	▽ Not Encountered
IAD	▼ Not Encountered
AD	▼ Not Performed

OLSSON, INC.
3990 FOX STREET
DENVER, COLORADO 80216

STARTED:	12/5/19	FINISHED:	12/5/19
DRILL CO.:	VINE LABS	DRILL RIG:	CME 55
DRILLER:	VINE LABS	LOGGED BY:	S. GOETZ

METHOD: CONTINUOUS FLIGHT AUGER

BOREHOLE REPORT NO. B-2

Sheet 1 of 1

PROJECT NAME **88th and Catalina Apartments**	CLIENT **City of Thornton**
PROJECT NUMBER **019-2365**	LOCATION **Thornton, CO**

☒ Split Spoon

⧓ Modified California Sampler

ELEVATION (ft)	MATERIAL DESCRIPTION	DEPTH (ft)	SAMPLE TYPE NUMBER	CLASSIFICATION (USCS)	BLOWS/6" N-VALUE	UNC. STR. (tsf)	MOISTURE (%)	DRY DENSITY (pcf)	LL/PI (%)	ADDITIONAL DATA/ REMARKS
	APPROX. SURFACE ELEV. (ft): 5116	0								
	ASPHALT ***0.5'***									
5115	*6-inches asphalt pavement*									
	FILL *sandy fat clay with some interbedded gravel lenses, stiff, brown with some dark brown to black, moist*		SS 1		5-4-5 N=9		17.4		51/29	
	grades to very stiff, dry		MC 2		9-15		7.3	114.3		
		5								
5110	***6.0'***									
	SANDY SILTY CLAY *fine grained, stiff, light brown to brown, moist*		MC 3		6-6		21.7	87.8		P-200 = 66.3%
	9.0'									
	SILTY CLAYEY SAND *fine to coarse grained with gravel, dense, light brown, dry*	10	SS 4		17-18-18 N=36		1.8			
5105										
	15.0'	15	SS 5		18-26-14 N=40		2.8			
	CLAYSTONE *highly weathered, gray to dark brown, moist*									
5100										
	20.0'	20	MC 6		16-38		18.3	110.6	57/31	
	BASE OF BORING AT 20.0 FEET									

WATER LEVEL OBSERVATIONS	
WD	∇ Not Encountered
IAD	▼ Not Encountered
AD	⊻ Not Performed

OLSSON, INC.
3990 FOX STREET
DENVER, COLORADO 80216

STARTED:	12/5/19	FINISHED:	12/5/19
DRILL CO.:	VINE LABS	DRILL RIG:	CME 55
DRILLER:	VINE LABS	LOGGED BY:	S. GOETZ

METHOD: CONTINUOUS FLIGHT AUGER

APPENDIX C

Laboratory Test Results

OLSSON, INC.
3990 FOX STREET
DENVER, COLORADO 80216

SUMMARY OF LABORATORY RESULTS

PAGE 1 OF 1

PROJECT NAME: 88th and Catalina Apartments

PROJECT NUMBER: 019-2365

CLIENT: City of Thornton

PROJECT LOCATION: Thornton, CO

BORING NUMBER	SAMPLE I.D.	SAMPLE DEPTH (ft)	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	VOID RATIO	SATURATION (%)	UNCONFINED STRENGTH (tsf)	STRAIN (%)	ATTERBERG LIMITS			P-200	USCS CLASS.
									LIQUID LIMIT	PLASTIC LIMIT	PLASTIC INDEX		
B-1	**MC-1**	1.0 - 2.0'	27.6	90.9	0.854	87.2							
B-1	**MC-2**	3.5 - 4.5'	22.0						42	20	22	70.6	CL
B-1	**SS-3**	6.0 - 7.5'	2.7										
B-1	**SS-4**	9.0 - 10.5'	0.6										
B-1	**SS-5**	14.0 - 15.5'	2.9										
B-1	**MC-6**	19.0 - 19.9'	16.8										
B-2	**SS-1**	1.0 - 2.5'	17.4						51	22	29		
B-2	**MC-2**	3.5 - 4.5'	7.3	114.3	0.475	41.5							
B-2	**MC-3**	6.0 - 7.0'	21.7	87.8	0.920	63.6						66.3	
B-2	**SS-4**	9.0 - 10.5'	1.8										
B-2	**SS-5**	14.0 - 15.5'	2.8										
B-2	**MC-6**	19.0 - 20.0'	18.3	110.6	0.523	94.3			57	26	31		

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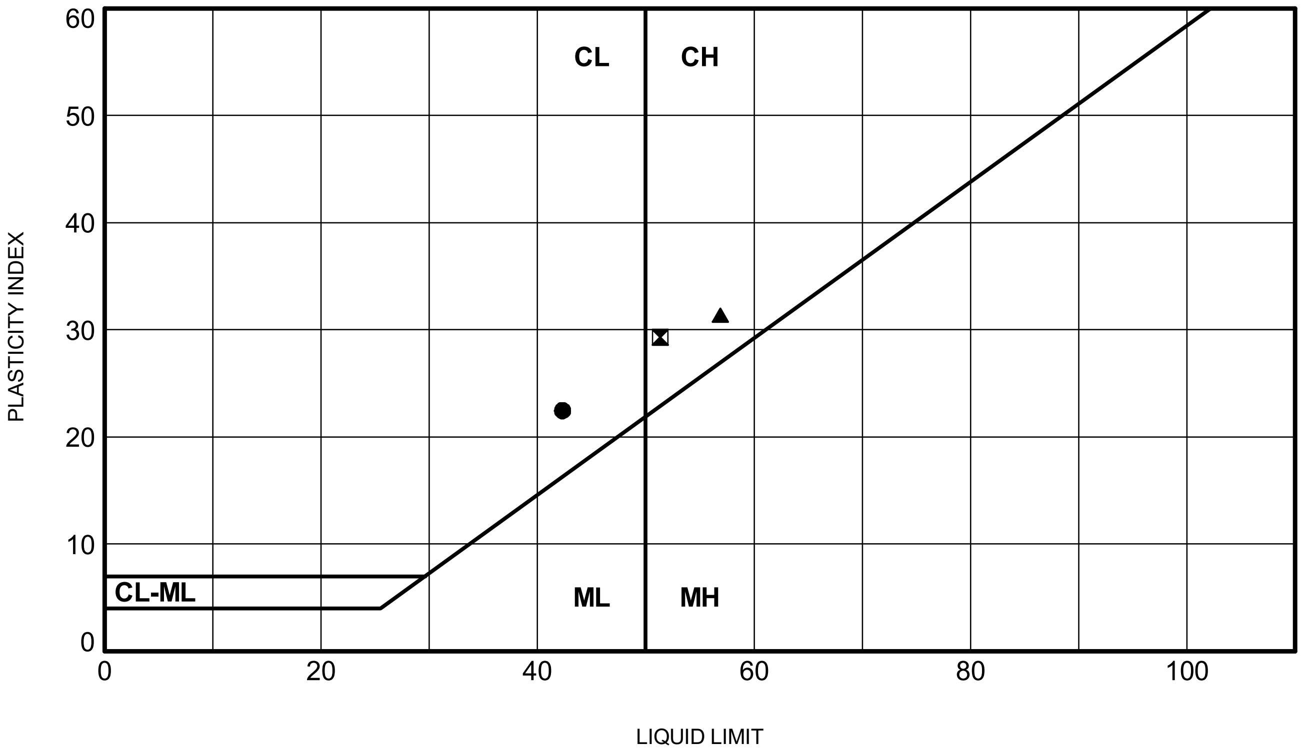
DENVER, COLORADO 80216

ATTERBERG LIMITS RESULTS

PROJECT NAME: 88th and Catalina Apartments
CLIENT: City of Thornton
PROJECT NUMBER: 019-2365
PROJECT LOCATION: Thornton, CO



	Boring No.	Sample ID	Depth (ft)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	Fines (%)	Classification (USCS)
●	**B-1**	**MC-2**	**3.5 - 4.5**	**42**	**20**	**22**	**70.6**	**CL**
⧗	**B-2**	**SS-1**	**1.0 - 2.5**	**51**	**22**	**29**		
▲	**B-2**	**MC-6**	**19.0 - 20**	**57**	**26**	**31**		

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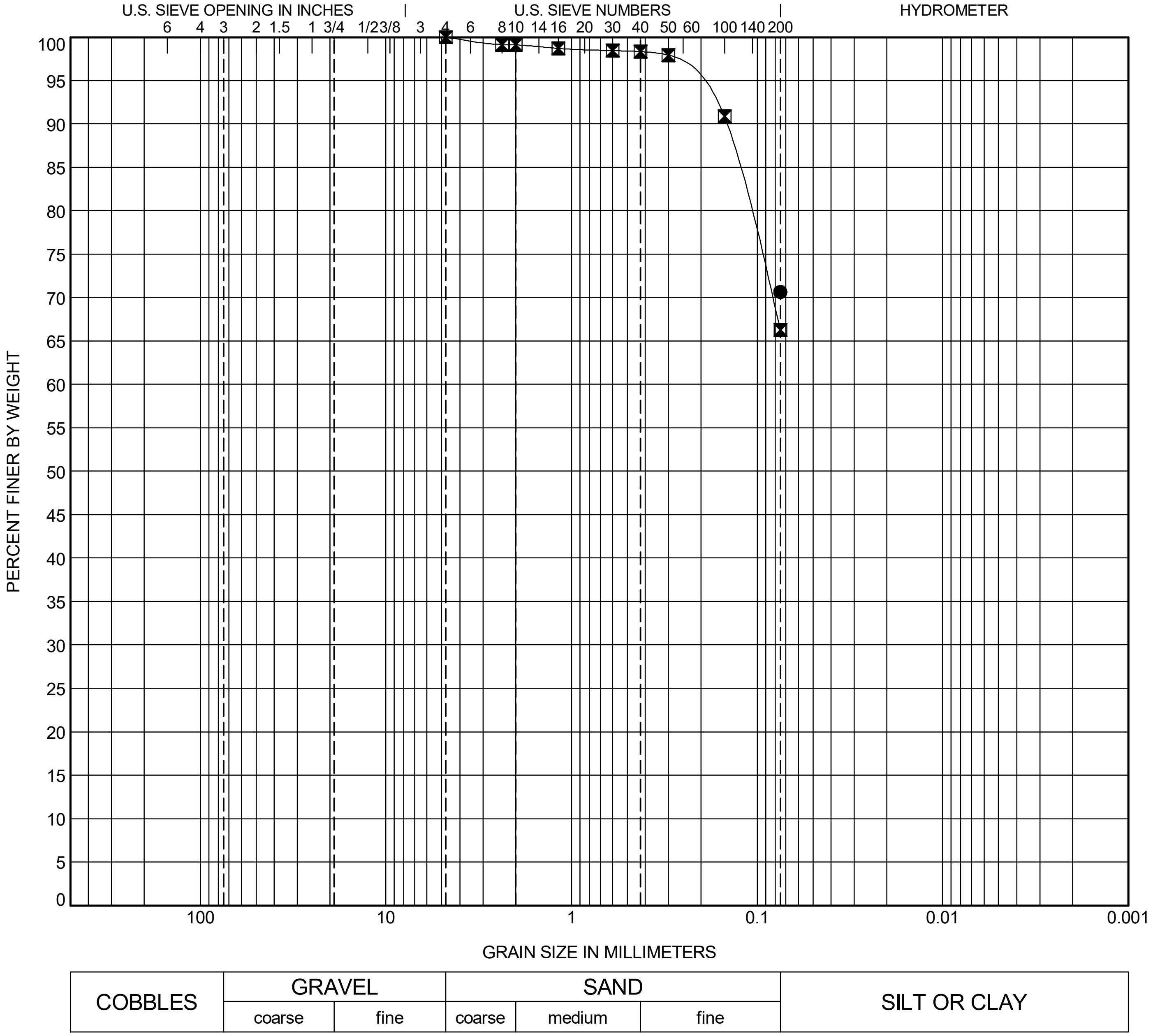
GRAIN SIZE DISTRIBUTION

PROJECT NAME: 88th and Catalina Apartments

CLIENT: City of Thornton

PROJECT NUMBER: 019-2365

PROJECT LOCATION: Thornton, CO



Boring No.	Sample ID	Depth (ft)	Classification	LL	PL	PI	Cc	Cu
● **B-1**	**MC-2**	**3.5 - 4.5'**	**Lean clay with sand (CL)**	**42**	**20**	**22**		
☒ **B-2**	**MC-3**	**6.0 - 7.0'**	**Sandy Lean clay (CL)**					

Boring No.	Sample ID	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● **B-1**	**MC-2**							**70.6**	
☒ **B-2**	**MC-3**	**4.75**				**0.0**	**33.7**	**66.3**	

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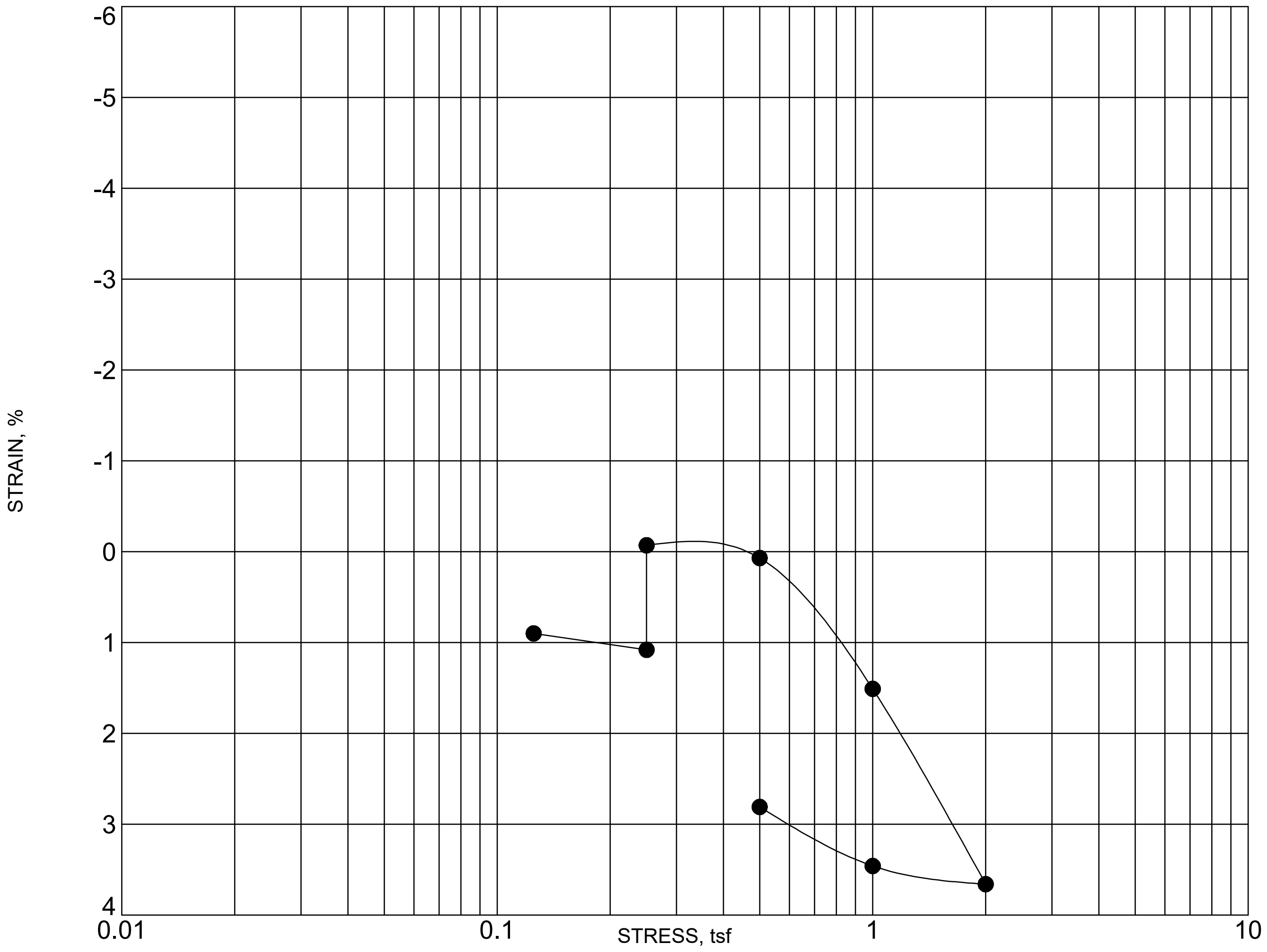
SWELL / CONSOLIDATION TEST

PROJECT NAME: 88th and Catalina Apartments

CLIENT: City of Thornton

PROJECT NUMBER: 019-2365

PROJECT LOCATION: Thornton, CO



Boring No: B-1

Sample ID: MC-1

Sample Depth: 1.0 - 2.0'

Start Date: 12/9/2019

Technician: N. Rasmussen

Apparatus: DNV Swell D

Specific Gravity: 2.7

Initial Water Content (%): 27.6

Final Water Content (%): 29.4

Initial Dry Density (pcf): 90.9

Initial Void Ratio: 0.854

Final Void Ratio: 0.791

Initial Degree of Saturation (%): 87.2

Final Degree of Saturation (%): 100.0

Est. Preconsolidation Stress (tsf):

Laboratory Water Type: Distilled

Test Procedure Method: C

Interpretation Procedure: NA

Stress at Inundation (tsf): 0.25

Specimen Trimming Method: Ring Sampler

ATTERBERG LIMITS

LL	PL	PI	Classification

Sample Description: Fill - lean clay with sand, brown with some orange brown

Notes: Swell potential (0.25 tsf surcharge): 1.15%
Swell pressure: 0.9 tsf

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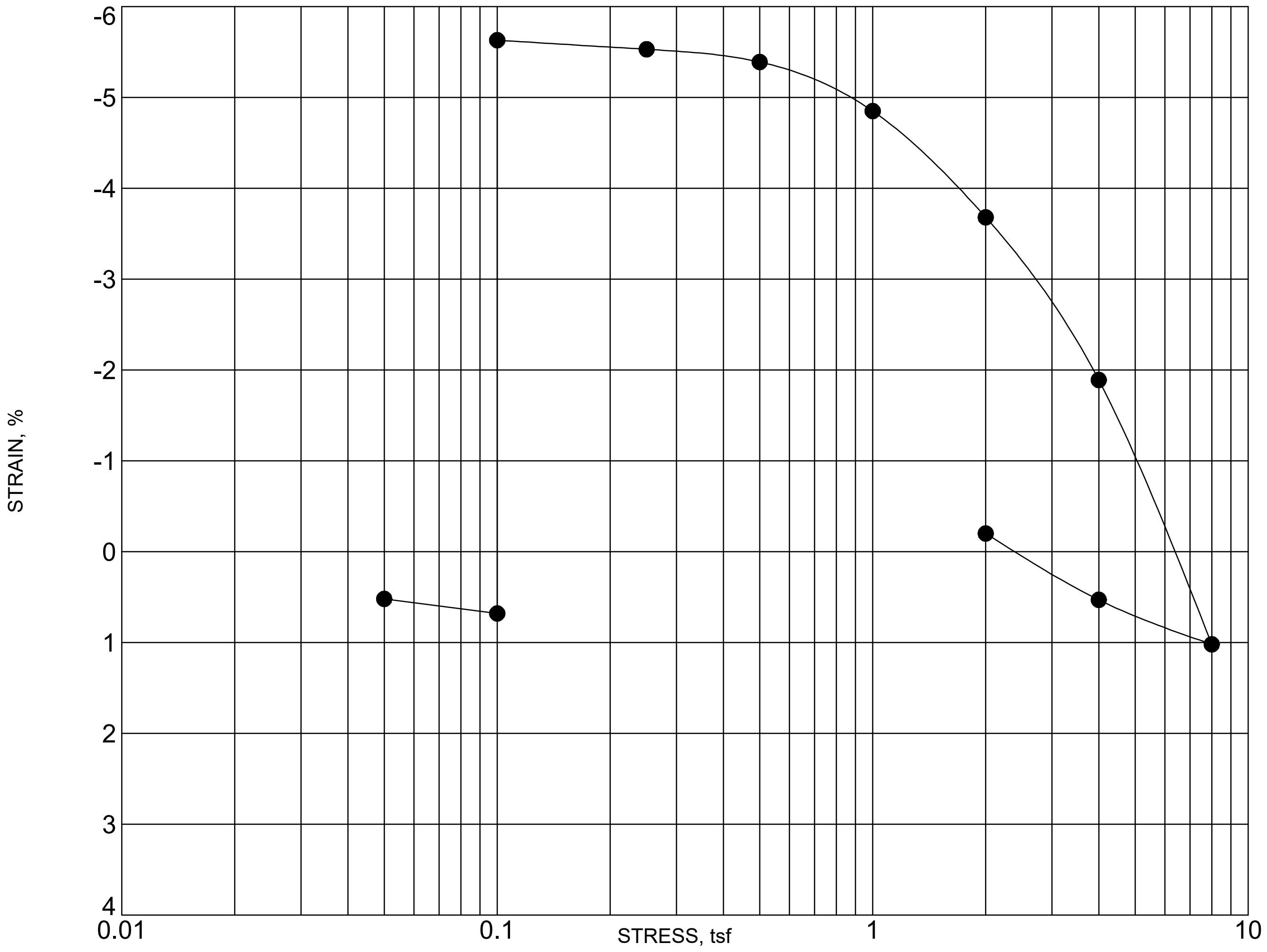
DENVER, COLORADO 80216

SWELL / CONSOLIDATION TEST

PROJECT NAME: 88th and Catalina Apartments
CLIENT: City of Thornton
PROJECT NUMBER: 019-2365
PROJECT LOCATION: Thornton, CO



Boring No: B-2
Sample ID: MC-2
Sample Depth: 3.5 - 4.5'
Start Date: 12/9/2019
Technician: N. Rasmussen
Apparatus: DNV Swell E
Specific Gravity: 2.7

Initial Water Content (%): 7.3
Final Water Content (%): 27.1
Initial Dry Density (pcf): 114.3
Initial Void Ratio: 0.473
Final Void Ratio: 0.688
Initial Degree of Saturation (%): 41.4
Final Degree of Saturation (%): 100.0

Est. Preconsolidation Stress (tsf):
Laboratory Water Type: Distilled
Test Procedure Method: C
Interpretation Procedure: NA
Stress at Inundation (tsf): 0.10
Specimen Trimming Method: Ring Sampler

ATTERBERG LIMITS

LL	PL	PI	Classification

Sample Description: Fill - sandy fat clay, dark brown

Notes: Swell potential (0.10 tsf surcharge): 6.31%
Swell pressure: 7.3 tsf

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3990 Fox Street TEL 303.237.2072
Denver, CO 80216 FAX 303.237.2659
www.olsson.com

Soil Corrosion Suite

Project Information

Project Name:	88th and Catalina Apartments
Project Number:	019-2365
Client Name:	City of Thornton
Project Location:	Thornton, CO

Sample and Test Information

Sample Location:	Composite: B-1 MC-1, B-1 MC-6, B-2 MC-2, B-2 MC-6
Sample Description:	Fat clay with some highly weathered claystone, brown to dark brown
Laboratory Technician:	N. Rasmussen
Date Tested:	12/16/2019

Test Results

Water Soluble Sulfate (Colorado Procedure CP-L-2103)

Dilution	Reading	Concentration, mg/L	Concentration, % mass
100:1	0	-	-

Water Soluble Chloride (Colorado Procedure CP-L-2104)

Dilution	Concentration, ppm	Concentration, % mass
Third	177	0.0177

pH (ASTM G51)

pH Meter Reading
6.65

Electrical Resistivity (ASTM G57, -#10)

Readings (ohm*cm)
860
653
680
767

Lowest Resistivity (ohm*cm)
653

Sample portion passing the #10 sieve used in testing. Each reading performed after additional water was added.