NOTICE OF MEETING
HILLSIDE REVIEW BOARD
CITY OF ST. GEORGE
WASHINGTON COUNTY, UTAH

Public Notice

Notice is hereby given that the Hillside Review Board of the City of St. George, Washington County, Utah, will hold meetings at the referenced site on **Wednesday, January 25, 2023,** commencing on-site at approximately 9:00 a.m.

The estimated site times are in bold. The agenda for the meeting is as follows:

1. Consider a request for a hillside development permit to build a new townhome development on the property located at 1100 W Curly Hollow Dr. **Meeting time is approx. 9:00 am**

2. Consider a request for a hillside development permit to make modifications to the ridgeline along the southeast slope of the Tech Ridge Development. **Meeting time is approx. 10:00 am**

3. Consider a request for a hillside development permit to construct the southeast access road from 250 West St. to the Tech Ridge Development. **Meeting time is approx. 10:00 am**

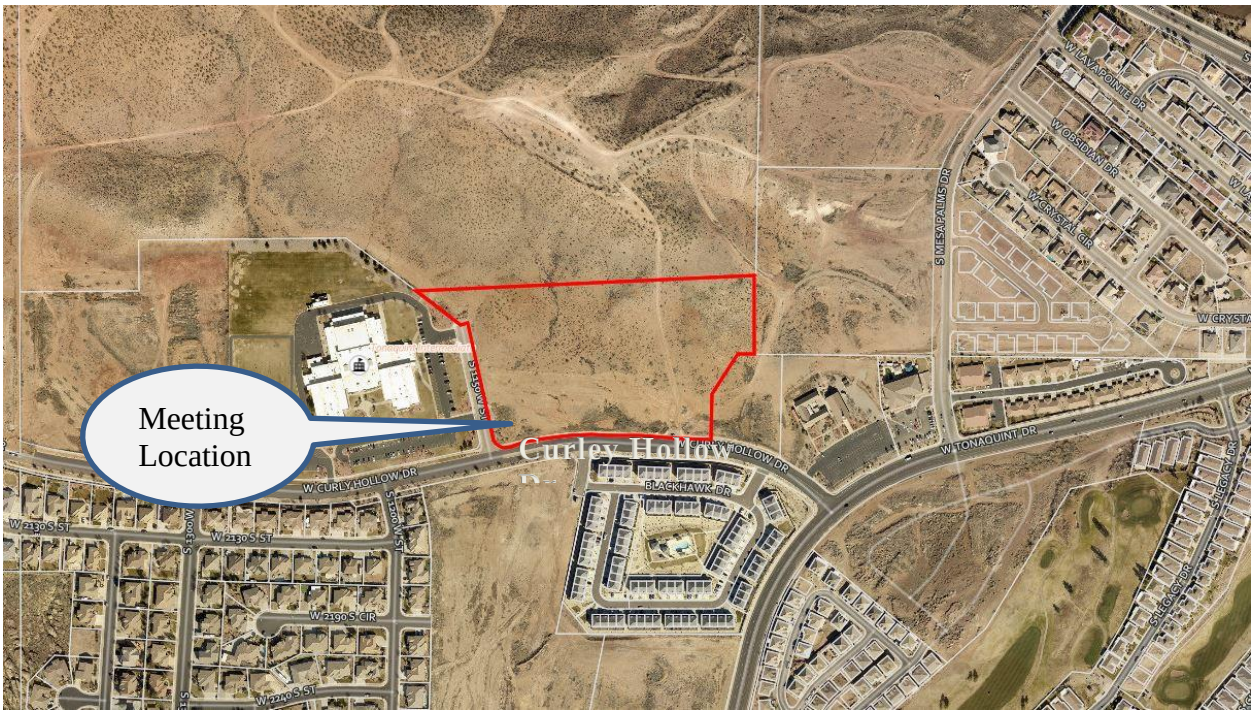
4. Approval of the meeting minutes from the November 30, 2022, and the December 14, 2022, meetings.

Carol Davidson, AICP, CFM, CPM
Senior Planner
Development Services

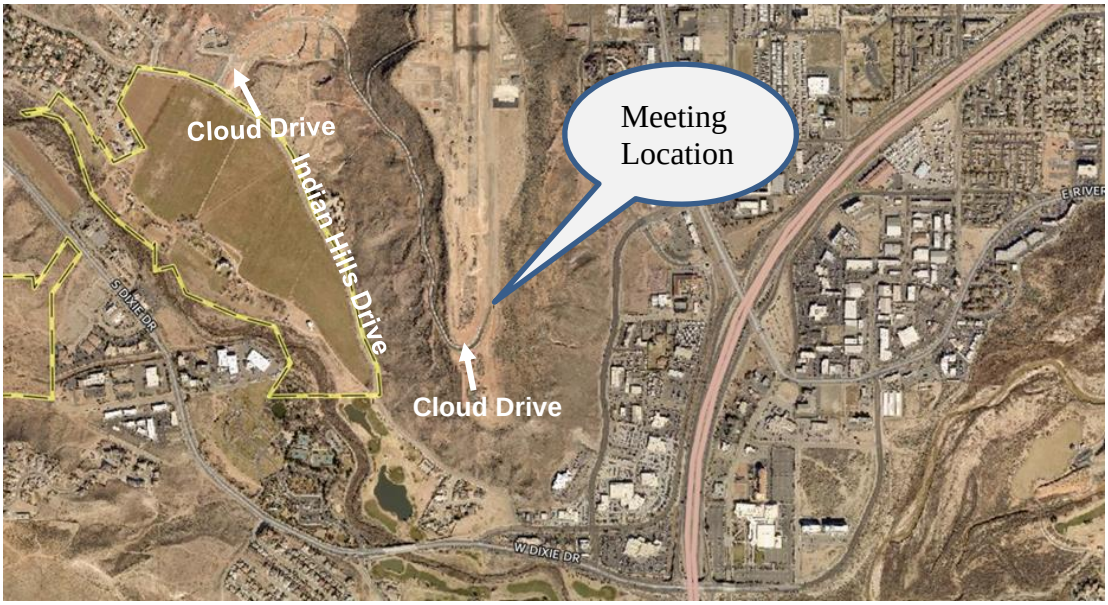
Reasonable Accommodation: The City of St. George will make efforts to provide reasonable accommodations to disabled members of the public in accessing City programs. Please contact the City Human Resources Office at (435) 627-4674 at least 24 hours in advance if you have special needs.

Meeting Locations

Item #1 – 1100 W Curly Hollow Dr



Item #2 & 3 – At the terminus of Cloud Drive in Tech Ridge

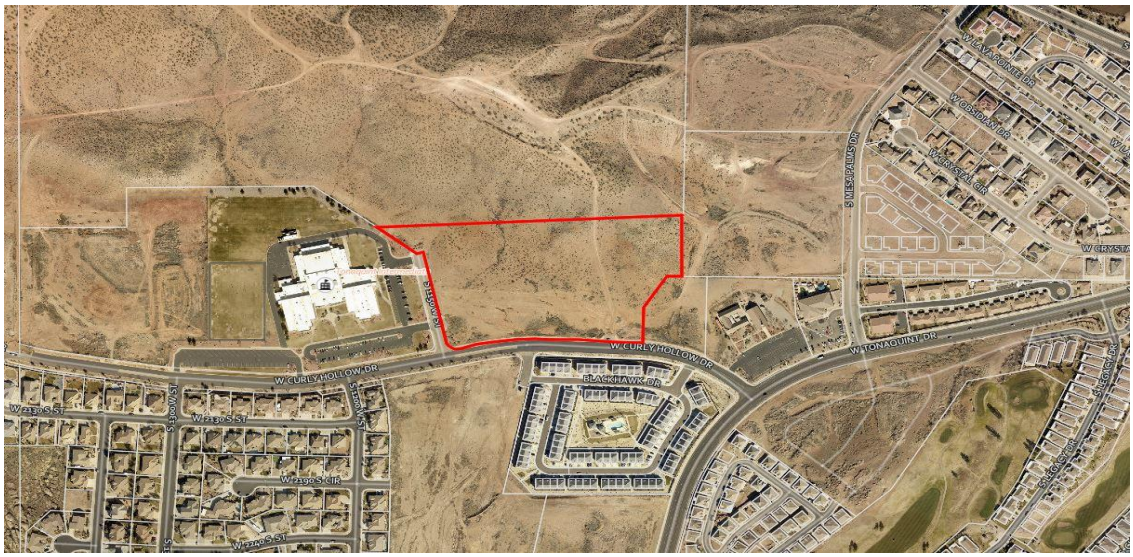


St.George
Community Development

ITEM 1
Hillside Permit

HILLSIDE REVIEW BOARD AGENDA REPORT: **01/25/2022**

Rosewood Townhomes Hillside Development Permit (Case No. 2023-HS-001)		
Request:	A Hillside Development Permit to allow disturbance of areas in the 20-30%, 30-40% and 40% and above slope areas. This application is in anticipation of the construction of Rosewood Townhomes.	
Applicant:	Tim Stewart	
Representative:	Jared Bates	
Location:	1100 W Curly Hollow Dr	
General Plan:	MDR (Multi-Family Residential)	
Existing Zoning:	R-1-8, R-1-10	
Surrounding Zoning:	North	R-1-10 (Single Family Residential 10,000 sq ft lot)
	South	R-1-10 (Single Family Residential 10,000 sq ft lots) & R-3 (Multi-Family)
	East	R-1-10 (Single Family Residential 10,000 sq ft lots), PD-R (Planned Development Residential)
	West	R-1-8 (Single Family residential 8,000 sq ft lots)
Land Area:	Approximately 14.99 acres	



BACKGROUND

This is a request to obtain a hillside permit for the property located at 1100 W Curly Hollow Dr. The applicants are proposing to build a new townhome development on this property. This property is in the hillside overlay. Section 10-13A-7 of the Zoning Regulations requires that all major development (i.e., cut greater than 4', etc.) on slopes above 20% requires a 'hillside development permit' granted by the City Council upon recommendation from the Hillside Review Board and the Planning Commission.

APPLICABLE ORDINANCE(S) *(Selected portions)*

10-13A-1: Density and Disturbance Standards

A. The hillside development overlay zone (HDOZ) limits development densities and provides specific development incentives to transfer underlying zone densities from hillsides (sending areas) to less steep slopes or more safe development areas (receiving areas), within a development.

B. For those portions of a proposed development with natural slopes twenty percent (20%) or less, development density follows the density and development standards in the underlying zone.

C. For those portions of a proposed development with natural slopes from twenty-one percent (21%) to thirty percent (30%), development activity shall not disturb more than thirty percent (30%) of the parcel within this slope category.

D. For those portions of a proposed development with natural slopes from thirty-one percent (31%) to forty percent (40%), development activity shall not disturb more than five percent (5%) of the area within this slope category.

E. A proposed development may not disturb slopes in excess of forty percent (40%).

10-13A-2: Slope and Slope Areas Determined

A. Slope shall be determined for each significant portion of a development parcel.

B. *Procedure:* The applicant shall map the location of the natural slope by using the following procedure:

1. *Preparation of Contour Maps:* The applicant shall submit an accurate, current contour map, prepared and certified by a licensed professional engineer or surveyor, which shows all land contours at intervals no greater than five feet (5'), drawn at a one-inch equals one hundred feet (1" = 100') scale maximum.

2. *Verification through Field Surveys:* The city engineer or designee may require the applicant to submit a field survey to verify the accuracy of the contour map.

C. *Determination of Slope Areas:* Using the contour map, natural slopes shall be calculated using points identified as natural slopes of twenty percent (20%), thirty percent (30%), and forty percent (40%), and shall be located on the contour map and connected by a continuous line. That area bounded by said lines and intersecting property lines shall be used for determining project density. Small washes or outcrops, which have slopes distinctly different from surrounding property, and are not part of the contiguous topography, may be excluded from the slope determination.

EXHIBITS PROVIDED

1. Exhibit A – Site Plan
   "Exhibit A" in the packet shows the location of the new commercial development.

2. Exhibit B –Grading Plan
   "Exhibit B" in the packet shows the proposed preliminary grading plan.

3. Exhibit C – Slope Analysis Map
   "Exhibit C" in the packet shows the overall slope analysis for the area to be disturbed.

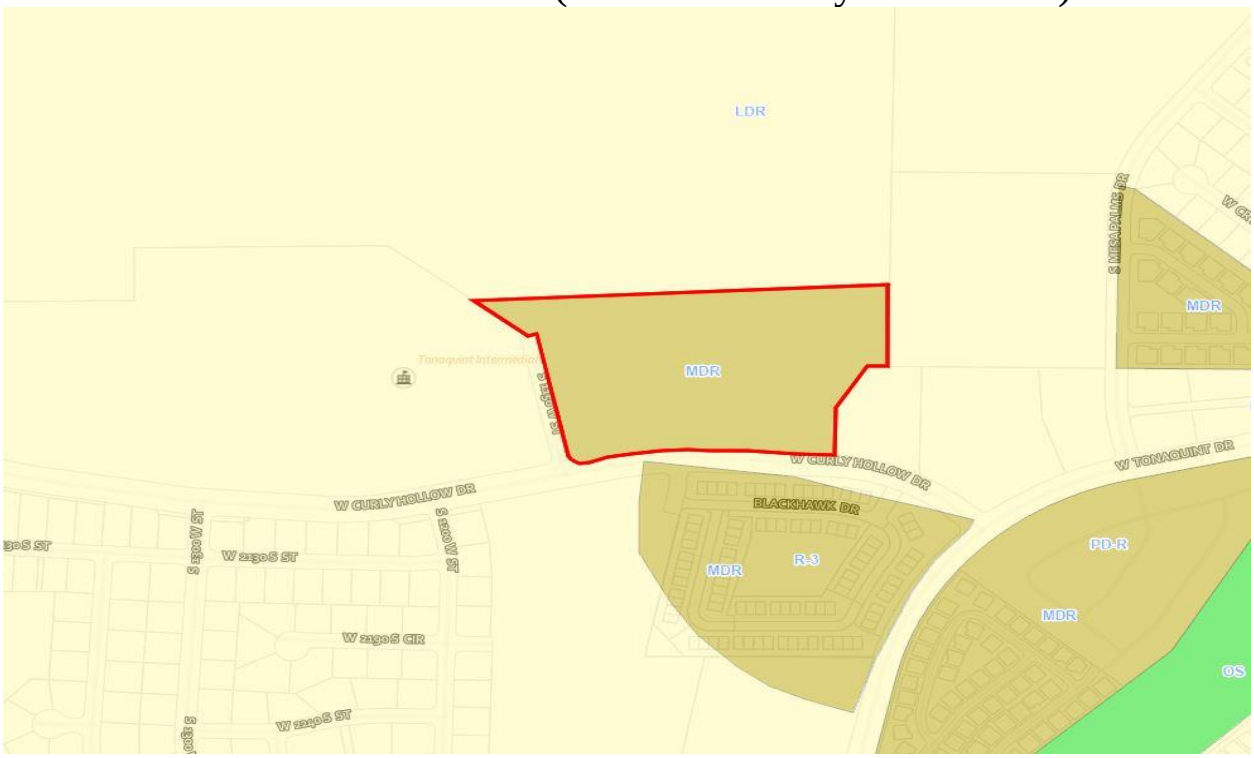
4. Exhibit D – Geotechnical Report
   "Exhibit D" – This is the Geotechnical report for Rosewood Townhomes.

5. Exhibit E – Drainage Report
   "Exhibit E – This is the Drainage Report for Rosewood Townhomes.

RECOMMENDATION

Section 10-13A-8(B)(1) of the "Hillside Review Board Powers and Duties" states that the hillside board can make recommendations to "adopt, modify or reject a proposal" to the Planning Commission (PC).

General Plan – MDR (Medium Density Residential)



Zoning - C-3 (General Commercial)

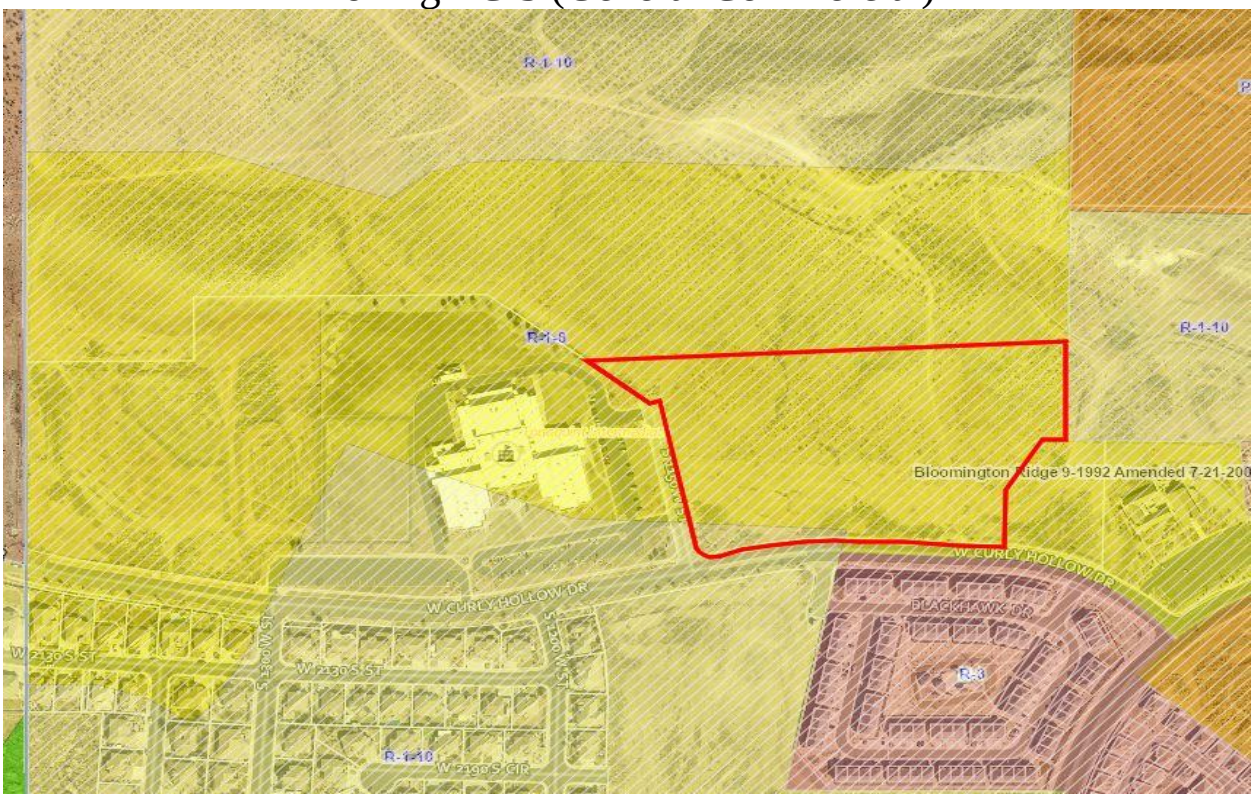


EXHIBIT A
Site Plan

EXHIBIT B
Grading Plan

EXHIBIT C
Slope Analysis Map

Exhibit D
Geotechnical Report

Exhibit E
Drainage Report

PHASE	BLDG #	PRIVATE STREET/PARKING	LIMITED COMMON	COMMON AREA/OPENSPACE
1	6 PLEX=42,054 SF 4 PLEX=18,728 SF TOTALS=60,782 SF	38,547 SF	6 PLEX= 7,560 SF 4 PLEX= 3,368 SF TOTALS=10,928 SF	87,850 SF
2	6 PLEX=28,036 SF 4 PLEX=23,410 SF TOTALS=51,446 SF	62,197 SF	6 PLEX= 5,040 SF 4 PLEX= 4,210 SF TOTALS= 9,250 SF	139,412 SF
3	6 PLEX= 7,009 SF 4 PLEX=37,456 SF TOTALS=44,465 SF	30,856 SF	6 PLEX= 1,260 SF 4 PLEX= 6,736 SF TOTALS= 7,996 SF	109,256 SF
TOTALS	6 PLEX= 77,099 SF 4 PLEX= 79,594 SF TOTALS=156,693 SF	131,600 SF	28,174 SF	336,518 SF

PROJECT TOTAL = 652,985 SQ. FT.

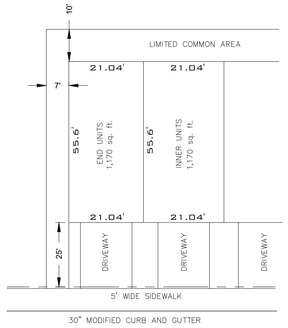
PROJECT INFORMATION

PROPOSED ZONING – PD GENERAL PLAN – HDR/MDR	
TOTAL AREA	14.99 ACRES 652,985 SQ. FT.
PROJECT DENSITY	8.94 UNITS PER ACRE
TOWNHOMES	134 UNITS
PARCEL NUMBER	SG-6-3-2-2001

RECREATION AREA REQUIRED = 200 SQ. FT. PER UNIT
RECREATION AREA PER 134 UNITS = 26,800 SQ. FT. = 0.49 ACRES

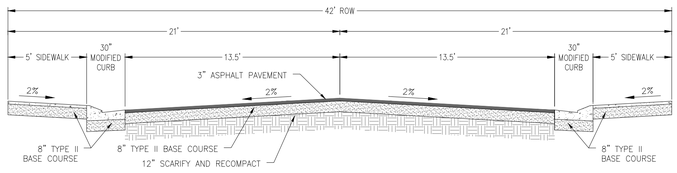
CUT/FILL

CUT = 41,849 CY
FILL = 35,035 CY
NET(CUT) = 6,814 CY

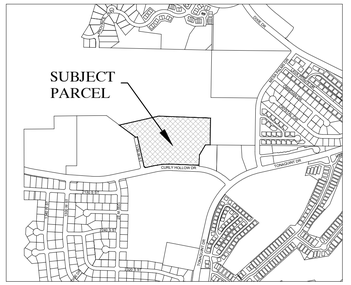


30" MODIFIED CURB AND GUTTER

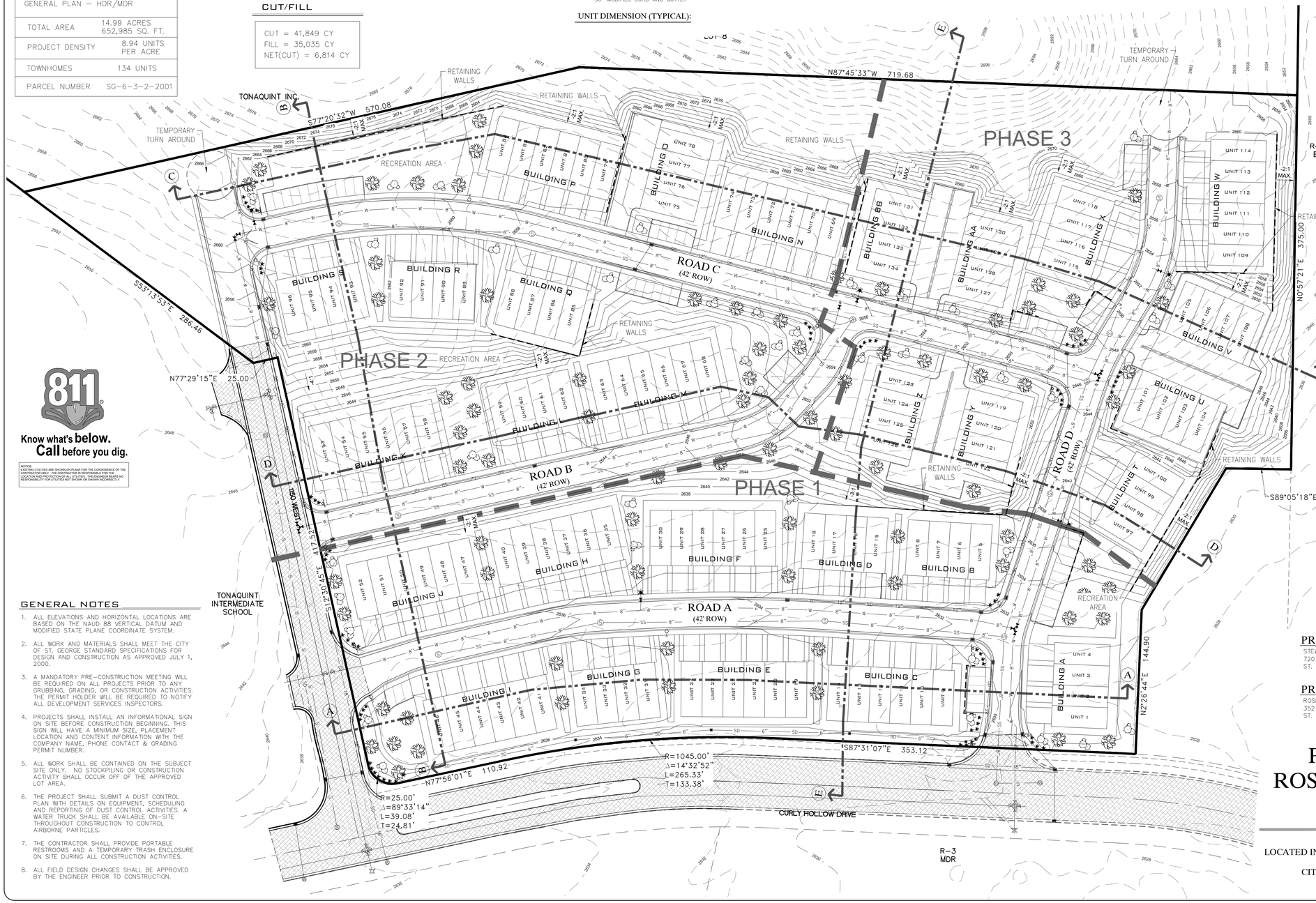
UNIT DIMENSION (TYPICAL):



ROADWAY CROSS SECTION



VICINITY MAP



LEGEND

- EXISTING 1' CONTOUR
- EXISTING 5' CONTOUR
- PROPOSED 1' CONTOUR
- PROPOSED 5' CONTOUR
- EXISTING ASPHALT PAVEMENT
- PROPOSED ASPHALT PAVEMENT
- PROPOSED BLOCK WALL
- EXISTING WATER
- EXISTING SANITARY SEWER
- EXISTING IRRIGATION
- EXISTING STORM DRAIN
- PROPOSED WATER
- PROPOSED SANITARY SEWER
- PROPOSED STORM DRAIN
- PROPOSED SEWER MANHOLE
- PROPOSED FIRE HYDRANT
- PROPOSED CATCH BASIN

0 50' 100'
SCALE: 1"=50'

GENERAL NOTES

1. ALL ELEVATIONS AND HORIZONTAL LOCATIONS ARE BASED ON THE NAUD 88 VERTICAL DATUM AND MODIFIED STATE PLANE COORDINATE SYSTEM.
2. ALL WORK AND MATERIALS SHALL MEET THE CITY OF ST. GEORGE STANDARD SPECIFICATIONS FOR DESIGN AND CONSTRUCTION AS APPROVED JULY 1, 2000.
3. A MANDATORY PRE-CONSTRUCTION MEETING WILL BE REQUIRED ON ALL PROJECTS PRIOR TO ANY GRUBBING, GRADING, OR CONSTRUCTION ACTIVITIES. THE PERMIT HOLDER WILL BE REQUIRED TO NOTIFY ALL DEVELOPMENT SERVICES INSPECTORS.
4. PROJECTS SHALL INSTALL AN INFORMATIONAL SIGN ON SITE BEFORE CONSTRUCTION BEGINNING. THIS SIGN WILL HAVE A MINIMUM SIZE, PLACEMENT LOCATION AND CONTENT INFORMATION WITH THE COMPANY NAME, PHONE CONTACT & GRADING PERMIT NUMBER.
5. ALL WORK SHALL BE CONTAINED ON THE SUBJECT SITE ONLY. NO STOCKPILING OR CONSTRUCTION ACTIVITY SHALL OCCUR OFF OF THE APPROVED LOT AREA.
6. THE PROJECT SHALL SUBMIT A DUST CONTROL PLAN WITH DETAILS ON EQUIPMENT, SCHEDULING AND REPORTING OF DUST CONTROL ACTIVITIES. A WATER TRUCK SHALL BE AVAILABLE ON-SITE THROUGHOUT CONSTRUCTION TO CONTROL AIRBORNE PARTICLES.
7. THE CONTRACTOR SHALL PROVIDE PORTABLE RESTROOMS AND A TEMPORARY TRASH ENCLOSURE ON SITE DURING ALL CONSTRUCTION ACTIVITIES.
8. ALL FIELD DESIGN CHANGES SHALL BE APPROVED BY THE ENGINEER PRIOR TO CONSTRUCTION.

811 Know what's below. Call before you dig.

NOTICE:
EXISTING UTILITIES ARE SHOWN ON PLANS FOR THE CONVENIENCE OF THE CONTRACTOR. IT SHALL BE THE CONTRACTOR'S RESPONSIBILITY FOR LOCATION AND PROTECTION OF ALL UTILITIES. THE ENGINEER BEARS NO RESPONSIBILITY FOR UTILITIES NOT SHOWN OR SHOWN INCORRECTLY.

PROJECT OWNER/ DEVELOPER

STEWART ENTERPRISES
720 SOUTH RIVER ROAD, SUITE A-115
ST. GEORGE, UT 84790
CONTACT: TIM STEWART
(435) 703-4302

PROJECT ENGINEER

ROSENBERG ASSOCIATES
352 EAST RIVERSIDE DRIVE, SUITE A2
ST. GEORGE, UT 84790
CONTACT: JARED BATES
(435) 673-8586

PRELIMINARY PLAT ROSEWOOD TOWNHOMES, ST. GEORGE

A 134 UNIT TOWNHOME DEVELOPMENT
LOCATED IN SECTION 1, TOWNSHIP 43 SOUTH, RANGE 16 WEST OF THE SALT LAKE BASE AND MERIDIAN
CITY OF ST. GEORGE, WASHINGTON COUNTY, UTAH.

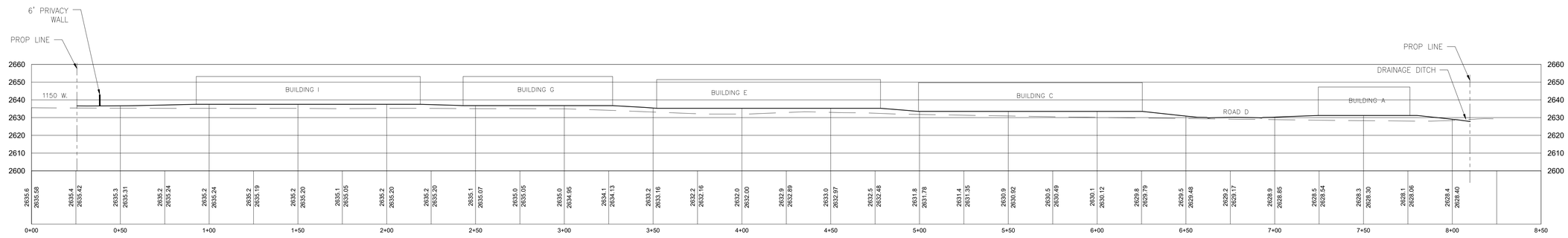
DATE: 05/05/2022
JOB NO.: 13231-22
DESIGNED BY: ALN
CHECKED BY: JWB
DWG: CON PLANS
DATE
REVISIONS

ROSENBERG ASSOCIATES
CIVIL ENGINEERS • LAND SURVEYORS
352 East Riverside Drive, Suite A-2 St. George, Utah 84790
Ph (435) 673-8586 Fx (435) 673-8397 www.racivil.com

PRELIMINARY PLAT
FOR
ROSEWOOD TOWNHOMES
ST GEORGE
UTAH

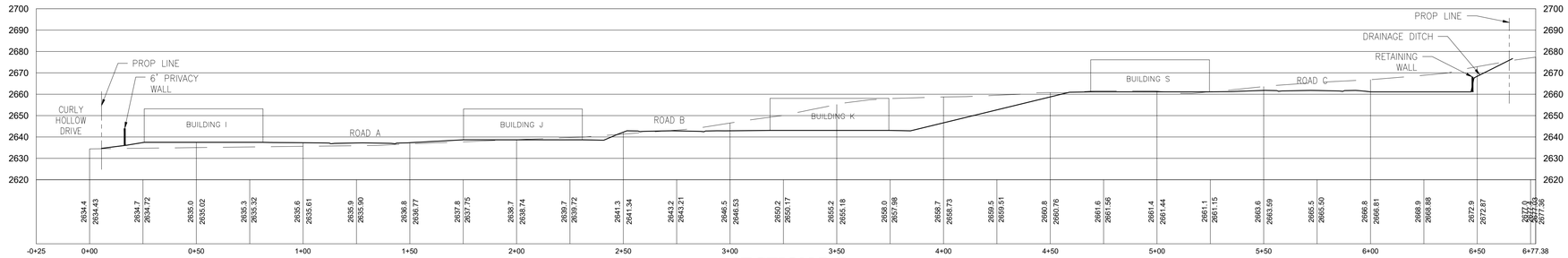
PROFESSIONAL ENGINEER
JARED W. BATES
12/9/2022
7865819
STATE OF UTAH

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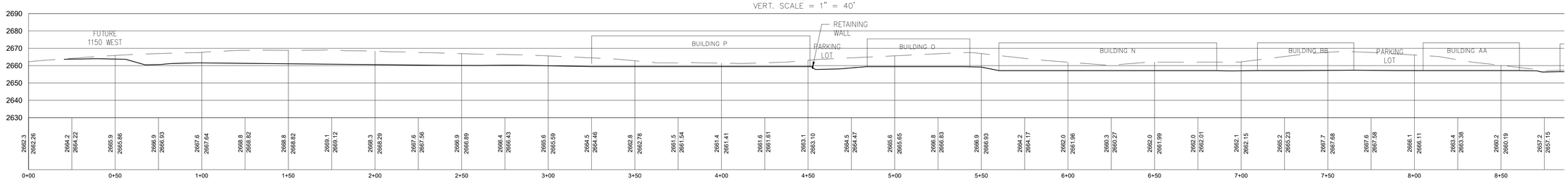
SECTION A-A

HORIZ. SCALE = 1" = 40'
VERT. SCALE = 1" = 40'



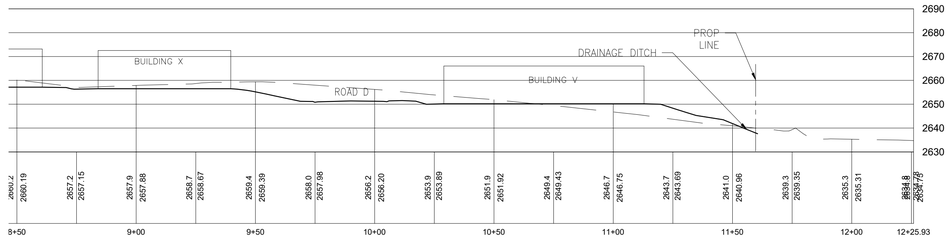
SECTION B-B

HORIZ. SCALE = 1" = 40'
VERT. SCALE = 1" = 40'



SECTION C-C

HORIZ. SCALE = 1" = 40'
VERT. SCALE = 1" = 40'



SECTION C-C (CONT.)

HORIZ. SCALE = 1" = 40'
VERT. SCALE = 1" = 40'

DATE:	05/05/2022
JOB NO.:	13231-22
DESIGNED BY:	ALN
CHECKED BY:	JWB
DWG:	CON PLANS

DATE
REVISIONS

ROSENBERG ASSOCIATES
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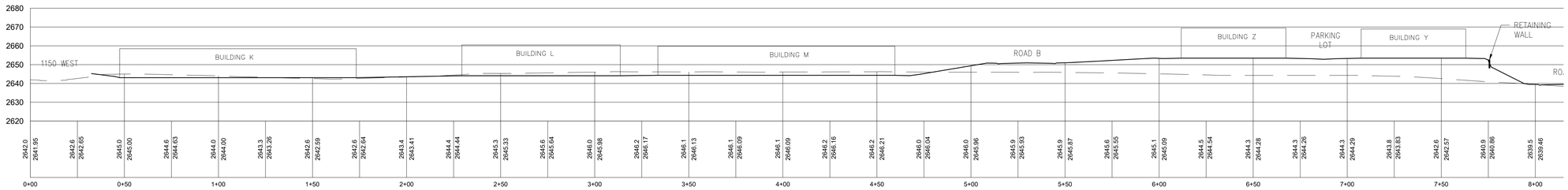
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Ph (435) 673-8586 Fx (435) 673-8397 www.racivil.com

CROSS SECTIONS FOR ROSEWOOD TOWNHOMES

ST GEORGE
UTAH

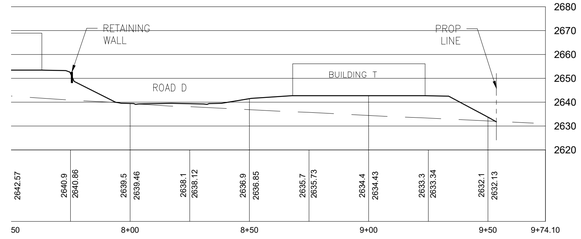
PROFESSIONAL ENGINEER
JARED W. BATES
12/20/2022
STATE OF UTAH

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2 OF 3 SHEETS



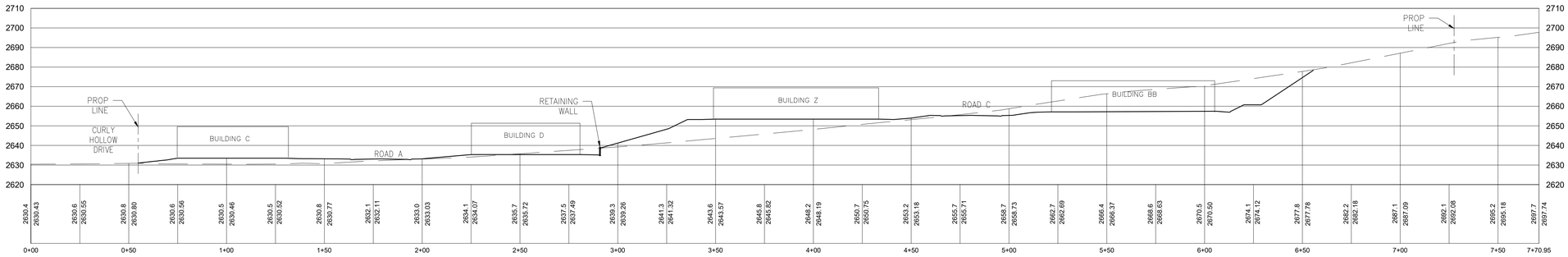
SECTION D-D

HORIZ. SCALE = 1" = 40'
VERT. SCALE = 1" = 40'



SECTION D-D (CONT.)

HORIZ. SCALE = 1" = 40'
VERT. SCALE = 1" = 40'



SECTION E-E

HORIZ. SCALE = 1" = 40'
VERT. SCALE = 1" = 40'

DATE: 05/05/2022
JOB NO.: 13231-22
DESIGNED BY: ALN
CHECKED BY: JWB
DWG: CON PLANS
DATE
REVISIONS

ROSENBERG ASSOCIATES
CIVIL ENGINEERS • LAND SURVEYORS

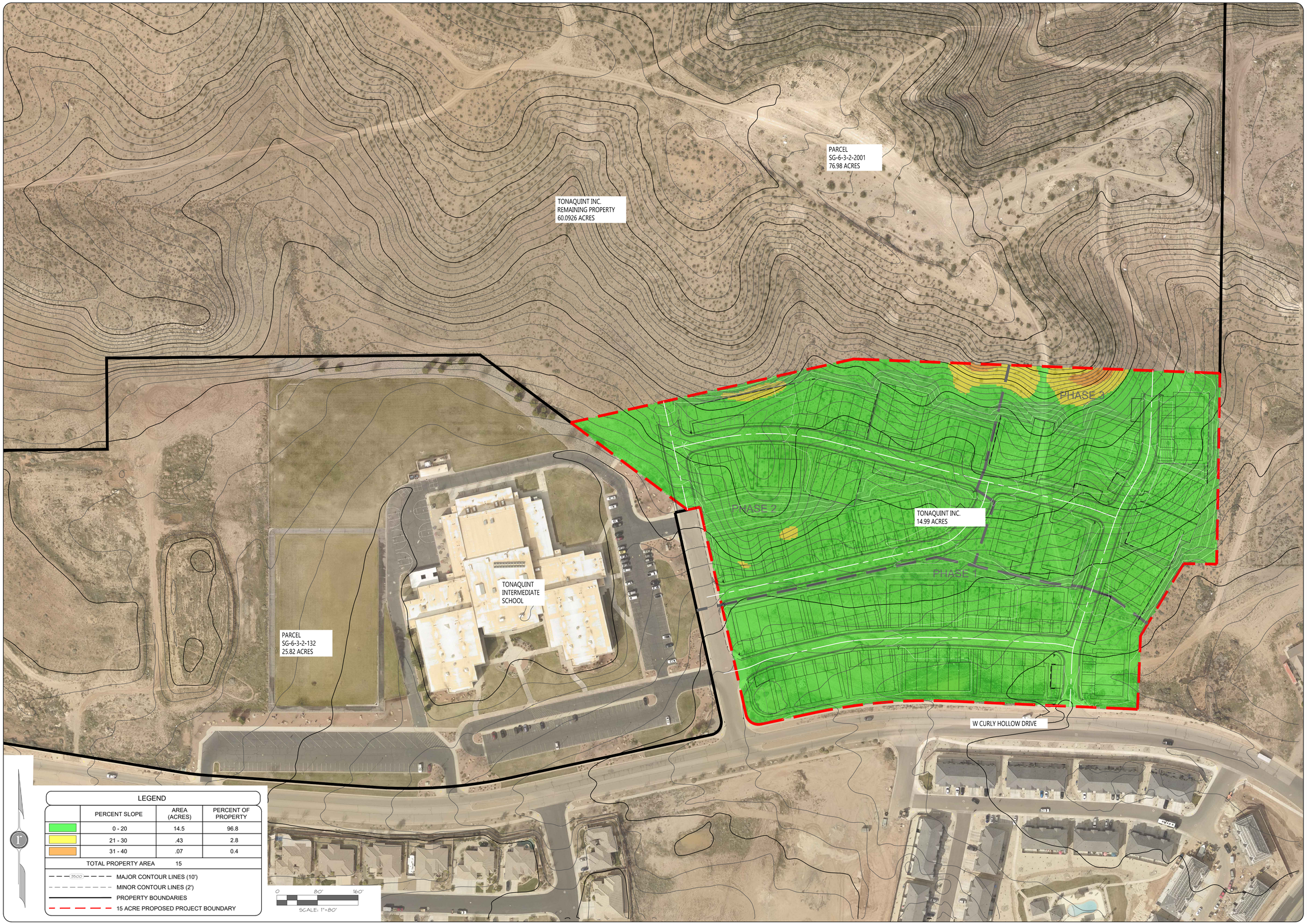
352 East Riverside Drive,
Suite A-2 St. George, Utah
84790
Ph (435) 673-8586 Fx (435)
673-8397 www.racivil.com

CROSS SECTIONS FOR ROSEWOOD TOWNHOMES

ST GEORGE
UTAH

PROFESSIONAL ENGINEER
JARED W. BATES
12/20/2022
STATE OF UTAH

SHEET
3
3 OF 3 SHEETS



LEGEND

	PERCENT SLOPE	AREA (ACRES)	PERCENT OF PROPERTY
	0 - 20	14.5	96.8
	21 - 30	.43	2.8
	31 - 40	.07	0.4
TOTAL PROPERTY AREA		15	

- 5500 MAJOR CONTOUR LINES (10')
- MINOR CONTOUR LINES (2')
- PROPERTY BOUNDARIES
- 15 ACRE PROPOSED PROJECT BOUNDARY

0 80' 160'

SCALE: 1"=80'

DATE:	4/4/2022
JOB NO.:	13231-22
DESIGNED BY:	WJP
CHECKED BY:	JWB
DWG:	SLOPE

REVISIONS

DATE

ROSENBERG ASSOCIATES
CIVIL ENGINEERS • LAND SURVEYORS

352 East Riverside Drive, Suite A-2
St. George, Utah 84790
Ph (435) 673-8586 Fx (435) 673-8397
www.racivil.com

SLOPE ANALYSIS WITH SITE AND GRADING

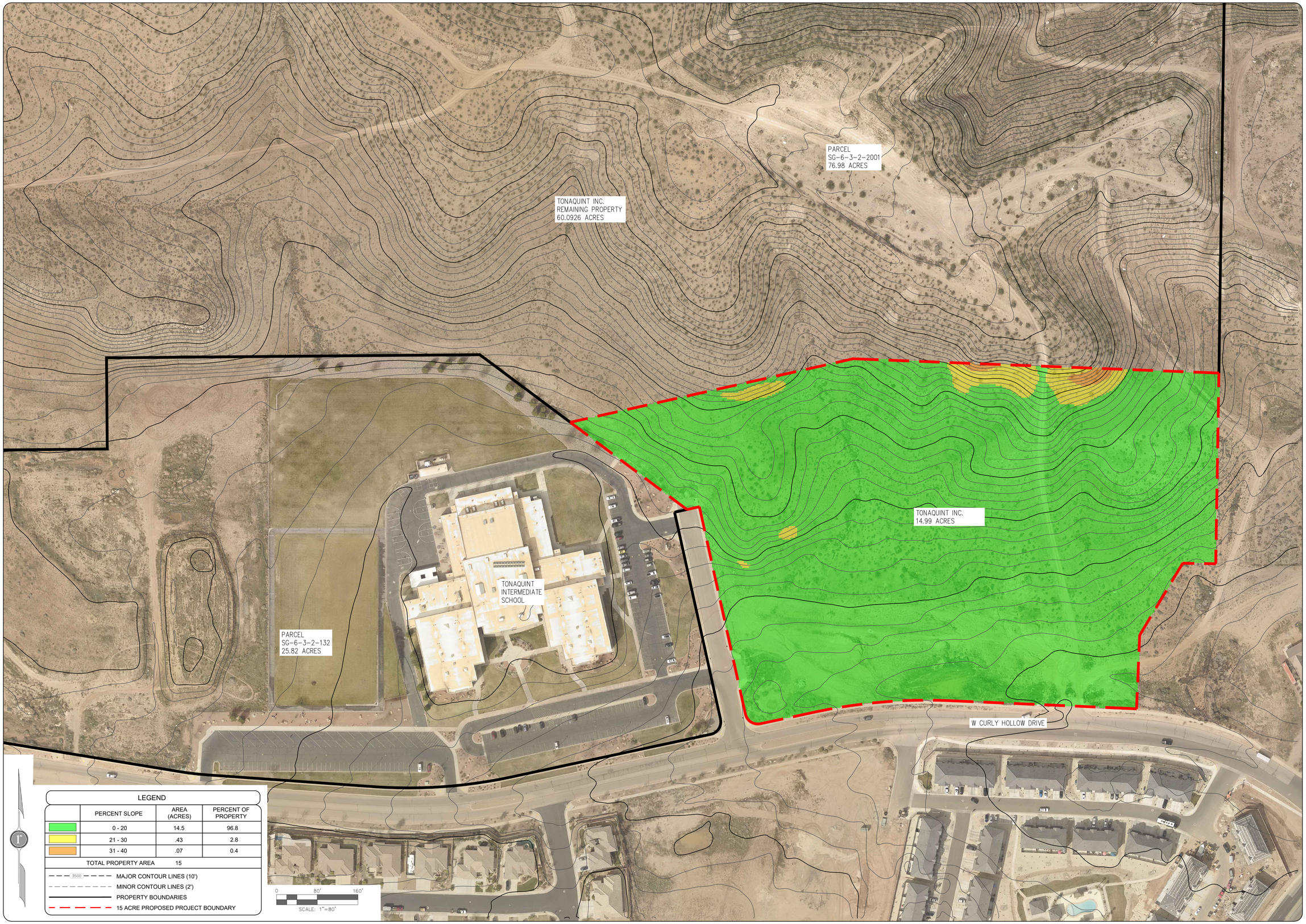
FOR

ROSEWOOD TOWNHOMES

ST. GEORGE
UTAH

PROFESSIONAL ENGINEER
JARED W. BATES
4/20/2022
STATE OF UTAH

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1 OF 1 SHEETS



DATE:	4/4/2022
JOB NO.:	13231-22
DESIGNED BY:	WJP
CHECKED BY:	JWB
DWG:	SLOPE

REVISIONS
DATE

ROSENBERG ASSOCIATES
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352 East Riverside Drive, Suite A-2
St. George, Utah 84790
Ph (435) 673-8586 Fx (435) 673-8397
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SLOPE ANALYSIS
FOR
ROSEWOOD TOWNHOMES
ST. GEORGE
UTAH

PROFESSIONAL ENGINEER
JARED W. BATES
7868574
STATE OF UTAH
1/20/2023

SHEET
1
1 OF 1 SHEETS

AGEC

Applied GeoTech

GEOTECHNICAL INVESTIGATION

ROSEWOOD TOWNHOMES

ST. GEORGE, UTAH

PREPARED FOR:

STEWART ENTERPRISES, LC
720 SOUTH RIVER ROAD, SUITE A115
ST. GEORGE, UTAH 84791-1591

ATTENTION: TIM STEWART

PROJECT NO. 2221859

DECEMBER 2, 2022

1420 South 270 East • St. George, Utah 84790 • (435) 673-6850 • FAX (435) 673-1044

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SITE AND TEST PIT PHOTOS APPENDIX

SUMMARY

1. AGEC was requested to conduct a geotechnical investigation and to provide geotechnical recommendations for the proposed Rosewood Apartments project located north of Curly Hollow Drive and east of 1150 West in St. George, Utah. Our investigation included the excavation of 14 test pits at the approximate locations shown on Figure 2.

2. The existing site topography consists of level area along Curly Hollow Drive on the south then slopes up moderately to the north with approximately 40 feet across the property. The proposed grading indicates cuts and fills along each row of buildings that will also require retaining slopes. We anticipate the retaining will be accomplished with rock walls.

3. The subsurface conditions generally consist of near surface bedrock with a layer of sandy lean clay to clayey sand overlying mudstone bedrock throughout the site. There was clayey gravel with sand near the southeast portion of the site above the mudstone bedrock. In addition, sandstone bedrock was encountered below the mudstone within Test Pit TP-5 at a depth of approximately 6 feet. The mudstone was encountered at depths of approximately 1 to 6 feet below the existing surface and extended to the maximum depths investigated, approximately 15 feet. The mudstone is known as "blue clay" and is moderately to highly expansive when wetted.

4. The depth to mudstone is critical for limiting the potential amount of surface heave. Our experience has shown that approximately 15 feet of separation is necessary to limit surface heave to less than 1 inch. The separation is determined from the pad grade to the depth of the mudstone and may be achieved by overexcavation or raising pad grades to provide the separation. If the overexcavation alternative is used, we recommend a depth of removal of 15 feet and 2 feet of additional removal and replacement of the mudstone that processed (moisture conditioned) and recompacted at the based of the excavation. Use of various materials and grading recommendations are provided in the report.

   The on-site non-mudstone materials may be re-used as structural fill. The removed mudstone should be placed in non-structural areas or discarded off site. Consideration may also be given to mixing the mudstone with non-expansive materials for re-use. Our experience has shown that mix ratios of 2 parts (non expansive) to 1 part mudstone (expansive) may be used up to within 5 feet of the pad grade. AGEC should verify through additional laboratory testing proper mixing ratios.

5. We also recommend the use of micro piles (deep foundation system) may also be used if the alternative of overexcavation described in No. 4 above is not used. Micro piles typically extend into the mudstone approximately 20 feet and support a grade beam system that allows the structure to be supported below the "active zone" of the mudstone estimated to be approximately 10 feet within the upper portion of the mudstone. Our experience has shown either alternative has been proven as a reliable foundation support. Various factors of costs associated with each alternative may also be evaluated to determine the appropriate foundation support (overexcavation or micro-piles).

6. Portions of the bedrock is generally moderately hard and may be difficult to excavate, particularly in utility trenches.

7. Due to the expansive mudstone throughout the site, we do not recommend using retention to meet the Low Impact Drainage (LID) requirements. Site drainage recommendations should be implemented as recommended in the site drainage section of this report.

8. Detailed recommendations for subgrade preparation, materials, foundations, drainage and pavement are included in the report.

9. This summary should not be used independent of the information presented in the body of this report.

SCOPE OF WORK

AGEC was requested to conduct a geotechnical investigation and to provide geotechnical recommendations for the proposed Rosewood Apartments project to be located north of Curly Hollow Drive and east of 1150 West in St. George, Utah as shown on Figure 1. The study has included the excavation of 14 test pits to evaluate the subsurface conditions at the site. The locations of the explorations are shown on Figure 2. This report summarizes the subsurface conditions for the project.

AGEC has reviewed the grading plans prepared by Rosenberg Associates. The recommendations are for grading, foundations, pavement and drainage are included within this report.

Our scope of work was conducted in general accordance with our proposal dated August 27, 2022.

SITE CONDITIONS

The project site consists of the property shown on Figure 1. The existing site topography consists of level area along Curly Hollow Drive on the south end of the site and then slopes up to the north with an elevation change of approximately 40 feet. Adjacent to the north and east is undeveloped property. To the west is the existing Tonaquint Intermediate School. Across Curly Hollow Drive to the south is the Blackhawk Townhomes and the Tonaquint Residential development.

The property contains a sparce amount of vegetation consisting of small grass and bushes. Several site photos are included in the Appendix.

FIELD STUDY

The field study was conducted on September 12, 2022. The exploration locations were determined using a hand held Global Positioning Survey (GPS) and the exploration elevations were determined using the provided contours on the Rosenberg Associates grading plan. The approximate locations of the explorations are shown on Figure 2. The test pits were excavated with a track mounted excavator. The explorations were logged by a representative of AGEC and samples were obtained for laboratory testing.

SUBSURFACE SOIL AND BEDROCK CONDITIONS

The subsurface conditions generally consist of sandy lean clay to clayey sand overlying mudstone bedrock throughout the site. Clayey gravel with sand was encountered near the southeast portion of the site above the mudstone bedrock. In addition, sandstone bedrock was encountered below the mudstone within Test Pit TP-5 at a depth of approximately 6 feet. The mudstone was encountered at depths of approximately 1 to 6 feet below the existing surface and extended to the maximum depths investigated, approximately 15 feet. The mudstone is known as "blue clay" and is moderately to highly expansive when wetted.

Descriptions of each soil and bedrock type observed follow:

Sandy Lean Clay (CL) - The sandy lean clay is generally weathered mudstone mixed with varied amounts of sand and gravel. The sandy lean clay is stiff to very stiff, generally dry to slightly moist, and brown to grey in color.

Laboratory tests conducted on samples of the sandy lean clay indicates moisture contents of 1 to 7 percent with and in-place dry density of 116 pounds per cubic foot (pcf) and a fines (percent passing the No. 200 sieve) content ranging from 54 to 93 percent. Atterberg Limits tests indicate liquid limits of 27 to 39 percent and plasticity indexes of 11 to 25 percent.

Moisture-Density relationship tests (proctors) indicate the maximum dry density varies from 124.0 to 137.5 pcf and an optimum moisture content varying from 6.5 to 10.5 percent.

Clayey Sand (SC) - The clayey sand contains occasional gravel that is subrounded and has occasional cobble size material. The clayey sand varies from loose to medium dense, dry to slightly moist and brown in color.

Laboratory tests conducted on samples of the clayey sand indicate in-place moisture contents ranging from 1 to 4 percent, in-place dry densities ranging from 101 to 117 pcf and fines contents ranging from 23 to 45 percent.

Clayey Gravel (GC) - The clayey gravel contains varied amounts of sand with occasional cobbles. The clayey gravel is medium dense to dense, dry to slightly moist and brown in color.

Laboratory tests indicate a moisture content of 3 percent and fines content of 32 percent.

Mudstone Bedrock - The mudstone is known in the area as blue clay and is soft to moderately hard, slightly moist and is gray to red to purple in color. The mudstone is generally medium to highly plastic.

Laboratory tests conducted on samples of the mudstone bedrock indicate in-place moisture contents ranging from 4 to 10 percent, fines contents ranging from 68 to 90 percent. Atterberg Limits tests indicate liquid limits ranging from 28 to 46 percent and plasticity indexes ranging from 14 to 27 percent.

Sandstone Bedrock- The sandstone is generally moderately hard, dry and gray in color.

The Logs, Legend and Notes of Test Pits are shown on Figures 3-4. The laboratory test results are also shown on Figures 3 and 4 and are summarized in the Summary of Laboratory Testing, Table 1. Figures 5 and 6 provide the moisture-density relation (proctor) test results. Several photos of the test pits are included in the Appendix of this report.

SUBSURFACE WATER

Groundwater was not encountered within the explorations to the depths investigated. Fluctuations in groundwater may occur over time. An evaluation of such fluctuations was beyond the scope of this report.

PROPOSED CONSTRUCTION

This project includes the development of approximately 15 acres and is planned to be developed into 136 townhomes as shown on Figure 2. The townhomes are grouped within 31 buildings of approximately 4 to 6 units per building. There area various streets and public improvements throughout the planned development.

We anticipate that buildings will be slab on grade, wood-framed structures likely 2 to 3 stories in height. We anticipate walls loads of up to 3 to 4 kips per lineal foot and column loads up to 50 kips.

Based on the grading plan, we anticipate cuts and fills may be up to 10 feet. We also anticipate the need for retaining.

If the proposed construction is significantly different than described, AGEC should be contacted to further evaluate our recommendations.

RECOMMENDATIONS

Based on subsurface soil conditions, engineering analysis, and the proposed construction, the following recommendations are provided:

A. Grading Recommendations

Based on the existing topography and the proposed grading plan, a moderate amount of grading will likely occur. We anticipate that cuts and fills will be on the order of 5 to 10 feet. The majority of the grading will comprise excavation of the near surface sand and clay along with deeper mudstone bedrock materials.

1. Subgrade Preparation

General: Prior to placing fill, the non-graded portion of the site should be grubbed to remove vegetation and soil containing roots and organics. The amount of material should be limited to primarily vegetation. These materials should be disposed off site.

Subsequent to grubbing and prior to placing fill, the subgrade should be prepared by scarifying approximately 12 inches and compacting the subgrade. If the subgrade consists of bedrock, scarification is not necessary. The existing soils are generally dry and will require significant amounts of moisture to achieve the compaction.

Roadways: The subgrade is anticipated to vary from silty sand to lean clay to clayey sand materials. If during the grading, mudstone is encountered within 3 feet of the subgrade surface, the mudstone should be removed to 3 feet below subgrade and replaced with suitable non-expansive materials.

Building Pads: Pads that are located where expansive mudstone is encountered within 15 feet of the pad grade, the pad should be overexcavated to remove the mudstone down to at least 17 feet below pad grade. The bottom two feet of the removal and replacement may consist of re-using the mudstone following moisture conditioning. We recommend the mudstone be moisture conditioned 0 to 4 percent over the optimum moisture content and properly recompacted. The contractor should provide verification of the limits and depths by survey.

2. Excavation

In general, we anticipate that excavation of the bedrock at the site will likely require heavy duty excavation equipment. The bedrock material is known to be difficult to excavate.

3. Grading Slopes and Trenches

The following table provides the maximum recommended slope steepness for a given slope condition. Slopes should include benches in accordance with the 2018 IBC.

Slope Condition	Maximum Slope (Horizontal:Vertical)
Permanent Cut Slopes in Overburden Soils	2:1
Unretained, Properly Compacted Fill	2:1
Permanent Cut Slopes in Moderately Hard Bedrock	1/4:1
Utility Trenches in Bedrock (OSHA Soil Class A)	½:1

Fill slopes should be graded by overbuilding and then cutting back to the desired grade to provide a compacted slope face. Fill placed on existing slopes steeper than 3:1 should be placed using a benching procedure to key the fill into the existing slope. Benches should be of sufficient width to allow adequate area for the compaction equipment.

Steeper trenches may require the use of shoring or a trench box to provide as safe work environment. Safe trench excavation is the responsibility of the contractor.

4. Materials

The on site, non-mudstone materials may be re-used as site grading fill. The mudstone may be re-used in the 15 to 17 feet range within deeper overexcavations. The removed mudstone may also be placed in non-structural areas or discarded off site. Consideration may also be given to mixing the mudstone with non-expansive materials for re-use. Our experience has shown that mix ratios of 2 parts (non expansive) to 1 part mudstone (expansive) may be used up to within 5 feet of the pad grade. AGEC should be contacted to provide additional laboratory testing for proper mixing ratios.

If additional materials are imported, the materials should be non-expansive, non-gypsiferous, granular soil. Listed below are the materials recommended for imported fill.

Area	Fill Type	Recommendations
Foundations/slabs	Site grading/ structural fill	**-200** <35%, **LL** <30% Maximum size: 4 inches Solubility < 1%
Underslab (upper 4 inches)	Base Course	-200 <12% Maximum size: 1 inch Solubility < 1%

-200 = Percent Passing the No. 200 Sieve

LL = Liquid Limit

5. Compaction

Compaction of materials placed at the site should equal or exceed the following minimum densities when compared to the maximum dry density as determined by ASTM D-1557:

Area	Percent Compaction
Subgrade	90
Footings/building pad	95
Site grading	95
Utility trenches	95
Wall backfill	95

To facilitate the compaction process, the overburden soil and processed, non-expansive bedrock should be moisture conditioned to within 2 percentage points of the optimum moisture content as determined by ASTM D-1557 prior to placement.

Fill should be placed in loose lift thicknesses which do not exceed the capacity of the equipment being utilized. Generally, 6 to 8-inch loose lifts are adequate. Lift thicknesses should be reduced to 4-inches for hand compaction equipment.

6. Surface Drainage General Recommendations

Positive site drainage should be maintained during the course of construction. After construction has been completed, positive drainage of the surface water away from the buildings in each direction must be maintained. To reduce infiltration adjacent to foundations we recommend the following:

a. A minimum slope of 6 inches in the first 10 feet from the perimeters of the structures should be provided.

b. Roof gutter systems should be installed around the perimeters of the structures. Roof downspouts should discharge away from the buildings so as to prevent ponding adjacent to foundations. We recommend piping roof gutter downspouts of site directly into the adjacent curb and gutter.

c. Placement of 3 to 4 foot wide concrete aprons around the perimeters of the structures.

d. Landscaping requiring water should not be placed adjacent to foundations or within 10 feet of foundations.

e. Due to the presence of the underlying expansive layers, we recommend protection of the underlying foundation support soils with a 10 mil impermeable PVC membrane. The membrane should be attached to the perimeter foundation of the residence and slope away from the residence at a 5 percent slope into a perimeter drain trench to collect and discharge water off site. The drain trench should include gravel and a 4-inch perforated PVC pipe to collect and transport water off site. It is critical the line extend into line both sides and the bottom of the trench.

f. Below grade portions of walls/fences which are backfilled with soil should be protected with an impermeable membrane and a subsurface drain on the backfilled side. A gravel covered, perforated PVC pipe should also be placed at the base of the wall to carry water to a discharge point. This is intended to reduce the potential for salt weathering and sulfate attack on concrete/masonry.

7. Surface Drainage- Low Impact Development (LID)

AGEC has reviewed the Dixie Storm Water Coalition Guide for the Low Impact Development (LID) dated June 20, 2020. The following evaluation is provided:

Using Figure 2 (flow chart), Step 2 indicates a "NO" for acceptable native soils. Using Table 3 (matrix) the shallow bedrock and expansive mudstone prohibits the use of the majority of the BMP's. BMP's BR-1 (Rain Garden), BR-2 (Bioretention Cell), BR-4 (Vegetated Strip), BR-5 (Tree Box Filter), D-3 (Dry Well) and HR-1 (Harvest and Reuse) are noted as "any" or these matrix options available, while the others have been eliminated through the matrix flow chart. Although, these options are available, due to the expansive and shallow bedrock on the site, the use of these BMP's would be detrimental to the project.

As an alternative, we recommend the use of a site drainage plan to allow water to drain to regional storm drainages or to off site detention or locations.

We recommend that structures with rain gutters and site drains exit to the curb and surface flow to the storm drains.

Based on the evaluation for use of on-site retention, it is our recommendation that BMP's with surface infiltration that will potentially wet the expansive mudstone/clay or may perch and flow laterally on shallow bedrock not be used.

The infiltration from this type of drainage may result in surface heave and damage to infrastructure and structures.

B. Foundations (Conventional and Deep/Micropiles)

1. **Conventional spread and spot footings:** For lots/pads where the subgrade was overexcavated and/or raised to provide a separation of 15 feet between the pad grade and the expansive mudstone, the following foundations recommendations may be used:

a. Bearing Material

The proposed residences may be supported on conventional spread footings bearing on properly compacted structural fill underlain by a properly prepared subgrade. Specifically, the subgrade should be prepared during site grading by overexcavating the building pads to remove unsuitable soils and bedrock as recommended in the Subgrade Preparation section of this report.

b. Bearing Pressures

Footings bearing on properly compacted structural fill may be designed for the following net allowable bearing pressures.

Load Condition	Net Allowable Bearing Pressure (psf)
Walls	2,000
Spots/Columns	2,500

c. Footing Width and Embedment

Footings should have a minimum width of 18 inches and should be embedded at least 12 inches below the lowest adjacent grade.

d. Temporary Loading Conditions

The allowable bearing pressures may be increased by one-half for temporary loading conditions such as wind or seismic loads.

e. Settlement

We estimate that settlement will be approximately 1 inch for footings designed as indicated above due to the load of the structure. Differential settlement is estimated to be approximately ½ inch.

f. Foundation Base

The base of excavations should be cleared of loose or deleterious material prior to placement of fill or concrete.

g. Foundation Setback

Foundations should be set back from the top crest of slopes or retaining structures. For fill slopes, foundations should be setback a horizontal distance equal to are greater than ⅓ the total slope height.

2. **Deep Foundations /Micropiles:** Where the lots/pads have expansive mudstone within 15 feet of the pad grade and the pad was not raised or overexcavated to provide the minimum 15 feet separation, the following foundation recommendations are provided below. The use of deep foundation elements (micropiles) incorporates that grade beams span the distance between piers and support a structural floor with a crawl space below.

a. The deep foundations (proposed to be micropiles) should extend at least 20 feet into the underlying expansive mudstone with a minimum total length of 25 feet.

b. End bearing should not be considered for micropile capacity. Micropiles should be of sufficient diameter to allow for placement of grout around reinforcing steel.

c. Micropiles should be designed using the parameters provided in the attached Table 2, Drilled Micropile Design Parameters.

d. The piles should be structurally reinforced to resist tensile forces on the pile due to negative skin friction. The tensile force may be calculated utilizing at least 10 feet of pier length with an ultimate skin friction of 1,000 pounds per square foot (psf). A greased PVC bond breaker may also be considered to reduce uplift forces on the micropiles. Bond breakers should be verified by load testing.

e. Piles should be placed as far apart as practical in order to achieve minimum dead load recommendations and a minimum of three diameters apart center to center.

f. Care should be taken to assure the micropiles are not over-sized (mushroomed) at the ground surface, which could provide an area where swelling soil/rock could exert uplift forces on the piles. A PVC bond breaker or a steel pipe may be placed at the surface to provide a straight pile.

g. Grout should be placed using a tremmie extended to near the bottom of the drill hole to ensure the drill hole is filled without voids. The tremmie should be raised as the grout is pumped.

h. The water cement ratio of the grout should be on the order of 0.45 to 0.50. This should be verified during construction using a grout scale to verify the grout has a specific gravity on the order of 1.8 to 1.9. The grout volume should be recorded for each micropile constructed to ensure the appropriate volume is placed.

i. If water enters the micropile holes, it would be necessary to place grout immediately after the hole is completed using a tremmie. The tremmie will also displace water out of the hole as grout is placed. Failure to place grout the day of drilling may require re-drilling for additional bedrock penetration.

j. Micropile holes should also be inspected to verify caving does not occur below the ground surface which could also result in additional uplift forces. Casing the drill hole may be necessary if the caving occurs to ensure a straight shaft with a consistent diameter

k. Centralizers should be used on the steel reinforcing bar at approximately a 7 to 10 foot spacing to ensure the appropriate grout cover on the reinforcing.

C. Concrete Slab-on-Grade

1. Slab Support

Concrete slabs may be supported on a zone of properly prepared (overexcavated) and compacted fill as stated in the Subgrade Preparation and Materials sections.

2. Underslab Base Course

A 4-inch layer of properly compacted base course should be placed below slabs to provide a firm and consistent subgrade and promote even curing of the concrete.

3. Vapor Barrier

A vapor barrier should be placed below slabs in areas which will receive sensitive floor coverings or coverings which are impermeable. Vapor barriers also provide protection from salt and sulfate attack.

D. **Lateral Earth Pressures**

1. Lateral Resistance for Footings

Lateral resistance for spread footings is controlled by sliding resistance developed between the footing and the subgrade soil. An ultimate friction value of 0.40 may be used in design for ultimate lateral resistance of footings bearing on properly compacted on-site soils. The friction value may be increased to 0.45 if the foundations bear on imported structural fill.

2. Retaining Structures

The following equivalent fluid weights are given for design of subgrade walls and retaining structures. The active condition is where the wall moves away from the soil. The passive condition is where the wall moves into the soil and the at-rest condition is where the wall does not move. We recommend the basement walls be designed in an at-rest condition.

The values listed below assume a horizontal surface adjacent the top and bottom of the wall.

Description	Active	At-Rest	Passive
Granular Backfill - Equivalent Fluid Weight	35 pcf	55 pcf	325 pcf
Granular Backfill- Earth Pressure Coefficient	0.28	0.44	-
Fine-Grained Backfill, (Processed/mixed mudstone) - Equivalent Fluid Weight	50 pcf	65 pcf	190 pcf
Fine-Grained backfill - Earth Pressure Coefficient	0.36	0.55	-

Care should be taken to prevent percolation of surface water into the backfill material adjacent to the retaining walls. The risk of hydrostatic buildup can be reduced by placing a subdrain behind the walls consisting of free-draining gravel wrapped in a filter fabric.

3. Seismic Conditions

Under seismic conditions, the equivalent fluid weight should be modified as follows according to the Mononobe-Okabe method assuming a level backfill condition:

Lateral Earth Pressure Condition	Seismic Modification (2% PE in 50 yrs)	
	Granular Backfill	Fine-Grained Backfill
Active	9 pcf increase	10 pcf increase
At-rest	no increase	no increase
Passive	22 pcf decrease	16 pcf decrease

The resultant of the seismic increase should be placed up ½ the distance up from the base of the wall.

4. Safety Factors

The values recommended assume mobilization of the soil to achieve the assumed soil strength. Conventional safety factors used for structural analysis for such items as overturning and sliding resistance should be used in design.

E. Seismicity, Liquefaction and Faulting

1. Listed below is a summary of the site parameters as required by the 2018 International Building Code and ASCE 7-16:

Description	Seismic Parameter
	2,500 yr event (≈2% PE in 50 yrs)
Site Class	C
S_s (0.2 second period)	0.50g
S_1 (1 second period)	0.16g
PGA	0.22g
F_a	1.30
F_v	1.50
F_{pga}	1.20

The values provided above were generated using the ASCE 7-16 Seismic Hazard Tool. Based on the observed subsurface conditions, a ground motion hazard analysis (GMHA) as per ASCE 7-16 is not required by the 2018 International Building Code.

2. Liquefaction

Based on subsurface conditions encountered in the borings and the test pits, the subsurface soils and bedrock observed are non-liquefiable during a seismic event.

3. Faulting

Based on a review of available geologic literature, there are no mapped faults extending near or through the site.

F. **Soil Corrosion**

Based upon our experience in the area, the on-site soils, bedrock, and many imported sources may contain sulfates in sufficient concentration to be corrosive to concrete. Therefore, we recommend concrete elements that will be exposed to the on-site soils be designed in accordance with provisions provided in the American Concrete Institute Manual of Concrete Practice (ACI) 318-14. Tables 19.3.1.1 and 19.3.2.1 of ACI 318-14 should be referenced for design of concrete elements utilizing a Sulfate Exposure Class of S2.

Consideration should also be given to cathodic protection of buried metal pipes. We recommend utilizing PVC pipes where local building codes allow.

G. **Roadway-Pavements**

1. Subgrade Support

We anticipate that the subgrade materials beneath the pavement areas will consist of clayey sand and sandy lean clay. A California Bearing Ratio (CBR) of 5 percent was assumed for a properly compacted subgrade for purposes of design.

2. Pavement Thickness

Based on the assumed traffic loadings and St. George City traffic indexes, a 20-year design life, and AASHTO design methods, the following pavement sections are recommended.

Pavement Section		
Location	**Asphaltic Concrete (inches)**	**Base Course (inches)**
Interior Roads/Parking	2.5	8
Dumpster Pad*	3	8
Entry Area (focused traffic) **	3	8

* We also recommend that 5 inches of Portland Cement Concrete (PCC) overlying 8 inches of base course be considered in the dumpster pad area.
** AGEC recommends that the entry and areas of focused traffic be increased to 3 inches of asphaltic concrete.

3. Pavement Materials

The pavement materials should meet City of St. George specifications for gradation and quality. The pavement thicknesses indicated above assume that the base course is a high quality material with a CBR of at least 50 percent and the asphaltic concrete has a minimum Marshall stability of 1,800 pounds. Other materials may be considered for use in the pavement section. The use of other materials may result in other pavement material thicknesses.

4. Drainage

The collection and diversion of drainage away from the pavement surface is extremely important to the satisfactory performance of the pavement section. Proper drainage should be provided.

H. Construction Testing and Observations

We recommend the following testing and observations be done as a minimum as required by the City of St. George.

1. Observe grubbing and verify removal of soil containing roots and organics.

2. Observe that recommended overexcavation depths are achieved in the building pads and beneath roadways. The lateral extent of the building pad should be located by survey (not included in AGEC's Scope of Services) and include the area which extends at least 5 feet beyond the buildable area as per city set-back requirements. Additional test pits and engineering observation may be necessary during site/pad grading to assist in locating and defining the potentially expansive layers of mudstone bedrock.

3. Observe that recommended structural fill depths are provided below foundations and slabs.

4. Conduct compaction testing on fill placed below foundations and in building pads. We recommend testing each foot of fill placed.

5. Conduct construction materials testing on city improvements at a frequency which meets or exceeds St. George City requirements.

6. If deep foundations are used, provide special inspections per the IBC or structural engineer requirements.

I. Geotechnical Recommendation Review

The client should familiarize themselves with the information contained in this report. If specific questions arise or if the client does not fully understand the conclusions/recommendations provided, AGEC should be contacted to provide clarification.

LIMITATIONS

This report has been prepared in accordance with generally accepted soil and foundation engineering practices in the area for the use of the client for design purposes. The conclusions and recommendations included within the report are based on the information obtained from the field and laboratory testing, the information from the referenced studies and our experience in the area. Variations in the subsurface conditions may not become evident until excavation is conducted. If the subsurface conditions are found to be significantly different from those described above, we should be notified to reevaluate our recommendations.

If you have any questions or if we can be of further service please call.

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.



G. Wayne Rogers, P.E.

Reviewed by JRH, P.E.

P:\2022 Project Files\2221800\2221859 - GT - Rosewood To rt.wpd



ROSEWOOD TOWNHOMES
ST. GEORGE, UTAH

N

Not to Scale

2221859	AGEC	Vicinity Map	Figure 1

ROSEWOOD TOWNHOMES
ST. GEORGE, UTAH

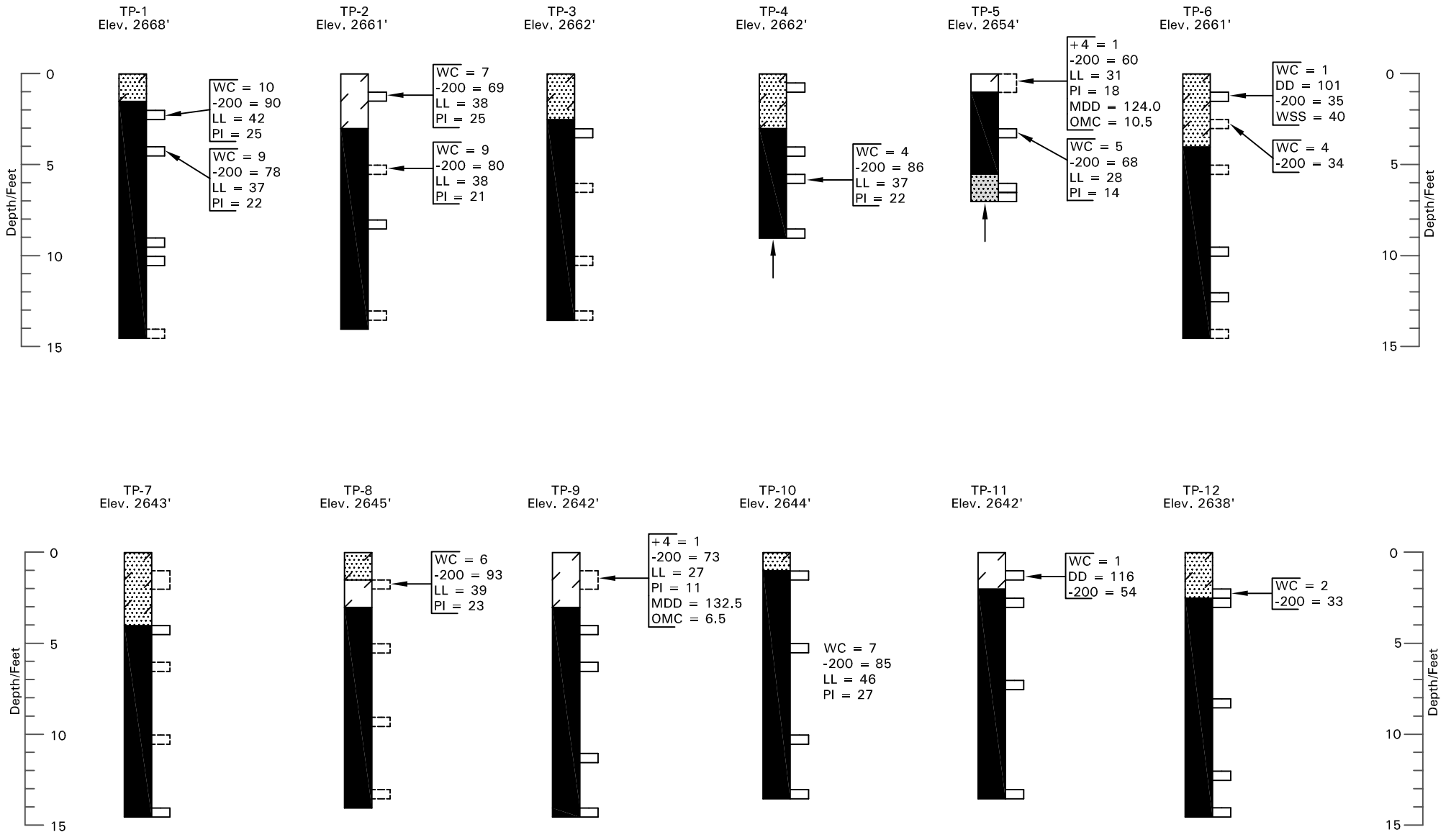


⊠ Approximate test pit location

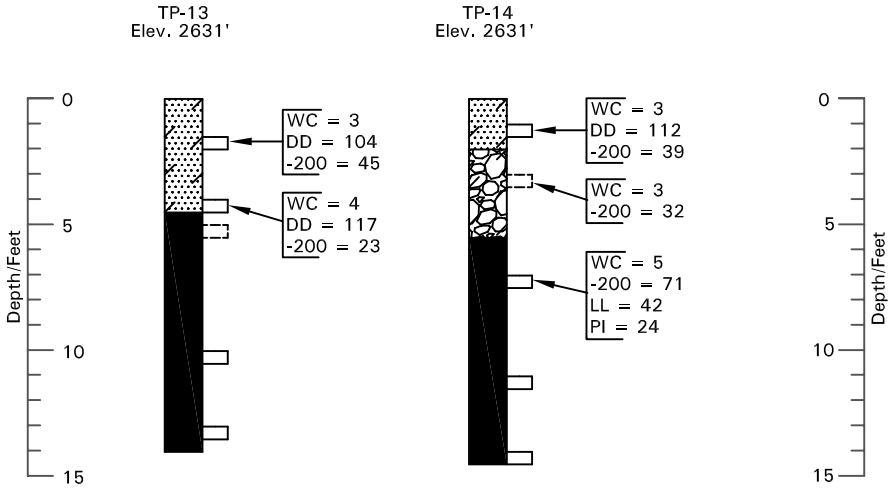
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0 100 200 feet

2221859	AGEC	Site Plan	Figure 2



2221859	AGEC	Logs of Test Pits	Figure 3



LEGEND:

Sandy Lean Clay (CL); consists of weathered mudstone mixed with varied amounts of sand and gravel, stiff to very stiff, dry to slightly moist, brown to grey in color.

Clayey Sand (SC); occasional gravel, subrounded, some cobbles, loose to medium dense, dry to slightly, brown in color.

Clayey Gravel with Sand (GC); contains varied amounts of sand with occasional cobbles, medium dense to dense, dry to slightly moist, brown in color.

Mudstone Bedrock; soft to moderately hard, slightly moist, medium to highly plastic, grey to red to purple in color.

Sandstone Bedrock; moderately hard, dry, grey in color.

Indicates relatively undisturbed block sample taken.

Indicates disturbed sample taken.

Indicates practical excavator refusal on bedrock.

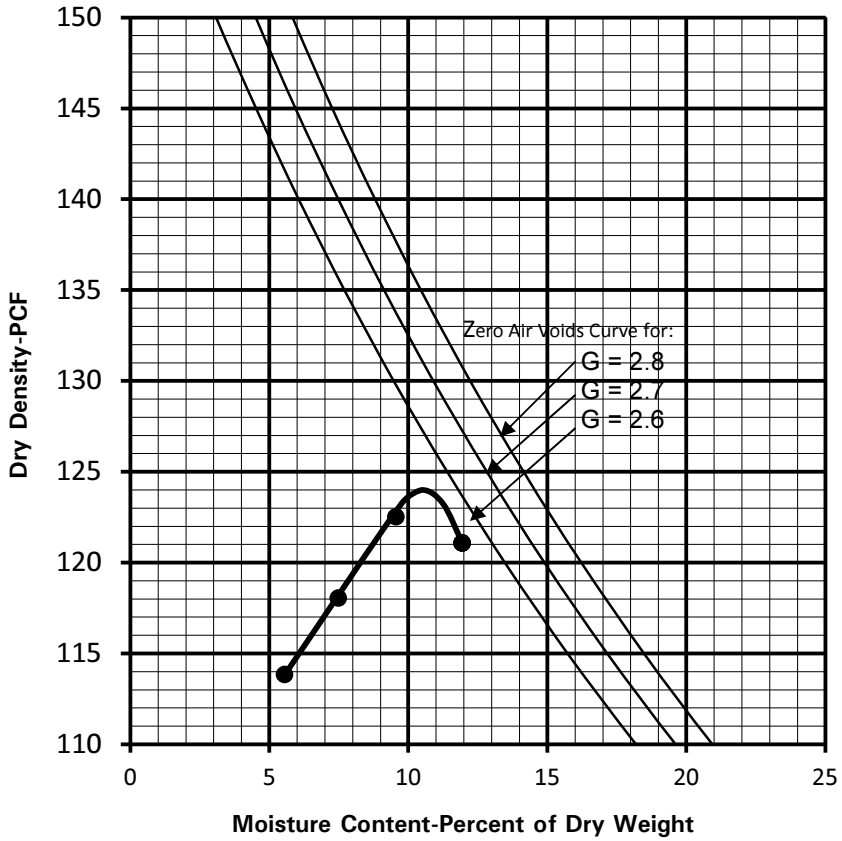
NOTES:

1. The test pits were excavated on September 12, 2022 with a track mounted excavator.
2. The locations of the test pits were measured by a hand held GPS as shown on the site plan, Figure 2.
3. The elevations of the test pits were determined by interpolation between the contours of the site plan provided.
4. The test pit locations and elevations should be considered accurate only to the degree implied by the method used.
5. The lines between the materials shown on the test pit logs represent the approximate boundaries between material types and the transitions may be gradual.
6. Free water was not encountered in the test pits at the time of excavation.
7. WC = water content (%);
   DD = dry density (pcf);
   +4 = percent retained on the No. 4 sieve;
   -200 = percent passing No. 200 sieve;
   LL = liquid limit (%);
   PI = plasticity index (%);
   MDD = maximum dry density (pcf);
   OMC = optimum moisture content (%);
   WSS = water soluble sulfates (ppm).

AGEC

Applied GeoTech

Project: Rosewood Townhomes



Sample Date:	10/12/22
Sample No.	221013B
Maximum Dry Density:	124.0
Optimum Moisture:	10.5
Atterberg Limits	
Liquid Limit:	31%
Plasticity Index:	18%
Gradation	
Gravel:	1%
Sand:	39%
Silt & Clay:	60%

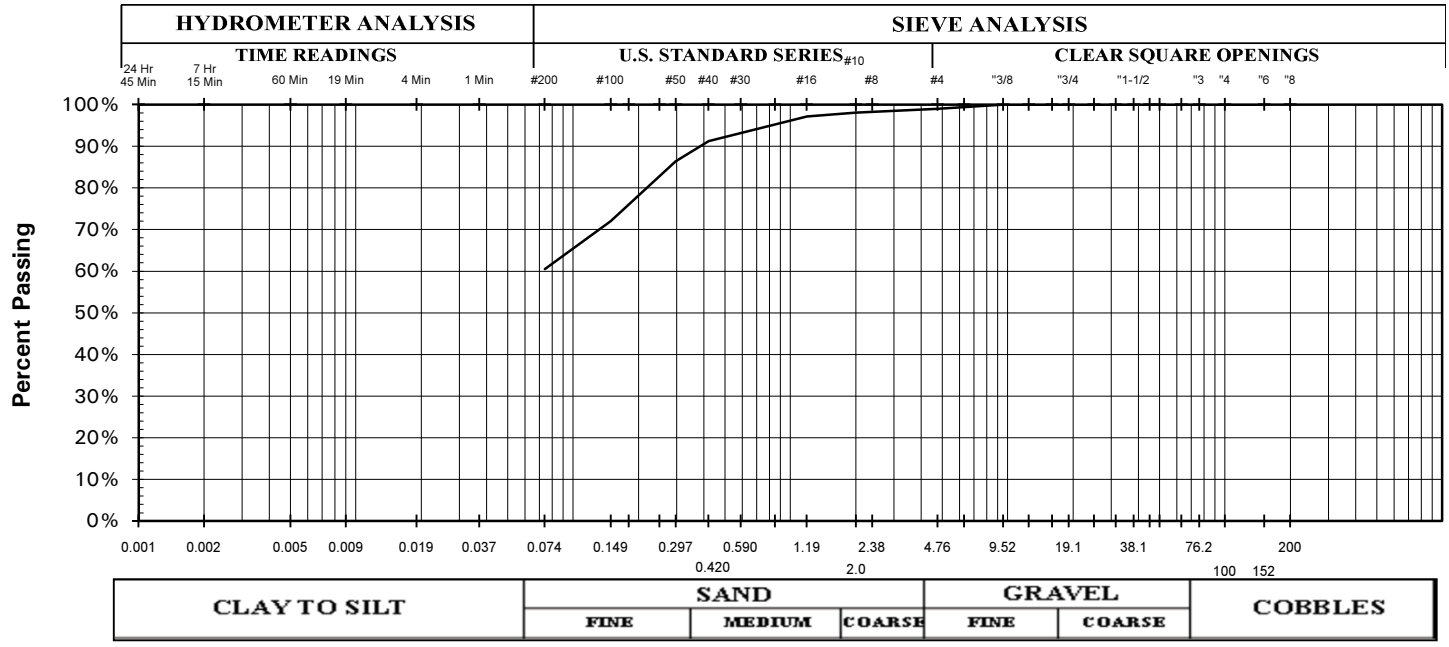
Moisture - Density Relationship Test Procedure: ASTM D-1557 B

Reviewed By: TT

USCS Classification: sandy lean clay (CL)

AASHTO Classification: A-6

Sample Location: TP-5 @ 0-1'



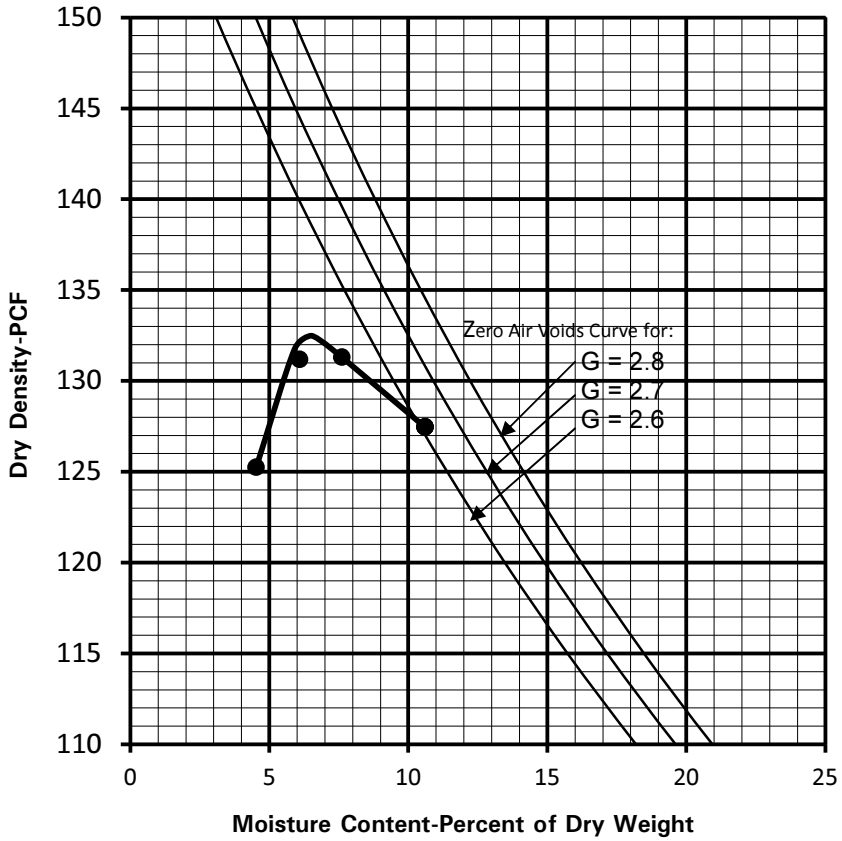
GRADATION AND MOISTURE-DENSITY RELATIONSHIP RESULTS

Project No.: 2221859

Figure: 5

AGEC
Applied GeoTech

Project: Rosewood Townhomes



Sample Date:	10/12/22
Sample No.	221013C
Maximum Dry Density:	132.5
Optimum Moisture:	6.5

Atterberg Limits

Liquid Limit:	27%
Plasticity Index:	11%

Gradation

Gravel:	1%
Sand:	26%
Silt & Clay:	73%

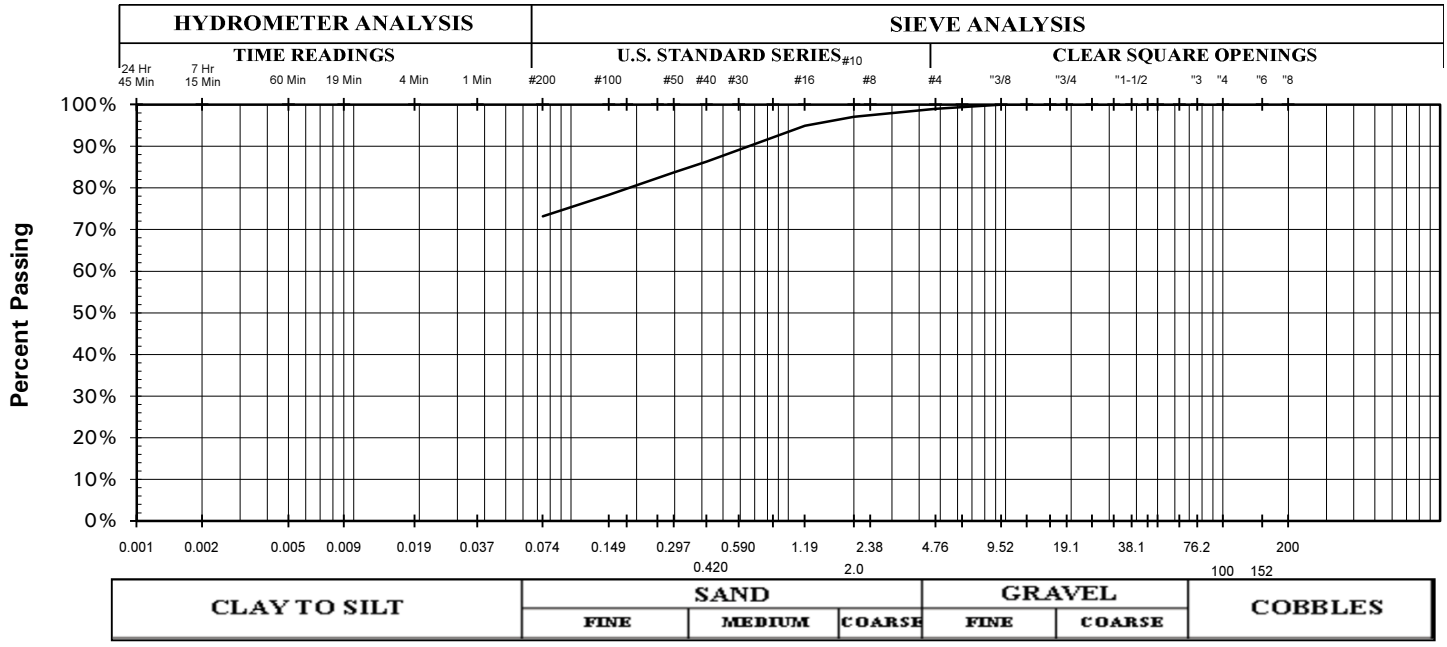
Moisture - Density Relationship Test Procedure: ASTM D-1557 B

Reviewed By: TT

USCS Classification: lean clay with sand (CL)

AASHTO Classification: A-6

Sample Location: TP-9 @ 1-2'



GRADATION AND MOISTURE-DENSITY RELATIONSHIP RESULTS

Project No.: 2221859

Figure: 6

Applied Geotechnical Engineering Consultants, Inc.

Table 1 - Summary of Laboratory Test Results

Rosewood Townhomes

Project No. 2221859

Sample Location				Gradation			Atterberg Limits		Moisture-Density Relationship			
Test Pit No.	Depth (ft)	Natural Moisture Content (%)	Natural Dry Density (pcf)	Gravel (%)	Sand (%)	Silt/Clay (%)	Liquid Limit (%)	Plastic Index (%)	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	Water Soluble Sulfates (ppm)	Soil Type
TP-1	2	10				90	42	25				Mudstone Bedrock
TP-1	8	9				78	37	22				Mudstone Bedrock
TP-2	1	7				69	38	25				Sandy Lean Clay (CL)
TP-2	5	9				80	38	21				Mudstone Bedrock
TP-4	6	4				86	37	22				Mudstone Bedrock
TP-5	0-1			1	39	60	31	18	124.0	10.5		Sandy Lean Clay (CL)
TP-5	3	5				68	28	14				Mudstone Bedrock
TP-6	1	1	101			35					40	Clayey Sand (SC)
TP-6	2½	4				34						Clayey Sand (SC)
TP-8	1½	6				93	39	23				Lean Clay (CL)
TP-9	1-2			1	26	73	27	11	132.5	6.5		Sandy Lean Clay (CL)
TP-10	5	7				85	46	27				Mudstone Bedrock
TP-11	1	1	116			54						Sandy Lean Clay (CL)
TP-12	2	2				33						Clayey Sand (SC)
TP-13	1½	3	104			45						Clayey Sand (SC)

Applied Geotechnical Engineering Consultants, Inc.

Table 1 - Summary of Laboratory Test Results

Rosewood Townhomes

Project No. 2221859

Sample Location				Gradation			Atterberg Limits		Moisture-Density Relationship			
Test Pit No.	Depth (ft)	Natural Moisture Content (%)	Natural Dry Density (pcf)	Gravel (%)	Sand (%)	Silt/Clay (%)	Liquid Limit (%)	Plastic Index (%)	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	Water Soluble Sulfates (ppm)	Soil Type
TP-13	4	4	117			23						Clayey Sand (SC)
TP-14	1	3	112			39						Clayey Sand (SC)
TP-14	3	3				32						Clayey Gravel (GC)
TP-14	7	5				71	42	24				Mudstone Bedrock

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.

TABLE 2
DRILLED MICROPILE DESIGN PARAMETERS

Rosewood Townhomes Project No. 2221859

Soil Type	Soil Properties				Lateral Design Parameters			Axial Design Parameters	
	Effective Unit Weight (pcf)	Unconfined Compressive Strength (psf)	Cohesion (psf)	Friction Angle (Degrees)	Horizontal Modulus (pci)	Ultimate Passive Resistance (psf)	Strain @ 50% Yield (k_{rm})	Ultimate Skin Friction (psf)	Ultimate Uplift Skin Friction (psf)
Active Mudstone (upper 10 feet)	100	6,000	3,000	0	2,000	27,000	0.006	1,500	1,000
Firm Mudstone (> 10 feet)	130	12,000	6,000	0	3,000	54,000	0.004	2,000	1,350

APPENDIX

SITE AND TEST PIT PHOTOS



Photo No. 1, View of property from near SEC looking NW.



Photo No. 2, View of property from near SWC, looking east along Curly Hollow Drive



Photo No. 3, View of property from SWC looking north along 1150 West Street



Photo No. 4, View of property from near NEC looking south.



Photo No. 5, View of property from near NEC looking SW.



Photo No. 6, view of Test Pit TP-1



Photo No. 7, View of Test Pit TP-1, Arrow indicates approximate boundary or top of mudstone/blue clay



Photo No. 8, View of Test Pit TP-1, excavated material.



Photo No. 9, View of Test Pit TP-13



Photo No. 10, View of Test Pit, TP-13 excavated material



Photo No. 11, View of Test Pit, TP-14



Photo No. 12, View of Test Pit, TP-14 excavated material

DRAINAGE CONTROL REPORT- DRAFT

Rosewood Townhomes
St. George, Utah

Prepared For:
Stewart Enterprises
720 South River Road, Suite A-115
St. George, UT 84790
(435) 703-4302



Rosenberg Associates
Project No: 13231-22

January 3, 2023

This report for the drainage design of Rosewood Townhomes was prepared by me (or under my direct supervision) in accordance with the provisions of Washington County Flood Control Authority (WCFCA) Storm Drainage Systems Design and Management Manual and was designed to comply with the provisions thereof. I understand that the City of St. George and WCFCA do not and will not assume liability for drainage facilities design.

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APPENDIX A – GENERAL

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Figure 2 – *Existing Conditions*
Figure 3 – *Developed Conditions*
Figure 4 – *FEMA - Flood Insurance Rate Map*
NRCS Soil Report
NOAA Atlas 14 – Point Precipitation Frequency Estimates
Farmer-Fletcher Modified 3-hr Distribution Table

APPENDIX B – EXISTING CONDITIONS DRAINAGE

HEC-HMS Model Diagram
Existing Watershed Hydrology Model Input Spreadsheets
Existing Conditions HEC-HMS Model and Output Tables

APPENDIX C – DEVELOPED CONDTIONS DRAINAGE

HEC-HMS Model Diagram
Developed Watershed Hydrology Model Input Spreadsheets
Developed Conditions HEC-HMS Model and Output Tables
Detention Calculations
Flow Master Worksheet output
MS4 Retention Volume Calculation

1.0 PROJECT LOCATION

The proposed Rosewood Townhomes project includes construction of 136 townhomes and street improvements in St. George, Utah. Proposed improvements are located north of Curly Hollow Drive and east of 1150 Street, within Section 2, Township 43 South, Range 16 West, Salt Lake Base and Meridian.

See Figure 1 in Appendix, *Vicinity Map*

2.0 EXISTING DRAINAGE CONDITIONS

2.1 EXISTING ON-SITE DRAINAGE

The 14.99 acre project area is comprised of natural desert vegetation, with slopes ranging from 5.0 – 24.4% to the south. Onsite soils are mostly comprised of *Eroded land-Shalet complex (EB)* – hydrologic soil type "D", with *Junction fine sandy loam (JaC)* – hydrologic soil type "A" within the southern section of the property. Stormwater generated within the site generally sheet flows to the south towards Curly Hollow Road.

2.2 EXISTING OFF-SITE DRAINAGE

Runoff generated from areas north of the project area currently sheet flows to the south and enters the site. Runoff from areas west of the site is routed south along 1150 W Street and does not enter the site. Runoff generated within areas east and south of the site do not enter the site as these areas are lower in elevation than the project area.

See Figure 2 in Appendix, *Existing Drainage Conditions*

2.3 PREVIOUS DRAINAGE STUDIES/RELATED DRAINAGE STUDIES

No previous drainage studies were referenced for this project.

2.4 MASTER PLANNING INFORMATION

As per the City of St. George Storm Water Master Plan (2009), a 42" storm drain system is to be installed along the south side of W Curly Hollow Drive. Since 2009, an elliptical RCP line has been installed at this location. No further proposed improvements are recommended with this project's vicinity per the City of St. George Storm Water Master Plan (2009). Upsizing of the lines that run east and then south at the intersection of Road D and W Curly Hollow Drive is required to accommodate flows exiting the project area.

2.5 FLOODPLAIN AND EROZION HAZARD INFORMATION

According to the FEMA Flood Insurance Rate Map[1] numbered 49053C1028G, dated April 2, 2009, the site is located in Zone X.

See Figure 4 in Appendix, *Excerpt from FEMA Flood Insurance Rate Map.*

[1] National Flood Insurance Program, Flood Insurance Rate Map, Washington County, Utah Map Number 49053C 1028G, Effective Date April 2, 2009.

2.6 REQUIRED PERMITS/PLANS

Proposed earthwork will require a Grading Permit and the proposed Storm Water Pollution Prevention Plan (SWPPP) should comply with the City of St. George established best management practices. The grading plan and SWPPP (including NOI and NOT) will be submitted independent of this study prior to construction.

2.7 HILLSIDE CONCERNS

The proposed project falls within hillside overlay ordinance Bloomington Ridge 9-1992. The project will be presented to the hillside committee for review and approval.

3.0 DEVELOPED DRAINAGE CONDITIONS

3.1 DEVELOPED ON-SITE DRAINAGE

Runoff generated in the eastern section of Subarea A sheet flows into curb and gutter and is routed south to be intercepted by storm drain inlets along 1150 W Street or Road C. Runoff generated in the western section of Subarea A flows to the east and does not enter the site. Runoff generated in Subarea B flows south to be intercepted by a storm drain inlet along Road C. Runoff generated in Subarea C flows south into curb and gutter and is routed east to be intercepted by storm drain inlets along Road C. Runoff generated in the northern section of Subarea D flows north to curb and gutter and is routed east and then west to be intercepted by storm drain inlets along Road B. Runoff generated in the southern section of Subarea D flows south to curb and gutter and is routed west to be intercepted by storm drain inlets along Road B. Runoff generated in Subarea E flows east to curb and gutter and is routed south to be intercepted by storm drain inlets along Road D. Runoff generated in Subarea F flows east to be intercepted by a drainage swale that routes flows south to W Curly Hollow Drive. Runoff generated in the eastern portion of Subarea G flows north to curb and gutter and is routed east to be intercepted by storm drain inlets along Road B. Runoff generated in the western portion of Subarea G flows north to curb and gutter and is routed west to be intercepted by storm drain inlets along Road B. Runoff generated in Subarea H flows south to curb and gutter and is routed east to be intercepted by storm drains along Road A or Road D. Runoff generated in Subarea I flows north to curb and gutter and is routed east to be intercepted by storm drain inlets along Road A. Runoff generated in Subarea J flows south to landscape drains and is routed east to storm drain inlets along Road D.

Building finished floor elevations shall be at or above elevations shown on the construction plans to enable runoff to drain from the structures to the roadways.

3.2 DEVELOPED OFF-SITE DRAINAGE

Runoff generated in Subarea off A flows south into proposed drainage swales and is routed west or east to be intercepted by a 2X2 catch basin north of Road C.

See Figure 3 in Appendix, *Developed Drainage Conditions*

4.0 HYDROLOGIC ANALYSIS

4.1 HYDROLOGIC CALCULATIONS

HEC-HMS[2] Version 4.9 was used to perform the hydrologic analysis for this study. Curve numbers for existing and developed conditions were calculated using a custom Natural Resources Conservation Service (NRCS) Soil Report and the TR-55 Table 2-2a, which assumes directly connected impervious areas. Time of concentration (T_c) was calculated as 0.6 times the Travel Time (T_t) as included in TR-55 which is based on the summation of sheet flow, shallow concentrated flow, and channel flow for each subarea (TR-55 eqs. 3-1 through 3-4). A modified Farmer-Fletcher distribution is used for the 3-hour storm events (the distribution is modified based on the local 1 hour and 3 hour rainfall depths) and the SCS Type II distribution is used for the 24-hour storm events. Simulated precipitation values were determined using the Point Precipitation Frequency Estimates (Latitude: 37.1029˚, Longitude: -113.6465˚) from the NOAA Atlas 14[3]. Utilizing the model input values listed in Tables 1 & 2, the HEC-HMS model yielded the design storm peak flow values summarized in Tables 3 & 4.

TABLE 1 – HYDRAULIC MODEL INPUT – EXISTING CONDITIONS

Subarea		Area		SCS	Flow Length	Average Slope	Lag Time	
Name	Description	(acre)	(sq mi)	CN	(ft.)	S (%)	(hr.)	(min)
SUB A	Site	14.99	0.02342	81	842	4.6%	0.06	3.709
OFF A	North of site	5.79	0.00905	88	457	10.4%	0.03	1.728

TABLE 2 – HYDRAULIC MODEL INPUT – DEVELOPED CONDITIONS

Subarea		Area		SCS	Flow Length	Average Slope	Lag Time	
Name	Description	(acre)	(sq mi)	CN	(ft.)	S (%)	(hr.)	(min)
SUB A	Northwest of townhomes	0.64	0.00100	94	194	6.6%	0.00	0.165
SUB B	Northwest portion north of Road C	0.32	0.00050	94	300	4.2%	0.02	1.341
SUB C	North of Road C	3.83	0.00598	94	796	3.2%	0.06	3.370
SUB D	In between Road C and Road B	1.76	0.00275	95	1,026	1.3%	0.03	2.100
SUB E	East of Road D, flows west	1.40	0.00218	95	714	4.1%	0.02	1.070
SUB F	East of Road D, flows east	0.90	0.00140	85	172	3.3%	0.01	0.776
SUB G	South of Road B, flows north	1.53	0.00238	97	592	1.2%	0.03	1.761
SUB H	North of Road A, flows south	2.91	0.00455	90	735	2.9%	0.05	2.982
SUB I	South of Road A, flows north	1.05	0.00165	97	653	1.1%	0.03	1.924
SUB J	South of Road A, flows south	0.66	0.00103	76	99	3.2%	0.01	0.712
OFF A	North of site	5.79	0.00905	88	457	10.4%	0.03	1.728

[2] U.S. Army Corps of Engineers, Hydraulic Engineering Circular Hydrologic Modeling System (HEC-HMS) software, Version 4.9

[3] NOAA's National Weather Service. Precipitation Frequency Data Server. Retrieved November 30, 2022

TABLE 3 – HYDRAULIC MODEL OUTPUT – EXISTING CONDITIONS

Subarea		3-Hour Storm		24-Hour Storm	
		Existing		Existing	
Name	Description	10-Year (cfs)	100-Year (cfs)	10-Year (cfs)	100-Year (cfs)
SUB A	Site	1.6	11.1	2.7	7.6
OFF A	North of Site	2.3	8.7	2.3	4.8
SITE	Site Outfall	3.8	18.7	5.0	12.4

TABLE 4 – HYDRAULIC MODEL OUTPUT – DEVELOPED CONDITIONS

Subarea		3-Hour Storm		24-Hour Storm	
		Developed		Developed	
Name	Description	10-Year (cfs)	100-Year (cfs)	10-Year (cfs)	100-Year (cfs)
SUB A	Northwest of townhomes	0.6	1.6	0.4	0.7
SUB B	Northwest portion north of Road C	0.3	0.8	0.2	0.4
SUB C	North of Road C	3.6	9.1	2.6	4.4
SUB D	In between Road C and Road B	1.9	4.7	1.3	2.1
SUB E	East of Road D, flows west	1.6	3.8	1.0	1.7
SUB F	East of Road D, flows east	0.2	1.0	0.3	0.6
SUB G	South of Road B, flows north	2.3	5.1	1.3	2.0
SUB H	North of Road A, flows south	1.6	5.2	1.4	2.8
SUB I	South of Road A, flows north	1.5	3.4	0..9	1.3
SUB J	South of Road A, flows south	<0.1	0.3	<0.1	0.2
OFF A	North of site	2.3	8.7	2.3	4.8
SITE	Site Outfall	15.7	42.0	11.8	21.0

4.2 COMPARISON OF PEAK FLOW VALUES

Based on information shown in Tables 3 and 4, the proposed development increases runoff within the site 21 CFS [Post (SITE) - Pre (SITE)] during the 100-year 3-hour event.

5.0 PROPOSED DRAINAGE IMPROVEMENTS

5.1 STORMDRAIN DESIGN

The runoff generated within the proposed development is generally routed to the south, with flows intercepted by inlets on grade or in sag as mentioned in the Developed Onsite Drainage section. All flow is routed through poly pipes ranging in size from 12" to 24". See the construction plans for pipe sizes and locations. The existing storm drain pipe that runs east and then south at the intersection of Road D and Curly Hollow Drive is to be removed and replaced to accommodate proposed flow volumes.

The proposed storm drain is designed to convey the onsite and offsite 100-year 3-hour event. See the Appendix for hydraulic calculations.

5.2 DETENTION & RETENTION

The City of St. George Drainage Manual requires the peak storm runoff exiting a site not be increased by new development. Detention facilities are to be designed to attenuate the peak from the 100-year, 24-hour storm, 10-year, 24-hour storm, or the 100-year, 3-hour storm, whichever case requires the largest storage volume. For this site, the 100-year 3-hour storm controlled, producing a required detention of 18,450 cubic feet. Detention facilities are not recommended for this project as improvements reduce overall site runoff.

The Small Municipal Separate Storm Sewer System (MS4) General Permit requires new development to prevent the off-site discharge of the precipitation from all rainfall events less than or equal to the 80th percentile rainfall event or a predevelopment hydrologic condition, whichever is less. The 80th percentile depth for the Dixie Storm Water Coalition Region is 0.44-inches. Based on the retention volume equation #1, the Water Quality Retention Volume (WQRV) required for this site is 12,210.43 ft^3. For this site, no retention options are available due to technical infeasibilities as listed in the Geotech report.

The proposed Low Impact Development (LID) Best Management Practices (BMPs) proposed with this development are consistent with the findings and recommendations provided with the Geotechnical Investigation – Rosewood Townhomes document prepared by AGEC, December 2, 2022.

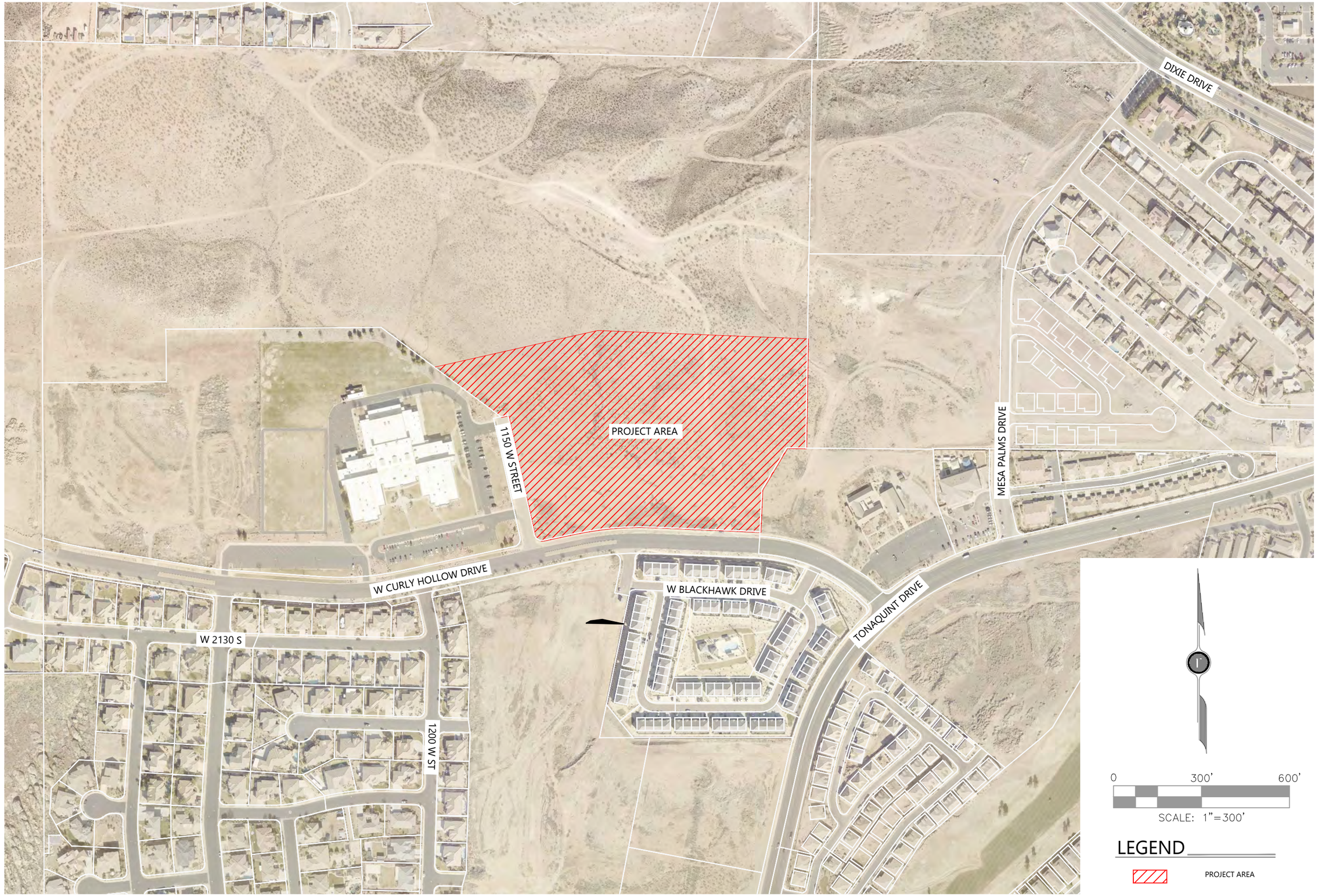
A copy of the Stormwater Quality Report is included with the Appendix.

6.0 CONCLUSIONS

It is the opinion of Rosenberg Associates that the proposed recommendations and drainage improvements included in this study and shown in the improvement plans will effectively convey storm water through the site. Drainage improvement designs are intended to be compliant with the City of St. George drainage requirements and computations/methods used to create designs were completed using the current standard of care.

APPENDIX A

Figure 1 – *Vicinity Map*
Figure 2 – *Existing Conditions*
Figure 3 – *Developed Conditions*
Figure 4 – *FEMA - Flood Insurance Rate Map*
NRCS Custom Soil Resource Report
NOAA Atlas 14 – Point Precipitation Frequency Estimate
Farmer-Fletcher Modified 3-hour Distribution Table



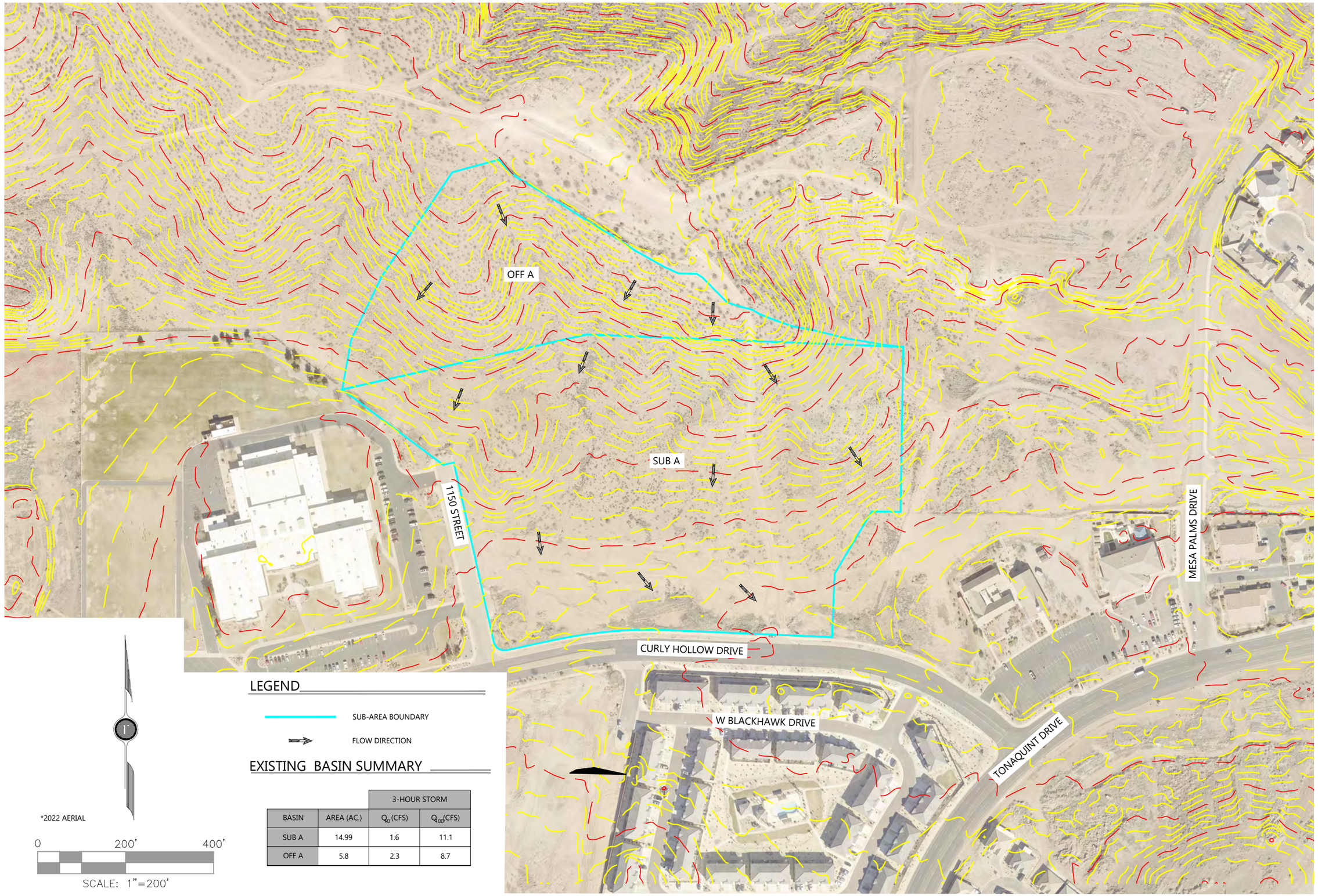
DATE:	11/30/2022
JOB NO.:	13231-22
DESIGNED BY:	WJP
CHECKED BY:	JWB
DWG:	VICINITY

REVISIONS DATE

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VICINITY MAP
FOR
ROSEWOOD TOWNHOMES
ST. GEORGE
UTAH

SHEET
1
1 OF 4 SHEETS



*2022 AERIAL

0 200’ 400’

SCALE: 1”=200’

LEGEND

SUB-AREA BOUNDARY

FLOW DIRECTION

EXISTING BASIN SUMMARY

		3-HOUR STORM	
BASIN	AREA (AC.)	Q_0 (CFS)	Q_{100}(CFS)
SUB A	14.99	1.6	11.1
OFF A	5.8	2.3	8.7

DATE: 11/30/2022
JOB NO.: 13231-22
DESIGNED BY: WJP
CHECKED BY: JWB
DWG: EXISTING COND

REVISIONS DATE

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EXISTING CONDITIONS
FOR
ROSEWOOD TOWNHOMES
ST. GEORGE
UTAH

SHEET
2
2 OF 4 SHEETS

LEGEND

SUB-AREA BOUNDARY

FLOW DIRECTION

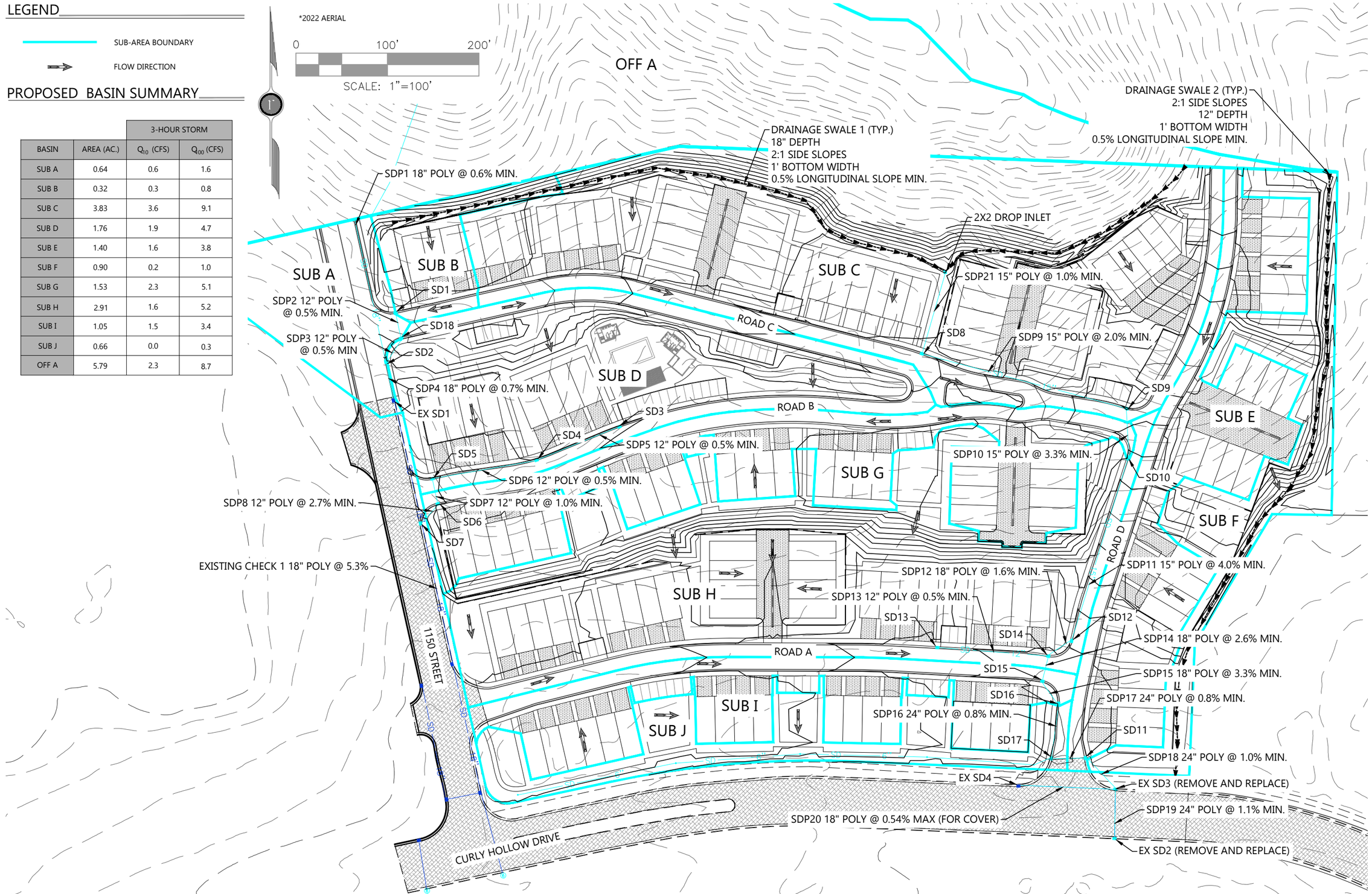
PROPOSED BASIN SUMMARY

		3-HOUR STORM	
BASIN	AREA (AC.)	Q_{10} (CFS)	Q_{100} (CFS)
SUB A	0.64	0.6	1.6
SUB B	0.32	0.3	0.8
SUB C	3.83	3.6	9.1
SUB D	1.76	1.9	4.7
SUB E	1.40	1.6	3.8
SUB F	0.90	0.2	1.0
SUB G	1.53	2.3	5.1
SUB H	2.91	1.6	5.2
SUB I	1.05	1.5	3.4
SUB J	0.66	0.0	0.3
OFF A	5.79	2.3	8.7

*2022 AERIAL

0 100' 200'

SCALE: 1"=100'



DATE: 12/9/2022
JOB NO.: 13231-22
DESIGNED BY: WJP
CHECKED BY: JWB
DWG: PROPOSED COND

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DATE

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PROPOSED CONDITIONS
FOR
ROSEWOOD TOWNHOMES
ST. GEORGE
UTAH

SHEET
3
3 OF 4 SHEETS

National Flood Hazard Layer FIRMette

FEMA

113°36'41"W 37°4'39"N



0 250 500 1,000 1,500 2,000 Feet

1:6,000

113°36'3"W 37°4'10"N

Basemap: USGS National Map: Orthoimagery: Data refreshed October, 2020

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

- **SPECIAL FLOOD HAZARD AREAS**
  - Without Base Flood Elevation (BFE) *Zone A, V, A99*
  - With BFE or Depth *Zone AE, AO, AH, VE, AR*
  - Regulatory Floodway
- **OTHER AREAS OF FLOOD HAZARD**
  - 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
  - Future Conditions 1% Annual Chance Flood Hazard *Zone X*
  - Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
  - Area with Flood Risk due to Levee *Zone D*
- **OTHER AREAS**
  - NO SCREEN Area of Minimal Flood Hazard *Zone X*
  - Effective LOMRs
  - Area of Undetermined Flood Hazard *Zone D*
- **GENERAL STRUCTURES**
  - Channel, Culvert, or Storm Sewer
  - Levee, Dike, or Floodwall
- **OTHER FEATURES**
  - 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
  - Coastal Transect
  - Base Flood Elevation Line (BFE)
  - Limit of Study
  - Jurisdiction Boundary
  - Coastal Transect Baseline
  - Profile Baseline
  - Hydrographic Feature
- **MAP PANELS**
  - Digital Data Available
  - No Digital Data Available
  - Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 11/29/2022 at 1:25 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

LEGEND

PROJECT AREA

1"

DATE:	11/30/2022
JOB NO.:	13231-22
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DWG:	FIRM

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SHEET
4
4 OF 4 SHEETS

United States Department of Agriculture

NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for Washington County Area, Utah



November 30, 2022

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil

scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and

identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report
Soil Map



Map Scale: 1:4,980 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 50 100 200 300

Feet: 0 200 400 800 1200

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 12N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Washington County Area, Utah
Survey Area Data: Version 16, Aug 31, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jun 1, 2018—Aug 1, 2018

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
EB	Eroded land-Shalet complex, warm	66.3	52.6%
GP	Gravel pits	6.1	4.8%
JaC	Junction fine sandy loam, 2 to 5 percent slopes	35.9	28.5%
WBD	Winkel gravelly fine sandy loam, 1 to 8 percent slopes	17.7	14.0%
Totals for Area of Interest		**126.0**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate

pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Washington County Area, Utah

EB—Eroded land-Shalet complex, warm

Map Unit Setting

National map unit symbol: j8ds
Elevation: 3,600 to 5,550 feet
Mean annual precipitation: 10 to 13 inches
Mean annual air temperature: 52 to 56 degrees F
Frost-free period: 165 to 170 days
Farmland classification: Not prime farmland

Map Unit Composition

Eroded land: 78 percent
Shalet and similar soils: 20 percent
Minor components: 2 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Eroded Land

Setting

Landform: Erosion remnants
Parent material: Residuum weathered from shale

Description of Shalet

Setting

Landform: Swales
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Residuum weathered from shale

Typical profile

H1 - 0 to 4 inches: clay loam
H2 - 4 to 12 inches: clay loam
H3 - 12 to 16 inches: weathered bedrock

Properties and qualities

Slope: 2 to 20 percent
Depth to restrictive feature: 4 to 15 inches to paralithic bedrock
Drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately high (0.00 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 20 percent
Gypsum, maximum content: 10 percent
Maximum salinity: Nonsaline to slightly saline (0.0 to 4.0 mmhos/cm)
Sodium adsorption ratio, maximum: 5.0
Available water supply, 0 to 60 inches: Very low (about 2.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s

Hydrologic Soil Group: D
Ecological site: R030XY134UT - Desert Shallow Loam (Creosotebush)
Hydric soil rating: No

Minor Components

Badland
Percent of map unit: 2 percent

GP—Gravel pits

Map Unit Composition
Gravel pit: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Gravel Pit

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8s
Hydric soil rating: No

JaC—Junction fine sandy loam, 2 to 5 percent slopes

Map Unit Setting
National map unit symbol: j8f4
Elevation: 2,700 to 3,400 feet
Mean annual precipitation: 8 to 11 inches
Mean annual air temperature: 57 to 67 degrees F
Frost-free period: 190 to 195 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition
Junction and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Junction

Setting
Landform: Alluvial fans, hills
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Concave, convex
Across-slope shape: Convex

Typical profile

H1 - 0 to 2 inches: fine sandy loam
H2 - 2 to 9 inches: fine sandy loam
H3 - 9 to 21 inches: fine sandy loam
H4 - 21 to 32 inches: fine sandy loam
H5 - 32 to 60 inches: fine sandy loam

Properties and qualities

Slope: 1 to 5 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 20 percent
Gypsum, maximum content: 7 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: Moderate (about 7.2 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: A
Ecological site: R030XY110UT - Desert Loam (Creosotebush)
Hydric soil rating: No

Minor Components

Tobler

Percent of map unit: 5 percent

Harrisburg

Percent of map unit: 5 percent

Junction

Percent of map unit: 5 percent

WBD—Winkel gravelly fine sandy loam, 1 to 8 percent slopes

Map Unit Setting

National map unit symbol: j8h9
Elevation: 2,800 to 4,000 feet
Mean annual precipitation: 8 to 11 inches
Mean annual air temperature: 57 to 61 degrees F
Frost-free period: 190 to 195 days
Farmland classification: Not prime farmland

Map Unit Composition

Winkel and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Winkel

Setting

Landform: Mesas
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Calcareous material weathered from basalt, limestone, and wind-deposited sand.

Typical profile

H1 - 0 to 1 inches: gravelly fine sandy loam
H2 - 1 to 6 inches: gravelly fine sandy loam
H3 - 6 to 12 inches: very gravelly fine sandy loam
H4 - 12 to 16 inches: extremely cobbly fine sandy loam
H5 - 16 to 20 inches: indurated
H6 - 20 to 24 inches: unweathered bedrock

Properties and qualities

Slope: 1 to 8 percent
Depth to restrictive feature: 11 to 19 inches to petrocalcic; 14 to 24 inches to lithic bedrock
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately high (0.00 to 0.60 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 5.0
Available water supply, 0 to 60 inches: Very low (about 1.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: D
Ecological site: R030XY134UT - Desert Shallow Loam (Creosotebush)
Hydric soil rating: No

Minor Components

Harrisburg

Percent of map unit: 5 percent

Lava flows

Percent of map unit: 5 percent

Bermesa

Percent of map unit: 5 percent

Soil Information for All Uses

Soil Reports

The Soil Reports section includes various formatted tabular and narrative reports (tables) containing data for each selected soil map unit and each component of each unit. No aggregation of data has occurred as is done in reports in the Soil Properties and Qualities and Suitabilities and Limitations sections.

The reports contain soil interpretive information as well as basic soil properties and qualities. A description of each report (table) is included.

Soil Physical Properties

This folder contains a collection of tabular reports that present soil physical properties. The reports (tables) include all selected map units and components for each map unit. Soil physical properties are measured or inferred from direct observations in the field or laboratory. Examples of soil physical properties include percent clay, organic matter, saturated hydraulic conductivity, available water capacity, and bulk density.

Physical Soil Properties

This table shows estimates of some physical characteristics and features that affect soil behavior. These estimates are given for the layers of each soil in the survey area. The estimates are based on field observations and on test data for these and similar soils.

Depth to the upper and lower boundaries of each layer is indicated.

Particle size is the effective diameter of a soil particle as measured by sedimentation, sieving, or micrometric methods. Particle sizes are expressed as classes with specific effective diameter class limits. The broad classes are sand, silt, and clay, ranging from the larger to the smaller.

Sand as a soil separate consists of mineral soil particles that are 0.05 millimeter to 2 millimeters in diameter. In this table, the estimated sand content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

Silt as a soil separate consists of mineral soil particles that are 0.002 to 0.05 millimeter in diameter. In this table, the estimated silt content of each soil layer is

given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

Clay as a soil separate consists of mineral soil particles that are less than 0.002 millimeter in diameter. In this table, the estimated clay content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

The content of sand, silt, and clay affects the physical behavior of a soil. Particle size is important for engineering and agronomic interpretations, for determination of soil hydrologic qualities, and for soil classification.

The amount and kind of clay affect the fertility and physical condition of the soil and the ability of the soil to adsorb cations and to retain moisture. They influence shrink-swell potential, saturated hydraulic conductivity (Ksat), plasticity, the ease of soil dispersion, and other soil properties. The amount and kind of clay in a soil also affect tillage and earthmoving operations.

Moist bulk density is the weight of soil (ovendry) per unit volume. Volume is measured when the soil is at field moisture capacity, that is, the moisture content at 1/3- or 1/10-bar (33kPa or 10kPa) moisture tension. Weight is determined after the soil is dried at 105 degrees C. In the table, the estimated moist bulk density of each soil horizon is expressed in grams per cubic centimeter of soil material that is less than 2 millimeters in diameter. Bulk density data are used to compute linear extensibility, shrink-swell potential, available water capacity, total pore space, and other soil properties. The moist bulk density of a soil indicates the pore space available for water and roots. Depending on soil texture, a bulk density of more than 1.4 can restrict water storage and root penetration. Moist bulk density is influenced by texture, kind of clay, content of organic matter, and soil structure.

Saturated hydraulic conductivity (Ksat) refers to the ease with which pores in a saturated soil transmit water. The estimates in the table are expressed in terms of micrometers per second. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Saturated hydraulic conductivity (Ksat) is considered in the design of soil drainage systems and septic tank absorption fields.

Available water capacity refers to the quantity of water that the soil is capable of storing for use by plants. The capacity for water storage is given in inches of water per inch of soil for each soil layer. The capacity varies, depending on soil properties that affect retention of water. The most important properties are the content of organic matter, soil texture, bulk density, and soil structure. Available water capacity is an important factor in the choice of plants or crops to be grown and in the design and management of irrigation systems. Available water capacity is not an estimate of the quantity of water actually available to plants at any given time.

Linear extensibility refers to the change in length of an unconfined clod as moisture content is decreased from a moist to a dry state. It is an expression of the volume change between the water content of the clod at 1/3- or 1/10-bar tension (33kPa or 10kPa tension) and oven dryness. The volume change is reported in the table as percent change for the whole soil. The amount and type of clay minerals in the soil influence volume change.

Linear extensibility is used to determine the shrink-swell potential of soils. The shrink-swell potential is low if the soil has a linear extensibility of less than 3 percent; moderate if 3 to 6 percent; high if 6 to 9 percent; and very high if more than 9 percent. If the linear extensibility is more than 3, shrinking and swelling can cause

damage to buildings, roads, and other structures and to plant roots. Special design commonly is needed.

Organic matter is the plant and animal residue in the soil at various stages of decomposition. In this table, the estimated content of organic matter is expressed as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter. The content of organic matter in a soil can be maintained by returning crop residue to the soil.

Organic matter has a positive effect on available water capacity, water infiltration, soil organism activity, and tilth. It is a source of nitrogen and other nutrients for crops and soil organisms.

Erosion factors are shown in the table as the K factor (Kw and Kf) and the T factor. Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and Ksat. Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

Erosion factor Kw indicates the erodibility of the whole soil. The estimates are modified by the presence of rock fragments.

Erosion factor Kf indicates the erodibility of the fine-earth fraction, or the material less than 2 millimeters in size.

Erosion factor T is an estimate of the maximum average annual rate of soil erosion by wind and/or water that can occur without affecting crop productivity over a sustained period. The rate is in tons per acre per year.

Wind erodibility groups are made up of soils that have similar properties affecting their susceptibility to wind erosion in cultivated areas. The soils assigned to group 1 are the most susceptible to wind erosion, and those assigned to group 8 are the least susceptible. The groups are described in the "National Soil Survey Handbook."

Wind erodibility index is a numerical value indicating the susceptibility of soil to wind erosion, or the tons per acre per year that can be expected to be lost to wind erosion. There is a close correlation between wind erosion and the texture of the surface layer, the size and durability of surface clods, rock fragments, organic matter, and a calcareous reaction. Soil moisture and frozen soil layers also influence wind erosion.

Reference:
United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. (http://soils.usda.gov)

Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Physical Soil Properties–Washington County Area, Utah														
Map symbol and soil name	**Depth**	**Sand**	**Silt**	**Clay**	**Moist bulk density**	**Saturated hydraulic conductivity**	**Available water capacity**	**Linear extensibility**	**Organic matter**	**Erosion factors**			**Wind erodibility group**	**Wind erodibility index**
										Kw	**Kf**	**T**		
	In	*Pct*	*Pct*	*Pct*	*g/cc*	*micro m/sec*	*In/In*	*Pct*	*Pct*					
EB—Eroded land-Shalet complex, warm														
Eroded land	—	—	—	—	—	—	—	—	—					
Shalet	0-4	-35-	-34-	27-31- 35	1.10-1.15-1.20	0.42-0.92-1.41	0.16-0.18-0.20	0.0- 1.5- 2.9	0.5- 0.8-1.0	.28	.28	2	4L	86
	4-12	-35-	-34-	27-31- 35	1.10-1.15-1.20	0.42-0.92-1.41	0.16-0.18-0.20	0.0- 1.5- 2.9	0.0- 0.5-1.0	.32	.32			
	12-16	—	—	—	—	0.00-0.71-1.41	—	—	—					
GP—Gravel pits														
Gravel pit	—	—	—	—	—	—	—	—	—					
JaC—Junction fine sandy loam, 2 to 5 percent slopes														
Junction	0-2	-70-	-22-	3- 8- 12	1.50-1.60-1.70	14.11-28.23-42.34	0.10-0.12-0.14	0.0- 1.5- 2.9	0.5- 0.8-1.0	.24	.24	5	3	86
	2-9	-70-	-22-	3- 8- 12	1.45-1.55-1.65	14.11-28.23-42.34	0.10-0.12-0.14	0.0- 1.5- 2.9	0.5- 0.8-1.0	.32	.32			
	9-21	-70-	-22-	3- 8- 12	1.45-1.55-1.65	14.11-28.23-42.34	0.10-0.12-0.14	0.0- 1.5- 2.9	0.0- 0.5-1.0	.32	.32			
	21-32	-70-	-22-	3- 8- 12	1.45-1.55-1.65	14.11-28.23-42.34	0.10-0.12-0.14	0.0- 1.5- 2.9	0.0- 0.5-1.0	.32	.32			
	32-60	-70-	-22-	3- 8- 12	1.45-1.55-1.65	14.11-28.23-42.34	0.10-0.12-0.14	0.0- 1.5- 2.9	0.0- 0.5-1.0	.32	.32			

Physical Soil Properties–Washington County Area, Utah														
Map symbol and soil name	**Depth**	**Sand**	**Silt**	**Clay**	**Moist bulk density**	**Saturated hydraulic conductivity**	**Available water capacity**	**Linear extensibility**	**Organic matter**	**Erosion factors**			**Wind erodibility group**	**Wind erodibility index**
										Kw	**Kf**	**T**		
	In	*Pct*	*Pct*	*Pct*	*g/cc*	*micro m/sec*	*In/In*	*Pct*	*Pct*					
WBD—Winkel gravelly fine sandy loam, 1 to 8 percent slopes														
Winkel	0-1	-70-	-22-	3- 8- 12	1.35-1.43-1.50	14.11-28.23-42.34	0.07-0.08-0.09	0.0- 1.5- 2.9	0.0- 0.5-1.0	.20	.32	1	5	56
	1-6	-70-	-22-	3- 8- 12	1.35-1.43-1.50	14.11-28.23-42.34	0.07-0.08-0.09	0.0- 1.5- 2.9	0.0- 0.5-1.0	.24	.37			
	6-12	-70-	-22-	3- 8- 12	1.35-1.43-1.50	14.11-28.23-42.34	0.05-0.06-0.07	0.0- 1.5- 2.9	0.0- 0.5-1.0	.15	.37			
	12-16	-70-	-22-	3- 8- 12	1.40-1.48-1.55	14.11-28.23-42.34	0.04-0.05-0.06	0.0- 1.5- 2.9	0.0- 0.5-1.0	.10	.37			
	16-20	—	—	—	—	0.00-2.12-4.23	—	—	—					
	20-24	—	—	—	—	0.07-70.61-141.14	—	—	—					

Engineering Properties

This table gives the engineering classifications and the range of engineering properties for the layers of each soil in the survey area.

Hydrologic soil group is a group of soils having similar runoff potential under similar storm and cover conditions. The criteria for determining Hydrologic soil group is found in the National Engineering Handbook, Chapter 7 issued May 2007(http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba). Listing HSGs by soil map unit component and not by soil series is a new concept for the engineers. Past engineering references contained lists of HSGs by soil series. Soil series are continually being defined and redefined, and the list of soil series names changes so frequently as to make the task of maintaining a single national list virtually impossible. Therefore, the criteria is now used to calculate the HSG using the component soil properties and no such national series lists will be maintained. All such references are obsolete and their use should be discontinued. Soil properties that influence runoff potential are those that influence the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to a seasonal high water table, saturated hydraulic conductivity after prolonged wetting, and depth to a layer with a very slow water transmission rate. Changes in soil properties caused by land management or climate changes also cause the hydrologic soil group to change. The influence of ground cover is treated independently. There are four hydrologic soil groups, A, B, C, and D, and three dual groups, A/D, B/D, and C/D. In the dual groups, the first letter is for drained areas and the second letter is for undrained areas.

The four hydrologic soil groups are described in the following paragraphs:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Depth to the upper and lower boundaries of each layer is indicated.

Texture is given in the standard terms used by the U.S. Department of Agriculture. These terms are defined according to percentages of sand, silt, and clay in the fraction of the soil that is less than 2 millimeters in diameter. "Loam," for example, is soil that is 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the content of particles coarser than sand is 15 percent or more, an appropriate modifier is added, for example, "gravelly."

Classification of the soils is determined according to the Unified soil classification system (ASTM, 2005) and the system adopted by the American Association of State Highway and Transportation Officials (AASHTO, 2004).

The Unified system classifies soils according to properties that affect their use as construction material. Soils are classified according to particle-size distribution of the fraction less than 3 inches in diameter and according to plasticity index, liquid limit, and organic matter content. Sandy and gravelly soils are identified as GW, GP, GM, GC, SW, SP, SM, and SC; silty and clayey soils as ML, CL, OL, MH, CH, and OH; and highly organic soils as PT. Soils exhibiting engineering properties of two groups can have a dual classification, for example, CL-ML.

The AASHTO system classifies soils according to those properties that affect roadway construction and maintenance. In this system, the fraction of a mineral soil that is less than 3 inches in diameter is classified in one of seven groups from A-1 through A-7 on the basis of particle-size distribution, liquid limit, and plasticity index. Soils in group A-1 are coarse grained and low in content of fines (silt and clay). At the other extreme, soils in group A-7 are fine grained. Highly organic soils are classified in group A-8 on the basis of visual inspection.

If laboratory data are available, the A-1, A-2, and A-7 groups are further classified as A-1-a, A-1-b, A-2-4, A-2-5, A-2-6, A-2-7, A-7-5, or A-7-6. As an additional refinement, the suitability of a soil as subgrade material can be indicated by a group index number. Group index numbers range from 0 for the best subgrade material to 20 or higher for the poorest.

Percentage of rock fragments larger than 10 inches in diameter and 3 to 10 inches in diameter are indicated as a percentage of the total soil on a dry-weight basis. The percentages are estimates determined mainly by converting volume percentage in the field to weight percentage. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Percentage (of soil particles) passing designated sieves is the percentage of the soil fraction less than 3 inches in diameter based on an ovendry weight. The sieves, numbers 4, 10, 40, and 200 (USA Standard Series), have openings of 4.76, 2.00, 0.420, and 0.074 millimeters, respectively. Estimates are based on laboratory tests of soils sampled in the survey area and in nearby areas and on estimates made in the field. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Liquid limit and *plasticity index* (Atterberg limits) indicate the plasticity characteristics of a soil. The estimates are based on test data from the survey area or from nearby areas and on field examination. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

References:

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Absence of an entry indicates that the data were not estimated. The asterisk '*' denotes the representative texture; other possible textures follow the dash. The criteria for determining the hydrologic soil group for individual soil components is found in the National Engineering Handbook, Chapter 7 issued May 2007(http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba). Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Engineering Properties–Washington County Area, Utah														
Map unit symbol and soil name	Pct. of map unit	Hydrologic group	Depth	USDA texture	Classification		Pct Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
					Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
			In				*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*
EB—Eroded land-Shalet complex, warm														
Shalet	20	D	0-4	Clay loam	CL	A-6	0- 0- 0	0- 0- 0	90-95-100	85-93-100	80-90-100	55-63-70	30-35-40	10-15-20
			4-12	Clay loam	CL	A-6	0- 0- 0	0- 0- 0	90-95-100	85-93-100	80-90-100	55-63-70	30-35-40	10-15-20
			12-16	Weathered bedrock	—	—	—	—	—	—	—	—	—	—
JaC—Junction fine sandy loam, 2 to 5 percent slopes														
Junction	85	A	0-2	Fine sandy loam	SC-SM, SM	A-4	0- 0- 0	0- 0- 0	100-100-100	90-95-100	75-80-85	35-43-50	15-20-25	NP-3 -5
			2-9	Fine sandy loam	SC-SM, SM	A-4	0- 0- 0	0- 0- 0	100-100-100	90-95-100	75-80-85	35-43-50	15-20-25	NP-3 -5
			9-21	Fine sandy loam	SC-SM, SM	A-4	0- 0- 0	0- 0- 0	100-100-100	90-95-100	75-80-85	35-43-50	15-20-25	NP-3 -5
			21-32	Fine sandy loam	SC-SM, SM	A-4	0- 0- 0	0- 0- 0	100-100-100	90-95-100	75-80-85	35-43-50	15-20-25	NP-3 -5
			32-60	Fine sandy loam	SC-SM, SM	A-4	0- 0- 0	0- 0- 0	100-100-100	90-95-100	75-80-85	35-43-50	15-20-25	NP-3 -5

Engineering Properties–Washington County Area, Utah														
Map unit symbol and soil name	Pct. of map unit	Hydrologic group	Depth	USDA texture	Classification		Pct Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
					Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
			In				*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*
WBD—Winkel gravelly fine sandy loam, 1 to 8 percent slopes														
Winkel	85	D	0-1	Gravelly fine sandy loam	SM	A-4, A-2-4	0- 0- 0	0- 5- 10	75-80-85	70-75-80	50-55-60	30-35-40	15-20-25	NP-3 -5
			1-6	Gravelly fine sandy loam	SM	A-4, A-2-4	0- 0- 0	0- 5- 10	75-80-85	70-75-80	50-55-60	30-35-40	15-20-25	NP-3 -5
			6-12	Very gravelly fine sandy loam	GM	A-1-b	0- 0- 0	10-15-20	40-45-50	35-40-45	25-30-35	15-20-25	15-20-25	NP-3 -5
			12-16	Extremely cobbly fine sandy loam	GM, GC-GM	A-1-b, A-2	0- 0- 0	50-55-60	40-45-50	35-40-45	30-35-40	15-23-30	15-20-25	NP-3 -5
			16-20	Indurated	—	—	—	—	—	—	—	—	—	—
			20-24	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—

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NOAA Atlas 14, Volume 1, Version 5
Location name: Saint George, Utah, USA*
Latitude: 37.0734°, Longitude: -113.6062°
Elevation: 2635.88 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.125** (0.107-0.146)	**0.160** (0.139-0.189)	**0.217** (0.186-0.253)	**0.266** (0.227-0.312)	**0.343** (0.289-0.401)	**0.410** (0.340-0.480)	**0.487** (0.395-0.574)	**0.574** (0.452-0.679)	**0.707** (0.535-0.853)	**0.822** (0.605-0.999)
10-min	**0.190** (0.164-0.222)	**0.243** (0.212-0.287)	**0.330** (0.284-0.385)	**0.404** (0.346-0.475)	**0.522** (0.440-0.611)	**0.624** (0.517-0.732)	**0.742** (0.601-0.874)	**0.874** (0.688-1.03)	**1.08** (0.815-1.30)	**1.25** (0.922-1.52)
15-min	**0.236** (0.203-0.275)	**0.301** (0.263-0.355)	**0.408** (0.352-0.477)	**0.501** (0.429-0.589)	**0.648** (0.545-0.757)	**0.774** (0.642-0.907)	**0.920** (0.745-1.08)	**1.08** (0.853-1.28)	**1.34** (1.01-1.61)	**1.55** (1.14-1.89)
30-min	**0.317** (0.273-0.371)	**0.406** (0.353-0.478)	**0.550** (0.473-0.643)	**0.675** (0.578-0.794)	**0.872** (0.734-1.02)	**1.04** (0.864-1.22)	**1.24** (1.00-1.46)	**1.46** (1.15-1.73)	**1.80** (1.36-2.17)	**2.09** (1.54-2.54)
60-min	**0.392** (0.338-0.459)	**0.502** (0.437-0.592)	**0.680** (0.586-0.796)	**0.836** (0.715-0.982)	**1.08** (0.909-1.26)	**1.29** (1.07-1.51)	**1.53** (1.24-1.81)	**1.81** (1.42-2.13)	**2.22** (1.68-2.68)	**2.59** (1.90-3.14)
2-hr	**0.475** (0.419-0.544)	**0.590** (0.523-0.682)	**0.772** (0.683-0.888)	**0.934** (0.819-1.07)	**1.19** (1.02-1.36)	**1.39** (1.18-1.60)	**1.63** (1.35-1.88)	**1.90** (1.54-2.22)	**2.31** (1.80-2.73)	**2.66** (2.02-3.18)
3-hr	**0.526** (0.470-0.596)	**0.656** (0.588-0.747)	**0.843** (0.755-0.957)	**1.00** (0.891-1.13)	**1.24** (1.09-1.41)	**1.44** (1.24-1.64)	**1.67** (1.41-1.90)	**1.91** (1.59-2.24)	**2.31** (1.86-2.76)	**2.67** (2.08-3.21)
6-hr	**0.653** (0.587-0.735)	**0.816** (0.739-0.922)	**1.04** (0.935-1.17)	**1.22** (1.09-1.38)	**1.49** (1.31-1.68)	**1.71** (1.49-1.94)	**1.95** (1.67-2.23)	**2.22** (1.87-2.56)	**2.63** (2.14-3.07)	**2.97** (2.37-3.52)
12-hr	**0.785** (0.710-0.874)	**0.985** (0.889-1.10)	**1.24** (1.11-1.38)	**1.45** (1.30-1.61)	**1.73** (1.54-1.93)	**1.95** (1.71-2.18)	**2.18** (1.89-2.45)	**2.42** (2.07-2.75)	**2.76** (2.31-3.17)	**3.06** (2.51-3.56)
24-hr	**0.898** (0.835-0.962)	**1.12** (1.04-1.20)	**1.39** (1.30-1.49)	**1.61** (1.51-1.72)	**1.91** (1.78-2.04)	**2.14** (1.98-2.29)	**2.38** (2.19-2.54)	**2.61** (2.39-2.80)	**2.93** (2.66-3.20)	**3.18** (2.86-3.59)
2-day	**0.978** (0.919-1.04)	**1.22** (1.14-1.30)	**1.51** (1.42-1.61)	**1.74** (1.64-1.85)	**2.05** (1.92-2.18)	**2.29** (2.14-2.43)	**2.53** (2.35-2.69)	**2.77** (2.57-2.96)	**3.09** (2.84-3.31)	**3.34** (3.05-3.62)
3-day	**1.04** (0.979-1.10)	**1.29** (1.22-1.37)	**1.60** (1.51-1.69)	**1.84** (1.74-1.94)	**2.16** (2.04-2.28)	**2.41** (2.26-2.55)	**2.66** (2.49-2.81)	**2.91** (2.71-3.09)	**3.24** (2.99-3.45)	**3.49** (3.20-3.75)
4-day	**1.10** (1.04-1.16)	**1.36** (1.29-1.45)	**1.69** (1.60-1.78)	**1.93** (1.83-2.03)	**2.27** (2.15-2.38)	**2.53** (2.39-2.66)	**2.79** (2.62-2.94)	**3.05** (2.85-3.22)	**3.39** (3.14-3.59)	**3.65** (3.36-3.88)
7-day	**1.25** (1.18-1.33)	**1.55** (1.46-1.65)	**1.91** (1.81-2.02)	**2.19** (2.07-2.30)	**2.55** (2.41-2.68)	**2.82** (2.66-2.96)	**3.08** (2.90-3.24)	**3.34** (3.13-3.51)	**3.66** (3.42-3.87)	**3.89** (3.62-4.13)
10-day	**1.38** (1.29-1.47)	**1.72** (1.62-1.83)	**2.12** (2.00-2.25)	**2.43** (2.29-2.57)	**2.84** (2.67-2.99)	**3.13** (2.95-3.31)	**3.43** (3.21-3.62)	**3.71** (3.47-3.94)	**4.07** (3.79-4.33)	**4.33** (4.01-4.63)
20-day	**1.71** (1.60-1.82)	**2.13** (2.00-2.27)	**2.61** (2.46-2.77)	**2.96** (2.79-3.14)	**3.39** (3.19-3.59)	**3.69** (3.47-3.91)	**3.98** (3.73-4.21)	**4.23** (3.96-4.49)	**4.54** (4.24-4.82)	**4.73** (4.42-5.03)
30-day	**2.02** (1.89-2.16)	**2.52** (2.36-2.69)	**3.09** (2.90-3.29)	**3.51** (3.30-3.73)	**4.03** (3.79-4.28)	**4.40** (4.13-4.67)	**4.75** (4.45-5.04)	**5.07** (4.74-5.39)	**5.46** (5.09-5.81)	**5.72** (5.31-6.11)
45-day	**2.41** (2.24-2.59)	**3.01** (2.81-3.24)	**3.72** (3.47-3.98)	**4.24** (3.95-4.52)	**4.88** (4.56-5.19)	**5.34** (4.98-5.66)	**5.76** (5.37-6.11)	**6.14** (5.72-6.53)	**6.58** (6.13-7.00)	**6.85** (6.39-7.32)
60-day	**2.73** (2.53-2.93)	**3.41** (3.17-3.67)	**4.20** (3.91-4.50)	**4.78** (4.45-5.10)	**5.50** (5.12-5.87)	**6.00** (5.58-6.41)	**6.48** (6.01-6.92)	**6.91** (6.41-7.39)	**7.41** (6.86-7.95)	**7.72** (7.14-8.31)

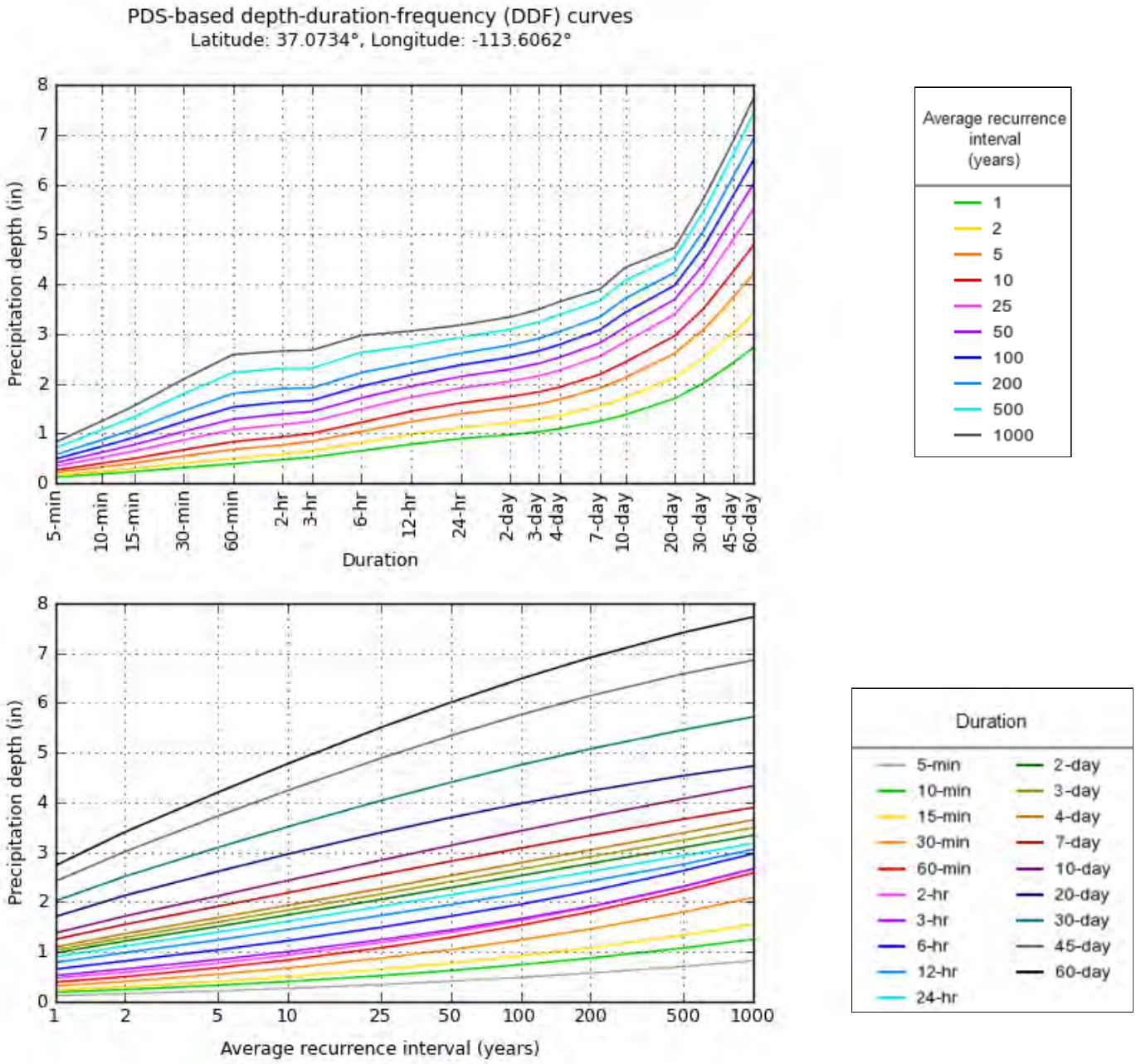
[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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PF graphical



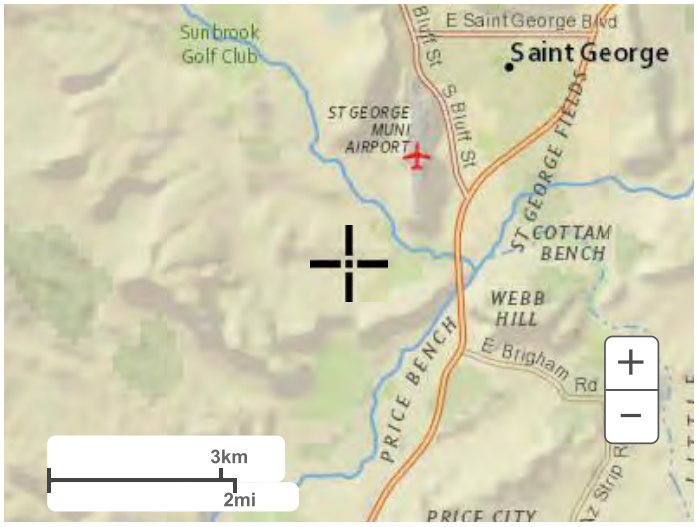
NOAA Atlas 14, Volume 1, Version 5

Created (GMT): Wed Nov 30 16:28:31 2022

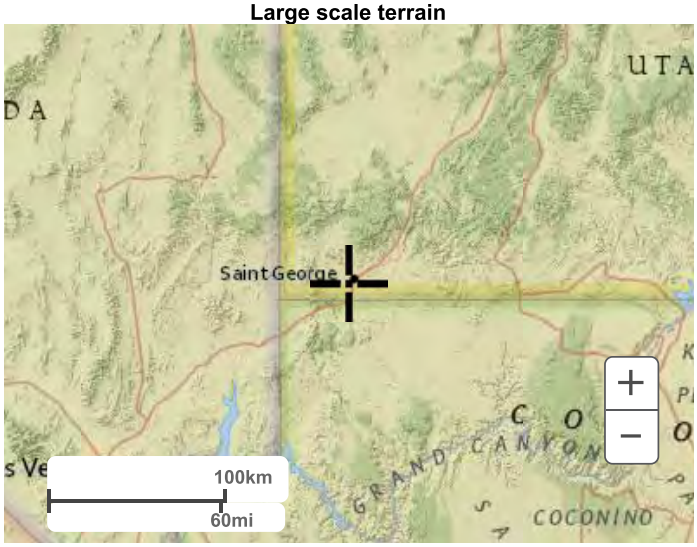
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Maps & aerials

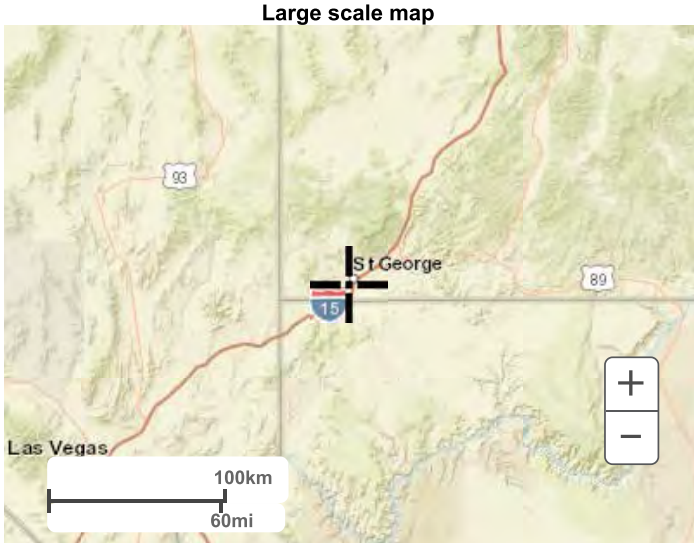
Small scale terrain



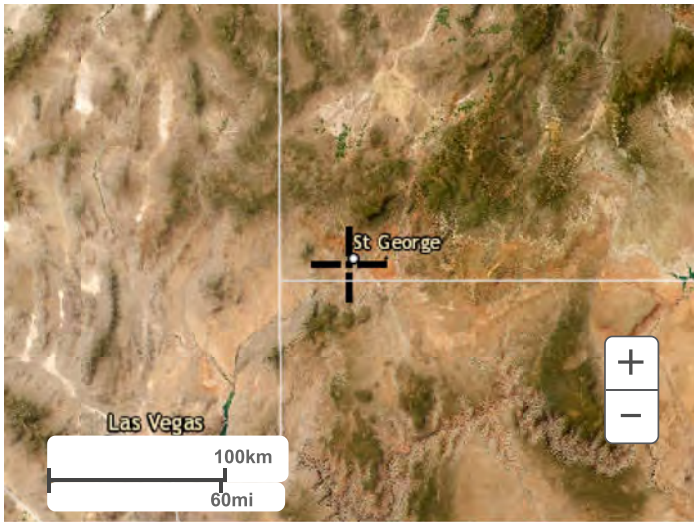
Large scale terrain



Large scale map



Large scale aerial



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US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

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PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 11/30/2022

SUBJECT: 3-hr Distribution Table CHKD: JWB DATE: 11/30/2022

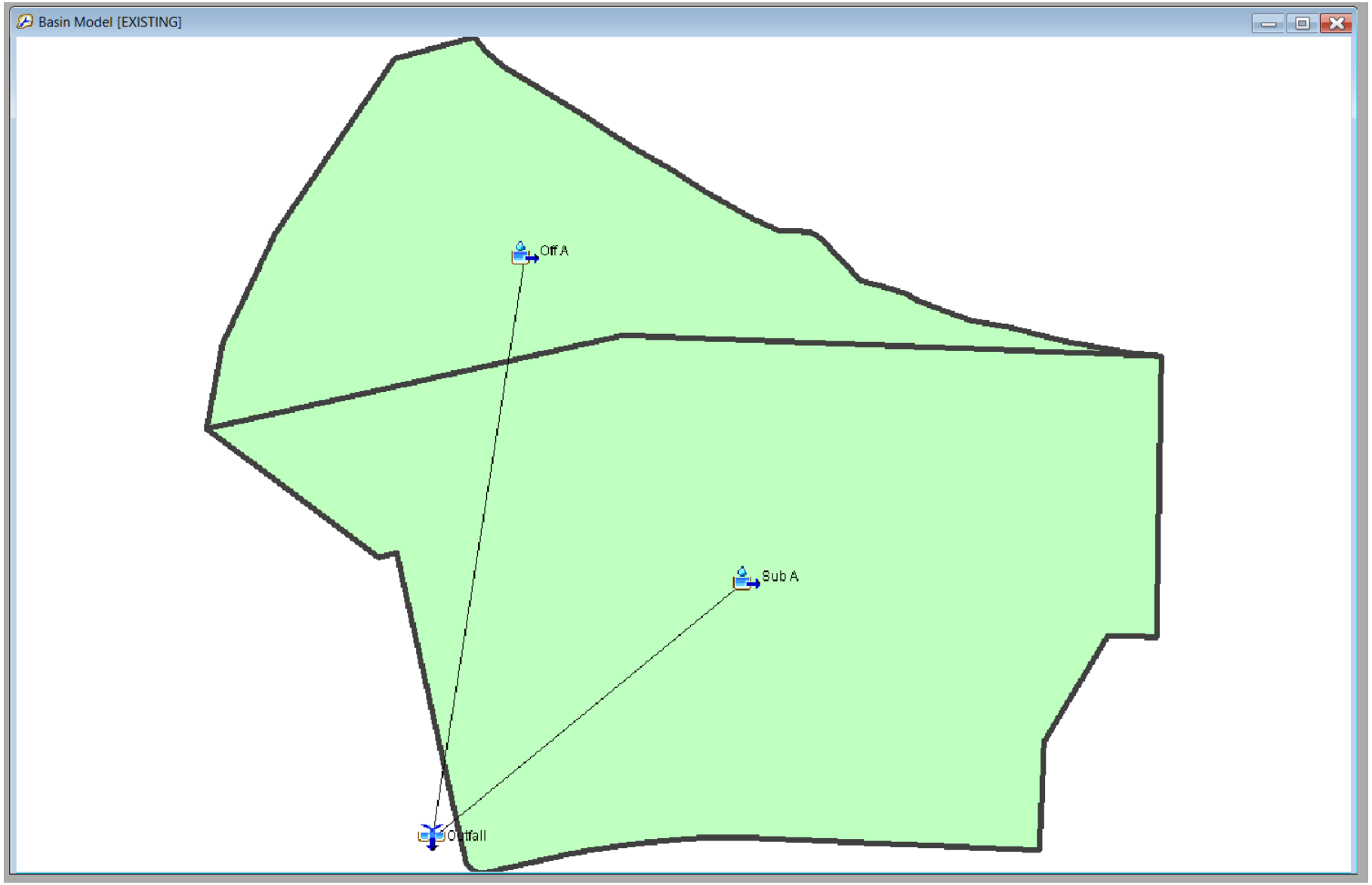
Farmer-Fletcher Modified 3-hour Storm Distribution

	10 Year Storm		100 Year Storm	
1 hour Depth	0.836 (in)		1.53 (in)	
3 Hour Depth	1 (in)		1.67 (in)	

Time (min)		Incr.	Cumulative	Incr.	Cumulative
0		0	0	0	0
5		0.006833	0.006833	0.005833	0.005833
10		0.006833	0.013667	0.005833	0.011667
15		0.006833	0.020500	0.005833	0.017500
20		0.006833	0.027333	0.005833	0.023333
25		0.006833	0.034167	0.005833	0.029167
30		0.006833	0.041000	0.005833	0.035000
35	0.285	0.238260	0.279260	0.436050	0.471050
40	0.225	0.188100	0.467360	0.344250	0.815300
45	0.157	0.131252	0.598612	0.240210	1.055510
50	0.100	0.083600	0.682212	0.153000	1.208510
55	0.060	0.050160	0.732372	0.091800	1.300310
60	0.046	0.038456	0.770828	0.070380	1.370690
65	0.034	0.028424	0.799252	0.052020	1.422710
70	0.026	0.021736	0.820988	0.039780	1.462490
75	0.020	0.016720	0.837708	0.030600	1.493090
80	0.018	0.015048	0.852756	0.027540	1.520630
85	0.016	0.013376	0.866132	0.024480	1.545110
90	0.013	0.010868	0.877000	0.019890	1.565000
95		0.006833	0.883833	0.005833	1.570833
100		0.006833	0.890667	0.005833	1.576667
105		0.006833	0.897500	0.005833	1.582500
110		0.006833	0.904333	0.005833	1.588333
115		0.006833	0.911167	0.005833	1.594167
120		0.006833	0.918000	0.005833	1.600000
125		0.006833	0.924833	0.005833	1.605833
130		0.006833	0.931667	0.005833	1.611667
135		0.006833	0.938500	0.005833	1.617500
140		0.006833	0.945333	0.005833	1.623333
145		0.006833	0.952167	0.005833	1.629167
150		0.006833	0.959000	0.005833	1.635000
155		0.006833	0.965833	0.005833	1.640833
160		0.006833	0.972667	0.005833	1.646667
165		0.006833	0.979500	0.005833	1.652500
170		0.006833	0.986333	0.005833	1.658333
175		0.006833	0.993167	0.005833	1.664167
180		0.006833	1.000000	0.005833	1.670000
Total:		1		1.67	

APPENDIX B

Existing HEC-HMS Model Diagram
Existing Watershed Hydrology Model Input Spreadsheets
Existing Conditions HEC-HMS Output Tables


Basin Model [EXISTING]
Off A
Sub A
Outfall

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PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 11/30/2022

SUBJECT: Existing Site Hydrology Information CHKD: JWB DATE: 11/30/2022

Subarea		Flow Length	Average Slope	Area		
Name	*Description*	*(ft)*	*S (%)*	*ft^2*	*Acres*	*mi^2*
SUB A	Site	842	4.6%	652,985	14.99	0.02342
OFF A	North of site	457	10.4%	252,272	5.79	0.00905

ROSENBERG ASSOCIATES
CIVIL ENGINEERS • LAND SURVEYORS

PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 11/30/2022

SUBJECT: NRCS Curve Number CHKD: JWB DATE: 11/30/2022

NRCS CURVE NUMBER CHART

Land Use Description	SCS Curve Number (CN) Values			
	Group A	Group B	Group C	Group D
Cultivated Land				
Cultivated Land; Without Conservation Treatment	72	81	88	91
Cultivated Land; With Conservation Treatment	62	71	78	81
Pasture or Range Land				
Pasture or Range Land; Poor Condition	68	79	86	89
Pasture or Range Land; Good Condition	39	61	74	80
Open Spaces (Lawns, Parks, etc.)				
Open Space; Poor Condition; Grass Cover < 50%	68	79	86	89
Open Space; Fair Condition; Grass Cover 50% to 75%	49	69	79	84
Open Space; Good Condition; Grass Cover > 75%	39	61	74	80
Impervious Areas				
Impervious Areas; Paved Parking Lots, Roofs, Driveways	98	98	98	98
Impervious Areas; Streets and Roads; Paved; Curbs and Storm Sewers	98	98	98	98
Impervious Areas; Streets and Roads; Paved; Open Ditches (w/ Right-of-Way)	83	89	92	93
Impervious Areas; Streets and Roads; Gravel (w/ Right-of-Way)	76	85	89	91
Impervious Areas; Streets and Roads; Dirt (w/ Right-of-Way)	72	82	87	89
Urban Commercial and Industrial Districts				
Urban Districts; Commercial and Business; Average 85% Impervious	89	92	94	95
Urban Districts; Industrial; Average 72% Impervious	81	88	91	93
Residential Districts				
Residential Districts; 1/8 Acre (Town Houses); Average 65% Impervious	77	85	90	92
Residential Districts; 1/4 Acre; Average 38% Impervious	61	75	83	87
Residential Districts; 1/3 Acre; Average 30% Impervious	57	72	81	86
Residential Districts; 1/2 Acre; Average 25% Impervious	54	70	80	85
Residential Districts; 1 Acre; Average 20% Impervious	51	68	79	84
Residential Districts; 2 Acre; Average 12% Impervious	46	65	77	82
Western Desert Urban Areas				
Natural Desert Vegetation (Pervious Areas Only)	63	77	85	88
Artificial Desert Landscaping	96	96	96	96
Developing Urban Area (No Vegetation)				
Newly Graded Area (Pervious Only)	77	86	91	94

SUB A 81 Weighted Average

OFF A 88 Natural Desert Vegetation (Pervious Areas Only)

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CIVIL ENGINEERS LAND SURVEYORS

SHEET 2 OF _____

PROJECT NO. _____

PROJECT: Rosewood Townhomes BY: WJP DATE: 11/30/22

SUBJECT: Existing NRCS Curve Number CHECKED BY: _____ DATE: _____

Sub A total area = 14.99 ac

~~WBP A~~ EB - Soil Group D - area = 10.5 ac

88 : Natural desert veg - 10.5 ac / .7

JaC - soil group A - area = 4.49 ac

63 - Natural Desert veg - 4.49 ac / .3

$(88 * .7) + (63 * .3) = \boxed{81}$

off A - total area = 5.79 ac - Group D

~~EB Soil group D - area = 3.7 ac~~

~~88 = Natural desert veg = 3.7 ac /~~

natural desert veg = $\boxed{88}$

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PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 11/30/2022

SUBJECT: TR 55 Worksheet CHKD: JWB DATE: 11/30/2022

X Pre-developed ___ Post-developed

Subarea: SUB A

Sheet Flow

Surface Description	Mannings 'n' n	Flow Length L (ft) ≤100ft	2-yr 24-hr P_2 (in)	Average slope s (ft/ft)
	0.05	50	1.12	0.0460

$$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$$

T_t 0.05 hr
2.831 min

Shallow Concentrated Flow

	Ground Type	Flow Length L (ft)	Average Velocity V(ft/s)	Average slope s (ft/ft)
	G	100.800	3.46	0.0460

P - (paved) Pavement and small upland gullies
G - (unpaved) Grassed waterways
N - nearly bare and untilled (overland flow); and alluvial fans western mountain regions
C - Cultivated straight row crops
S - Short-grass pasture
M - Minimum tillage cultivation, contour or strip-cropped, and woodlands
F - Forest with heavy ground litter and hay meadows

T_t 0.0081 hr
0.485 min

$$T_t = \frac{L}{3600\,V}$$

Channel Flow

Mannings 'n' n	x-sectional flow area, a (ft^2)	Wetted Perimeter P_w	Average slope s (ft/ft)	Flow Length L (ft)
0.05	15.00	30.07	0.0460	691.00

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n} \qquad r = \frac{a}{P_w}$$

$$T_t = \frac{L}{3600\,V}$$

Hydraulic radius r=a/Pw	Average Velocity V(ft/s)
0.50	4.02

T_t 0.04775 hr
2.865 min

Watershed or sub area T_c add up T_t

Lag time =tc*.6

Subarea:	T_c	0.06	hr
SUB A		3.709	min

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PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 11/30/2022

SUBJECT: TR 55 Worksheet CHKD: JWB DATE: 11/30/2022

X Pre-developed ___ Post-developed

Subarea: OFF A

Sheet Flow

Surface Description	Mannings 'n' n	Flow Length L (ft) ≤100ft	2-yr 24-hr P_2 (in)	Average slope s (ft/ft)
	0.05	40.00	1.12	0.1040

$$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$$

T_t 0.03 hr
1.709 min

Shallow Concentrated Flow

	Ground Type	Flow Length L (ft)	Average Velocity V(ft/s)	Average slope s (ft/ft)
	G	50.00	5.20	0.1040

P - (paved) Pavement and small upland gullies
G - (unpaved) Grassed waterways
N - nearly bare and untilled (overland flow); and alluvial fans western mountain regions
C - Cultivated straight row crops
S - Short-grass pasture
M - Minimum tillage cultivation, contour or strip-cropped, and woodlands
F - Forest with heavy ground litter and hay meadows

T_t 0.0027 hr
0.160 min

$$T_t = \frac{L}{3600\,V}$$

Channel Flow

Mannings 'n' n	x-sectional flow area, a (ft^2)	Wetted Perimeter P_w	Average slope s (ft/ft)	Flow Length L (ft)
0.05	15.00	30.07	0.1040	366.70

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n} \qquad r = \frac{a}{P_w}$$

$$T_t = \frac{L}{3600\,V}$$

Hydraulic radius r=a/Pw	Average Velocity V(ft/s)
0.50	6.04

T_t 0.01685 hr
1.011 min

Watershed or sub area T_c add up T_t

Lag time =tc*.6

Subarea:	T_c	0.03	hr
OFF A		1.728	min

Project: Rosewood Townhomes Simulation Run: PRE 10-3

Start of Run: 01Jan2000, 00:00 Basin Model: EXISTING
End of Run: 01Jan2000, 04:00 Meteorologic Model: 10-3
Compute Time: 12Dec2022, 10:17:47 Control Specifications: 10YR-3HR

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Sub A	0.0234	1.6	01Jan2000, 00:55	0.10
Off A	0.0090	2.3	01Jan2000, 00:45	0.25
Outfall	0.0324	3.8	01Jan2000, 00:50	0.14

Project: Rosewood Townhomes Simulation Run: PRE 10-24

Start of Run: 01Jan2000, 00:00 Basin Model: EXISTING
End of Run: 02Jan2000, 05:00 Meteorologic Model: 10-24
Compute Time: 12Dec2022, 10:17:46 Control Specifications: 24HR

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Sub A	0.0234	2.7	01Jan2000, 12:00	0.37
Off A	0.0090	2.3	01Jan2000, 12:00	0.66
Outfall	0.0324	5.0	01Jan2000, 12:00	0.45

Project: Rosewood Townhomes Simulation Run: PRE 100-3

Start of Run: 01Jan2000, 00:00 Basin Model: EXISTING
End of Run: 01Jan2000, 04:00 Meteorologic Model: 100-3
Compute Time: 12Dec2022, 10:17:49 Control Specifications: 100YR-3HR

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Sub A	0.0234	11.1	01Jan2000, 00:50	0.41
Off A	0.0090	8.7	01Jan2000, 00:45	0.71
Outfall	0.0324	18.7	01Jan2000, 00:45	0.49

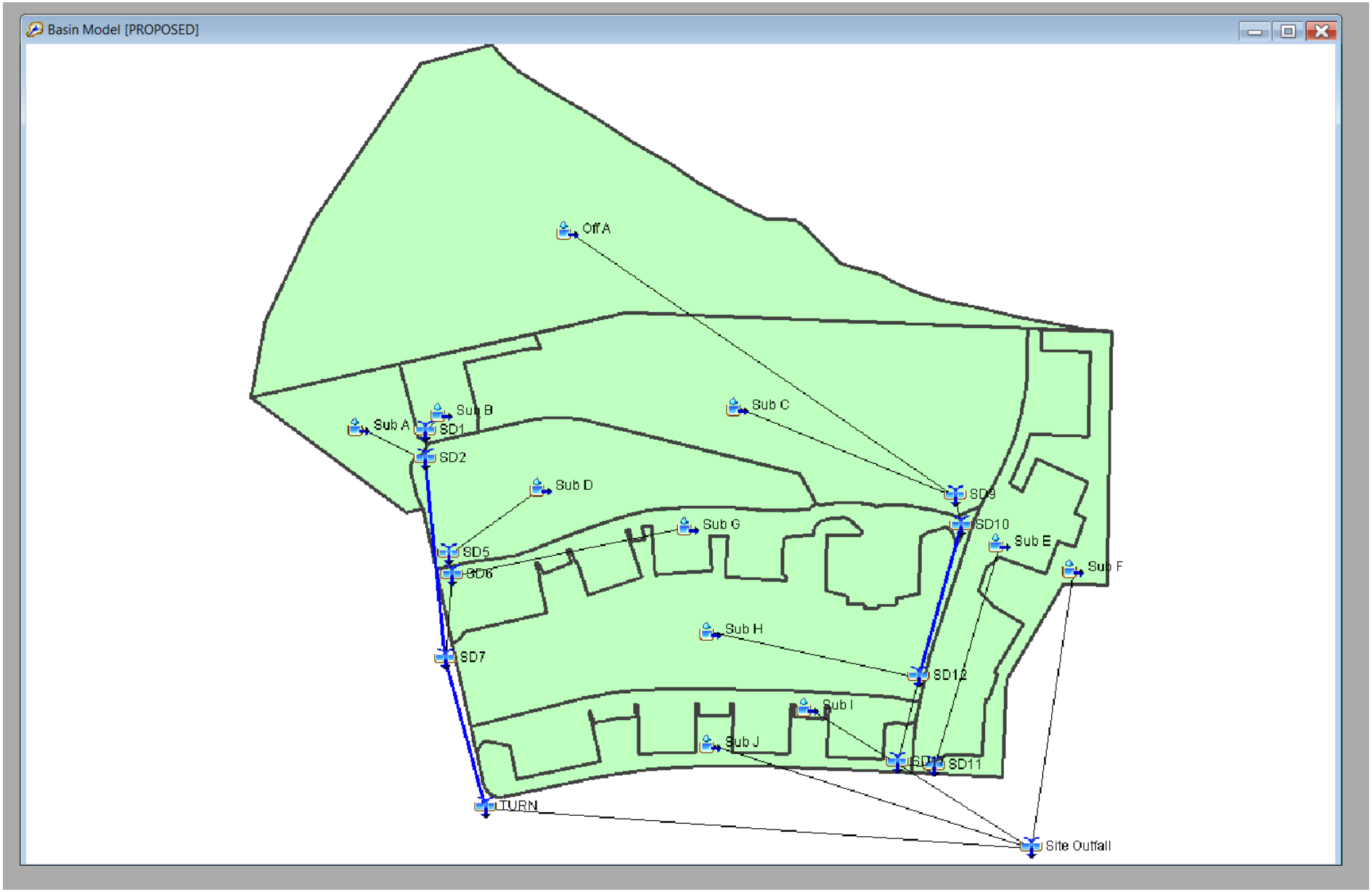
Project: Rosewood Townhomes Simulation Run: PRE 100-24

Start of Run: 01Jan2000, 00:00 Basin Model: EXISTING
End of Run: 02Jan2000, 05:00 Meteorologic Model: 100-24
Compute Time: 12Dec2022, 10:17:48 Control Specifications: 24HR

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Sub A	0.0234	7.6	01Jan2000, 12:00	0.86
Off A	0.0090	4.8	01Jan2000, 12:00	1.28
Outfall	0.0324	12.4	01Jan2000, 12:00	0.97

APPENDIX C

HEC-HMS Model Diagram
Developed Watershed Hydrology Model Input Spreadsheets
Hand scan – SCS Curve # for Proposed Conditions Subarea A
Developed Conditions HEC-HMS Model and Output Tables
Detention Calculations
Flow Master Worksheet output
MS4 Retention Volume Calculation


Basin Model [PROPOSED]
Off A
Sub A
Sub B
SD1
SD2
Sub C
Sub D
SD9
SD10
Sub E
Sub F
Sub G
SD5
SD6
Sub H
SD7
SD12
Sub I
Sub J
SD11
TURN
Site Outfall

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PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: Proposed Site Hydrology Information CHKD: JWB DATE: 12/1/2022

Subarea		Flow Length	Average Slope	Area		
Name	*Description*	*(ft)*	*S (%)*	*ft^2*	*Acres*	*mi^2*
SUB A	Northwest of townhomes	194	6.6%	27,817	0.64	0.00100
SUB B	Northwest portion north of Road C	300	4.2%	13,849	0.32	0.00050
SUB C	North of Road C	796	3.2%	166,759	3.83	0.00598
SUB D	Inbetween Road C and Road B	1,026	1.3%	76,612	1.76	0.00275
SUB E	East of Road D, flows west	714	4.1%	60,894	1.40	0.00218
SUB F	East of Road D, flows east	172	3.3%	39,017	0.90	0.00140
SUB G	South of Road B, flows north	592	1.2%	66,438	1.53	0.00238
SUB H	North of Road A, flows south	735	2.9%	126,840	2.91	0.00455
SUB I	South of Road A, flows north	653	1.1%	45,862	1.05	0.00165
SUB J	South of Road A, flows south	99	3.2%	28,657	0.66	0.00103
OFF A	North of site	457	10.4%	252,272	5.79	0.00905

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PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: NRCS Curve Number CHKD: JWB DATE: 12/1/2022

NRCS CURVE NUMBER CHART

Land Use Description	SCS Curve Number (CN) Values			
	Group A	Group B	Group C	Group D
Cultivated Land				
Cultivated Land; Without Conservation Treatment	72	81	88	91
Cultivated Land; With Conservation Treatment	62	71	78	81
Pasture or Range Land				
Pasture or Range Land; Poor Condition	68	79	86	89
Pasture or Range Land; Good Condition	39	61	74	80
Open Spaces (Lawns, Parks, etc.)				
Open Space; Poor Condition; Grass Cover < 50%	68	79	86	89
Open Space; Fair Condition; Grass Cover 50% to 75%	49	69	79	84
Open Space; Good Condition; Grass Cover > 75%	39	61	74	80
Impervious Areas				
Impervious Areas; Paved Parking Lots, Roofs, Driveways	98	98	98	98
Impervious Areas; Streets and Roads; Paved; Curbs and Storm Sewers	98	98	98	98
Impervious Areas; Streets and Roads; Paved; Open Ditches (w/ Right-of-Way)	83	89	92	93
Impervious Areas; Streets and Roads; Gravel (w/ Right-of-Way)	76	85	89	91
Impervious Areas; Streets and Roads; Dirt (w/ Right-of-Way)	72	82	87	89
Urban Commercial and Industrial Districts				
Urban Districts; Commercial and Business; Average 85% Impervious	89	92	94	95
Urban Districts; Industrial; Average 72% Impervious	81	88	91	93
Residential Districts				
Residential Districts; 1/8 Acre (Town Houses); Average 65% Impervious	77	85	90	92
Residential Districts; 1/4 Acre; Average 38% Impervious	61	75	83	87
Residential Districts; 1/3 Acre; Average 30% Impervious	57	72	81	86
Residential Districts; 1/2 Acre; Average 25% Impervious	54	70	80	85
Residential Districts; 1 Acre; Average 20% Impervious	51	68	79	84
Residential Districts; 2 Acre; Average 12% Impervious	46	65	77	82
Western Desert Urban Areas				
Natural Desert Vegetation (Pervious Areas Only)	63	77	85	88
Artificial Desert Landscaping	96	96	96	96
Developing Urban Area (No Vegetation)				
Newly Graded Area (Pervious Only)	77	86	91	94

SUB A	94	Weighted Average
SUB B	94	Weighted Average
SUB C	94	Weighted Average
SUB D	95	Weighted Average
SUB E	95	Weighted Average
SUB F	85	Weighted Average
SUB G	97	Weighted Average
SUB H	90	Weighted Average
SUB I	97	Weighted Average
SUB J	76	Weighted Average
OFF A	88	Natural Desert Vegetation

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SHEET 4 OF _____

PROJECT NO. _____

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/22

SUBJECT: Proposed NRCS Curve Number CHECKED BY: _____ DATE: _____

NDV = natural desert veg

Sub A - .64 acres

88 - Natural desert veg - .29 ac / .45

98 - Imp - .35 ac / .55

(88 * .45) + (98 * .55) = 94

Sub B - .32 ac

88 - NDV - .13 ac / .4

98 - Imp: .19 ac / .6

(88 * .4) + (98 * .6) = 94

Sub C - 3.83 ac

88 - NVD - 1.63 ac / .43

98 - Imp - 2.2 ac / .57

(88 * .43) + (98 * .6) = 94

Sub d - 1.76 ac

88 - NVD - .53 ac / .3

98 - Imp - 1.23 ac / .7

(88 * .3) + (98 * .7) = 95

Sub e - 1.4 ac

- Group D - .9 ac

88 - NVD - .07 ac / .077

98 - Imp - .83 ac / .92

(88 * .077) + (98 * .92) = 97

- Group A - .5 ac

63 - NVD - .08 ac / .16

98 - Imp - .42 ac / .84

(63 * .16) + (98 * .84) = 92

Total = (97 * .64) + (92 * .36) = 95

ROSENBERG ASSOCIATES™
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SHEET 5 OF _____

PROJECT NO. _____

PROJECT: Rosewood Townhomes BY: WSP DATE: 12/2/22

SUBJECT: Proposed NRCS Curve Number CHECKED BY: _____ DATE: _____

Sub f - .9 ac

Group D - .52 ac

88 - NVD - .38 ac / .73

98 - Imp - .14 ac / .27

(88 * .73) + (98 * .27) = 91

Group A - .38 ac

63 - NVD - .23 ac / .6

98 - Imp - .15 ac / .4

(63 * .6) + (98 * .4) = 77

Total = (91 * .58) + (77 * .42) = 85

Sub g - 1.53 ac

Group D - 1.34 ac

88 - NVD - .07 ac / .05

98 - Imp - 1.27 ac / .95

(88 * .05) + (98 * .95) = 97

Group A - .19 ac

63 - NVD - .006 ac / .03

98 - Imp - .184 ac / .97

(63 * .03) + (98 * .97) = 97

total = 97

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CIVIL ENGINEERS LAND SURVEYORS

SHEET 6 OF _____

PROJECT NO. _____

PROJECT: Rosewood Townhomes BY: WDP DATE: 12/2/22

SUBJECT: Proposed NRCS Curve Number CHECKED BY: _____ DATE: _____

Sub H - 2.91 ac

Group D - 1.15 ac

88 - NDV - .67 ac / .58

98 - Imp .48 ac / .42

(88 * .58) + (98 * .42) = 92

Group A - 1.76

63 - NDV - .51 - .29

98 - Imp - 1.29 ac - .71

(63 * .29) + (98 * .71) = 88

Total = (92 * .4) + (88 * .6) = 90

Sub I - 1.05

63 - NDV - .06 ac / .06

98 Imp - .99 ac / .94

(63 * .06) + (98 * .94) = 96

Sub J - .66 ac

83 - NDV - .42 ac / .64

98 - Imp - .24 ac / .36

(63 * .64) + (98 * .36) = 76

ROSENBERG ASSOCIATES
CIVIL ENGINEERS • LAND SURVEYORS

PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: TR 55 Worksheet CHKD: JWB DATE: 12/1/2022

____ Pre-developed X Post-developed

Subarea: SUB A

Sheet Flow

Surface Description	Mannings 'n' n	Flow Length L (ft) ≤100ft	2-yr 24-hr P_2 (in)	Average slope s (ft/ft)
	0.01	0	1.12	0.0660

$$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$$

T_t 0.00 hr
0.000 min

Shallow Concentrated Flow

	Ground Type	Flow Length L (ft)	Average Velocity V(ft/s)	Average slope s (ft/ft)
	P	0.000		0.0660

P - (paved) Pavement and small upland gullies
G - (unpaved) Grassed waterways
N - nearly bare and untilled (overland flow); and alluvial fans western mountain regions
C - Cultivated straight row crops
S - Short-grass pasture
M - Minimum tillage cultivation, contour or strip-cropped, and woodlands
F - Forest with heavy ground litter and hay meadows

T_t 0 hr
0.000 min

$$T_t = \frac{L}{3600\,V}$$

Channel Flow

Mannings 'n' n	x-sectional flow area, a (ft^2)	Wetted Perimeter P_w	Average slope s (ft/ft)	Flow Length L (ft)
0.01	2.87	16.89	0.0660	194.10

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n} \qquad r = \frac{a}{P_w}$$

$$T_t = \frac{L}{3600\,V}$$

Hydraulic radius r=a/Pw	Average Velocity V(ft/s)
0.17	11.74

T_t 0.00459 hr
0.276 min

Watershed or sub area T_c add up T_t

Lag time =tc*.6

Subarea:	T_c	0.00	hr
SUB A		0.165	min

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PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: TR 55 Worksheet CHKD: JWB DATE: 12/1/2022

____ Pre-developed X Post-developed

Subarea: SUB B

Sheet Flow

Surface Description	Mannings 'n' n	Flow Length L (ft) ≤100ft	2-yr 24-hr P_2 (in)	Average slope s (ft/ft)
	0.05	20.00	1.12	0.0420

$$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$$

T_t 0.02 hr
1.410 min

Shallow Concentrated Flow

	Ground Type	Flow Length L (ft)	Average Velocity V(ft/s)	Average slope s (ft/ft)
	G	100.00	3.31	0.0420

P - (paved) Pavement and small upland gullies
G - (unpaved) Grassed waterways
N - nearly bare and untilled (overland flow); and alluvial fans western mountain regions
C - Cultivated straight row crops
S - Short-grass pasture
M - Minimum tillage cultivation, contour or strip-cropped, and woodlands
F - Forest with heavy ground litter and hay meadows

T_t 0.0084 hr
0.504 min

$$T_t = \frac{L}{3600\,V}$$

Channel Flow

Mannings 'n' n	x-sectional flow area, a (ft^2)	Wetted Perimeter P_w	Average slope s (ft/ft)	Flow Length L (ft)
0.01	2.87	16.89	0.0420	180.40

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n} \qquad r = \frac{a}{P_w}$$

$$T_t = \frac{L}{3600\,V}$$

Hydraulic radius r=a/Pw	Average Velocity V(ft/s)
0.17	9.37

T_t 0.00535 hr
0.321 min

Watershed or sub area T_c add up T_t

Lag time =tc*.6

Subarea:	T_c	0.02	hr
SUB B		1.341	min

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CIVIL ENGINEERS • LAND SURVEYORS

PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: TR 55 Worksheet CHKD: JWB DATE: 12/1/2022

____ Pre-developed X Post-developed

Subarea: SUB C

Sheet Flow

Surface Description	Mannings 'n' n	Flow Length L (ft) ≤100ft	2-yr 24-hr rainfall P_2 (in)	Average slope s (ft/ft)
	0.05	63.00	1.12	0.0320

$$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$$

T_t 0.07 hr
3.938 min

Shallow Concentrated Flow

	Ground Type	Flow Length L (ft)	Average Velocity V(ft/s)	Average slope s (ft/ft)
	P	72.90	3.64	0.0320

P - (paved) Pavement and small upland gullies
G - (unpaved) Grassed waterways
N - nearly bare and untilled (overland flow); and alluvial fans western mountain regions
C - Cultivated straight row crops
S - Short-grass pasture
M - Minimum tillage cultivation, contour or strip-cropped, and woodlands
F - Forest with heavy ground litter and hay meadows

T_t 0.0056 hr
0.334 min

$$T_t = \frac{L}{3600\,V}$$

Channel Flow

Mannings 'n' n	x-sectional flow area, a (ft^2)	Wetted Perimeter P_w	Average slope s (ft/ft)	Flow Length L (ft)
0.01	2.87	16.89	0.0320	660.00

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n} \qquad r = \frac{a}{P_w}$$

$$T_t = \frac{L}{3600\,V}$$

Hydraulic radius r=a/Pw	Average Velocity V(ft/s)
0.17	8.18

T_t 0.02242 hr
1.345 min

Watershed or sub area T_c add up T_t

Lag time =tc*.6

Subarea:	T_c		
SUB C		3.370	min

T_c 0.06 hr

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CIVIL ENGINEERS • LAND SURVEYORS

PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: TR 55 Worksheet CHKD: JWB DATE: 12/1/2022

____ Pre-developed X Post-developed

Subarea: SUB D

Sheet Flow

Surface Description	Mannings 'n' n	Flow Length L (ft) ≤100ft	2-yr 24-hr rainfall P_2 (in)	Average slope s (ft/ft)
	0.01	6.00	1.12	0.0130

$$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$$

T_t 0.00 hr
0.237 min

Shallow Concentrated Flow

	Ground Type	Flow Length L (ft)	Average Velocity V(ft/s)	Average slope s (ft/ft)
	G	0.00		0.0130

P - (paved) Pavement and small upland gullies
G - (unpaved) Grassed waterways
N - nearly bare and untilled (overland flow); and alluvial fans western mountain regions
C - Cultivated straight row crops
S - Short-grass pasture
M - Minimum tillage cultivation, contour or strip-cropped, and woodlands
F - Forest with heavy ground litter and hay meadows

T_t 0 hr
0.000 min

$$T_t = \frac{L}{3600\,V}$$

Channel Flow

Mannings 'n' n	x-sectional flow area, a (ft^2)	Wetted Perimeter P_w	Average slope s (ft/ft)	Flow Length L (ft)
0.01	2.87	16.89	0.0130	1,020.00

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n} \qquad r = \frac{a}{P_w}$$

$$T_t = \frac{L}{3600\,V}$$

Hydraulic radius r=a/Pw	Average Velocity V(ft/s)
0.17	5.21

T_t 0.05437 hr
3.262 min

Watershed or sub area T_c add up T_t

Lag time =tc*.6

Subarea:	T_c		
		0.03	hr
SUB D		2.100	min

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CIVIL ENGINEERS • LAND SURVEYORS

PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: TR 55 Worksheet CHKD: JWB DATE: 12/1/2022

____ Pre-developed X Post-developed

Subarea: SUB E

Sheet Flow

Surface Description	Mannings 'n' n	Flow Length L (ft) ≤100ft	2-yr 24-hr rainfall P_2 (in)	Average slope s (ft/ft)
	0.01	20	1.12	0.0410

$$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$$

T_t 0.01 hr
0.393 min

Shallow Concentrated Flow

	Ground Type	Flow Length L (ft)	Average Velocity V(ft/s)	Average slope s (ft/ft)
	P	62.00	4.12	0.041

P - (paved) Pavement and small upland gullies
G - (unpaved) Grassed waterways
N - nearly bare and untilled (overland flow); and alluvial fans western mountain regions
C - Cultivated straight row crops
S - Short-grass pasture
M - Minimum tillage cultivation, contour or strip-cropped, and woodlands
F - Forest with heavy ground litter and hay meadows

T_t 0.0042 hr
0.251 min

$$T_t = \frac{L}{3600\ V}$$

Channel Flow

Mannings 'n' n	x-sectional flow area, a (ft^2)	Wetted Perimeter P_w	Average slope s (ft/ft)	Flow Length L (ft)
0.01	2.87	16.89	0.0410	632.40

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$$

$$r = \frac{a}{P_w}$$

Hydraulic radius r=a/Pw	Average Velocity V(ft/s)
0.17	9.25

$$T_t = \frac{L}{3600\ V}$$

T_t 0.01898 hr
1.139 min

Watershed or sub area T_c add up T_t

Lag time =tc*.6

Subarea:	T_c		
SUB E		1.070	min

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CIVIL ENGINEERS • LAND SURVEYORS

PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: TR 55 Worksheet CHKD: JWB DATE: 12/1/2022

____ Pre-developed X Post-developed

Subarea: SUB F

Sheet Flow

Surface Description	Mannings 'n' n	Flow Length L (ft) ≤100ft	2-yr 24-hr rainfall P_2 (in)	Average slope s (ft/ft)
	0.01	20	1.12	0.0330

$$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$$

T_t 0.01 hr
0.429 min

Shallow Concentrated Flow

	Ground Type	Flow Length L (ft)	Average Velocity V(ft/s)	Average slope s (ft/ft)
	G	152.00	2.93	0.0330

P - (paved) Pavement and small upland gullies
G - (unpaved) Grassed waterways
N - nearly bare and untilled (overland flow); and alluvial fans western mountain regions
C - Cultivated straight row crops
S - Short-grass pasture
M - Minimum tillage cultivation, contour or strip-cropped, and woodlands
F - Forest with heavy ground litter and hay meadows

T_t 0.0144 hr
0.864 min

$$T_t = \frac{L}{3600\,V}$$

Channel Flow

Mannings 'n' n	x-sectional flow area, a (ft^2)	Wetted Perimeter P_w	Average slope s (ft/ft)	Flow Length L (ft)
0.01	2.87	16.89	0.03	0.00

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n} \qquad r = \frac{a}{P_w}$$

$$T_t = \frac{L}{3600\,V}$$

Hydraulic radius r=a/Pw	Average Velocity V(ft/s)
0.17	8.30

T_t 0 hr
0.000 min

Watershed or sub area T_c add up T_t

Lag time =tc*.6

Subarea:	T_c	0.01	hr
SUB F		0.776	min

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PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: TR 55 Worksheet CHKD: JWB DATE: 12/1/2022

____ Pre-developed X Post-developed

Subarea: SUB G

Sheet Flow

Surface Description	Mannings 'n' n	Flow Length L (ft) ≤100ft	2-yr 24-hr rainfall P_2 (in)	Average slope s (ft/ft)
	0.01	25	1.12	0.0120

$$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$$

T_t 0.01 hr
0.768 min

Shallow Concentrated Flow

	Ground Type	Flow Length L (ft)	Average Velocity V(ft/s)	Average slope s (ft/ft)
	P	67.20	2.23	0.0120

P - (paved) Pavement and small upland gullies
G - (unpaved) Grassed waterways
N - nearly bare and untilled (overland flow); and alluvial fans western mountain regions
C - Cultivated straight row crops
S - Short-grass pasture
M - Minimum tillage cultivation, contour or strip-cropped, and woodlands
F - Forest with heavy ground litter and hay meadows

T_t 0.0084 hr
0.503 min

$$T_t = \frac{L}{3600\,V}$$

Channel Flow

Mannings 'n' n	x-sectional flow area, a (ft^2)	Wetted Perimeter P_w	Average slope s (ft/ft)	Flow Length L (ft)
0.01	2.87	16.89	0.0120	500.00

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n} \qquad r = \frac{a}{P_w}$$

$$T_t = \frac{L}{3600\,V}$$

Hydraulic radius r=a/Pw	Average Velocity V(ft/s)
0.17	5.01

T_t 0.02774 hr
1.664 min

Watershed or sub area T_c add up T_t

Lag time =tc*.6

Subarea:	T_c	0.03	hr
SUB G		1.761	min

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PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: TR 55 Worksheet CHKD: JWB DATE: 12/1/2022

____ Pre-developed X Post-developed

Subarea: SUB H

Sheet Flow

Surface Description	Mannings 'n' n	Flow Length L (ft) ≤100ft	2-yr 24-hr rainfall P_2 (in)	Average slope s (ft/ft)
	0.05	50	1.12	0.0290

$$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$$

T_t 0.06 hr
3.404 min

Shallow Concentrated Flow

	Ground Type	Flow Length L (ft)	Average Velocity V(ft/s)	Average slope s (ft/ft)
	G	25.00	2.75	0.029

P - (paved) Pavement and small upland gullies
G - (unpaved) Grassed waterways
N - nearly bare and untilled (overland flow); and alluvial fans western mountain regions
C - Cultivated straight row crops
S - Short-grass pasture
M - Minimum tillage cultivation, contour or strip-cropped, and woodlands
F - Forest with heavy ground litter and hay meadows

T_t 0.0025 hr
0.152 min

$$T_t = \frac{L}{3600\,V}$$

Channel Flow

Mannings 'n' n	x-sectional flow area, a (ft^2)	Wetted Perimeter P_w	Average slope s (ft/ft)	Flow Length L (ft)
0.01	2.87	16.89	0.03	660.00

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$$

$$r = \frac{a}{P_w}$$

Hydraulic radius r=a/Pw	Average Velocity V(ft/s)
0.17	7.78

$$T_t = \frac{L}{3600\,V}$$

T_t 0.02356 hr
1.413 min

Watershed or sub area T_c add up T_t

Lag time =tc*.6

Subarea:	T_c		
SUB H		2.982	min

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CIVIL ENGINEERS • LAND SURVEYORS

PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: TR 55 Worksheet CHKD: JWB DATE: 12/1/2022

____ Pre-developed X Post-developed

Subarea: SUB I

Sheet Flow

Surface Description	Mannings 'n' n	Flow Length L (ft) ≤100ft	2-yr 24-hr rainfall P_2 (in)	Average slope s (ft/ft)
	0.01	25	1.12	0.0110

$$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$$

T_t 0.01 hr
0.795 min

Shallow Concentrated Flow

	Ground Type	Flow Length L (ft)	Average Velocity V(ft/s)	Average slope s (ft/ft)
	P	52.70	2.13	0.011

P - (paved) Pavement and small upland gullies
G - (unpaved) Grassed waterways
N - nearly bare and untilled (overland flow); and alluvial fans western mountain regions
C - Cultivated straight row crops
S - Short-grass pasture
M - Minimum tillage cultivation, contour or strip-cropped, and woodlands
F - Forest with heavy ground litter and hay meadows

T_t 0.0069 hr
0.412 min

$$T_t = \frac{L}{3600\,V}$$

Channel Flow

Mannings 'n' n	x-sectional flow area, a (ft^2)	Wetted Perimeter P_w	Average slope s (ft/ft)	Flow Length L (ft)
0.01	2.87	16.89	0.01	575.00

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n} \qquad r = \frac{a}{P_w}$$

$$T_t = \frac{L}{3600\,V}$$

Hydraulic radius r=a/Pw	Average Velocity V(ft/s)
0.17	4.79

T_t 0.03332 hr
1.999 min

Watershed or sub area T_c add up T_t

Lag time =tc*.6

Subarea:	T_c		
SUB I		1.924	min

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PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: TR 55 Worksheet CHKD: JWB DATE: 12/1/2022

____ Pre-developed X Post-developed

Subarea: SUB J

Sheet Flow

Surface Description	Mannings 'n' n	Flow Length L (ft) ≤100ft	2-yr 24-hr rainfall P_2 (in)	Average slope s (ft/ft)
	0.01	50	1.12	0.0320

$$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$$

T_t 0.02 hr
0.903 min

Shallow Concentrated Flow

	Ground Type	Flow Length L (ft)	Average Velocity V(ft/s)	Average slope s (ft/ft)
	G	49.00	2.89	0.032

P - (paved) Pavement and small upland gullies
G - (unpaved) Grassed waterways
N - nearly bare and untilled (overland flow); and alluvial fans western mountain regions
C - Cultivated straight row crops
S - Short-grass pasture
M - Minimum tillage cultivation, contour or strip-cropped, and woodlands
F - Forest with heavy ground litter and hay meadows

T_t 0.0047 hr
0.283 min

$$T_t = \frac{L}{3600\,V}$$

Channel Flow

Mannings 'n' n	x-sectional flow area, a (ft^2)	Wetted Perimeter P_w	Average slope s (ft/ft)	Flow Length L (ft)
0.01	2.87	16.89	0.03	0.00

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$$

$$r = \frac{a}{P_w}$$

Hydraulic radius r=a/Pw	Average Velocity V(ft/s)
0.17	8.18

$$T_t = \frac{L}{3600\,V}$$

T_t 0 hr
0.000 min

Watershed or sub area T_c add up T_t

Lag time =tc*.6

Subarea:	T_c	0.01	hr
SUB J		0.712	min

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PROJECT NO. 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: TR 55 Worksheet CHKD: JWB DATE: 12/1/2022

____ Pre-developed X Post-developed

Subarea: OFF A

Sheet Flow

Surface Description	Mannings 'n' n	Flow Length L (ft) ≤100ft	2-yr 24-hr rainfall P_2 (in)	Average slope s (ft/ft)
	0.05	40	1.12	0.1040

$$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$$

T_t 0.03 hr
1.709 min

Shallow Concentrated Flow

	Ground Type	Flow Length L (ft)	Average Velocity V(ft/s)	Average slope s (ft/ft)
	G	50.00	5.20	0.104

P - (paved) Pavement and small upland gullies
G - (unpaved) Grassed waterways
N - nearly bare and untilled (overland flow); and alluvial fans western mountain regions
C - Cultivated straight row crops
S - Short-grass pasture
M - Minimum tillage cultivation, contour or strip-cropped, and woodlands
F - Forest with heavy ground litter and hay meadows

T_t 0.0027 hr
0.160 min

$$T_t = \frac{L}{3600\,V}$$

Channel Flow

Mannings 'n' n	x-sectional flow area, a (ft^2)	Wetted Perimeter P_w	Average slope s (ft/ft)	Flow Length L (ft)
0.05	15.00	30.07	0.10	366.70

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$$

$$r = \frac{a}{P_w}$$

Hydraulic radius r=a/Pw	Average Velocity V(ft/s)
0.50	6.05

$$T_t = \frac{L}{3600\,V}$$

T_t 0.01685 hr
1.011 min

Watershed or sub area T_c add up T_t

Lag time =tc*.6

Subarea:	T_c		
OFF A		0.03	hr
		1.728	min

Project: Rosewood Townhomes Simulation Run: POST 10-3

Start of Run: 01Jan2000, 00:00 Basin Model: PROPOSED
End of Run: 01Jan2000, 04:00 Meteorologic Model: 10-3
Compute Time: 12Dec2022, 10:17:39 Control Specifications: 10YR-3HR

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Off A	0.0090	2.3	01Jan2000, 00:45	0.25
Sub A	0.0010	0.6	01Jan2000, 00:45	0.50
Sub B	0.0005	0.3	01Jan2000, 00:45	0.50
Sub C	0.0060	3.6	01Jan2000, 00:45	0.50
Sub D	0.0027	1.9	01Jan2000, 00:45	0.56
Sub E	0.0022	1.6	01Jan2000, 00:45	0.56
Sub F	0.0014	0.2	01Jan2000, 00:50	0.17
Sub G	0.0024	2.3	01Jan2000, 00:40	0.71
Sub H	0.0046	1.6	01Jan2000, 00:45	0.32
Sub I	0.0016	1.5	01Jan2000, 00:40	0.71
Sub J	0.0010	0.0	01Jan2000, 01:05	0.04
SD1	0.0005	0.3	01Jan2000, 00:45	0.50
SD2	0.0015	0.9	01Jan2000, 00:45	0.50
Reach 1 (SD1 to EX SD1)	0.0015	0.9	01Jan2000, 00:45	0.50
SD5	0.0027	1.9	01Jan2000, 00:45	0.56
SD6	0.0051	4.1	01Jan2000, 00:40	0.63
SD7	0.0051	4.1	01Jan2000, 00:40	0.63
EX SD1	0.0015	0.9	01Jan2000, 00:45	0.50
Reach 2 (EX SD1 to EX SD4)	0.0066	5.0	01Jan2000, 00:45	0.60
SD9	0.0150	6.0	01Jan2000, 00:45	0.35
SD10	0.0150	6.0	01Jan2000, 00:45	0.35
Reach 3 (SD7 to SD8)	0.0150	5.9	01Jan2000, 00:45	0.35
SD12	0.0196	7.5	01Jan2000, 00:45	0.35
SD11	0.0022	1.6	01Jan2000, 00:45	0.56
SD17	0.0234	10.5	01Jan2000, 00:45	0.39
TURN	0.0066	5.0	01Jan2000, 00:45	0.60
Site Outfall	0.0324	15.7	01Jan2000, 00:45	0.41

Project: Rosewood Townhomes Simulation Run: POST 10-24

Start of Run: 01Jan2000, 00:00 Basin Model: PROPOSED
End of Run: 02Jan2000, 05:00 Meteorologic Model: 10-24
Compute Time: 12Dec2022, 10:17:36 Control Specifications: 24HR

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Off A	0.0090	2.3	01Jan2000, 12:00	0.66
Sub A	0.0010	0.4	01Jan2000, 12:00	1.04
Sub B	0.0005	0.2	01Jan2000, 12:00	1.04
Sub C	0.0060	2.6	01Jan2000, 12:00	1.04
Sub D	0.0027	1.3	01Jan2000, 12:00	1.11
Sub E	0.0022	1.0	01Jan2000, 12:00	1.11
Sub F	0.0014	0.3	01Jan2000, 12:00	0.52
Sub G	0.0024	1.3	01Jan2000, 12:00	1.29
Sub H	0.0046	1.4	01Jan2000, 12:00	0.77
Sub I	0.0016	0.9	01Jan2000, 12:00	1.29
Sub J	0.0010	0.0	01Jan2000, 12:00	0.23
SD1	0.0005	0.2	01Jan2000, 12:00	1.04
SD2	0.0015	0.7	01Jan2000, 12:00	1.04
Reach 1 (SD1 to EX SD1)	0.0015	0.7	01Jan2000, 12:00	1.04
SD5	0.0027	1.3	01Jan2000, 12:00	1.11
SD6	0.0051	2.6	01Jan2000, 12:00	1.20
SD7	0.0051	2.6	01Jan2000, 12:00	1.20
EX SD1	0.0015	0.7	01Jan2000, 12:00	1.04
Reach 2 (EX SD1 to SD4)	0.0066	3.2	01Jan2000, 12:00	1.16
SD9	0.0150	5.0	01Jan2000, 12:00	0.81
SD10	0.0150	5.0	01Jan2000, 12:00	0.81
Reach 3 (SD7 to SD8)	0.0150	4.9	01Jan2000, 12:00	0.81
SD12	0.0196	6.4	01Jan2000, 12:00	0.80
SD11	0.0022	1.0	01Jan2000, 12:00	1.11
SD17	0.0234	8.3	01Jan2000, 12:00	0.87
TURN	0.0066	3.2	01Jan2000, 12:00	1.16
Site Outfall	0.0324	11.8	01Jan2000, 12:00	0.89

Project: Rosewood Townhomes Simulation Run: POST 100-3

Start of Run: 01Jan2000, 00:00 Basin Model: PROPOSED
End of Run: 01Jan2000, 04:00 Meteorologic Model: 100-3
Compute Time: 12Dec2022, 10:17:44 Control Specifications: 100YR-3HR

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Off A	0.0090	8.7	01Jan2000, 00:45	0.71
Sub A	0.0010	1.6	01Jan2000, 00:40	1.09
Sub B	0.0005	0.8	01Jan2000, 00:40	1.09
Sub C	0.0060	9.1	01Jan2000, 00:45	1.09
Sub D	0.0027	4.7	01Jan2000, 00:40	1.17
Sub E	0.0022	3.8	01Jan2000, 00:40	1.17
Sub F	0.0014	1.0	01Jan2000, 00:45	0.56
Sub G	0.0024	5.1	01Jan2000, 00:40	1.35
Sub H	0.0046	5.2	01Jan2000, 00:45	0.82
Sub I	0.0016	3.4	01Jan2000, 00:40	1.35
Sub J	0.0010	0.3	01Jan2000, 00:50	0.26
SD1	0.0005	0.8	01Jan2000, 00:40	1.09
SD2	0.0015	2.3	01Jan2000, 00:40	1.09
Reach 1 (SD1 to EX SD1)	0.0015	2.3	01Jan2000, 00:40	1.09
SD5	0.0027	4.7	01Jan2000, 00:40	1.17
SD6	0.0051	9.7	01Jan2000, 00:40	1.25
SD7	0.0051	9.7	01Jan2000, 00:40	1.25
EX SD1	0.0015	2.3	01Jan2000, 00:40	1.09
Reach 2 (EX SD1 to EX SD4)	0.0066	11.6	01Jan2000, 00:40	1.22
SD9	0.0150	17.8	01Jan2000, 00:45	0.86
SD10	0.0150	17.8	01Jan2000, 00:45	0.86
Reach 3 (SD7 to SD8)	0.0150	17.8	01Jan2000, 00:45	0.86
SD12	0.0196	22.9	01Jan2000, 00:45	0.85
SD11	0.0022	3.8	01Jan2000, 00:40	1.17
SD17	0.0234	29.5	01Jan2000, 00:45	0.92
TURN	0.0066	11.6	01Jan2000, 00:40	1.22
Site Outfall	0.0324	42.0	01Jan2000, 00:45	0.94

Project: Rosewood Townhomes Simulation Run: POST 100-24

Start of Run: 01Jan2000, 00:00 Basin Model: PROPOSED
End of Run: 02Jan2000, 05:00 Meteorologic Model: 100-24
Compute Time: 12Dec2022, 10:17:41 Control Specifications: 24HR

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Off A	0.0090	4.8	01Jan2000, 12:00	1.28
Sub A	0.0010	0.7	01Jan2000, 12:00	1.75
Sub B	0.0005	0.4	01Jan2000, 12:00	1.75
Sub C	0.0060	4.4	01Jan2000, 12:00	1.75
Sub D	0.0027	2.1	01Jan2000, 12:00	1.85
Sub E	0.0022	1.7	01Jan2000, 12:00	1.85
Sub F	0.0014	0.6	01Jan2000, 12:00	1.08
Sub G	0.0024	2.0	01Jan2000, 12:00	2.05
Sub H	0.0046	2.8	01Jan2000, 12:00	1.42
Sub I	0.0016	1.3	01Jan2000, 12:00	2.05
Sub J	0.0010	0.2	01Jan2000, 12:00	0.62
SD1	0.0005	0.4	01Jan2000, 12:00	1.75
SD2	0.0015	1.1	01Jan2000, 12:00	1.75
Reach 1 (SD1 to EX SD1)	0.0015	1.1	01Jan2000, 12:00	1.76
SD5	0.0027	2.1	01Jan2000, 12:00	1.85
SD6	0.0051	4.1	01Jan2000, 12:00	1.94
SD7	0.0051	4.1	01Jan2000, 12:00	1.94
EX SD1	0.0015	1.1	01Jan2000, 12:00	1.76
Reach 2 (EX SD1 to SD4)	0.0066	5.2	01Jan2000, 12:00	1.90
SD9	0.0150	9.2	01Jan2000, 12:00	1.47
SD10	0.0150	9.2	01Jan2000, 12:00	1.47
Reach 3 (SD7 to SD8)	0.0150	9.2	01Jan2000, 12:00	1.47
SD12	0.0196	11.9	01Jan2000, 12:00	1.46
SD11	0.0022	1.7	01Jan2000, 12:00	1.85
SD17	0.0234	15.0	01Jan2000, 12:00	1.54
TURN	0.0066	5.2	01Jan2000, 12:00	1.90
Site Outfall	0.0324	21.0	01Jan2000, 12:00	1.56

ROSENBERG ASSOCIATES
CIVIL ENGINEERS • LAND SURVEYORS

PROJECT NO: 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: Detention Calculations CHKD: JWB DATE: 12/1/2022

DETENTION FOR 100-YEAR, 3-HOUR STORM
Pre-Developed Peak Flow: 18.7 cfs

Date	Time	Peak Flow Exist LOT (cfs)	Peak Flow Pro LOT (cfs)	Detention Volume (cu ft)
1-Jan-00	12:00	0	0	0
1-Jan-00	12:05	0	0	0
1-Jan-00	12:10	0	0	0
1-Jan-00	12:15	0	0	0
1-Jan-00	12:20	0	0	0
1-Jan-00	12:25	0	0	0
1-Jan-00	12:30	0	0	0
1-Jan-00	12:35	1.3	15.9	0
1-Jan-00	12:40	11.6	39	6,090
1-Jan-00	12:45	18.7	42	6,990
1-Jan-00	12:50	18.3	33	4,290
1-Jan-00	12:55	13.9	22.3	1,080
1-Jan-00	13:00	10.7	16.2	0
1-Jan-00	13:05	8.3	12	0
1-Jan-00	13:10	6.4	9.2	0
1-Jan-00	13:15	5	7.1	0
1-Jan-00	13:20	4.3	6	0
1-Jan-00	13:25	3.8	5.3	0
1-Jan-00	13:30	3.2	4.5	0
1-Jan-00	13:35	1.7	2.2	0
1-Jan-00	13:40	1.1	1.4	0
1-Jan-00	13:45	0.9	1.3	0
1-Jan-00	13:50	0.9	1.2	0
1-Jan-00	13:55	0.9	1.2	0
1-Jan-00	14:00	0.9	1.2	0
1-Jan-00	14:05	0.9	1.2	0
1-Jan-00	14:10	0.9	1.2	0
1-Jan-00	14:15	0.9	1.2	0
1-Jan-00	14:20	0.9	1.2	0
1-Jan-00	14:25	0.9	1.2	0
1-Jan-00	14:30	0.9	1.2	0
1-Jan-00	14:35	0.9	1.2	0
1-Jan-00	14:40	0.9	1.2	0
1-Jan-00	14:45	0	1.2	0
1-Jan-00	14:50	0	1.2	0
1-Jan-00	14:55	0	1.2	0

1-Jan-00	15:00	0	1.2	0
1-Jan-00	15:05	0	0.4	0
1-Jan-00	15:10	0	0.1	0
1-Jan-00	15:15	0	0	0
1-Jan-00	15:20	0	0	0
1-Jan-00	15:25	0	0	0
1-Jan-00	15:30	0	0	0
1-Jan-00	15:35	0	0	0
1-Jan-00	15:40	0	0	0
1-Jan-00	15:45	0	0	0
1-Jan-00	15:50	0	0	0
1-Jan-00	15:55	0	0	0
1-Jan-00	16:00	0	0	0
Total				**18,450**

ROSENBERG ASSOCIATES
CIVIL ENGINEERS • LAND SURVEYORS

PROJECT NO: 13231-22

PROJECT: Rosewood Townhomes BY: WJP DATE: 12/1/2022

SUBJECT: Detention Calculations CHKD: JWB DATE: 12/1/2022

DETENTION FOR 100-YEAR, 24-HOUR STORM
Pre-Developed Peak Flow: 12.4 cfs

Date	Time	Peak Flow Exist LOT (cfs)	Peak Flow Pro LOT (cfs)	Detention Volume (cu ft)
1-Jan-00	12:00	0	0	0
1-Jan-00	12:30	0	0.1	0
1-Jan-00	13:00	0	0.1	0
1-Jan-00	13:30	0	0.1	0
1-Jan-00	14:00	0	0.1	0
1-Jan-00	14:30	0	0.2	0
1-Jan-00	15:00	0	0.2	0
1-Jan-00	15:30	0	0.2	0
1-Jan-00	16:00	0	0.3	0
1-Jan-00	16:30	0	0.4	0
1-Jan-00	17:00	0	0.5	0
1-Jan-00	17:30	0.1	0.7	0
1-Jan-00	18:00	0.1	0.9	0
1-Jan-00	18:30	0.3	1.4	0
1-Jan-00	19:00	0.7	2.3	0
1-Jan-00	19:30	12.4	21	2,580
1-Jan-00	20:00	6.7	10.3	0
1-Jan-00	20:30	3.3	4.7	0
1-Jan-00	21:00	2.1	2.8	0
1-Jan-00	21:30	1.5	2	0
1-Jan-00	22:00	1.3	1.6	0
1-Jan-00	22:30	1.1	1.4	0
1-Jan-00	23:00	1	1.3	0
1-Jan-00	23:30	0.9	1.2	0
1-Jan-00	0:00	0.8	1	0
1-Jan-00	0:30	0.8	1	0
1-Jan-00	1:00	0.7	0.9	0
1-Jan-00	1:30	0.6	0.8	0
1-Jan-00	2:00	0.6	0.8	0
1-Jan-00	2:30	0.6	0.7	0
1-Jan-00	3:00	0.5	0.6	0
1-Jan-00	3:30	0.5	0.6	0
1-Jan-00	4:00	0.5	0.6	0
1-Jan-00	4:30	0.5	0.6	0
1-Jan-00	5:00	0.4	0.6	0
1-Jan-00	5:30	0.4	0.5	0

1-Jan-00	6:00	0.4	0.5	0
1-Jan-00	6:30	0.4	0.5	0
1-Jan-00	7:00	0.4	0.5	0
1-Jan-00	7:30	0.4	0.5	0
1-Jan-00	8:00	0.4	0.4	0
1-Jan-00	8:30	0.1	0.1	0
1-Jan-00	9:00	0	0	0
1-Jan-00	9:30	0	0	0
1-Jan-00	10:00	0	0	0
1-Jan-00	10:30	0	0	0
1-Jan-00	11:00	0	0	0
1-Jan-00	11:30	0	0	0
1-Jan-00	12:00	0	0	0
Total				**2,580**

Worksheet for Combination Inlet In Sag - SD5

Project Description

Solve For	Spread

Input Data

Discharge	1.31	cfs
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft
Opening Height	0.5	ft
Curb Throat Type	Horizontal	
Throat Incline Angle	90.00	degrees

Options

Calculation Option	Use Both

Results

Spread	5.8	ft
Depth	3.5	in
Gutter Depression	2.2	in
Total Depression	3.2	in
Open Grate Area	2.8	ft²
Active Grate Weir Length	5.1	ft

Worksheet for Combination Inlet In Sag - SD9

Project Description

Solve For	Spread

Input Data

Discharge	5.40	cfs
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft
Opening Height	0.5	ft
Curb Throat Type	Horizontal	
Throat Incline Angle	90.00	degrees

Options

Calculation Option	Use Both

Results

Spread	16.7	ft
Depth	6.2	in
Gutter Depression	2.2	in
Total Depression	3.2	in
Open Grate Area	2.8	ft²
Active Grate Weir Length	5.1	ft

Worksheet for Combination Inlet In Sag - SD14

Project Description

Solve For	Spread

Input Data

Discharge	1.76	cfs
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft
Opening Height	0.5	ft
Curb Throat Type	Horizontal	
Throat Incline Angle	90.00	degrees

Options

Calculation Option	Use Both

Results

Spread	7.3	ft
Depth	3.9	in
Gutter Depression	2.2	in
Total Depression	3.2	in
Open Grate Area	2.8	ft²
Active Grate Weir Length	5.1	ft

Worksheet for Combination Inlet On Grade - EX SD 2

Project Description

Solve For	Efficiency

Input Data

Discharge	0.08	cfs
Slope	0.045	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	100.00	%
Intercepted Flow	0.08	cfs
Bypass Flow	0.00	cfs
Spread	0.7	ft
Depth	0.9	in
Flow Area	0.0	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	3.20	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	1.000	
Side Flow Factor	0.043	
Grate Flow Ratio	1.000	
Equivalent Cross Slope	0.152	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.451	
Total Interception Length	3.4	ft

Worksheet for Combination Inlet On Grade - EX SD1

Project Description

Solve For	Efficiency

Input Data

Discharge	0.06	cfs
Slope	0.020	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	100.00	%
Intercepted Flow	0.06	cfs
Bypass Flow	0.00	cfs
Spread	0.7	ft
Depth	0.9	in
Flow Area	0.0	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	2.20	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	1.000	
Side Flow Factor	0.081	
Grate Flow Ratio	1.000	
Equivalent Cross Slope	0.152	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.649	
Total Interception Length	2.4	ft

Worksheet for Combination Inlet On Grade - SD2

Project Description

Solve For	Efficiency

Input Data

Discharge	0.23	cfs
Slope	0.020	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	100.00	%
Intercepted Flow	0.23	cfs
Bypass Flow	0.00	cfs
Spread	1.2	ft
Depth	1.5	in
Flow Area	0.1	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	3.07	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	1.000	
Side Flow Factor	0.046	
Grate Flow Ratio	1.000	
Equivalent Cross Slope	0.152	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.370	
Total Interception Length	4.2	ft

Worksheet for Combination Inlet On Grade - SD3

Project Description

Solve For	Efficiency

Input Data

Discharge	2.40	cfs
Slope	0.005	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	85.06	%
Intercepted Flow	2.04	cfs
Bypass Flow	0.36	cfs
Spread	8.9	ft
Depth	4.3	in
Flow Area	1.0	ft^2
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	2.48	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	1.000	
Side Flow Factor	0.066	
Grate Flow Ratio	0.682	
Equivalent Cross Slope	0.110	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.172	
Total Interception Length	9.0	ft

Worksheet for Combination Inlet On Grade - SD4

Project Description

Solve For	Efficiency

Input Data

Discharge	1.16	cfs
Slope	0.005	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	99.24	%
Intercepted Flow	1.15	cfs
Bypass Flow	0.01	cfs
Spread	5.7	ft
Depth	3.5	in
Flow Area	0.5	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	2.32	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	1.000	
Side Flow Factor	0.074	
Grate Flow Ratio	0.878	
Equivalent Cross Slope	0.136	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.265	
Total Interception Length	5.8	ft

Worksheet for Combination Inlet On Grade - SD6

Project Description

Solve For	Efficiency

Input Data

Discharge	3.30	cfs
Slope	0.060	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	90.00	%
Intercepted Flow	2.97	cfs
Bypass Flow	0.33	cfs
Spread	4.8	ft
Depth	3.3	in
Flow Area	0.4	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	7.99	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	0.921	
Side Flow Factor	0.009	
Grate Flow Ratio	0.925	
Equivalent Cross Slope	0.142	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.083	
Total Interception Length	18.6	ft

Worksheet for Combination Inlet On Grade - SD7

Project Description

Solve For	Efficiency

Input Data

Discharge	0.03	cfs
Slope	0.045	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	100.00	%
Intercepted Flow	0.03	cfs
Bypass Flow	0.00	cfs
Spread	0.5	ft
Depth	0.6	in
Flow Area	0.0	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	2.50	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	1.000	
Side Flow Factor	0.066	
Grate Flow Ratio	1.000	
Equivalent Cross Slope	0.152	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.680	
Total Interception Length	2.3	ft

Worksheet for Combination Inlet On Grade - SD8

Project Description

Solve For	Efficiency

Input Data

Discharge	4.50	cfs
Slope	0.027	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	81.70	%
Intercepted Flow	3.68	cfs
Bypass Flow	0.82	cfs
Spread	7.9	ft
Depth	4.1	in
Flow Area	0.8	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	5.62	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	1.000	
Side Flow Factor	0.016	
Grate Flow Ratio	0.740	
Equivalent Cross Slope	0.117	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.083	
Total Interception Length	18.7	ft

Worksheet for Combination Inlet On Grade - SD10

Project Description

Solve For	Efficiency

Input Data

Discharge	1.40	cfs
Slope	0.054	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	100.00	%
Intercepted Flow	1.40	cfs
Bypass Flow	0.00	cfs
Spread	1.9	ft
Depth	2.5	in
Flow Area	0.2	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	7.02	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	1.000	
Side Flow Factor	0.011	
Grate Flow Ratio	1.000	
Equivalent Cross Slope	0.152	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.128	
Total Interception Length	12.1	ft

Worksheet for Combination Inlet On Grade - SD11

Project Description

Solve For	Efficiency

Input Data

Discharge	3.80	cfs
Slope	0.050	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	90.64	%
Intercepted Flow	3.44	cfs
Bypass Flow	0.36	cfs
Spread	5.8	ft
Depth	3.6	in
Flow Area	0.5	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	7.36	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	0.978	
Side Flow Factor	0.010	
Grate Flow Ratio	0.869	
Equivalent Cross Slope	0.134	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.080	
Total Interception Length	19.3	ft

Worksheet for Combination Inlet On Grade - SD12

Project Description

Solve For	Efficiency

Input Data

Discharge	0.41	cfs
Slope	0.054	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	100.00	%
Intercepted Flow	0.41	cfs
Bypass Flow	0.00	cfs
Spread	1.2	ft
Depth	1.6	in
Flow Area	0.1	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	5.16	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	1.000	
Side Flow Factor	0.019	
Grate Flow Ratio	1.000	
Equivalent Cross Slope	0.152	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.215	
Total Interception Length	7.2	ft

Worksheet for Combination Inlet On Grade - SD13

Project Description

Solve For	Efficiency

Input Data

Discharge	3.90	cfs
Slope	0.013	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	78.66	%
Intercepted Flow	3.07	cfs
Bypass Flow	0.83	cfs
Spread	9.0	ft
Depth	4.3	in
Flow Area	1.0	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	3.96	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	1.000	
Side Flow Factor	0.030	
Grate Flow Ratio	0.677	
Equivalent Cross Slope	0.109	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.106	
Total Interception Length	14.7	ft

Worksheet for Combination Inlet On Grade - SD15

Project Description

Solve For	Efficiency

Input Data

Discharge	3.30	cfs
Slope	0.013	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	83.20	%
Intercepted Flow	2.75	cfs
Bypass Flow	0.55	cfs
Spread	8.2	ft
Depth	4.1	in
Flow Area	0.9	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	3.88	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	1.000	
Side Flow Factor	0.031	
Grate Flow Ratio	0.721	
Equivalent Cross Slope	0.115	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.117	
Total Interception Length	13.3	ft

Worksheet for Combination Inlet On Grade - SD16

Project Description

Solve For	Efficiency

Input Data

Discharge	0.65	cfs
Slope	0.005	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	100.00	%
Intercepted Flow	0.65	cfs
Bypass Flow	0.00	cfs
Spread	3.2	ft
Depth	2.9	in
Flow Area	0.3	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	2.29	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	1.000	
Side Flow Factor	0.076	
Grate Flow Ratio	0.988	
Equivalent Cross Slope	0.150	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.359	
Total Interception Length	4.3	ft

Worksheet for Combination Inlet On Grade - SD17

Project Description

Solve For	Efficiency

Input Data

Discharge	0.01 cfs
Slope	0.005 ft/ft
Gutter Width	2.00 ft
Gutter Cross Slope	0.110 ft/ft
Road Cross Slope	0.020 ft/ft
Roughness Coefficient	0.013
Local Depression	1.0 in
Local Depression Width	24.0 in
Grate Width	2.00 ft
Grate Length	3.1 ft
Grate Type	P-50 mm (P-1 -7/8")
Clogging	50.0 %
Curb Opening Length	3.1 ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	100.00 %
Intercepted Flow	0.01 cfs
Bypass Flow	0.00 cfs
Spread	0.5 ft
Depth	0.6 in
Flow Area	0.0 ft²
Gutter Depression	2.2 in
Total Depression	3.2 in
Velocity	0.83 ft/s
Splash Over Velocity	7.11 ft/s
Frontal Flow Factor	1.000
Side Flow Factor	0.336
Grate Flow Ratio	1.000
Equivalent Cross Slope	0.152 ft/ft
Active Grate Length	1.6 ft
Length Factor	2.086
Total Interception Length	0.7 ft

Worksheet for Combination Inlet On Grade - SD18

Project Description

Solve For	Efficiency

Input Data

Discharge	0.16	cfs
Slope	0.040	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Roughness Coefficient	0.013	
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft

Options

Calculation Option	Use Both
Grate Flow Option	Exclude None

Results

Efficiency	100.00	%
Intercepted Flow	0.16	cfs
Bypass Flow	0.00	cfs
Spread	0.9	ft
Depth	1.2	in
Flow Area	0.0	ft²
Gutter Depression	2.2	in
Total Depression	3.2	in
Velocity	3.64	ft/s
Splash Over Velocity	7.11	ft/s
Frontal Flow Factor	1.000	
Side Flow Factor	0.034	
Grate Flow Ratio	1.000	
Equivalent Cross Slope	0.152	ft/ft
Active Grate Length	1.6	ft
Length Factor	0.349	
Total Interception Length	4.4	ft

Worksheet for Ditch Inlet In Sag - (2X2 Drop Inlet)

Project Description

Solve For	Spread

Input Data

Discharge	8.60 cfs
Left Side Slope	2.000 H:V
Right Side Slope	2.000 H:V
Bottom Width	2.00 ft
Grate Width	2.00 ft
Grate Length	2.0 ft
Local Depression	1.0 in
Local Depression Width	24.0 in
Grate Type	P-50 mm (P-1 -7/8")
Clogging	50.0 %

Results

Spread	4.8 ft
Depth	8.5 in
Wetted Perimeter	5.2 ft
Top Width	4.83 ft
Open Grate Area	1.8 ft²
Active Grate Weir Length	6.0 ft

Worksheet for Draiange Swale - 2

Project Description	
Friction Method	Manning Formula
Solve For	Discharge

Input Data		
Roughness Coefficient	0.041	
Channel Slope	0.005	ft/ft
Normal Depth	12.0	in
Left Side Slope	2.000	H:V
Right Side Slope	2.000	H:V
Bottom Width	1.00	ft

Results		
Discharge	5.15	cfs
Flow Area	3.0	ft²
Wetted Perimeter	5.5	ft
Hydraulic Radius	6.6	in
Top Width	5.00	ft
Critical Depth	7.6	in
Critical Slope	0.037	ft/ft
Velocity	1.72	ft/s
Velocity Head	0.05	ft
Specific Energy	1.05	ft
Froude Number	0.391	
Flow Type	Subcritical	

GVF Input Data		
Downstream Depth	0.0	in
Length	0.0	ft
Number Of Steps	0	

GVF Output Data		
Upstream Depth	0.0	in
Profile Description	N/A	
Profile Headloss	0.00	ft
Downstream Velocity	0.00	ft/s
Upstream Velocity	0.00	ft/s
Normal Depth	12.0	in
Critical Depth	7.6	in
Channel Slope	0.005	ft/ft
Critical Slope	0.037	ft/ft

Worksheet for Drainage Swale- 1

Project Description	
Friction Method	Manning Formula
Solve For	Discharge

Input Data		
Roughness Coefficient	0.041	
Channel Slope	0.005	ft/ft
Normal Depth	18.0	in
Left Side Slope	2.000	H:V
Right Side Slope	2.000	H:V
Bottom Width	1.00	ft

Results		
Discharge	13.01	cfs
Flow Area	6.0	ft²
Wetted Perimeter	7.7	ft
Hydraulic Radius	9.3	in
Top Width	7.00	ft
Critical Depth	11.9	in
Critical Slope	0.033	ft/ft
Velocity	2.17	ft/s
Velocity Head	0.07	ft
Specific Energy	1.57	ft
Froude Number	0.413	
Flow Type	Subcritical	

GVF Input Data		
Downstream Depth	0.0	in
Length	0.0	ft
Number Of Steps	0	

GVF Output Data		
Upstream Depth	0.0	in
Profile Description	N/A	
Profile Headloss	0.00	ft
Downstream Velocity	0.00	ft/s
Upstream Velocity	0.00	ft/s
Normal Depth	18.0	in
Critical Depth	11.9	in
Channel Slope	0.005	ft/ft
Critical Slope	0.033	ft/ft

Worksheet for Existing Check 1

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010	
Channel Slope	0.053	ft/ft
Normal Depth	18.0	in
Diameter	18.0	in
Discharge	31.44	cfs

Results

Discharge	31.44	cfs
Normal Depth	18.0	in
Flow Area	1.8	ft²
Wetted Perimeter	4.7	ft
Hydraulic Radius	4.5	in
Top Width	0.00	ft
Critical Depth	17.9	in
Percent Full	100.0	%
Critical Slope	0.050	ft/ft
Velocity	17.79	ft/s
Velocity Head	4.92	ft
Specific Energy	6.42	ft
Froude Number	(N/A)	
Maximum Discharge	33.82	cfs
Discharge Full	31.44	cfs
Slope Full	0.053	ft/ft
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.0	in
Length	0.0	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.0	in
Profile Description	N/A	
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.0	%
Normal Depth Over Rise	100.0	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	18.0	in
Critical Depth	17.9	in
Channel Slope	0.053	ft/ft
Critical Slope	0.050	ft/ft

Worksheet for Existing Check 2

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.005 ft/ft
Normal Depth	18.0 in
Diameter	18.0 in
Discharge	10.03 cfs

Results

Discharge	10.03 cfs
Normal Depth	18.0 in
Flow Area	1.8 ft²
Wetted Perimeter	4.7 ft
Hydraulic Radius	4.5 in
Top Width	0.00 ft
Critical Depth	14.7 in
Percent Full	100.0 %
Critical Slope	0.005 ft/ft
Velocity	5.68 ft/s
Velocity Head	0.50 ft
Specific Energy	2.00 ft
Froude Number	(N/A)
Maximum Discharge	10.79 cfs
Discharge Full	10.03 cfs
Slope Full	0.005 ft/ft
Flow Type	Critical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	18.0 in
Critical Depth	14.7 in
Channel Slope	0.005 ft/ft
Critical Slope	0.005 ft/ft

Worksheet for Existing Check 3

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.005 ft/ft
Normal Depth	24.0 in
Diameter	24.0 in
Discharge	20.79 cfs

Results

Discharge	20.79 cfs
Normal Depth	24.0 in
Flow Area	3.1 ft²
Wetted Perimeter	6.3 ft
Hydraulic Radius	6.0 in
Top Width	0.00 ft
Critical Depth	19.6 in
Percent Full	100.0 %
Critical Slope	0.005 ft/ft
Velocity	6.62 ft/s
Velocity Head	0.68 ft
Specific Energy	2.68 ft
Froude Number	(N/A)
Maximum Discharge	22.37 cfs
Discharge Full	20.79 cfs
Slope Full	0.005 ft/ft
Flow Type	Critical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	24.0 in
Critical Depth	19.6 in
Channel Slope	0.005 ft/ft
Critical Slope	0.005 ft/ft

Worksheet for Gutter along east side of Road D-1

Project Description	
Solve For	Spread

Input Data	
Channel Slope	0.054 ft/ft
Discharge	1.52 cfs
Gutter Width	2.0 ft
Gutter Cross Slope	0.110 ft/ft
Road Cross Slope	0.020 ft/ft
Roughness Coefficient	0.013

Results	
Spread	2.0 ft
Flow Area	0.2 ft²
Depth	2.6 in
Gutter Depression	2.2 in
Velocity	7.15 ft/s

Worksheet for Gutter along east side of Road D-2

Project Description	
Solve For	Spread

Input Data	
Channel Slope	0.005 ft/ft
Discharge	3.80 cfs
Gutter Width	2.0 ft
Gutter Cross Slope	0.110 ft/ft
Road Cross Slope	0.020 ft/ft
Roughness Coefficient	0.013

Results	
Spread	11.2 ft
Flow Area	1.4 ft²
Depth	4.8 in
Gutter Depression	2.2 in
Velocity	2.66 ft/s

Worksheet for Gutter along north side of Road B- 2

Project Description	
Solve For	Spread

Input Data	
Channel Slope	0.005 ft/ft
Discharge	2.40 cfs
Gutter Width	2.0 ft
Gutter Cross Slope	0.110 ft/ft
Road Cross Slope	0.020 ft/ft
Roughness Coefficient	0.013

Results	
Spread	8.9 ft
Flow Area	1.0 ft²
Depth	4.3 in
Gutter Depression	2.2 in
Velocity	2.48 ft/s

Worksheet for Gutter along north side of Road A-1

Project Description	
Solve For	Spread

Input Data	
Channel Slope	0.013 ft/ft
Discharge	3.90 cfs
Gutter Width	2.0 ft
Gutter Cross Slope	0.110 ft/ft
Road Cross Slope	0.020 ft/ft
Roughness Coefficient	0.013

Results	
Spread	8.9 ft
Flow Area	1.0 ft²
Depth	4.3 in
Gutter Depression	2.2 in
Velocity	4.00 ft/s

Worksheet for Gutter along south side of Road B- 2

Project Description	
Solve For	Spread

Input Data	
Channel Slope	0.005 ft/ft
Discharge	2.00 cfs
Gutter Width	2.0 ft
Gutter Cross Slope	0.110 ft/ft
Road Cross Slope	0.020 ft/ft
Roughness Coefficient	0.013

Results	
Spread	8.0 ft
Flow Area	0.8 ft²
Depth	4.1 in
Gutter Depression	2.2 in
Velocity	2.43 ft/s

Worksheet for Gutter along south side of Road A-1

Project Description	
Solve For	Spread

Input Data	
Channel Slope	0.013 ft/ft
Discharge	2.60 cfs
Gutter Width	2.0 ft
Gutter Cross Slope	0.110 ft/ft
Road Cross Slope	0.020 ft/ft
Roughness Coefficient	0.013

Results	
Spread	7.1 ft
Flow Area	0.7 ft²
Depth	3.9 in
Gutter Depression	2.2 in
Velocity	3.83 ft/s

Worksheet for Gutter along west side of Road D-1

Project Description	
Solve For	Spread

Input Data	
Channel Slope	0.054 ft/ft
Discharge	1.82 cfs
Gutter Width	2.0 ft
Gutter Cross Slope	0.110 ft/ft
Road Cross Slope	0.020 ft/ft
Roughness Coefficient	0.013

Results	
Spread	2.6 ft
Flow Area	0.2 ft²
Depth	2.8 in
Gutter Depression	2.2 in
Velocity	7.42 ft/s

Worksheet for Gutter along west side of Road D-2

Project Description	
Solve For	Spread

Input Data	
Channel Slope	0.005 ft/ft
Discharge	0.01 cfs
Gutter Width	2.0 ft
Gutter Cross Slope	0.110 ft/ft
Road Cross Slope	0.020 ft/ft
Roughness Coefficient	0.013

Results	
Spread	0.5 ft
Flow Area	0.0 ft²
Depth	0.6 in
Gutter Depression	2.2 in
Velocity	0.83 ft/s

Worksheet for Combination Inlet In Sag - SD1

Project Description

Solve For	Spread

Input Data

Discharge	1.05	cfs
Gutter Width	2.00	ft
Gutter Cross Slope	0.110	ft/ft
Road Cross Slope	0.020	ft/ft
Local Depression	1.0	in
Local Depression Width	24.0	in
Grate Width	2.00	ft
Grate Length	3.1	ft
Grate Type	P-50 mm (P-1 -7/8")	
Clogging	50.0	%
Curb Opening Length	3.1	ft
Opening Height	0.5	ft
Curb Throat Type	Horizontal	
Throat Incline Angle	90.00	degrees

Options

Calculation Option	Use Both

Results

Spread	4.8	ft
Depth	3.3	in
Gutter Depression	2.2	in
Total Depression	3.2	in
Open Grate Area	2.8	ft²
Active Grate Weir Length	5.1	ft

Worksheet for SDP1 (future development)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.006 ft/ft
Normal Depth	18.0 in
Diameter	18.0 in
Discharge	10.58 cfs

Results

Discharge	10.58 cfs
Normal Depth	18.0 in
Flow Area	1.8 ft²
Wetted Perimeter	4.7 ft
Hydraulic Radius	4.5 in
Top Width	0.00 ft
Critical Depth	15.0 in
Percent Full	100.0 %
Critical Slope	0.006 ft/ft
Velocity	5.99 ft/s
Velocity Head	0.56 ft
Specific Energy	2.06 ft
Froude Number	(N/A)
Maximum Discharge	11.38 cfs
Discharge Full	10.58 cfs
Slope Full	0.006 ft/ft
Flow Type	Undefined

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	18.0 in
Critical Depth	15.0 in
Channel Slope	0.006 ft/ft
Critical Slope	0.006 ft/ft

Worksheet for SDP2 (SD1 to SD18)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.005 ft/ft
Normal Depth	12.0 in
Diameter	12.0 in
Discharge	3.27 cfs

Results

Discharge	3.27 cfs
Normal Depth	12.0 in
Flow Area	0.8 ft²
Wetted Perimeter	3.1 ft
Hydraulic Radius	3.0 in
Top Width	0.00 ft
Critical Depth	9.3 in
Percent Full	100.0 %
Critical Slope	0.006 ft/ft
Velocity	4.17 ft/s
Velocity Head	0.27 ft
Specific Energy	1.27 ft
Froude Number	(N/A)
Maximum Discharge	3.52 cfs
Discharge Full	3.27 cfs
Slope Full	0.005 ft/ft
Flow Type	Undefined

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	12.0 in
Critical Depth	9.3 in
Channel Slope	0.005 ft/ft
Critical Slope	0.006 ft/ft

Worksheet for SDP3 (SD18 to SD2)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.005 ft/ft
Normal Depth	12.0 in
Diameter	12.0 in
Discharge	3.27 cfs

Results

Discharge	3.27 cfs
Normal Depth	12.0 in
Flow Area	0.8 ft²
Wetted Perimeter	3.1 ft
Hydraulic Radius	3.0 in
Top Width	0.00 ft
Critical Depth	9.3 in
Percent Full	100.0 %
Critical Slope	0.006 ft/ft
Velocity	4.17 ft/s
Velocity Head	0.27 ft
Specific Energy	1.27 ft
Froude Number	(N/A)
Maximum Discharge	3.52 cfs
Discharge Full	3.27 cfs
Slope Full	0.005 ft/ft
Flow Type	Undefined

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	12.0 in
Critical Depth	9.3 in
Channel Slope	0.005 ft/ft
Critical Slope	0.006 ft/ft

Worksheet for SDP4 (SD2 TO EX SD1)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.007 ft/ft
Normal Depth	18.0 in
Diameter	18.0 in
Discharge	11.42 cfs

Results

Discharge	11.42 cfs
Normal Depth	18.0 in
Flow Area	1.8 ft²
Wetted Perimeter	4.7 ft
Hydraulic Radius	4.5 in
Top Width	0.00 ft
Critical Depth	15.5 in
Percent Full	100.0 %
Critical Slope	0.006 ft/ft
Velocity	6.46 ft/s
Velocity Head	0.65 ft
Specific Energy	2.15 ft
Froude Number	(N/A)
Maximum Discharge	12.29 cfs
Discharge Full	11.42 cfs
Slope Full	0.007 ft/ft
Flow Type	Undefined

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	18.0 in
Critical Depth	15.5 in
Channel Slope	0.007 ft/ft
Critical Slope	0.006 ft/ft

Worksheet for SDP5 (SD3 to SD4)

Project Description	
Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data		
Roughness Coefficient	0.010	
Channel Slope	0.005	ft/ft
Normal Depth	12.0	in
Diameter	12.0	in
Discharge	3.27	cfs

Results		
Discharge	3.27	cfs
Normal Depth	12.0	in
Flow Area	0.8	ft²
Wetted Perimeter	3.1	ft
Hydraulic Radius	3.0	in
Top Width	0.00	ft
Critical Depth	9.3	in
Percent Full	100.0	%
Critical Slope	0.006	ft/ft
Velocity	4.17	ft/s
Velocity Head	0.27	ft
Specific Energy	1.27	ft
Froude Number	(N/A)	
Maximum Discharge	3.52	cfs
Discharge Full	3.27	cfs
Slope Full	0.005	ft/ft
Flow Type	Undefined	

GVF Input Data		
Downstream Depth	0.0	in
Length	0.0	ft
Number Of Steps	0	

GVF Output Data		
Upstream Depth	0.0	in
Profile Description	N/A	
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.0	%
Normal Depth Over Rise	100.0	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	12.0	in
Critical Depth	9.3	in
Channel Slope	0.005	ft/ft
Critical Slope	0.006	ft/ft

Worksheet for SDP6 (SD4 to SD5)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.005 ft/ft
Normal Depth	12.0 in
Diameter	12.0 in
Discharge	3.27 cfs

Results

Discharge	3.27 cfs
Normal Depth	12.0 in
Flow Area	0.8 ft²
Wetted Perimeter	3.1 ft
Hydraulic Radius	3.0 in
Top Width	0.00 ft
Critical Depth	9.3 in
Percent Full	100.0 %
Critical Slope	0.006 ft/ft
Velocity	4.17 ft/s
Velocity Head	0.27 ft
Specific Energy	1.27 ft
Froude Number	(N/A)
Maximum Discharge	3.52 cfs
Discharge Full	3.27 cfs
Slope Full	0.005 ft/ft
Flow Type	Undefined

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	12.0 in
Critical Depth	9.3 in
Channel Slope	0.005 ft/ft
Critical Slope	0.006 ft/ft

Worksheet for SDP7 (SD5 to SD6)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.010 ft/ft
Normal Depth	12.0 in
Diameter	12.0 in
Discharge	4.63 cfs

Results

Discharge	4.63 cfs
Normal Depth	12.0 in
Flow Area	0.8 ft²
Wetted Perimeter	3.1 ft
Hydraulic Radius	3.0 in
Top Width	0.00 ft
Critical Depth	10.7 in
Percent Full	100.0 %
Critical Slope	0.009 ft/ft
Velocity	5.90 ft/s
Velocity Head	0.54 ft
Specific Energy	1.54 ft
Froude Number	(N/A)
Maximum Discharge	4.98 cfs
Discharge Full	4.63 cfs
Slope Full	0.010 ft/ft
Flow Type	Undefined

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	12.0 in
Critical Depth	10.7 in
Channel Slope	0.010 ft/ft
Critical Slope	0.009 ft/ft

Worksheet for SDP8 (SD6 to SD7)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.026 ft/ft
Normal Depth	12.0 in
Diameter	12.0 in
Discharge	7.47 cfs

Results

Discharge	7.47 cfs
Normal Depth	12.0 in
Flow Area	0.8 ft²
Wetted Perimeter	3.1 ft
Hydraulic Radius	3.0 in
Top Width	0.00 ft
Critical Depth	11.8 in
Percent Full	100.0 %
Critical Slope	0.023 ft/ft
Velocity	9.51 ft/s
Velocity Head	1.41 ft
Specific Energy	2.41 ft
Froude Number	(N/A)
Maximum Discharge	8.03 cfs
Discharge Full	7.47 cfs
Slope Full	0.026 ft/ft
Flow Type	Undefined

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	12.0 in
Critical Depth	11.8 in
Channel Slope	0.026 ft/ft
Critical Slope	0.023 ft/ft

Worksheet for SDP9 (SD8 to SD9)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.020 ft/ft
Normal Depth	15.0 in
Diameter	15.0 in
Discharge	11.88 cfs

Results

Discharge	11.88 cfs
Normal Depth	15.0 in
Flow Area	1.2 ft²
Wetted Perimeter	3.9 ft
Hydraulic Radius	3.8 in
Top Width	0.00 ft
Critical Depth	14.6 in
Percent Full	100.0 %
Critical Slope	0.018 ft/ft
Velocity	9.68 ft/s
Velocity Head	1.46 ft
Specific Energy	2.71 ft
Froude Number	(N/A)
Maximum Discharge	12.77 cfs
Discharge Full	11.88 cfs
Slope Full	0.020 ft/ft
Flow Type	Undefined

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	15.0 in
Critical Depth	14.6 in
Channel Slope	0.020 ft/ft
Critical Slope	0.018 ft/ft

Worksheet for SDP10 (SD9 to SD10)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.033 ft/ft
Normal Depth	15.0 in
Diameter	15.0 in
Discharge	15.25 cfs

Results

Discharge	15.25 cfs
Normal Depth	15.0 in
Flow Area	1.2 ft²
Wetted Perimeter	3.9 ft
Hydraulic Radius	3.8 in
Top Width	0.00 ft
Critical Depth	14.8 in
Percent Full	100.0 %
Critical Slope	0.030 ft/ft
Velocity	12.43 ft/s
Velocity Head	2.40 ft
Specific Energy	3.65 ft
Froude Number	(N/A)
Maximum Discharge	16.41 cfs
Discharge Full	15.25 cfs
Slope Full	0.033 ft/ft
Flow Type	Undefined

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	15.0 in
Critical Depth	14.8 in
Channel Slope	0.033 ft/ft
Critical Slope	0.030 ft/ft

Worksheet for SDP11 (SD10 to SD12)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.040 ft/ft
Normal Depth	15.0 in
Diameter	15.0 in
Discharge	16.79 cfs

Results

Discharge	16.79 cfs
Normal Depth	15.0 in
Flow Area	1.2 ft²
Wetted Perimeter	3.9 ft
Hydraulic Radius	3.8 in
Top Width	0.00 ft
Critical Depth	14.9 in
Percent Full	100.0 %
Critical Slope	0.037 ft/ft
Velocity	13.69 ft/s
Velocity Head	2.91 ft
Specific Energy	4.16 ft
Froude Number	(N/A)
Maximum Discharge	18.07 cfs
Discharge Full	16.79 cfs
Slope Full	0.040 ft/ft
Flow Type	Undefined

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	15.0 in
Critical Depth	14.9 in
Channel Slope	0.040 ft/ft
Critical Slope	0.037 ft/ft

Worksheet for SDP12 (SD12 to SD14)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.016 ft/ft
Normal Depth	18.0 in
Diameter	18.0 in
Discharge	17.27 cfs

Results

Discharge	17.27 cfs
Normal Depth	18.0 in
Flow Area	1.8 ft²
Wetted Perimeter	4.7 ft
Hydraulic Radius	4.5 in
Top Width	0.00 ft
Critical Depth	17.3 in
Percent Full	100.0 %
Critical Slope	0.014 ft/ft
Velocity	9.77 ft/s
Velocity Head	1.48 ft
Specific Energy	2.98 ft
Froude Number	(N/A)
Maximum Discharge	18.58 cfs
Discharge Full	17.27 cfs
Slope Full	0.016 ft/ft
Flow Type	Undefined

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	18.0 in
Critical Depth	17.3 in
Channel Slope	0.016 ft/ft
Critical Slope	0.014 ft/ft

Worksheet for SDP13 (SD13 to SD14)

Project Description	
Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data		
Roughness Coefficient	0.010	
Channel Slope	0.005	ft/ft
Normal Depth	12.0	in
Diameter	12.0	in
Discharge	3.27	cfs

Results		
Discharge	3.27	cfs
Normal Depth	12.0	in
Flow Area	0.8	ft²
Wetted Perimeter	3.1	ft
Hydraulic Radius	3.0	in
Top Width	0.00	ft
Critical Depth	9.3	in
Percent Full	100.0	%
Critical Slope	0.006	ft/ft
Velocity	4.17	ft/s
Velocity Head	0.27	ft
Specific Energy	1.27	ft
Froude Number	(N/A)	
Maximum Discharge	3.52	cfs
Discharge Full	3.27	cfs
Slope Full	0.005	ft/ft
Flow Type	Undefined	

GVF Input Data		
Downstream Depth	0.0	in
Length	0.0	ft
Number Of Steps	0	

GVF Output Data		
Upstream Depth	0.0	in
Profile Description	N/A	
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.0	%
Normal Depth Over Rise	100.0	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	12.0	in
Critical Depth	9.3	in
Channel Slope	0.005	ft/ft
Critical Slope	0.006	ft/ft

Worksheet for SDP14 (SD14 to SD15)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.026 ft/ft
Normal Depth	18.0 in
Diameter	18.0 in
Discharge	22.02 cfs

Results

Discharge	22.02 cfs
Normal Depth	18.0 in
Flow Area	1.8 ft²
Wetted Perimeter	4.7 ft
Hydraulic Radius	4.5 in
Top Width	0.00 ft
Critical Depth	17.7 in
Percent Full	100.0 %
Critical Slope	0.024 ft/ft
Velocity	12.46 ft/s
Velocity Head	2.41 ft
Specific Energy	3.91 ft
Froude Number	(N/A)
Maximum Discharge	23.68 cfs
Discharge Full	22.02 cfs
Slope Full	0.026 ft/ft
Flow Type	Critical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	18.0 in
Critical Depth	17.7 in
Channel Slope	0.026 ft/ft
Critical Slope	0.024 ft/ft

Worksheet for SDP15 (SD15 to SD16)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.033 ft/ft
Normal Depth	18.0 in
Diameter	18.0 in
Discharge	24.81 cfs

Results

Discharge	24.81 cfs
Normal Depth	18.0 in
Flow Area	1.8 ft²
Wetted Perimeter	4.7 ft
Hydraulic Radius	4.5 in
Top Width	0.00 ft
Critical Depth	17.8 in
Percent Full	100.0 %
Critical Slope	0.030 ft/ft
Velocity	14.04 ft/s
Velocity Head	3.06 ft
Specific Energy	4.56 ft
Froude Number	(N/A)
Maximum Discharge	26.68 cfs
Discharge Full	24.81 cfs
Slope Full	0.033 ft/ft
Flow Type	Critical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	18.0 in
Critical Depth	17.8 in
Channel Slope	0.033 ft/ft
Critical Slope	0.030 ft/ft

Worksheet for SDP16 (SD16 to SD17)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.008 ft/ft
Normal Depth	24.0 in
Diameter	24.0 in
Discharge	26.30 cfs

Results

Discharge	26.30 cfs
Normal Depth	24.0 in
Flow Area	3.1 ft²
Wetted Perimeter	6.3 ft
Hydraulic Radius	6.0 in
Top Width	0.00 ft
Critical Depth	21.5 in
Percent Full	100.0 %
Critical Slope	0.007 ft/ft
Velocity	8.37 ft/s
Velocity Head	1.09 ft
Specific Energy	3.09 ft
Froude Number	(N/A)
Maximum Discharge	28.29 cfs
Discharge Full	26.30 cfs
Slope Full	0.008 ft/ft
Flow Type	Critical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	24.0 in
Critical Depth	21.5 in
Channel Slope	0.008 ft/ft
Critical Slope	0.007 ft/ft

Worksheet for SDP17 (SD17 to SD11)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010
Channel Slope	0.008 ft/ft
Normal Depth	24.0 in
Diameter	24.0 in
Discharge	26.30 cfs

Results

Discharge	26.30 cfs
Normal Depth	24.0 in
Flow Area	3.1 ft²
Wetted Perimeter	6.3 ft
Hydraulic Radius	6.0 in
Top Width	0.00 ft
Critical Depth	21.5 in
Percent Full	100.0 %
Critical Slope	0.007 ft/ft
Velocity	8.37 ft/s
Velocity Head	1.09 ft
Specific Energy	3.09 ft
Froude Number	(N/A)
Maximum Discharge	28.29 cfs
Discharge Full	26.30 cfs
Slope Full	0.008 ft/ft
Flow Type	Critical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	24.0 in
Critical Depth	21.5 in
Channel Slope	0.008 ft/ft
Critical Slope	0.007 ft/ft

Worksheet for SDP18 (SD17 to SD18)

Project Description	
Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data	
Roughness Coefficient	0.010
Channel Slope	0.010 ft/ft
Normal Depth	24.0 in
Diameter	24.0 in
Discharge	29.11 cfs

Results	
Discharge	29.11 cfs
Normal Depth	24.0 in
Flow Area	3.1 ft²
Wetted Perimeter	6.3 ft
Hydraulic Radius	6.0 in
Top Width	0.00 ft
Critical Depth	22.2 in
Percent Full	100.0 %
Critical Slope	0.008 ft/ft
Velocity	9.27 ft/s
Velocity Head	1.33 ft
Specific Energy	3.33 ft
Froude Number	(N/A)
Maximum Discharge	31.32 cfs
Discharge Full	29.11 cfs
Slope Full	0.010 ft/ft
Flow Type	Critical

GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	100.0 %
Downstream Velocity	Infinity ft/s
Upstream Velocity	Infinity ft/s
Normal Depth	24.0 in
Critical Depth	22.2 in
Channel Slope	0.010 ft/ft
Critical Slope	0.008 ft/ft

Worksheet for SDP19 (EX SD3 to EX SD2)

Project Description	
Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data		
Roughness Coefficient	0.010	
Channel Slope	0.011	ft/ft
Normal Depth	24.0	in
Diameter	24.0	in
Discharge	30.84	cfs

Results		
Discharge	30.84	cfs
Normal Depth	24.0	in
Flow Area	3.1	ft²
Wetted Perimeter	6.3	ft
Hydraulic Radius	6.0	in
Top Width	0.00	ft
Critical Depth	22.5	in
Percent Full	100.0	%
Critical Slope	0.010	ft/ft
Velocity	9.82	ft/s
Velocity Head	1.50	ft
Specific Energy	3.50	ft
Froude Number	(N/A)	
Maximum Discharge	33.18	cfs
Discharge Full	30.84	cfs
Slope Full	0.011	ft/ft
Flow Type	Critical	

GVF Input Data		
Downstream Depth	0.0	in
Length	0.0	ft
Number Of Steps	0	

GVF Output Data		
Upstream Depth	0.0	in
Profile Description	N/A	
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.0	%
Normal Depth Over Rise	100.0	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	24.0	in
Critical Depth	22.5	in
Channel Slope	0.011	ft/ft
Critical Slope	0.010	ft/ft

Worksheet for SDP20 (EX SD3 to EX SD4)

Project Description	
Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data		
Roughness Coefficient	0.010	
Channel Slope	0.005	ft/ft
Normal Depth	18.0	in
Diameter	18.0	in
Discharge	10.03	cfs

Results		
Discharge	10.03	cfs
Normal Depth	18.0	in
Flow Area	1.8	ft²
Wetted Perimeter	4.7	ft
Hydraulic Radius	4.5	in
Top Width	0.00	ft
Critical Depth	14.7	in
Percent Full	100.0	%
Critical Slope	0.005	ft/ft
Velocity	5.68	ft/s
Velocity Head	0.50	ft
Specific Energy	2.00	ft
Froude Number	(N/A)	
Maximum Discharge	10.79	cfs
Discharge Full	10.03	cfs
Slope Full	0.005	ft/ft
Flow Type	Critical	

GVF Input Data		
Downstream Depth	0.0	in
Length	0.0	ft
Number Of Steps	0	

GVF Output Data		
Upstream Depth	0.0	in
Profile Description	N/A	
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.0	%
Normal Depth Over Rise	100.0	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	18.0	in
Critical Depth	14.7	in
Channel Slope	0.005	ft/ft
Critical Slope	0.005	ft/ft

Worksheet for SDP21 (2 X 2 Drop Inlet to SD8)

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010	
Channel Slope	0.010	ft/ft
Normal Depth	15.0	in
Diameter	15.0	in
Discharge	8.40	cfs

Results

Discharge	8.40	cfs
Normal Depth	15.0	in
Flow Area	1.2	ft²
Wetted Perimeter	3.9	ft
Hydraulic Radius	3.8	in
Top Width	0.00	ft
Critical Depth	13.6	in
Percent Full	100.0	%
Critical Slope	0.009	ft/ft
Velocity	6.84	ft/s
Velocity Head	0.73	ft
Specific Energy	1.98	ft
Froude Number	(N/A)	
Maximum Discharge	9.03	cfs
Discharge Full	8.40	cfs
Slope Full	0.010	ft/ft
Flow Type	Critical	

GVF Input Data

Downstream Depth	0.0	in
Length	0.0	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.0	in
Profile Description	N/A	
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.0	%
Normal Depth Over Rise	100.0	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	15.0	in
Critical Depth	13.6	in
Channel Slope	0.010	ft/ft
Critical Slope	0.009	ft/ft

Dixie Storm Water Coalition
St. George, Washington, Ivins, Santa Clara

Storm Water Quality Report

Date: 1/3/23

Project Name: Rosewood Townhomes

Project ID: 13231-22

Design Engineer: WJP

Is the project within a watershed that is 303(d) listed? YES

If yes:

Name of receiving water(s): SANTA CLARA-1 LOWER COLORADO RIVER

Listed Impairment(s): SELENIUM, TDS, TEMPERATURE

Does the watershed have an approved TMDL? NO

If yes:

Approved TMDL(s): 1,200 MG/L TDS, 4.6µg/L SELENIUM, TEMP TDML NOT SET

I have reviewed the storm water quality design and find this report to be complete, accurate, and current.

JARED BATES P.E. , Project Manager

PROFESSIONAL ENGINEER
JARED W. BATES
NO. 7886812
STATE OF UTAH
1/3/2023

Dixie Storm Water Coalition
St. George, Washington, Ivins, Santa Clara

Project Information

Type of Project (New Development, Redevelopment): NEW DEVELOPMENT

Area of Land Disturbance (ac): 14.99

Project Impervious Area (ac): 11.62

Project Imperviousness (%): 77.5

Project Volumetric Runoff Coefficient, R_V: 0.51

80th Storm Depth (in): 0.44

Project 80th Percentile Volume, V_{goal} (cf): 12,210

Subsurface Information

Groundwater

Depth to Groundwater (ft): >15 FT

Historical High Depth to Groundwater if known (ft): >15 FT

Source: GEOTECHNICAL INVESTIGATION ROSEWOOD TOWNHOMES AGEC (12/2/2022)

Groundwater Contamination at Site: NO

Soil Information

Infiltration Rate (in/hr): <0.000142

Hydrologic Soil Group: D

Source: NRCS SOIL SURVEY

Soil Contamination at Site: NO

Drinking Water

Within Drinking Water Source Area Protection: NO

Additional Relevant Site Information

Dixie Storm Water Coalition
St. George, Washington, Ivins, Santa Clara

LID Drainage Areas

Add additional rows as needed.

Contributing Drainage Area	Area (ac)	Impervious Area (ac)	Imperviousness (%)	Volumetric Runoff Coefficient, R_V	Water Quality Volume, WQV (cf)
CDA 1	14.99	11.62	77.52	0.51	12,210.43
CDA 2					
CDA 3					
CDA 4					
				Total WQV (cf)	12,210.4

LID BMP Design

Add additional rows as needed.

Contributing Drainage Area	LID BMP Type	Water Quality Volume, WQV (cf)	Runoff Retained (cf)	Percent of Runoff Captured (%)
CDA1	LOT BENCHING	12,210.43	0.0	0.0
CDA 2			0.0	
CDA 3				
CDA 4				
		Total Volume Retained (cf)	0.0	0.0

Percent of V_{goal} captured by LID BMPs: 0.0__%

If 100% of V_{goal} is not captured, document and provide narrative of technical infeasibilities and/or alternate compliance measures below:

Due to shallow bedrock and soil conditions , capturing 100% of V_goal is technically infeasible. See Geo-technical Report "GEOTECHNICAL INVESTIGATION ROSEWOOD TOWNHOMES AGEC (12/2/2022)" for additional information.

Describe additional storm water quality measures incorporated into the site:

The proposed project will be graded to developed benched lots; which will create longer travel distances for stormwater to travel throughout the site prior to being intercepted by storm drain inlets. The increase in travel distances results in reduced peak flows compared to the pre-project conditions.

Dixie Storm Water Coalition
St. George, Washington, Ivins, Santa Clara

Narrative of technical infeasibilities and/or alternate compliance measures below:

AGEC has reviewed the Dixie Storm Water Coalition Guide for the Low Impact Development (LID) dated June 20, 2020 and provided the evaluation:

• Using Figure 2 (flow chart), Step 2 indicates a "NO" for acceptable native soils.

• Using Table 3 (matrix) the shallow bedrock and expansive mudstone prohibits the use of the majority of the BMP's. BMP's BR-1 (Rain Garden), BR-2 (Bioretention Cell), BR-4 (Vegetated Strip), BR-5 (Tree Box Filter), D-3 (Dry Well) and HR-1 (Harvest and Reuse) are noted as "any" or these matrix options available, while the others have been eliminated through the matrix flow chart.

• Although, these options are available, due to the expansive and shallow bedrock on the site, the use of these BMP's would be detrimental to the project.

• As an alternative, we recommend the use of a site drainage plan to allow water to drain to localized drainages or to off site detention or retention locations.

• We recommend that residences pipe rain gutters and yard drains to the curb and surface flowing to the storm drains.

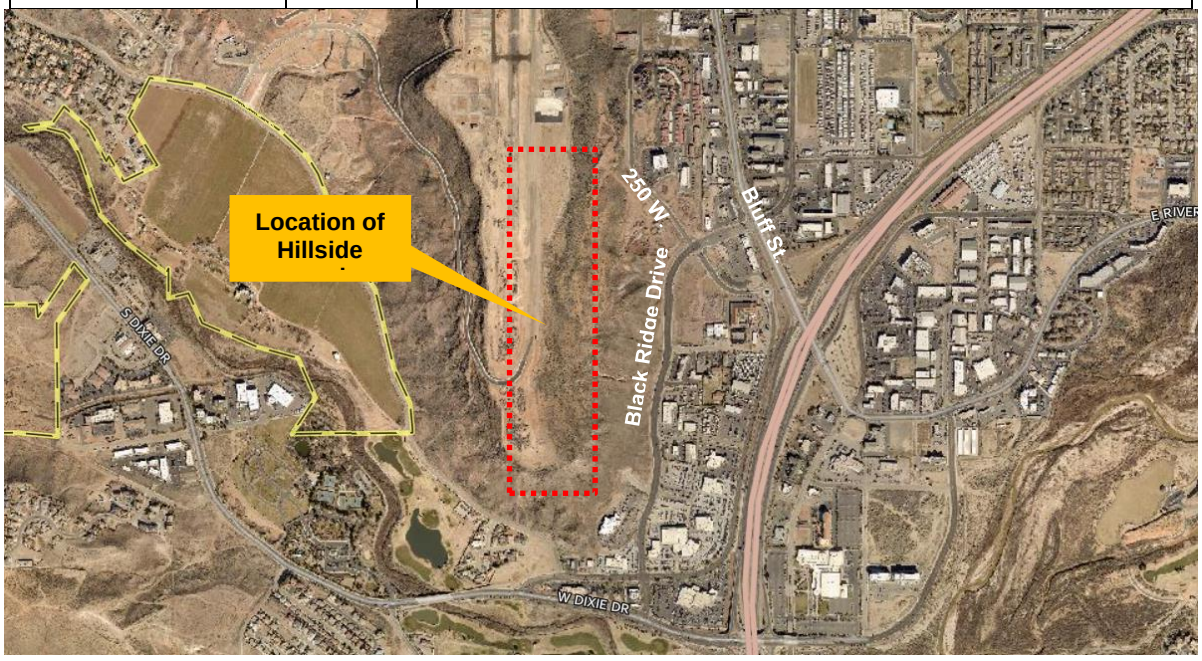
Based on the evaluation for use of on-site retention, it is our recommendation that BMP's with surface infiltration that will potentially wet the expansive mudstone/clay or may perch and flow laterally on shallow bedrock not be used. The infiltration from this type of drainage may result in surface heave and damage to infrastructure and structures.

St.George
Community Development

ITEM 2
Hillside Permit

HILLSIDE REVIEW BOARD AGENDA REPORT: **01/25/2023**

Tech Ridge Southeast Slope Hillside Development Permit (Case No. 2023-HS-002)		
Request:	Consider a Hillside Development Permit to make modifications to the ridgeline along the southeast slope of the Tech Ridge Development.	
Applicant:	Isaac Barlow	
Representative:	Mike Bradshaw	
Location:	250 West Street at approximately 1170 South	
General Plan:	COM (Commercial), OS (Open Space), and LDR (Low Density Residential)	
Existing Zoning:	R-1-10 (Single Family Residential 10,000sf), PD-MU (Planned Development Mixed Use), and OS (Open Space)	
Surrounding Zoning:	North	PD-MU and R-1-10
	South	PD-MU and R-1-10
	East	R-1-10
	West	OS, PD-MU



BACKGROUND

This is a request to obtain a hillside development permit to be able to perform work along the hillside located on the southeast portion of Tech Ridge adjacent to the proposed southeast access road that leads from 250 West Street to the Tech Ridge development. There is an existing ridgeline along the southeast portion of the Tech Ridge development that is prominent at certain locations but then fades out in other locations. This proposal is to add material to the areas where the ridgeline is not definite and to blend the new material into the existing prominent ridgeline. This proposal will add in fill and retaining walls to four specific locations. Refer to Exhibit C for the location of these four areas and the plans to alter the current lay of the land.

EXHIBITS PROVIDED

1. Exhibit A – Maps
   "Exhibit A" in the packet shows the general plan land use map and the zoning map.

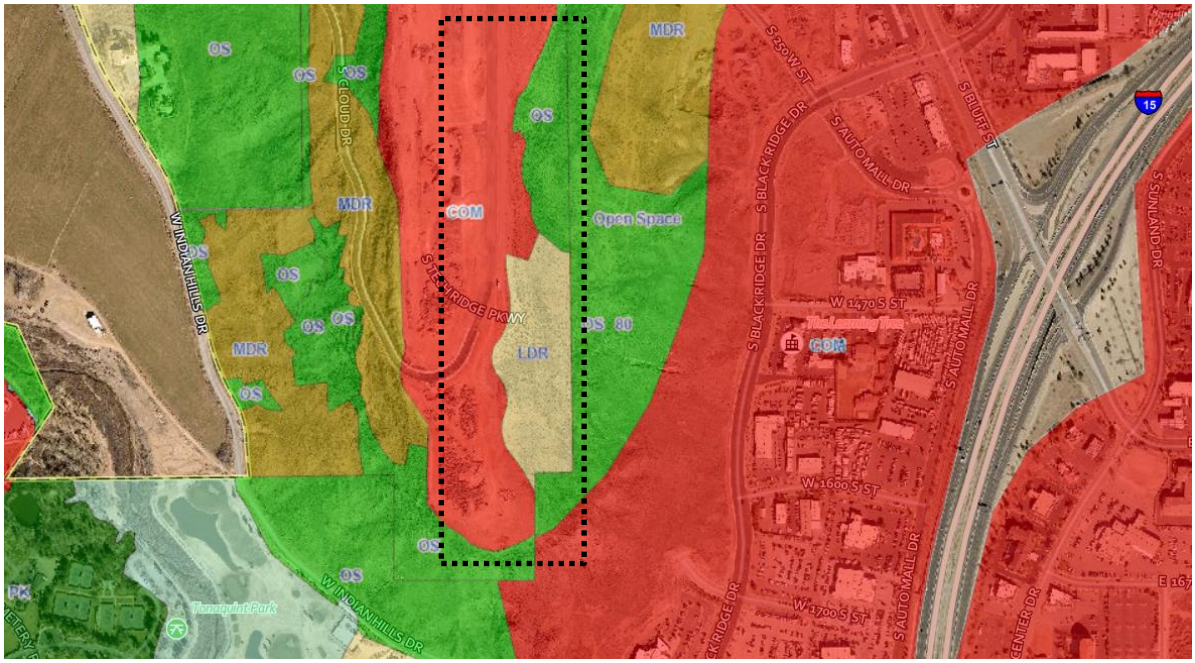
2. Exhibit B – Applicable Ordinances
   "Exhibit B" in the packet lists the applicable zoning regulation that apply to this case found in Title 10, Chapter 13A.

3. Exhibit C – Tech Ridge Southeast Hillside Protection Plan
   "Exhibit C" in the packet shows the development plan along with grading and slope analysis.

4. Exhibit D – Geotechnical Report
   "Exhibit D" in the packet shows the Geotech report for this proposal.

Exhibit A
MAPS

General Plan - COM



Zoning - R-1-10

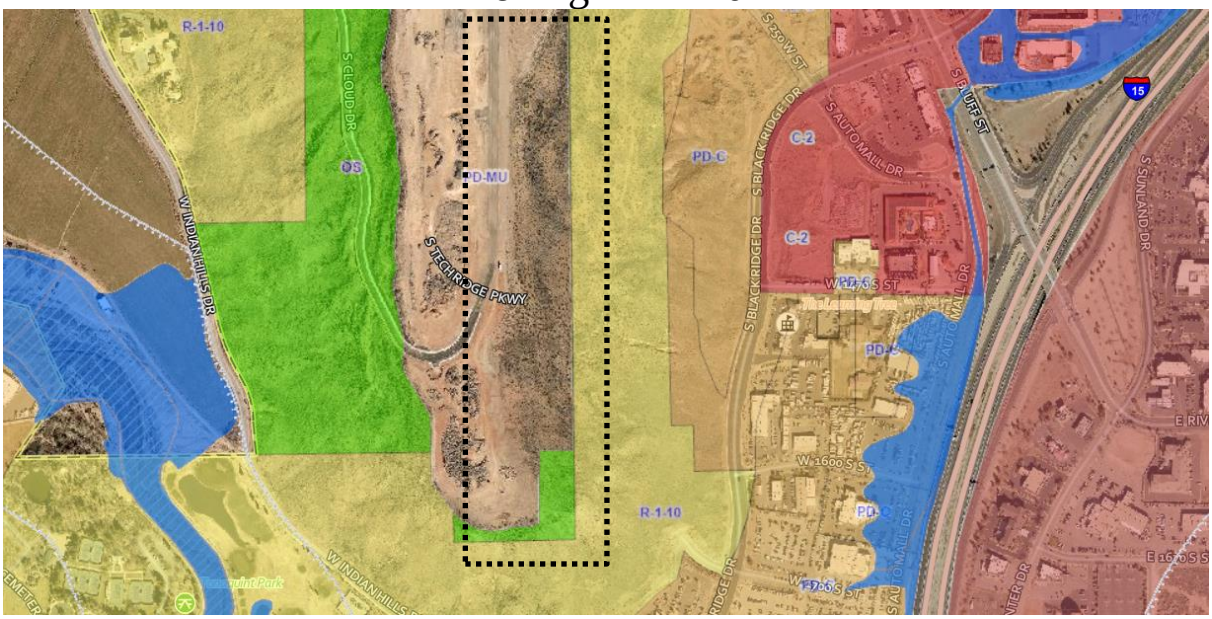


Exhibit B
APPLICABLE ORDINANCES

I. *Density and Disturbance Standards*

A. The hillside development overlay zone (HDOZ) limits development densities and provides specific development incentives to transfer underlying zone densities from hillsides (sending areas), to less steep slopes or more safe development areas (receiving areas), within a development.

B. For those portions of a proposed development with natural slopes twenty percent (20%) or less, development density follows the density and development standards in the underlying zone.

C. For those portions of a proposed development with natural slopes from twenty-one percent (21%) to thirty percent (30%), development activity shall not disturb more than thirty percent (30%) of the parcel within this slope category.

D. For those portions of a proposed development with natural slopes from thirty-one percent (31%) to forty percent (40%), development activity shall not disturb more than five percent (5%) of the area within this slope category.

E. A proposed development may not disturb slopes in excess of forty percent (40%).

F. The applicant may:

1. Transfer all development density from steeper slope categories (sending areas), to areas within the development with natural slopes of twenty percent (20%) or less (receiving areas); and

2. Develop additional bonus density, calculated from each slope category, as follows:

a. Natural slopes twenty percent (20%) or less transferred on a one-to-one (1:1) unit basis; plus

b. One (1) additional density unit for each density unit transferred from natural slopes of twenty-one percent (21%) to thirty percent (30%); plus

c. Two (2) additional density units for each density unit transferred from natural slopes of thirty-one percent (31%) to forty percent (40%).

3. Unit calculation for the receiving area shall be based on the requirements of the sending area zone.

G. Density transfers to the receiving area may occur without a zone change within the receiving area even though the resulting density or configuration may exceed the density limits of the receiving area zone. Other than density, the receiving area's zoning requirements apply to development in the receiving area. For instance, lot sizes may vary, but single-family zoning districts only allow single-family detached dwellings.

H. If the applicant proposes to develop within the twenty-one percent (21%) to forty percent (40%) slope area, the applicant cannot employ partial density transfers from the sending area and must propose a design, site development plans, and a grading plan that blends and harmonizes all aspects of the proposed development into the natural topography, and that minimizes road cuts and fills.

I. Non-disturb areas within a residential lot as shown on the slope analysis map shall not be used to calculate minimum lot size.

J. Disturbance standards do not apply to the city for limited city facilities: trails, parks, and utilities. (Ord. 2019-10-002, 10-10-2019)

II. Slope and Slope Areas Determined

A. Slope shall be determined for each significant portion of a development parcel.

B. Procedure: The applicant shall map the location of the natural slope by using the following procedure:

1. Preparation of Contour Maps: The applicant shall submit an accurate, current contour map, prepared and certified by a licensed professional engineer or surveyor, which shows all land contours at intervals no greater than five feet (5'), drawn at a one inch equals one hundred feet (1" = 100') scale maximum.

2. Verification through Field Surveys: The city engineer or designee may require the applicant to submit a field survey to verify the accuracy of the contour map.

C. Determination of Slope Areas: Using the contour map, natural slopes shall be calculated using points identified as natural slopes of twenty percent (20%), thirty percent (30%), and forty percent (40%), and shall be located on the contour map and connected by a continuous line. That area bounded by said lines and intersecting property lines shall be used for determining project density. Small washes or outcrops, which have slopes distinctly different from surrounding property, and are not part of the contiguous topography, may be excluded from the slope determination. (Ord. 2019-10-002, 10-10-2019)

III. Street Design

The following standards apply to public and private streets within the zone:

A. Street Grades: The maximum allowed street grade is fifteen percent (15%).

B. Intersections: Roads shall intersect at ninety-degree (90°) angles.

C. Intersection Spacing: Intersections should be spaced far enough apart so that the traffic stopped to make left turns at one intersection does not interfere with traffic movements at the adjacent intersections.

1. On low-volume streets such as access roads to minor collectors or minor collectors to minor collectors, the minimum spacing distance is one hundred twenty-five feet (125');

2. For minor collectors to major collectors, the minimum spacing distance is two hundred fifty feet (250').

D. Design Speed: The design of geometric features such as horizontal and vertical alignment will depend on the design speed selected for each street. The design speed is primarily determined by the street function and classification and is the maximum speed for safe and comfortable operation of a vehicle. Other than a major collector, all streets in hillside areas are classified as low speed streets (thirty-five (35) miles per hour or less).

Street Design Classification	Design Speed	Posted Speed
Minor collector	*30*	*30*
Local road	*25 – 30*	*25*
Hillside local	*25*	*25*
Hillside access	*25*	*25*

E. Clear Sight Distance at Intersections: Adequate, clear sight distance is required at intersections, as follows:

Posted Speed of Higher Order Road	Minimum Y	Desired Y
20	*210*	*240*
25	*260*	*300*
30	*310*	*380*
35	*365*	*475*

F. Vertical Curves and Intersection Relationship: The vertical alignment of residential streets shall comply with latest editions of AASHTO geometric design of highways and streets. See table below for listing of pertinent design criteria:

Design Speed	Crest "K" Value	Sag "K" Value
	Minimum Length of Vertical Curves	
20	*10*	*20*
25	*20*	*30*
30	*30*	*40*
35	*40*	*50*

L = KA (for minimum sight distance on a vertical curve).

L = Length of vertical curve for proper sight distance.

A = Algebraic difference in grade.

Vertical alignment with the intersection is also of special nature, and design alternatives may be required. As a guideline, the approach area where vehicles stop while waiting to enter an intersection shall not exceed four (4%) to five percent (5%) from the gutter line of the street being intersected for a distance of fifty feet (50'), though a range of fifty feet (50') to one hundred feet (100') is more desirable. This applies to all intersections, except those intersections where both intersecting streets are minor collectors. The landing area for a minor collector shall be designed for a grade of two percent (2%) to three percent (3%) for a distance of one hundred feet (100').

G. Safe Stopping Sight Distance: The minimum sight distance to be provided before a stop is required is included in the table below:

Design Speed	Computed	Recommended Distance	Add-On for 15% Grade
20	106.7	125	20
25	146.5	150	36
30	195.7	200	64
35	248.4	250	95

H. Horizontal Curves: The minimum centerline radius for horizontal curves on low-speed residential streets is:

Street Classification or Speed	Curve Radius in Feet
Minimum Centerline Radius	
Private streets	50 – 100
20 mph	100 – 150
25 mph	185
30 mph	310

I. Street Cross-Section Standards: The requirements for street cross-section configurations are based on the following factors:

1. Traffic capacity;

2. Design speed;

3. Projected traffic;

4. Designs to reduce scarring.

J. Alternate road cross sections, such as grade separated streets, may be used if applicable safety and traffic standards are met.

K. Elimination of sidewalk on one side of the road may be approved when elimination of one (1) sidewalk can appreciably reduce the amount of hillside disturbance. Other considerations may also warrant its elimination. When one (1) sidewalk is eliminated, the remaining sidewalk shall be increased by one foot (1') in width.

L. The following table sets forth the requirements for street standards for single-family residential development.

Maximum Grade	Street Classification	Width ROW	Width TBC	Pavement Width	Width Sidewalk	ADT
Street Cross-Section Standards for Single-Family Residential						
12%	Minor collector	60'	50'	45'	5'	1,500 – 3,500
15%	Local road	50'	40'	35'	4'	750 – 1,500
15%	Hillside local	45'	35'	30'	4'	150 – 750
15%	Hillside access	41'	31'	26'	4'	0 – 150

(Ord. 2019-10-002, 10-10-2019)

IV. Additional Design Standards

1. *Retaining walls shall be colored to blend into the surrounding natural geology.*

2. *Retaining wall height is limited to the heights set forth in chapter 18 of this title and the standards for rock wall construction.*

3. *Building exterior colors shall be earth tone and blend with the surrounding natural landscape.*

4. *In residential zones, "no disturbance" areas shall be held as the "common area" of a project. Common areas shall be owned and maintained by the homeowners' association or may be deeded to the city when accepted by the city.*

5. *In nonresidential zones, any "no disturbance" area shall be identified on the final site plan or final plat.*

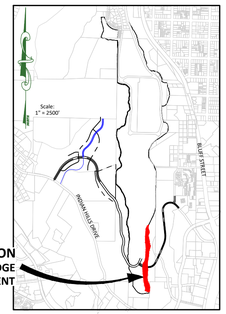
6. *Any required no disturbance area shall be identified on the ground with temporary fencing or other approved means to prevent accidental disturbance of the area during construction and such fencing shall be installed prior to issuance of a grading permit.*

7. *The building site shall be located on the flattest portion of the parcel.*

8. *No structure shall extend over any natural ridgeline. The structure shall be in contact with the ground at all edges. (Ord. 2019-10-002, 10-10-2019)*

Exhibit C

TECH RIDGE SOUTHEAST HILLSIDE PROTECTION PLAN

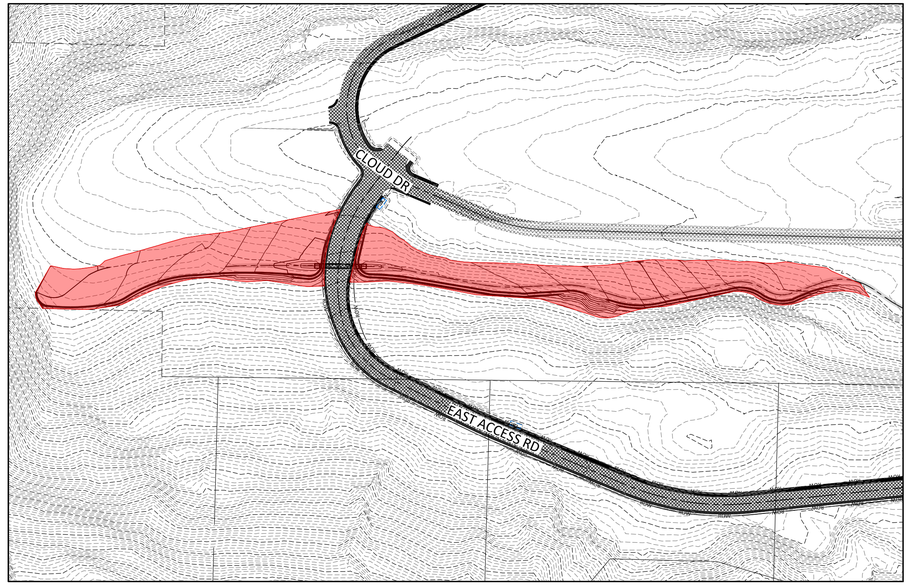


PROJECT LOCATION
TECH RIDGE
SOUTHEAST DEVELOPMENT

VICINITY MAP

TECH RIDGE SOUTHEAST DEVELOPMENT
HILLSIDE APPLICATION
FOR
TECH RIDGE DEVELOPMENT, LLC
LOCATED IN
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

SHEET INDEX	
SHEET NO.	DESCRIPTION
C1.0	COVER SHEET
C1.1	SHEET LAYOUT
C1.2	EXISTING GRADE SLOPE ANALYSIS
C1.3	OVERALL CUT AND FILL
C2.0	GRADING SECTIONS
C2.1- C2.3	SOUTHEAST DEVELOPMENT GRADING



GRAPHIC SCALE

200 0 100 200 400

(IN FEET)
1 inch = 200 ft.
If Printed 11x17 use Half Scale

NORTH

DEVELOPER

CITY OF ST. GEORGE
ATT: MR. CAMERON CUTLER
175 W 200 N
ST. GEORGE, UT 84770
EMAIL: CAMERON.CUTLER@SGCITY.ORG

ENGINEER

ALLIANCE CONSULTING
2303 N. CORAL CANYON BLVD. SUITE 201
WASHINGTON, UT 84780-0577
PHONE: (435) 673-8060
FAX: (435) 673-8065
ENGINEER: MR. DELOSS HAMMON P.E.
CONTACT: MR. MIKE BRADSHAW
EMAIL: mwb@allianceconsulting.us

GEOTECHNICAL REPORTS:

The contractor is responsible to read and fully understand the Geotech report and to coordinate with the geotechnical engineer throughout the grading process to ensure that the report's recommendations are implemented from the beginning to the end of the projects construction. The owner will contract with the geotechnical engineer for their representatives to be on site throughout the grading process to ensure full compliance with the geotechnical report's recommendations. Refer to following reports.

1. Applied GeoTech Geotechnical Investigation, Tech Ridge South Access Road, Project No. 2180295: Oct 19, 2018

GENERAL NOTES:

1. Unless shown otherwise on these plans, all construction shall conform to the codes and ordinances of St. George City, the State of Utah Administrative Codes, "The International Plumbing Code", and the "International Building Code" latest editions as administered by St. George City.
2. The Contractor shall be responsible for the location of and protection of all existing underground utilities and overhead power line during construction.
3. The Benchmark for this Project is the South 1/4 of Section 36, Township 42 South, Range 16 West Salt Lake Base and Meridian - St. George HCN #181 - Elevation: 2667.70
3. Existing contour and finish contour interval is 2 feet.
4. Any necessary design modifications shall be approved by the design engineer.
5. All grading to be within ±0.1' of proposed elevation.
6. Project shall install an information sign on site before construction begins. This sign shall have a minimum size, placement location and content information with the company name, phone & permit number.
7. A mandatory pre-construction meeting shall be required on all projects prior to any grubbing, grading, or construction activities. The permit holder shall be required to notify all Development Services inspectors.
8. Projects shall submit a dust control plan with details on equipment scheduling and reporting of dust control activities.
9. Follow Appendix J standards found in the IBC.
10. All work materials shall meet City of St. George standards.
11. The Developer will Maintain the Temporary Detention Basin until Decommission.

CONSTRUCTION NOTES:

1. All excavations and grading shall be in accordance with the requirements of the City of St. George [phone:435-627-4000], of the "International Building Code", 2018 edition, and the specifications and requirements included in the Tech Ridge Grading Recommendations...
1. All excavation, grading, and fill operations within the building area should be observed by the Field Engineer to verify subsoil conditions and determine adequacy of site preparation, suitability of fill materials and compliance with compaction requirements.
2. The Contractor shall provide suitable equipment to control dust and air pollution caused by construction operations. The Contractor shall also provide suitable mud and dirt containment to maintain clean conditions on the work site, access roadways, and adjacent properties.
3. Project shall submit a Dust Control Plan with details on equipment, scheduling and reporting of dust control activities.
4. Contractor is responsible and required to obtain their own UPDES/NOI permits.
5. It is the contractors responsibility to identify all and any SWPPP requirements.
6. Prior to and during compaction operations, all backfill material shall have the required moisture content uniform throughout each layer.
7. All Rip-Rap rock shall be approved by owner.
8. Contractor must coordinate with other Contractors working in areas.
9. Contractor must protect existing facilities.
10. All rock walls are to match in color and composition with the native basalt lava rock. Rock to be to be stained black.

Date: 12-29-2022

REVISIONS

No.	Date	by	Description
		ARL	

File Name
Southeast Ridge Walls.dwg

ALLIANCE CONSULTING
A PLANNING AND ENGINEERING FIRM

UTAH
2303 N CORAL CANYON BLVD
SUITE 201,
WASHINGTON, UT 84780
435-673-8060

NORTH DAKOTA
621 26th STREET W.
WILLISTON, ND 58801
701-572-8100

TECH RIDGE SOUTHEAST DEVELOPMENT HILLSIDE PROTECTION PLAN

FOR

CITY OF ST. GEORGE

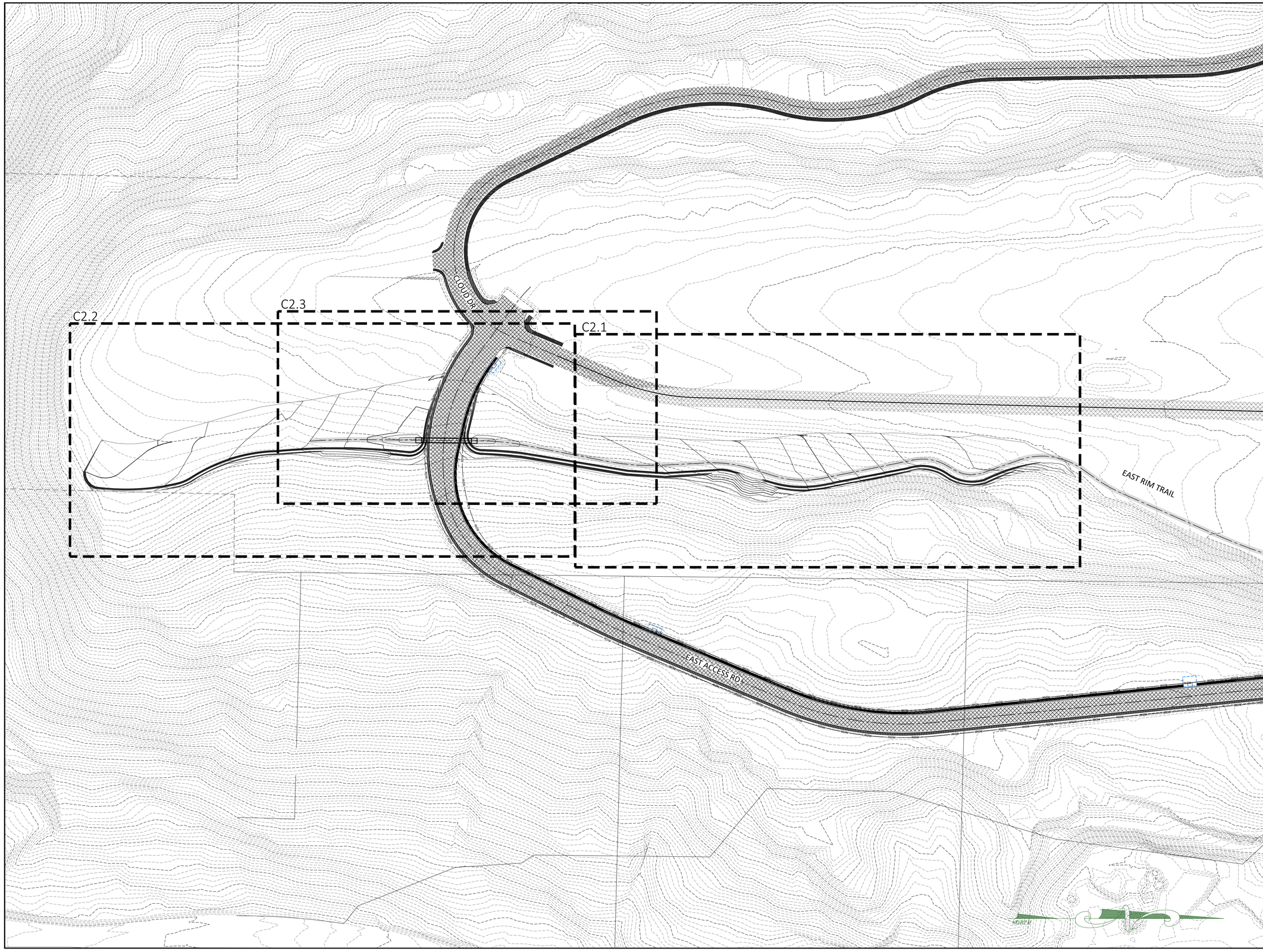
LOCATED IN SEC 36
T 42 SOUTH, R 16 WEST SLB&M
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

NOT FOR CONSTRUCTION REVIEW ONLY

Drawn By:	Scale:
ARL	1"=200'
Client No.	Project No.
4568	4568-21

Drawing Sheet
C1.0

Sheet 1 of 8 Sheets



Date:
12-30-2022

REVISIONS

No.	Date	by	Description
		ARL	

File Name
Southeast Ridge Walls.dwg

LEGEND

- EXISTING ASPHALT
- EXISTING CONCRETE
- (2622) EXISTING CONTOUR
- 2622 DESIGN CONTOUR

GRAPHIC SCALE

100 0 50 100 200

(IN FEET)
1 inch = 100 ft.
If Printed 11x17 use Half Scale

ALLIANCE CONSULTING
A PLANNING AND ENGINEERING FIRM

UTAH
2303 N CORAL CANYON BLVD
SUITE 201,
WASHINGTON, UT 84780
435-673-8060

NORTH DAKOTA
621 26th STREET W.
WILLISTON, ND 58801
701-572-8100

TECH RIDGE
SOUTHEAST DEVELOPMENT
HILLSIDE SHEET LAYOUT

FOR

CITY OF ST. GEORGE

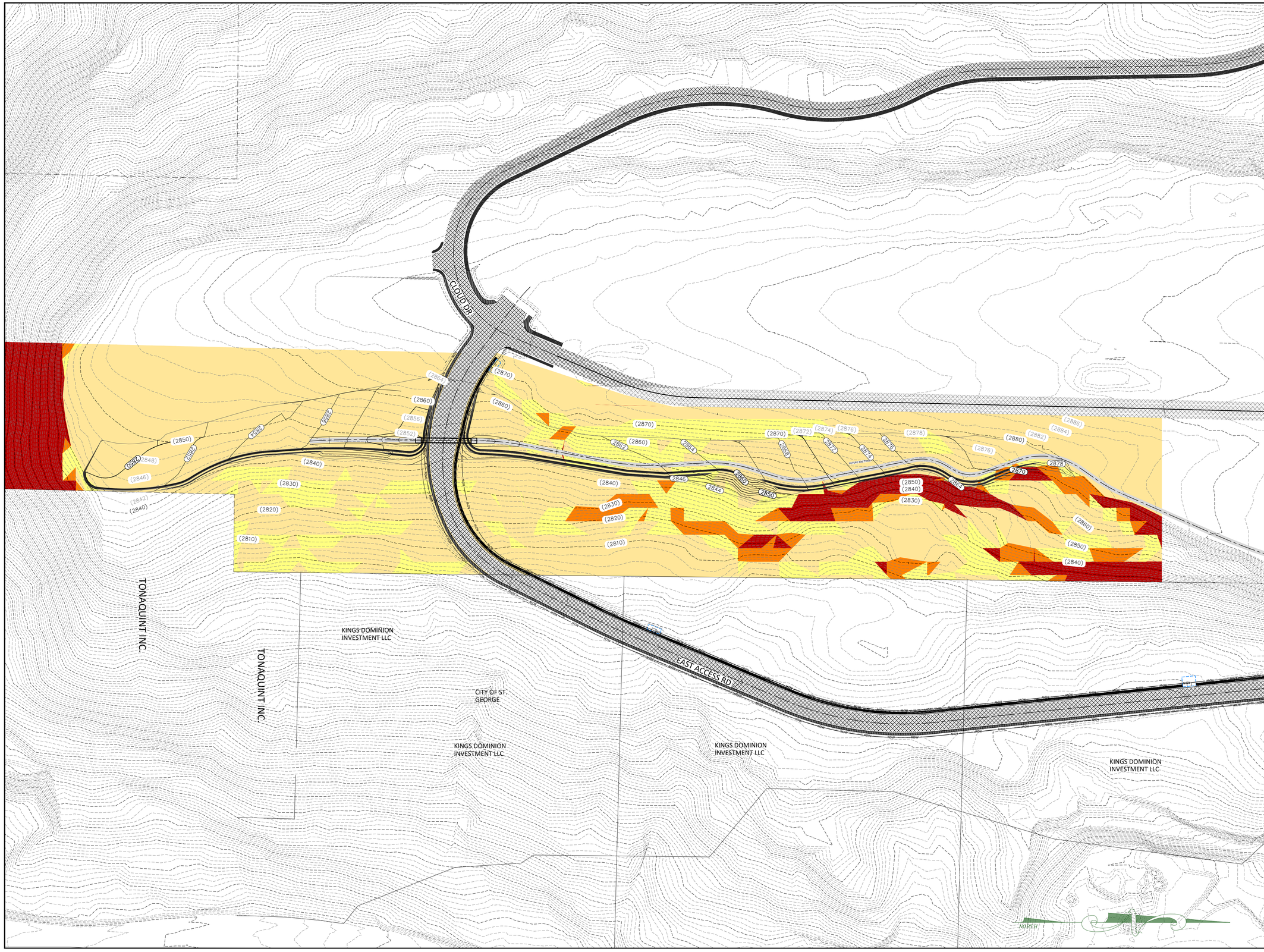
LOCATED IN SEC 36
T 42 SOUTH, R 16 WEST SLB&M
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

NOT FOR CONSTRUCTION
REVIEW ONLY

Drawn By:	Scale:
ARL	1"=100'
Client No.	Project No.
4568	4568-21

Drawing Sheet
C1.1

Sheet 2 of 8 Sheets



Date: 12-30-2022

REVISIONS

No.	Date	by	Description
		ARL	

File Name
Southeast Ridge Walls.dwg

SLOPE ANALYSIS LEGEND

- 0% to 20%
- 20% to 30%
- 30% to 40%
- 40% +

GRAPHIC SCALE

100 0 50 100 200

(IN FEET)
1 inch = 100 ft.
If Printed 11x17 use Half Scale

ALLIANCE CONSULTING
A PLANNING AND ENGINEERING FIRM

UTAH
2303 N CORAL CANYON BLVD
SUITE 201,
WASHINGTON, UT 84780
435-673-8060

NORTH DAKOTA
621 26th STREET W.
WILLISTON, ND 58801
701-572-8100

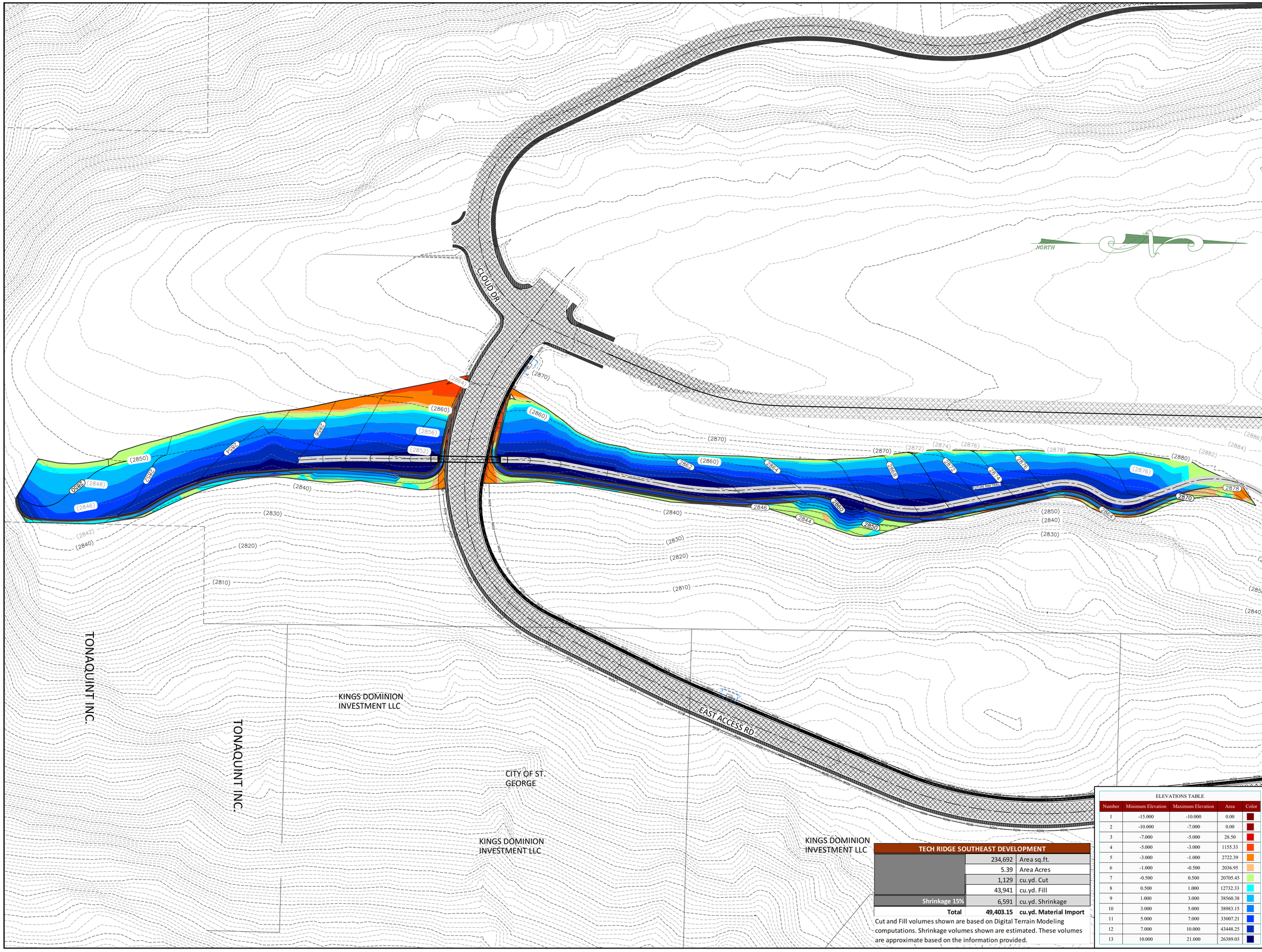
TECH RIDGE
SOUTHEAST DEVELOPMENT
HILLSIDE SLOPE ANALYSIS
FOR
CITY OF ST. GEORGE
LOCATED IN SEC 36
T 42 SOUTH, R 16 WEST SLB&M
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

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REVIEW ONLY

Drawn By:	Scale:
ARL	1"=100'
Client No. 4568	Project No. 4568-21

Drawing Sheet
C1.2

Sheet 3 of 8 Sheets



TECH RIDGE SOUTHEAST DEVELOPMENT		
	234,692	Area sq.ft.
	5.39	Area Acres
	1,129	cu.yd. Cut
	43,941	cu.yd. Fill
Shrinkage 15%	6,591	cu.yd. Shrinkage
Total	**49,403.15**	**cu.yd. Material Import**

Cut and Fill volumes shown are based on Digital Terrain Modeling computations. Shrinkage volumes shown are estimated. These volumes are approximate based on the information provided.

ELEVATIONS TABLE

Number	Minimum Elevation	Maximum Elevation	Area	Color
1	-15.000	-10.000	0.00	
2	-10.000	-7.000	0.00	
3	-7.000	-5.000	28.50	
4	-5.000	-3.000	1155.33	
5	-3.000	-1.000	2722.39	
6	-1.000	-0.500	2036.95	
7	-0.500	0.500	20705.45	
8	0.500	1.000	12732.33	
9	1.000	3.000	38560.38	
10	3.000	5.000	38983.15	
11	5.000	7.000	33007.21	
12	7.000	10.000	43448.25	
13	10.000	21.000	26389.03	

Date: 12-30-2022

REVISIONS

No.	Date	by	Description
		ARL	

File Name: Southeast Ridge Walls.dwg

LEGEND

EXISTING ASPHALT
EXISTING CONCRETE
EXISTING CONTOUR
DESIGN CONTOUR

GRAPHIC SCALE

80 0 40 80 160

(IN FEET)
1 inch = 80 ft.
If Printed 11x17 use Half Scale

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701-572-8100

TECH RIDGE
SOUTHEAST DEVELOPMENT
HILLSIDE CUT/FILLS

FOR

CITY OF ST. GEORGE

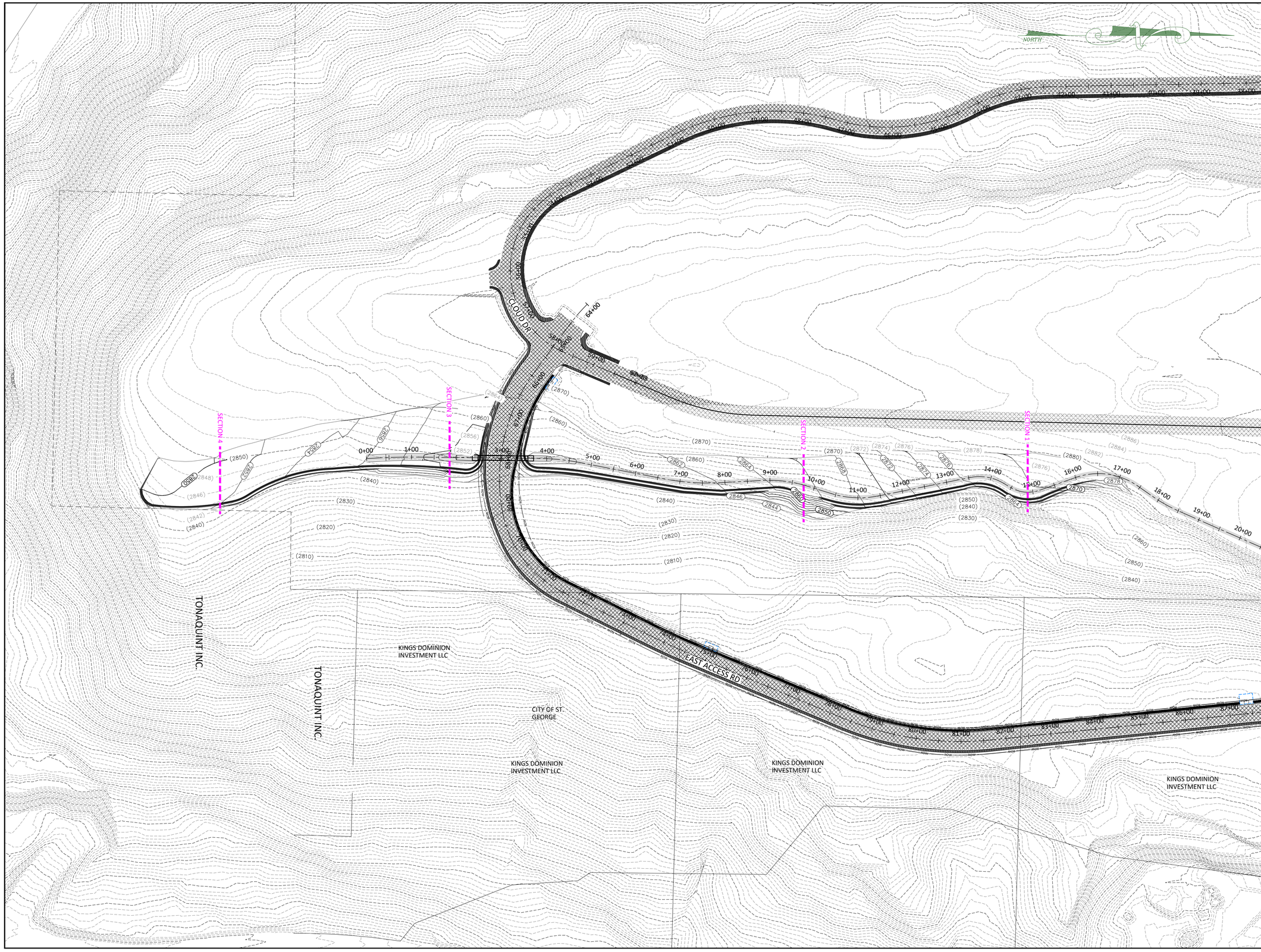
LOCATED IN SEC 36
T 42 SOUTH, R 16 WEST SLB&M
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

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ARL	1"=100'
Client No. 4568	Project No. 4568-21

Drawing Sheet
C1.3

Sheet 4 of 8 Sheets



Date: 12-30-2022

REVISIONS

No.	Date	by	Description
		ARL	

File Name
Southeast Ridge Walls.dwg

LEGEND

- EXISTING ASPHALT
- EXISTING CONCRETE
- (2622) EXISTING CONTOUR
- 2622 DESIGN CONTOUR
- SECTION ALIGNMENT

GRAPHIC SCALE

100 0 50 100 200

(IN FEET)
1 inch = 100 ft.
If Printed 11x17 use Half Scale

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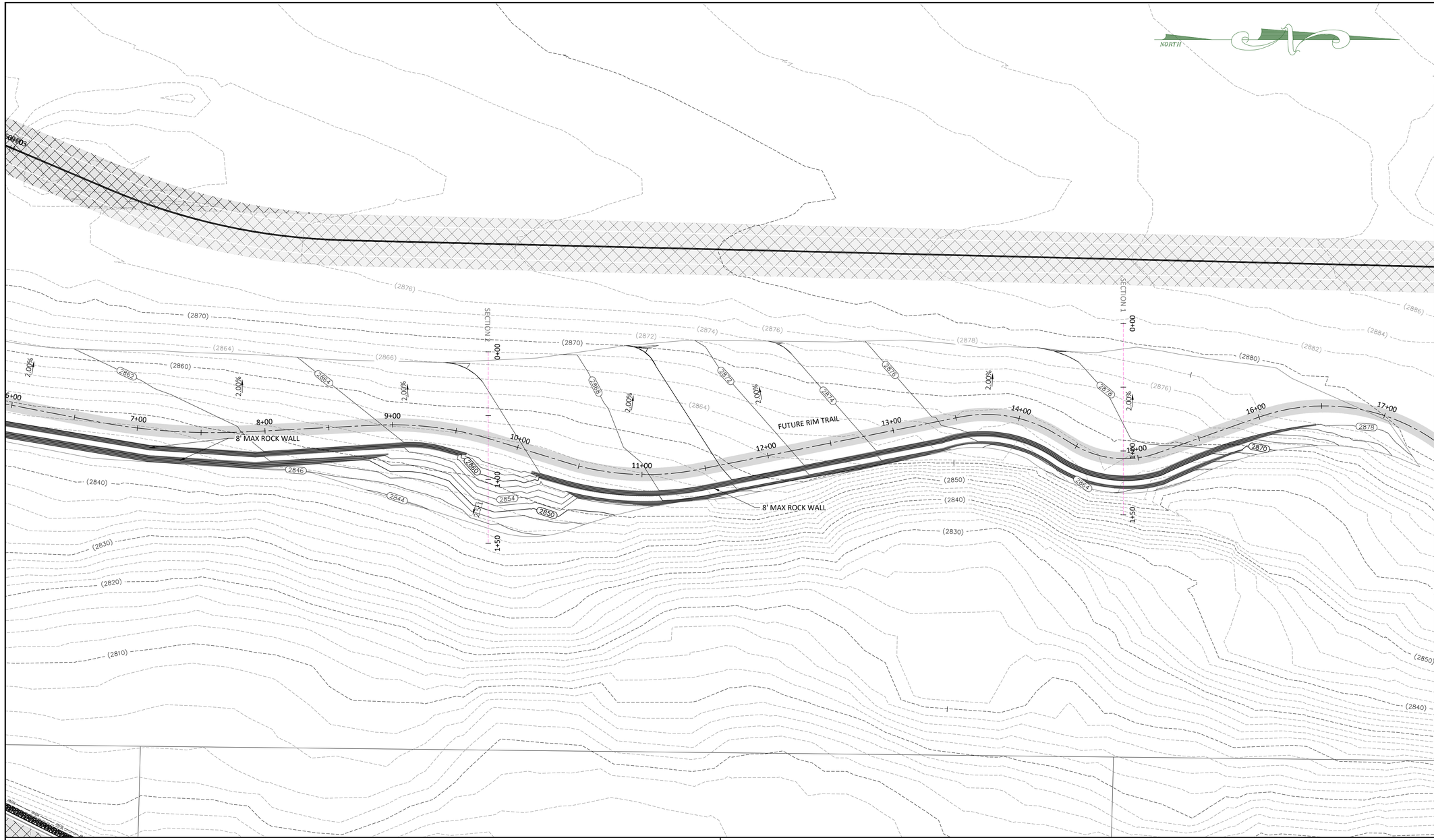
TECH RIDGE
SOUTHEAST DEVELOPMENT
HILLSIDE GRADING OVERALL
FOR
CITY OF ST. GEORGE
LOCATED IN SEC 12
T 154 NORTH, R 101 WEST 5 P.M.
CITY OF WILLISTON, WILLIAMS COUNTY, ND

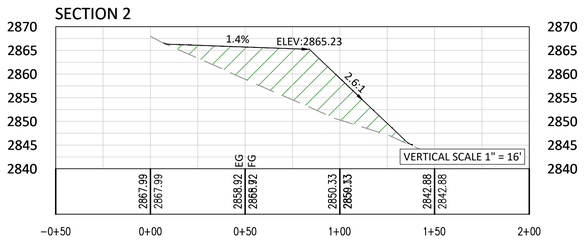
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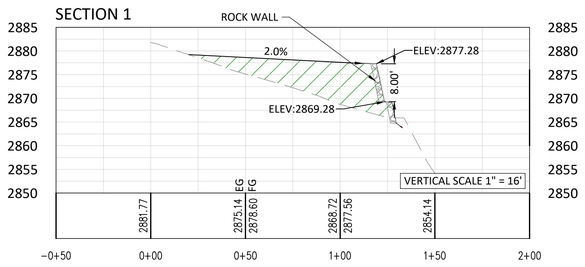
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ARL	1"=100'
Client No.	Project No.
4568	4568-21

Drawing Sheet
C2.0

Sheet 5 of 8 Sheets







Date: 12-30-2022

REVISIONS

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		ARL	

File Name
Southeast Ridge Walls.dwg

LEGEND

- EXISTING ASPHALT
- EXISTING CONCRETE
- (2622) EXISTING CONTOUR
- 2622 DESIGN CONTOUR
- SECTION ALIGNMENT

GRAPHIC SCALE

40 0 20 40 80

(IN FEET)
1 inch = 40 ft.
If Printed 11x17 use Half Scale

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701-572-8100

TECH RIDGE
SOUTHEAST DEVELOPMENT
HILLSIDE GRADING

FOR

CITY OF ST. GEORGE

LOCATED IN SEC 12
T 154 NORTH, R 101 WEST 5 P.M.
CITY OF WILLISTON, WILLIAMS COUNTY, ND

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Drawn By:	Scale:
ARL	1"=40'
Client No. 4568	Project No. 4568-21

Drawing Sheet
C2.1

Sheet 6 of 8 Sheets

Date: 12-30-2022

REVISIONS

No.	Date	by	Description
		ARL	

File Name
Southeast Ridge Walls.dwg

LEGEND

- EXISTING ASPHALT
- EXISTING CONCRETE
- (2622) EXISTING CONTOUR
- 2622 DESIGN CONTOUR
- SECTION ALIGNMENT

GRAPHIC SCALE

40 0 20 40 80

(IN FEET)
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701-572-8100

TECH RIDGE
SOUTHEAST DEVELOPMENT
HILLSIDE GRADING

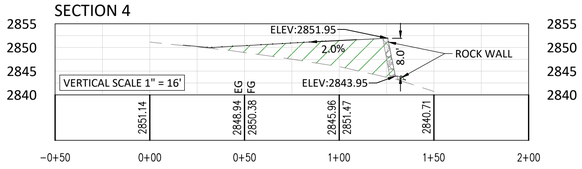
FOR

CITY OF ST. GEORGE

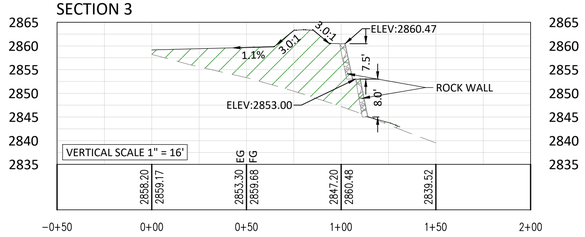
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SECTION 4



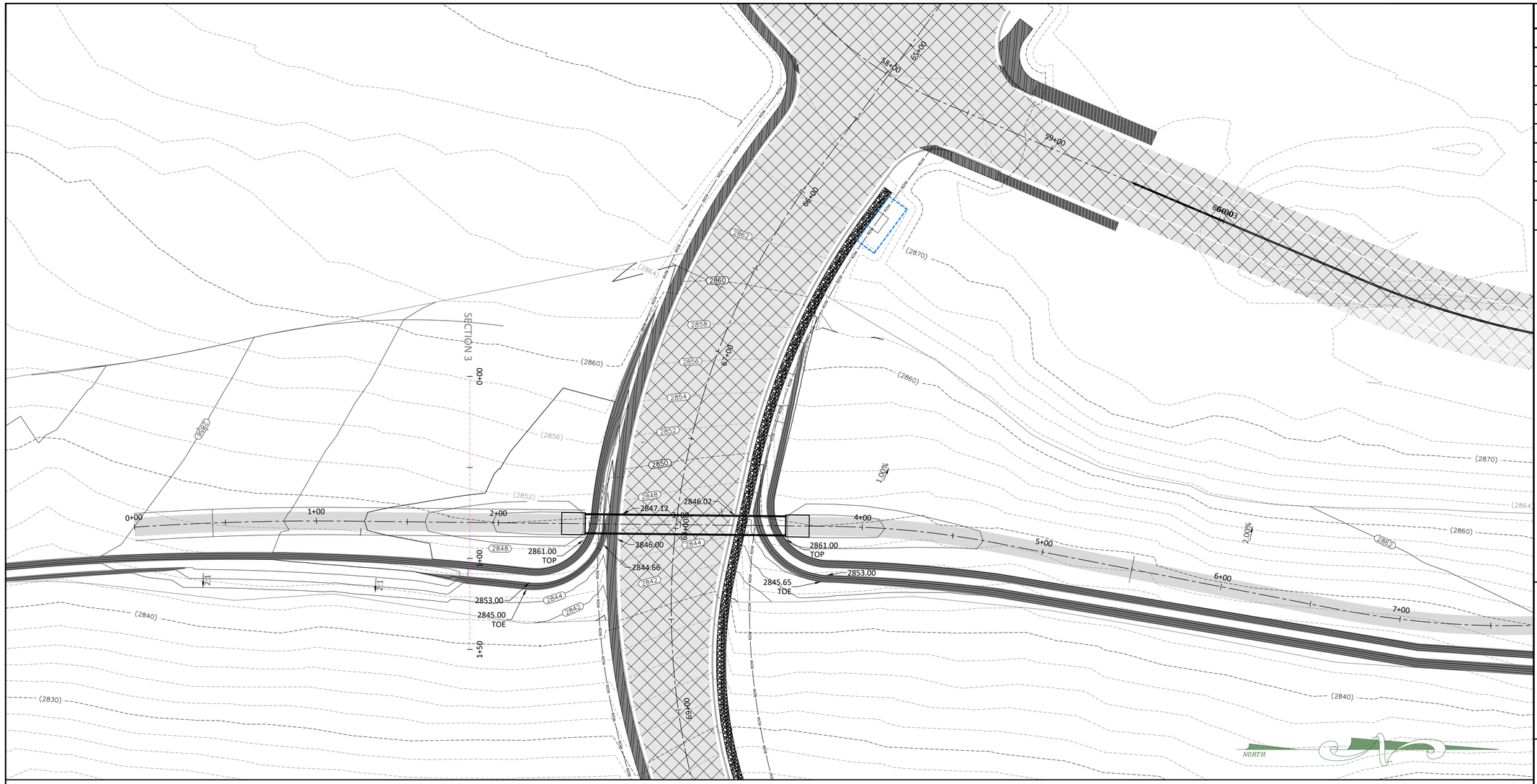
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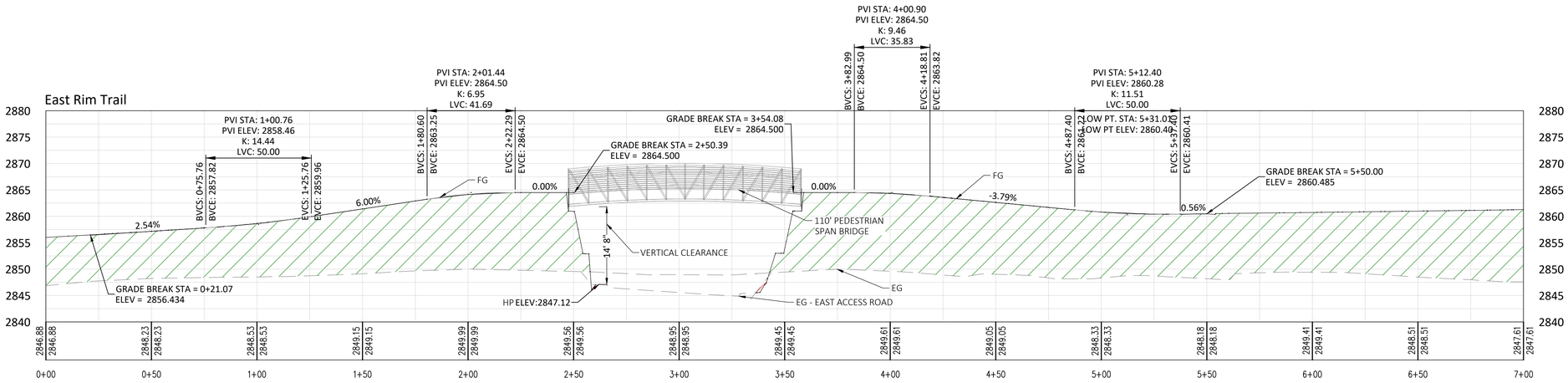


Drawn By: ARL	Scale: 1"=40'
Client No. 4568	Project No. 4568-21

Drawing Sheet
C2.2

Sheet 7 of 8 Sheets





Date: 12-30-2022

REVISIONS

No.	Date	by	Description
		ARL	

File Name: Southeast Ridge Walls.dwg

LEGEND

- EXISTING ASPHALT
- EXISTING CONCRETE
- (2622) EXISTING CONTOUR
- 2622 DESIGN CONTOUR
- SECTION ALIGNMENT

GRAPHIC SCALE

30 0 15 30 60

(IN FEET)
1 inch = 30 ft.
If Printed 11x17 use Half Scale

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701-572-8100

TECH RIDGE
SOUTHEAST DEVELOPMENT
HILLSIDE GRADING

FOR
CITY OF ST. GEORGE
LOCATED IN SEC 12
T 154 NORTH, R 101 WEST 5 P.M.
CITY OF WILLISTON, WILLIAMS COUNTY, ND

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Drawn By:	Scale:
ARL	1"=30'
Client No.	Project No.
4568	4568-21

Drawing Sheet
C2.3

Sheet 8 of 8 Sheets

Exhibit D
GEOTECHNICAL REPORT

AGEC
Applied GeoTech

GEOTECHNICAL INVESTIGATION

TECH RIDGE SOUTH ACCESS ROAD
ST. GEORGE, UTAH

PREPARED FOR:

TECH RIDGE, LLC
446 SOUTH MALL DRIVE
ST. GEORGE, UTAH 84790

ATTENTION: ISAAC BARLOW

PROJECT NO. 2180295 **OCTOBER 19, 2018**

1420 South 270 East • St. George, Utah 84790 • (435) 673-6850 • FAX (435) 673-1044

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SUMMARY

A. East Slope Stability

1. Much of the proposed roadway crosses historical landslide deposits.

2. An evaluation of the east slope stability was included in the scope of this investigation.

3. Based on the available information obtained from previous investigations, inclinometer measurements, and past performance of the slope, it is apparent that the east slope for this project is currently maintaining its stability.

   Using the information available from our subsurface exploration, the laboratory test results along with our experience in the area, it is our professional opinion that the stability of the east slope is marginal. Even with the lack of apparent movement, small changes in the slope configuration and/or weakening of the material in the slope could trigger future movement.

   The strength of the slope will be adversely impacted by water infiltration. Therefore, we recommend strict drainage recommendations be followed to reduce the risk of future slope instability.

B. Roadway

If construction of the roadway is to proceed, the following information and recommendations apply.

1. A variety of soil and bedrock types were encountered in the test pits. Lean clay, silt, silty sand, well graded sand with silt, silty gravel with sand, basalt, mudstone, and shale bedrock were encountered. Practical excavator refusal was encountered on stiff clay, boulders, basalt and shale bedrock

2. Potentially expansive mudstone, potentially expansive lean clay and potentially collapsible silty sand were encountered in the test pits.

3. Subsurface water was not encountered in the excavated test pits to the maximum depths investigated. Fluctuation in groundwater level may occur over time. An evaluation of such fluctuations is beyond the scope of this report.

4. The on-site granular soils such as the silty gravel with sand (GM), silty sand (SM), and well graded sand with silt (SW-SM) free of organics, debris, and material greater than 6 inches in size, are suitable for use as site grading fill. Oversized rocks (greater than 6 inches and smaller than 12 inches) may be used as fill at depths greater than 3 feet below finished subgrade. The oversized rock should be placed so that rock to rock contact is minimized to reduce potential for nesting and voids.

5. The on-site fine grained soils range between non-plastic silt to highly plastic mudstone. The silt and portions of the lean clay observed in test pits TP-7 and TP-8 are suitable for use as low permeable fill above expansive subgrade. The mudstone and expansive lean clay similar to that encountered in test pits TP-1, should not be used as fill within 6 feet of the finished roadway subgrade elevation.

6. Consolidation testing of remolded samples of mudstone and lean clay indicate the material remains expansive upon processing and adding moisture. However, the laboratory tests also indicate the expansion potential of the processed and remolded mudstone and lean clay can be reduced with moisture contents of 4 to 6 percent above the optimum moisture content and a compaction of approximately 90 percent of the modified proctor value (ASTM D-1557). Conversely, remolded samples with moisture contents below 4 percent and compaction near or above 95% will likely exhibit higher expansive properties.

7. The proposed roadway may be supported on a properly prepared subgrade as recommended in the Subgrade Preparation section of this report.

   The on-site, potentially expansive mudstone and expansive lean clay should be overexcavated to an appropriate depth beneath the proposed roadway. Overexcavation depths may be determined from the information provided in the Subgrade Preparation section of this report.

   Areas which expose near surface loose, dry, potentially collapsible silty sand should be overexcavated prior to placing fill as recommended in the Subgrade Preparations section of this report.

   Drainage recommendations are also provided in this report to reduce the risk of the underlying expansive subgrade.

   Moisture conditioning and compaction criteria are also included in this report. The calculated asphalt, untreated base course, and borrow thickness vary depending on subgrade and traffic loading.

8. The information provided in this summary should not be used independent of that provided within the body of this report.

SCOPE OF WORK

This report presents the results of a geotechnical investigation for the proposed south access road construction project to Tech Ridge located in St. George, Utah as shown on Figures 1 and 2. The geotechnical investigation includes access from the east and west sides of Tech Ridge. AGEC was requested to perform the following tasks:

1. Conduct a subsurface investigation to determine the subsurface conditions. The subsurface investigation included the excavation of 21 test pits along the roadway alignment. The first 13 test pits which include the west access road (TP-1 through TP-11) and a portion of the east access road (TP-12 and TP-13) were excavated with a track mounted excavator (CAT 336E) equipped with a 30-inch wide bucket. A ripper tooth attachment was also used to loosen boulders encountered during test pit excavations.

2. Log the subsurface soil profile and obtain samples of the subsurface soils to conduct laboratory testing.

3. Conduct a laboratory testing program on the subsurface soils to determine their engineering characteristics and determine the support value of the subsurface soil.

4. Prepare a report which presents the subsurface conditions encountered and recommendations for the geotechnical aspects of the project including slope stability of the eastern facing slope. Our conclusions and recommendations are based on the subsurface investigation, the results of laboratory testing and our engineering analysis.

This report was prepared in accordance with our "Proposal for Professional Geotechnical Services" dated, April 30, 2018.

SITE CONDITIONS

The existing site topography consists of sloping hillsides and relatively flat areas. A dry wash runs through the west side access from the north to the south. The majority of the hillside along the proposed alignment have been mapped geologically as ancient landslide deposits and consists of undulating hummocky terrain with relatively gently benches and steeper sloping areas. Existing vegetation across the site consists of sparse, low brush. Basalt boulders are also exposed at the surface across the site. Various dirt roads traverse the sides of both hill slopes.

PROPOSED CONSTRUCTION

The proposed project consists of constructing a 2 lane roadway to the west and a 4 lane roadway to the east near the south end of Tech Ridge. Detailed roadway cross-sections and grading plans for the east access road were not provided for the preparation of this report.

Based on a review of the plan and profile sheet (dated 03/28/2018) prepared by Alliance Consulting for the west access road, we anticipate cuts of up to 9 feet and fills on the order of 19 feet will be required to grade the proposed roadway. The grading plan also indicates a 12-foot by 12-foot underpass will be constructed over the existing drainage. A flexible pavement section is proposed for the project and we anticipate the project will include curb, gutter and sidewalk.

The Average Daily Traffic (ADT) provided by Alliance Consulting includes 2,500 to 5,000 vehicles for the west access and approximately 15,000 vehicles for the east access road. These ADT values correspond to a Traffic Index of 6 for the west side access road and 7 for the east side as provided by the City of St. George Design Criteria.

GEOLOGY AND GEOLOGIC HAZARDS

Geologic conditions at the site were evaluated by a review of geologic literature and aerial photographs. Aerial photographs used during the investigation were downloaded from the Utah Geological Survey website. They have photograph numbers of 810941 AM-4-1 and 2 and a photograph date of October 23, 1981.

A. Geologic Literature Review

The site is located in the transition zone of the Basin and Range, and Colorado Plateau provinces. Hayden and Willis (2011) map the area to be underlain by the Moenave and Chinle Formations (See Figure 1). The bedrock dips gently down to the north. The bedrock is capped by the Cedar Bench lava flow at the top of the hill. Alluvial and colluvial sediments overlie the bedrock at the northwest end of the road alignment. Landslide deposits are mapped for the south and central portions of the road alignment. A geologist from AGEC visited on September 12, 2018. The geology of the area was found to be consistent with mapping by Hayden and Willis (2011).

Geologic hazards mapped by Lund and others (2008) are mostly limited to landslide and rockfall. Rockfall is not generally a hazard for the road for the current condition of the hillside but could become a hazard depending on how cut slopes are developed for the road. Similarly, landslide is not currently a significant hazard on the slope in its present condition, but could be a concern with added water or steepened slopes. This will be addressed in the geotechnical study for the project.

B. Aerial Photograph Review

Based on review of aerial photographs of the site, faulting and debris flow are not potential hazards at the site. The area of landslide deposits appears to be similar to that mapped by Hayden and Willis (2011). Lineations formed in the landslide deposits and likely representative of intermediate landslide scarps are shown on Figure 1.

C. Seismicity

The property is located in the Intermountain Seismic Zone, which consists of an area of relatively high historical seismic activity. The most intense seismic ground shaking at the site is expected to originate from the Washington fault zone. The Washington fault zone is considered capable of producing earthquakes on the order of 7 to 7.5 magnitude and can result in significant seismic ground shaking at the site. The US Geological Survey data indicate that a peak ground acceleration in bedrock of 0.24g can be expected to have a 2 percent probability of being exceeded in a 50-year time period at this site (IBC, 2015). The St George fault zone may also add to the seismic hazard in the area, although there is no evidence that the fault displaces Holocene sediments, suggesting the fault may not be active. The St George Fault is not included in the Quaternary Fault and Fold Database (Utah Geological Survey, 2018).

ROADWAY SUBSURFACE CONDITIONS

On August 8 and 9, 2018, an engineer from AGEC visited the site and observed the excavation of 13 test pits at the approximate locations shown on Figure 2. The 8 additional test pits (TP-14 to TP-21) were excavated during a previous geotechnical investigation by AGEC in August of 1998. The subsurface profile observed within the excavated test pits at the site is highly variable and consists of lean clay, silt, silty sand with gravel, well graded sand with silt, silty gravel with sand, basalt, mudstone bedrock, and shale bedrock.

Potentially expansive mudstone was encountered in test pits TP-1, TP-2, TP-10, TP-14, and TP-15 as shown on Figures 3-5. Expansive lean clay was encountered in test pits TP-1, TP-3, TP-5, TP-6, TP-7, TP-8, TP-14, TP-16 and TP-20. The shale bedrock encountered in test pits TP-16, TP-19, and TP-21 may also contain expansive layers. The dry loose nature of the near surface silty sand with gravel encountered in test pit TP-10 indicates the material is potentially collapsible if exposed to water.

Practical excavator refusal was encountered on stiff clay and boulders in test pits TP-3, TP-7, TP-8 and TP-20. Practical excavator refusal on basalt was encountered in test pits TP-11, TP-12, TP-13, and TP-17 with refusal on shale bedrock encountered in test pit TP-19. The maximum depth investigated in the test pits was 19 feet.

Detailed descriptions of the bedrock and soil types observed follow.

Lean Clay - The lean clay is medium stiff to very stiff, moist, medium plastic, contains varied amounts of sand, gravel, and boulders (1 to 4 feet in size). The lean clay varies from red-brown to brown with white mottles in color.

Laboratory tests conducted on samples of the lean clay indicate in-place moisture contents ranging from 5 to 16 percent, in-place dry densities ranging from 93 to 124 pounds per cubic foot (pcf), gravel contents (percent retained on the No. 4 sieve) ranging from 0 to 12 percent, and fines contents (percent passing the No. 200 sieve) ranging from 62 to 96 percent. Atterberg Limits tests conducted on samples of the lean clay indicated liquid limits ranging from 27 to 48 percent and plasticity indices ranging from 14 to 35 percent.

Moisture-Density relationship (ASTM D-1557) tests conducted on samples of the lean clay from test pits TP-3 and TP-8 indicate maximum dry densities (MDD) ranging from 116.5 pcf to 123.5 pcf and optimum moisture contents (OMC) ranging from 10.0 to 12.5 percent. California Bearing Ratio (CBR) tests conducted on remolded samples of the lean clay indicate CBR values ranging from 4 to 5 percent. The samples were remolded to near 90 percent of the maximum dry density (ASTM D-1557) and approximately 2% above the optimum moisture content.

One-dimensional consolidation tests conducted on samples of the native lean clay indicate it is slightly moisture sensitive when wetted under a constant pressure of approximately 1,000 pounds per square foot (psf). Swell potentials of 1 to 1½ percent and swell pressures ranging from 2,650 psf to 3,500 psf were measured in the laboratory testing.

Remolded one-dimensional consolidation tests conducted on samples of the lean clay indicate moisture conditioned and remolded samples are still expansive when wetted. The remolded one-dimensional consolidation results indicate a reduction in expansion potential with an increase moisture content during processing.

Silt - The silt is medium stiff to stiff, slightly moist to moist, contains various amount of sand, and is reddish brown in color.

Laboratory tests conducted on samples of the silt indicate in-place moisture contents ranging from 6 to 17 percent, in-place dry densities ranging from 101 to 112 pcf, and a fines content ranging from 81 to 94 percent. Atterberg Limits tests conducted on samples of the silt indicate it is non-plastic.

Silty Sand - The silty sand is loose to medium dense, dry, fine to medium grained, contains occasional gravel, cobbles, and boulders and ranges in color from light reddish brown to brown in color.

Laboratory tests conducted on samples of the silty sand indicate in-place moisture contents ranging from 3 to 8 percent, in-place dry densities ranging from 88 to 108 pcf, a gravel content of 2 percent, and fines contents ranging from 35 to 48 percent. The relatively low dry density and moisture content of the near surface silty sand indicates it is potentially collapsible.

A Moisture-Density relationship (ASTM D-1557) test indicates the silty sand has a maximum dry density of 126.0 pcf and an optimum moisture content of 7.5 percent.

Well Graded Sand with Silt - The well graded sand with silt is medium dense, dry, contains gravel, and brown in color.

Laboratory tests conducted on samples of the silty to clayey gravel with sand indicate an in-place moisture content of 1 percent, and a fines content of 6 percent.

Silty Gravel with Sand - The silty gravel with sand is medium dense to dense, dry to moist, and light brown to brown in color.

Laboratory tests conducted on the silty gravel with sand from test pit TP-4 indicate an in-place moisture content of 11 percent.

Basalt - The basaltic rock is moderately hard to very hard, dry, highly fractured to less fractured, and black in color.

A Moisture-Density relationship (ASTM D-1557) test indicates the fractured basalt with silt and sand has a maximum dry density of 134.5 pcf and an optimum moisture content of 5.5 percent.

Mudstone - The mudstone, known locally as “blue clay” is soft to moderately hard, dry to moist, medium to highly plastic, and grey to purple in color.

Laboratory tests conducted on samples of the mudstone indicate in-place moisture contents ranging from 7 to 15 percent, in-place dry densities ranging from 96 to 118 pcf, and fines contents ranging from 59 to 99 percent. Atterberg Limits tests conducted on samples of the mudstone indicate liquid limits ranging from 35 to 76 percent and plasticity indexes ranging from 19 to 39 percent.

A Moisture-Density relationship (ASTM D-1557) test indicates the mudstone has a maximum dry density of 115.0 pcf and an optimum moisture content of 12.5 percent. A CBR test conducted on a remolded sample of the mudstone indicates a CBR value of 6 percent. The sample was remolded to near 90 percent of the maximum dry density (ASTM D-1557) and approximately 2 percent above the optimum moisture content.

One-dimensional consolidation tests conducted on natural samples of the mudstone indicate it is moisture sensitive (expansive) when wetted under a constant pressure of approximately 1,000 psf. Swell potentials of ½ to 1 percent with swell pressures of 2,170 to 4,000 psf were measured in the laboratory testing.

Remolded one-dimensional consolidation tests conducted on samples of the mudstone indicate moisture conditioned and remolded samples are still expansive when wetted. The remolded one-dimensional consolidation results indicate a reduction in expansion potential with an increase moisture content during processing.

Shale Bedrock - The shale bedrock is soft to hard, dry to slightly moist, interbedded with layers of siltstone and claystone, and dark brown to dark red in color.

Laboratory tests conducted on a sample of the shale bedrock indicate an in-place moisture content of 5 percent, an in-place dry density of 110 pcf, and a fines content of 71 percent.

The Logs, Legend and Notes of Test Pits are shown on Figures 3-5. The results of laboratory testing are also shown on Figures 3 and 4 and are summarized in the Summary of Laboratory Test Results, Table 1. The One-dimensional Consolidation Test Results are shown graphically on Figures 6-12. The Gradation/Soil Classification and Moisture-Density Relationship Test Results are shown graphically on Figures 13-17. The California Bearing Ratio Test Results are shown graphically on Figures 18-22.

ROADWAY SUBSURFACE WATER

Groundwater was not encountered during the subsurface investigation to the maximum depth investigated, approximately 19 feet. Fluctuations in the groundwater level may occur over time. An evaluation of such fluctuations is beyond the scope of this report.

EAST SLOPE STABILITY

AGEC previously investigated the subsurface conditions of the east facing slope by drilling five borings to depths varying from 110 to 250 feet. Inclinometer casings were installed at each of the five locations along with an adjacent boring to facilitate measurements of the groundwater level.

Our findings of the stability analysis are presented without the boring logs, laboratory test results, inclinometer measurements, and our calculations as stipulated in our agreement for this project.

Existing Conditions

As indicated on Figure 1, portions of both arms of the access road are located on landslide deposits. In addition to verifying the geologic mapping presented on Figure 1, the east hillside stability has been evaluated. Site conditions that reflect the material behavior and characteristics of the landslide include:

1. The hummocky nature of the ground surface along with the lineations associated with each of the landslide slumps .

2. Landslide masses will often reach equilibrium at a slope angle close to the internal material strengths. The ground surface slopes from 8 to 18 degrees (3 to 7:1 horizontal to vertical) which are consistent with the internal friction values obtained from our earlier studies and from samples tested in the laboratory.

Contributing Factors

In addition to the surface geology, the following items contribute to the status of the slope stability.

1. The bedding planes in the area generally slope down to the northeast at an angle of approximately 7 to 8 degrees.

2. The weakest clay sample tested from explorations conducted on the east slope has been found to have a residual coefficient of friction of 7.5 degrees. This angle closely matches the dip of the bedding plane. With this strength and bedding plane combination, slippage would occur on 7.5 degree downward slope if the interface strength is less than 7.5 degrees or slippage would also occur if there are areas or zones where the dip angle of the bedding plane is steeper than the 7.5 degrees.

3. Investigation into landslide movements on the east slope indicate a relatively thick deposit that contains layers of this potentially weak clay. Measurements indicate that the hillside movement occurs at multiple depths indicating similar strength characteristics throughout the deposit.

4. Groundwater was encountered in each of the deep borings.

Status of Movement

Inclinometers were installed at five locations to depths of 92 to 258 feet on the east hillside in 2007. Inclinometer Measurements were obtained in 2008, 2011 and April 4, 2018. The 2018 measurements on 4 of the 5 inclinometers are within the accuracy of the equipment indicating no measurable movement.

The inclinometer located immediately west of the vacant restaurant, located at 1090 South Bluff Street, was measured before 2011. Displacement was measured at multiple depths.

Geotechnical Testing Services (GTS) installed an inclinometer on a berm placed behind the restaurant. We understand that recent measurements by GTS indicate lateral movement of approximately 0.7 inches in the last 5 years.

Anticipated Performance

With the lack of measured movement in the 4 inclinometers over the past 10½ years along with the lack of surficial evidence of movement, it is apparent that the portion of the slope for this project is currently maintaining its stability. Using the information available from our subsurface exploration, the laboratory test results along with our experience in the area, it is our professional opinion that the stability of the slope is marginal even with the lack of apparent movement.

With these conditions, small changes in the slope configuration or weakening of the material strengths in the slope could trigger future movement.

As stated in the 1996 Transportation Research Board, Special Report 247, (entitled Landslides, Investigation and Mitigation), "…old landslides are often barely stable, and they may not have significant resistance to new loadings or other changed conditions that tend to reduce their stability. Changing natural drainage patterns on the surfaces of old landslides may significantly influence their stability and cause unwanted movements. Thus, the decision to construct transportation facilities over ancient landslides must be carefully investigated and appropriate consideration given to remedial measures and long-term stability".

It is important to recognize that marginal stability of the slope indicates that:

1. A calculated factor of safety using the parameters selected to characterize the materials in the slope and the existing configuration is near 1.0 and will not meet the standard acceptable level of at least 1.5.

2. Changes in the internal conditions and/or surficial geometry modifications may improve or reduce the ability of the slope to maintain its stability. It may not be practical to quantify with confidence the impact that internal changes may have provided.

3. It is a matter of time before more movement on the slope occurs. Determining a location and/or timing of such an event is not possible with the information currently available.

4. A seismic event could introduce sufficient lateral load to initiate slope movement.

Mitigation

If the decision is made to continue with construction of the roadway on the landslides, we recommend the following items be seriously considered:

1. Introduction of moisture into the subgrade should be minimized if not eliminated. This could be accomplished by:

    a. Collecting and transporting surface drainage off of the slope in watertight catch basins and piping. This is not standard storm drainage procedures therefore, this would require specific attention to verify that the improvements are watertight.

    b. Water ways should be lined to prevent seepage into the ground.

    c. Measures need to be taken to eliminate the potential for water to pond on the slope.

    d. No water bearing utilities should be installed within the landslide area.

2. Cut and fill slopes need to be minimized. Overall impact of potential grade changes should be evaluated and the consequence of the change found to be acceptable before proceeding.

3. Water entering the ground in all areas above the slope (within the Tech Ridge area) should be reduced and ideally eliminated. Some, if not all, of the methods described above should be considered within the Tech Ridge area.

ROADWAY RECOMMENDATIONS

The following recommendations are provided with the assumption that all stakeholders recognize and accept the risk of landslide movement. The recommendations are based on the proposed construction, information obtained from the field and laboratory testing, engineering analysis, and our experience in the area.

A. Site Grading

Based on the subsurface conditions and the proposed grading provided by Alliance Consulting, the following recommendations are provided:

1. Subgrade Preparation

a. *General Subgrade Preparation*: Prior to conducting site grading, vegetation and soil containing significant amounts of roots and organics should be removed. Loose/disturbed soil, debris, deleterious material, previously placed fill, and undiscovered fill should be removed to the full depth.

b. *Expansive Mudstone and Lean Clay Subgrade Areas*: To reduce the potential for wetting and subsequent swelling of the expansive subgrade supporting the proposed roadway, we recommend the expansive mudstone and lean clay areas be overexcavated to remove a portion of the expansive material and it replace with properly compacted, low permeable fill. The low permeable fill is intended to provide a less permeable zone which reduces the potential for infiltration of water to the underlying expansive mudstone and lean clay. If the natural moisture content of the expansive mudstone and lean clay is maintained, distress to the asphalt/sidewalk and curb will be reduced.

Prior to placing the low permeable fill and subsequent to overexcavation, the exposed subgrade should be scarified a minimum of 8 inches, moisture conditioned to 4 to 6 percentage points above the optimum moisture content and compacted to 90 percent of the maximum dry density as determined by ASTM D-1557.

We recommend overexcavation and replacement of the expansive mudstone and lean clay be performed to provide a low permeable zone above expansive materials and reduce the risk of wetting and potential heave. The surface heave estimates are provided in the following table. The estimates are based on an assumed active zone (wetted depth) of 10 feet. The heave estimates should be used to assist in determining the depth of overexcavation and replacement desired based on the associated risk of surface heave.

Depth to Expansive Soil Below Finished Subgrade Elevation (feet)	Estimated Potential Surface Heave (inches)
0	3 to 4½
2	2½ to 4
4	2 to 3
6	1 to 2½

c. *Sand, and Gravel Areas (All Other Subgrades Encountered)*: Subsequent to grubbing and prior to placing fill, base course, or asphalt pavement, the exposed subgrade beneath pavement and fill slope areas should be scarified to a depth of 8 inches, moisture conditioned and properly compacted to at least 95 percent of the maximum dry density as determined by ASTM D-1557.

If the exposed subgrade consists of loose, dry silty sand or silty gravel (potentially collapsible soils), we recommend this soil be overexcavated to remove the full depth of this material. An engineer from AGEC should observe the exposed subgrade to provide guidance regarding the subgrade preparation in these areas.

d. *Potentially Soft Subgrade (Encountered in Area of TP-4):* Potentially soft subgrade conditions may be encountered near TP-4 resulting from heavy equipment and very moist subgrade conditions observed in the test pit. If soft/pumping conditions are encountered subgrade stabilization may be implemented using overexcavation to remove the soft soils or by implementing gravel and geosynthetic reinforcement may be necessary. Additional details may be provided upon request.

2. Excavation/Earthwork

The on-site soils and soft mudstone bedrock may be excavated with conventional excavation equipment. Excavations extending into large boulders, potential cemented zones, basalt and hard shale bedrock will likely require the use of heavy excavation equipment such as a trackhoe equipped with rock teeth or a single ripper tooth. A rock hammer may also be necessary to excavate portions of the basalt or shale bedrock. Difficulty may be particularly evident in confined excavations.

3. Grading Slopes

Review of the grading plan for the west side access road indicates existing slopes along the road alignment of the project will be excavated and cut to construct the roadway. We also anticipate grading along the east side access road will require cuts into hillside. Our experience with soil cut and fill slopes in the area has shown soils will tend to erode over time to their natural angle of repose. The following table provides recommendations for guidance of cut slopes based on the observed onsite soils:

Expected Soil Condition	Grading Recommendations (Horizontal:Vertical)
Basalt	½:1
Lean Clay	¾ :1
Silty Sand and gravel	1:1
Shale and Mudstone Bedrock	½ :1 (if faced) or 1½ :1 (if not faced)

Mudstone and clay slopes cut steeper than 1½ :1 would remain stable, but will dessicate, and likely ravel naturally to approximately a 1½ :1 slope. This process will require long term maintenance to remove the accumulated soils deposited at the toe of the slope. If this process is not acceptable, steep slopes may be flattened or faced to provide protection from weathering and erosion. Stacked rockery facing or reinforced gunnite facing anchored with soil nails may be considered to protect steeper cut slopes. Design and recommendations associated with reinforced/stabilized cut slopes are beyond the scope of AGEC's services.

Additionally, several existing cut slopes are part of a larger ancient landslide deposit. This analysis does not address the potential development, re-activation or stabilization of larger scale slope movement as could be possible due to the site being part of the larger landslide deposit.

We recommend fill slopes constructed with onsite soil not exceed a 2:1 (horizontal:vertical) slope. Fill slopes should be graded by overbuilding and then cutting them back to the desired grade to provide a compacted slope face. Fill placed on existing slopes steeper than 4:1 (horizontal to vertical) should be placed using a benching procedure to "key" the fill into the existing slope. Benches should be of sufficient width to extend fill placement through loose/surficial soils or to meet the criteria given in the following table, whichever is greater.

Approximate Slope Grade (Horizontal:Vertical)	Bench Width (feet)
1:1	2
2:1	4
3:1	6
4:1	8

4. Materials

The on-site granular soils such as the silty gravel with sand (GM), silty sand (SM), and well graded sand with silt (SW-SM) free of organics, debris, and material greater than 6 inches in size, are suitable for use as site grading fill. Oversized rocks (greater than 6 inches and smaller than 12 inches) may be used as fill at depths greater than 3 feet below finished subgrade. The oversized rock should be placed so that rock to rock contact is avoided to reduce potential voids and nesting of rocks.

The on-site fine grained soils range between non-plastic silt to low to medium plastic lean clay and highly plastic mudstone. The silt and portions of the lean clay observed in test pits TP-7 and TP-8 are suitable for use as low permeable fill above expansive subgrade. The on-site expansive soils (mudstone and lean clay) free of organics may be used as site grading fill in areas not supporting the roadway. The mudstone and the expansive lean clay should not be used as fill within 6 feet of the finished roadway subgrade elevation without accepting potential surface heave risks.

Listed below are the materials recommended for fill.

Area	Fill Type	Soil Type
Roadway	Untreated Base Course	CBR > 70%, **200** < 12% Maximum size: 1 inch
Roadway	Site Grading and Embankment Fill	**-200** < 35%, **LL** < 30% Maximum size: 4 inches Solubility < 1%

-200 = Percent Passing the No. 200 Sieve

LL = Liquid Limit

The potential impact of the expansive characteristics of the underlying expansive mudstone and lean clay can be reduced by protecting the expansive material from becoming wet. Placement of relatively low permeable fill above the expansive soil/bedrock can help reduce the possibility of water coming in contact with the expansive material.

Low permeable fill used to replace removed expansive soil should meet at least one of the following options:

Option No.	Liquid Limit (%)	Percent Passing the No. 200 Sieve
1	50+	15-20
2	30-50	20-40
3	0-30	30-100

Based on the above criteria, we anticipate some of the on-site soils will be suitable for use as low permeable fill. Mixing of onsite soils (lean clay and mudstone) with non-expansive fill may be necessary to produce low permeable fill meeting the above requirements. If mixing will be considered, AGEC should be contacted to conduct additional laboratory testing to determine mixing/blending recommendations.

5. Compaction

Compaction of fill materials placed at the site should meet the following moisture content criteria and equal or exceed the following compaction criteria:

Area	Moisture Content	Percent Compaction
Low Permeable Fill	+2% to +4% above OMC	90%
Subgrade - Expansive Materials	+4% to +6% above OMC	90%
Subgrade - Non-expansive Materials	± 2% of OMC	90%
Roadway Fill - Expansive Materials	+4% to+ 6% above OMC	90%
Roadway Fill - Non-expansive Materials	± 2% of OMC	95%
Roadway Base Course	± 2% of OMC	95%

OMC = Optimum moisture content

Fill tested should be compared to the maximum dry density as determined by ASTM D-1557. Soils placed as site grading fill should be moisture conditioned to the above recommendations. Soil at the site was generally below the optimum moisture content and will require moisture conditioning prior to placement to achieve the required compaction.

It is critical that the low permeable fill is moisture conditioned over the optimum moisture content (as recommended) to provide the low permeable properties necessary for the application. If the low permeable fill is placed dry of the optimum moisture content, the permeability or infiltration rate of water will be higher.

Fill should be placed in lift thicknesses which do not exceed the capacity of the compaction equipment used. Generally 6 inch loose lifts are appropriate for heavy rubber-tire compaction equipment. Lift thickness should be reduced to 4 inches for hand compaction equipment. Fill placed at the site should be tested frequently to verify proper compaction.

B. Soil Corrosion

Our experience has shown the on-site soils, bedrock and many import soils may contain sulfates in sufficient concentration to be corrosive to concrete. Therefore, we recommend concrete elements that will be exposed to the on-site soils be designed in accordance with provisions provided in the American Concrete Institute Manual of Concrete Practice (ACI) 318-14 Chapter 19. Tables 19.3.1.1 and 19.3.2.1 of ACI 318-14 should be referenced for design of concrete elements utilizing a Sulfate Exposure Class of S2.

Consideration should also be given to cathodic protection of buried metal pipes. We recommend utilizing PVC pipes where local building codes allow.

C. Pavement Analysis and Design

The following pavement design criteria were used in our pavement design based on the UDOT Pavement Management and Pavement Design Manual dated November, 1998 and updated March, 2008.

- A 20 year design life with ADT values of 2,500 to 5,000 for the west access road and 15,000 for the east access road were provided by Alliance Consulting. These traffic conditions correspond to a Major Collector (TI = 6) for the west access roadway and a Minor Arterial (TI = 7) for the east access roadway according to the St. George City Design Specifications.
- A Standard Deviation of 0.45.
- Initial and Terminal Serviceabilities of 4.2 and 2.5, respectively.
- A Reliability of 90 percent.
- CBR values of 4 and 10 percent for varying on-site soil types.
- A Subgrade Resilient Modulus of 1500*CBR value.
- A Untreated Base Course Resilient Modulus of 27,000 psi.
- A Granular Borrow Resilient Modulus of 15,000 psi.
- Layer Coefficients of 0.4, 0.1, and 0.08 for the hot mix asphalt, untreated base course, and the granular borrow, respectively.
- A Drainage Coefficient of 1 for the untreated base course and the granular borrow.

D. Pavement Support, Section, and Materials

Based on the subsurface conditions encountered, UDOT/AASHTO Design methods, and a 20-year design life, the following recommendations are given. Although the following pavement sections are based on a 20 year design life, the life span of the pavement may be shorter if not properly maintained, drained, and due to the presence of expansive materials, and landslide deposits below the roadway on some portions of the project.

1. Subgrade Support

The subgrade should be prepared as outlined in the Site Grading section of this report. We anticipate the subgrade materials at the site will generally consist of lean clay, mudstone, silty sand and gravel, and silty gravel with sand.

AGEC measured CBR values ranging from 4 to 33 percent from remolded samples of the on-site soils obtained from the test pit excavations. For the purpose of this report, a CBR value of 4 was used for design of pavement supported over the mudstone and lean clay and a CBR value of 10 was used for the design of pavement supported over the remaining subgrade soils encountered at the site.

2. Pavement Thickness

Refer to the following tables for pavement section thicknesses.

East Access Roadway (TI = 7)

Subgrade Type	CBR Value	Asphalt Thickness (in)	Base Course Thickness (in)
Mudstone and Lean Clay	4	4	12
Other Soils	10	3½	8

West Access Roadway (TI = 6)

Subgrade Type	CBR Value	Asphalt Thickness (in)	Base Course Thickness (in)
Mudstone and Lean Clay	4	3½	8
Other Soils	10	3	6

3. Pavement Materials

The pavement materials should meet St. George City specifications for gradation and quality. The pavement thicknesses indicated above assume that the base course is a high quality material with a CBR of at least 50 percent and the asphaltic concrete has a minimum Marshal stability of 1,800 pounds.

Other materials may be considered for use in the pavement section. The use of other materials may result in other pavement material thicknesses.

E. Drainage and Maintenance

The collection and diversion of drainage away from the pavement surface is extremely important to the satisfactory performance and life span of the pavement section and the slope stability. Proper drainage and precautions presented in the stability section should be provided.

Due to the moisture sensitivity of the on-site mudstone and portions of the lean clay, it is critical that infiltration of water be minimized to reduce the potential for future movement of pavement and utilities. Maintaining natural soil moisture conditions of the moisture sensitive soil and bedrock reduces potential for expansion of underlying soil/bedrock and subsequent heave. To reduce infiltration, we recommend the following:

1. Maintain positive site drainage during and following construction. Ponding of water should be eliminated.

2. Surface drainage of streets should be maintained by providing sufficient crown/grade in the road to direct flows into the curb/gutter systems or off of roadway improvements in areas not including curb and gutter. Positive flow of the gutters should be provided and maintained.

3. Seams and joints in the asphalt and concrete should be properly sealed to reduce infiltration of water to the underlying expansive soil/bedrock.

4. Maintenance should be provided to maintain asphalt cracks which may occur over time.

F. Construction Materials Observation and Testing

Construction materials observation and testing should meet St. George City testing requirements. We also recommend the following be conducted during the construction of the roadway.

1. Verify that the subgrade is properly prepared prior to placing fill and the recommended overexcavation depths are achieved to expose the underlying competent basalt.

2. Observe the placement and conduct compaction testing on each foot of site grading fill placed in roadway areas and within utility trenches.

3. Conduct materials testing on road-base, concrete, and asphalt in accordance with St. George City standards.

G. Geotechnical Recommendation Review

The client should familiarize themselves with the information contained in this report. If specific questions arise or if the client does not fully understand the conclusions/recommendations provided, AGEC should be contacted to provide clarification.

LIMITATIONS

This report has been prepared in accordance with generally accepted soil engineering practices in the area for design purposes. The conclusions and recommendations included within the report are based on the information obtained from the borings drilled and the test pits excavated at the locations indicated on the site plan, the results of laboratory testing, the referenced documents and our experience in the area. Variations in the subsurface conditions may not become evident until additional exploration or excavation is conducted. If the subsurface soil or groundwater conditions are found to be different from what is described in this report, we should be notified to reevaluate the recommendations given.

Sincerely,

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.





Jake Erickson, P.E.

James E. Nordquist, P.E.

Reviewed by Arnold DeCastro, P.E.

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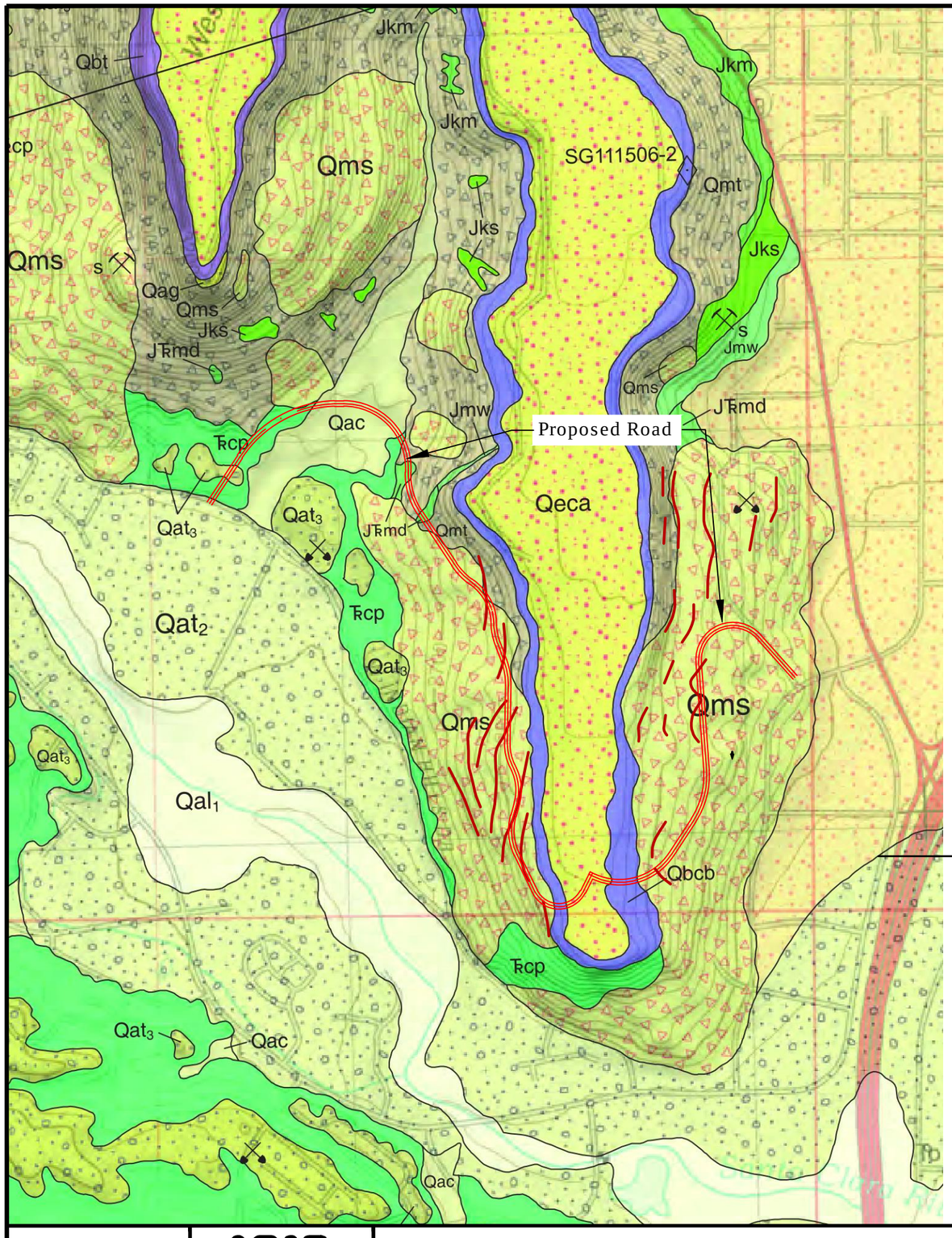
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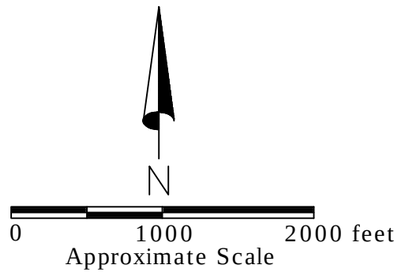
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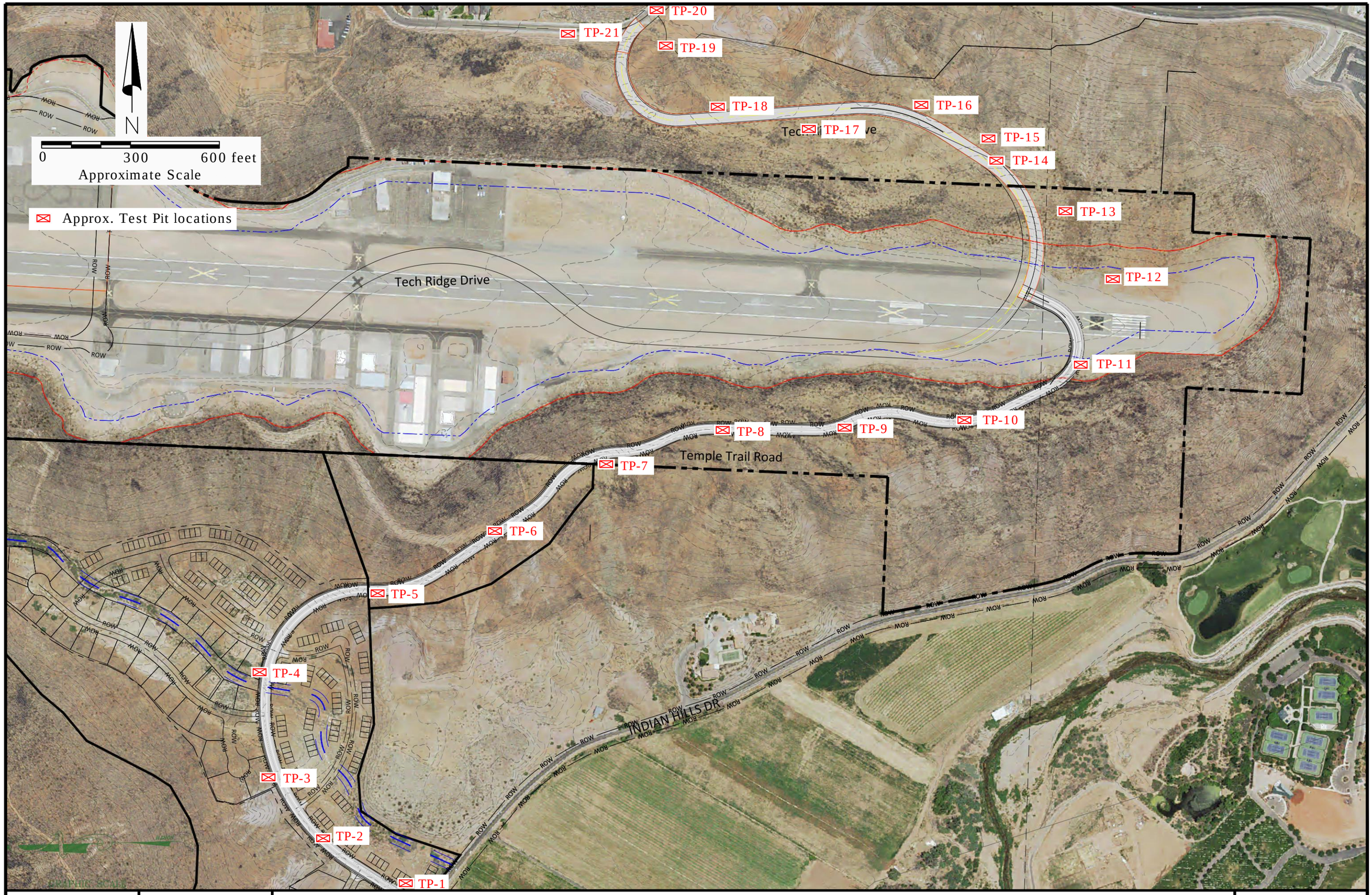
Explanation of Symbols and Geologic Units in Area of Proposed Road

Qal_1	-	Stream alluvium (Holocene)
Qac	-	Mixed alluvial and colluvial deposits (Holocene to upper Pleistocene)
Qeca	-	Eolian and alluvial deposits (Holocene to lower Pleistocene)
Qat_2	-	Alluvial-terrace deposits (Holocene)
Qat_3	-	Alluvial-terrace deposits (late Pleistocene)
Qmt	-	Talus deposits (Holocene to upper Pleistocene)
Qms	-	Landslide deposits (Holocene to middle Pleistocene)
Qbcb	-	Cedar Bench lava flow (lower Pleistocene)
Jmw	-	Whitmore Point Member of the Moenave Formation (Lower Jurassic)
JTrmd	-	Dinosaur Canyon Member of the Moenave Formation (Lower Jurassic)
Trcp	-	Petrified Forest Member of the Chinle Formation (Upper Triassic)
		Lineation within the landslide deposits
		Approximate location of proposed access roads

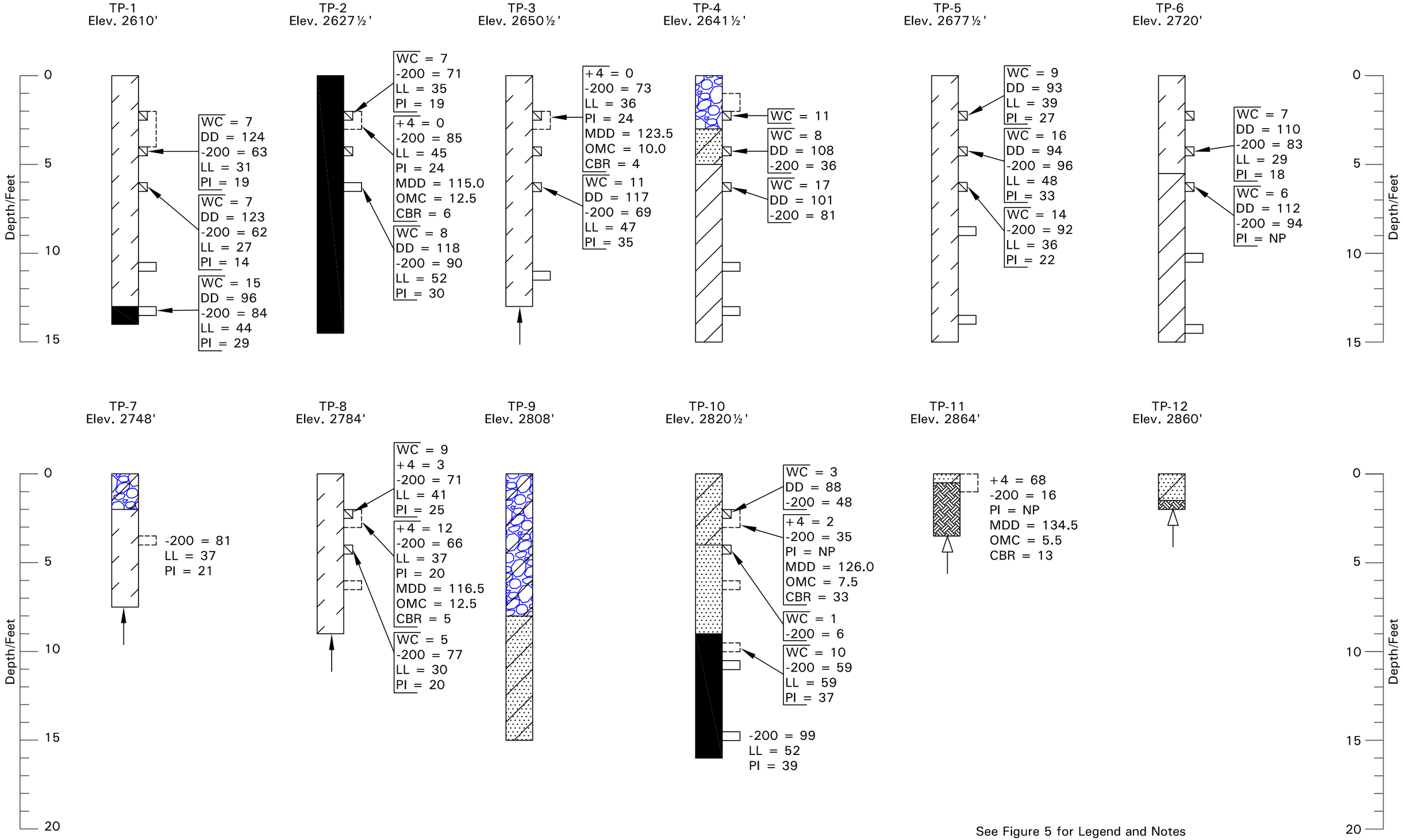
TECH RIDGE SOUTH ACCESS ROAD
ST. GEORGE, UTAH

Map taken from Hayden, J.M. and Willis, G.C., 2011; Geologic map of the St George quadrangle, Washington County, Utah, Utah Geological Survey Map 251DM.

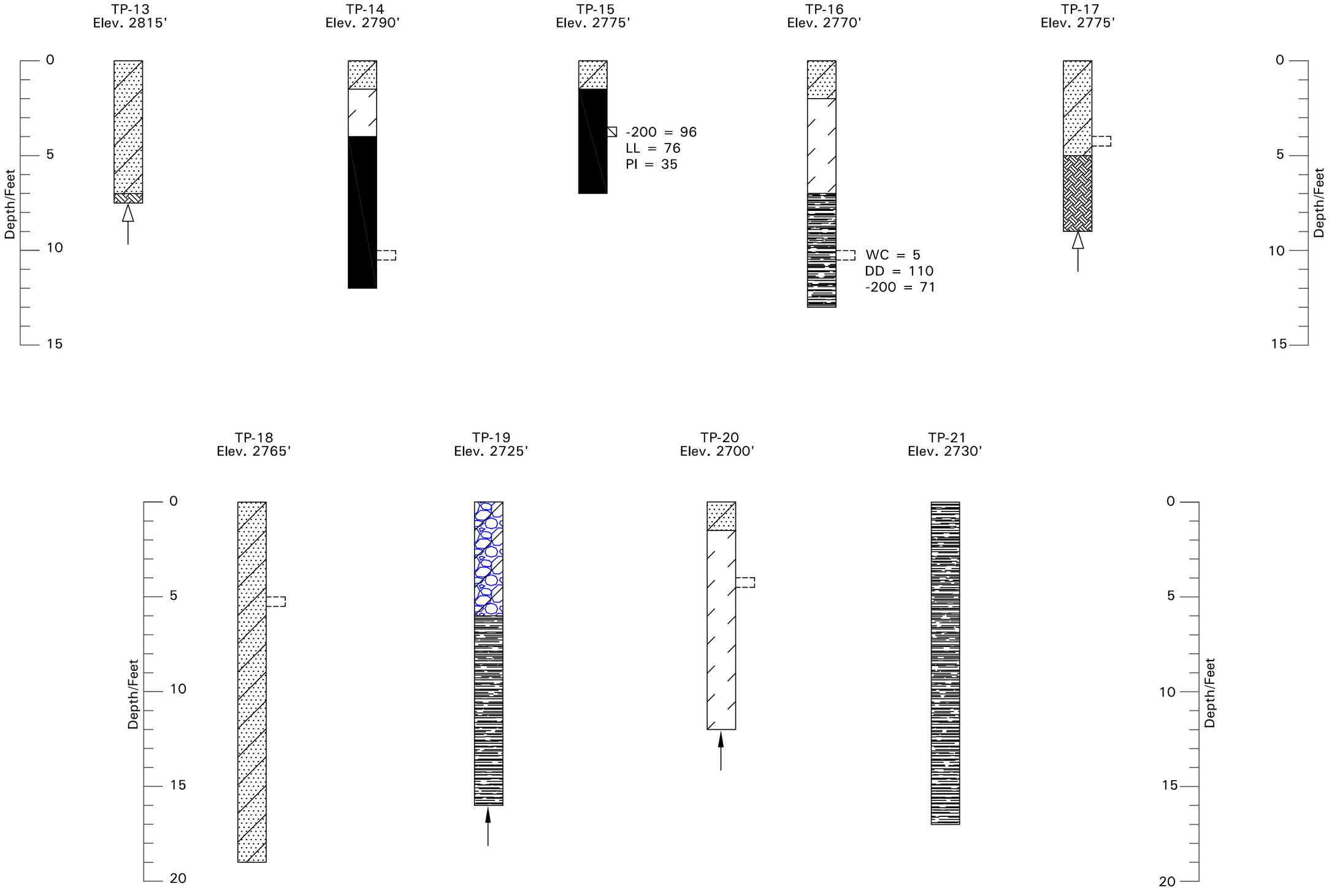
2180295	AGEC	Vicinity and Geologic Map	Figure 1



2180295	AGEC	Test Pit Locations	Figure 2



See Figure 5 for Legend and Notes



See Figure 5 for Legend and Notes

LEGEND:

Lean Clay (CL); medium stiff to very stiff, moist, medium plastic, contains varied amounts of sand, gravel, and boulders (1 to 4 feet in size), red-brown to brown with white mottles.

Silt (ML); medium stiff to stiff, slightly moist to moist, contains various amounts of sand, reddish brown.

Silty Sand (SM); loose to medium dense, dry, fine to medium grained, contains occasional gravel, cobbles and boulders (1 to 4 feet in size), light reddish brown to brown.

Well Graded Sand with Silt (SW-SM); medium dense, dry, contains gravel, brown.

Silty Gravel with Sand (GM); medium dense to dense, dry to moist, light brown to brown.

Basalt; moderately hard to very hard, dry, highly fractured near surface, black.

Mudstone; soft to moderately hard, dry to moist, medium to highly plastic, grey to purple.

Shale Bedrock; soft to hard, dry to slightly moist, interbedded with layers of siltstone and claystone, dark brown to dark red.

Indicates relatively undisturbed hand drive sample taken.

Indicates relatively undisturbed block sample taken.

Indicates disturbed sample taken.

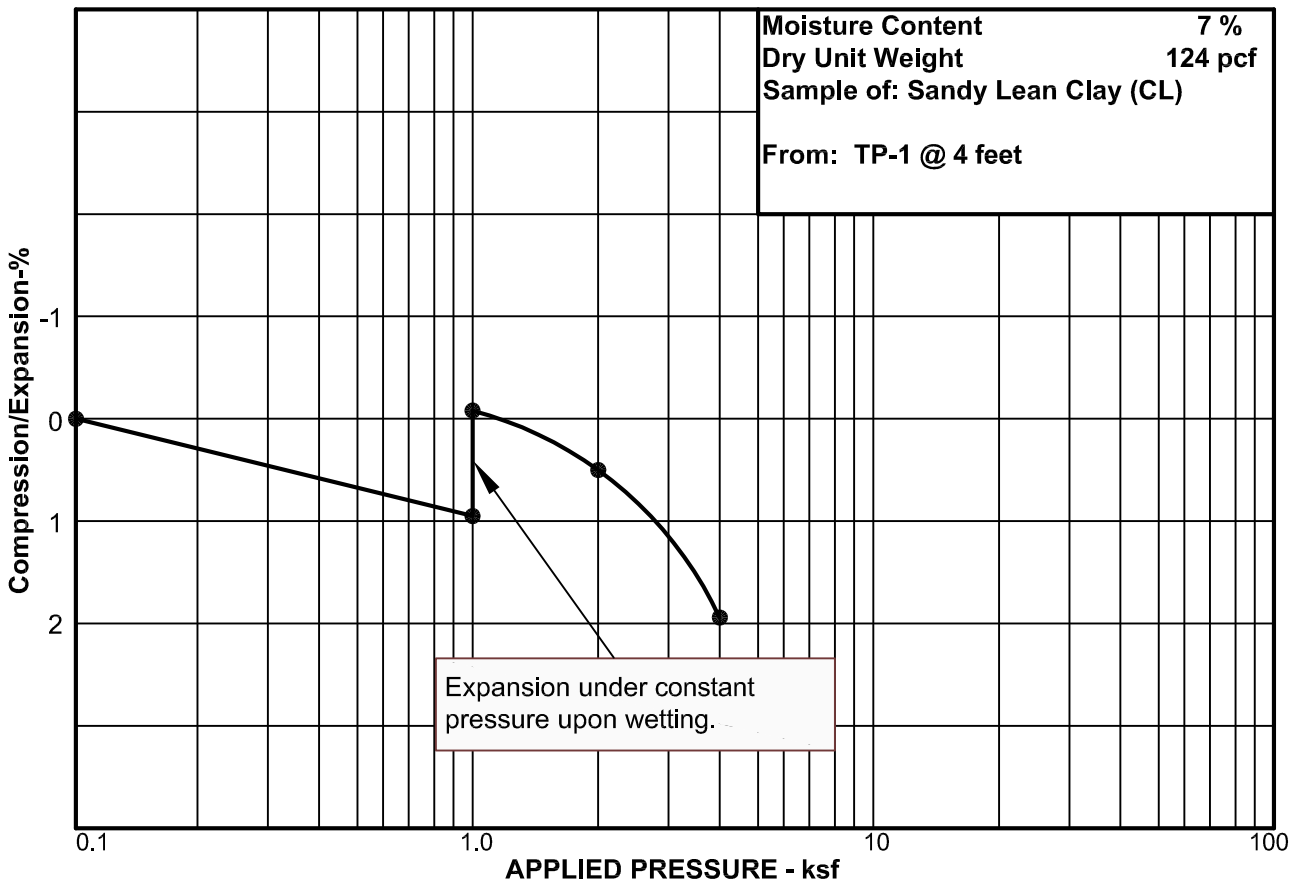
Indicates practical backhoe refusal on stiff clay and boulders or shale bedrock.

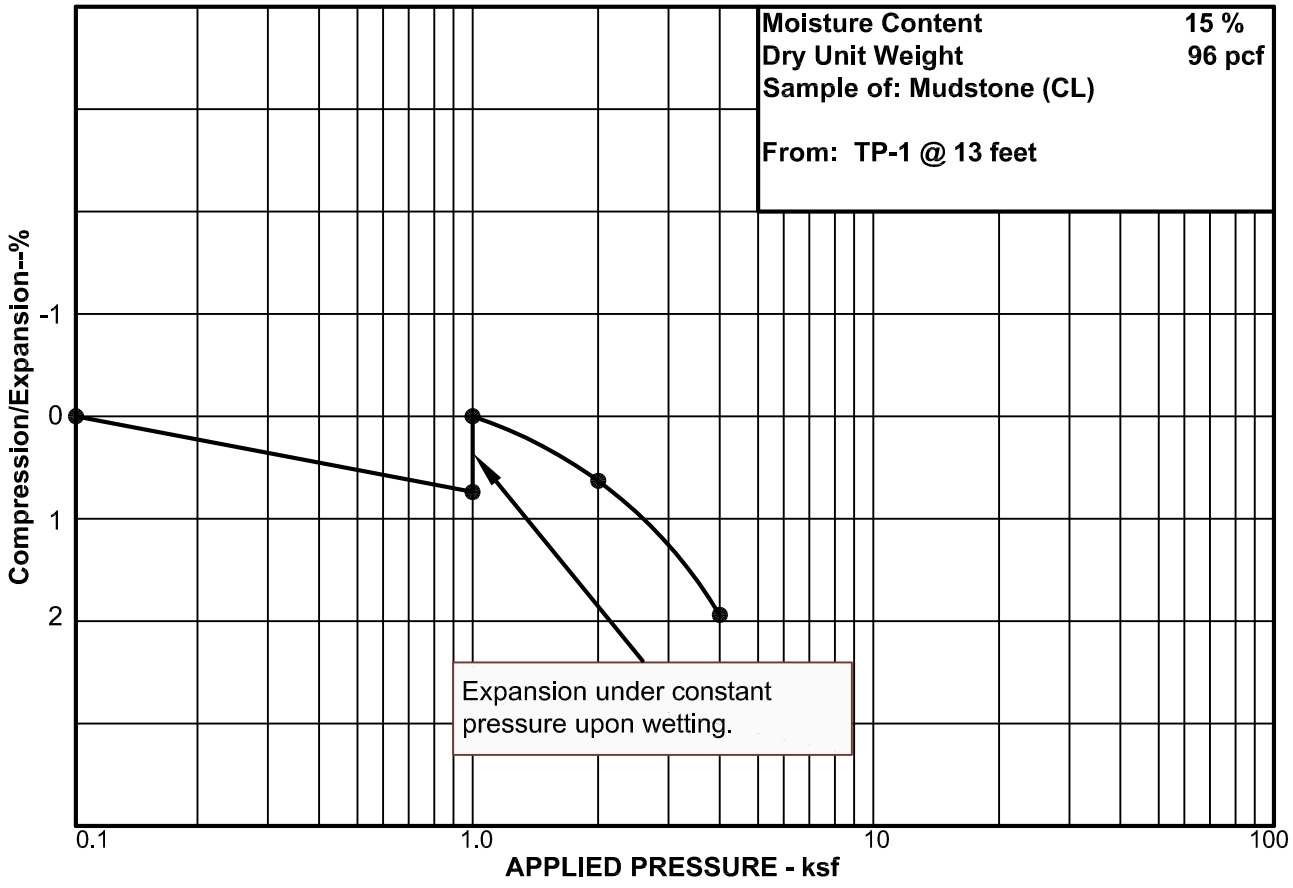
Indicates practical backhoe refusal on basalt.

NOTES:

1. Test pits TP-1 through TP-13 were excavated on August 8 and 9, 2018 and test pits TP-14 through TP-21 were excavated on August of 1998 with a trackhoe.
2. The locations and elevations of test pits TP-1 through TP-11 were measured using roadway centerline stakes, which were located using GPS by others.
3. The locations of test pits TP-12 through TP-21 were located by pacing from features shown on Figure 2. The elevations of test pits TP-12 through TP-21 were interpolated between contours shown on Figure 2.
4. The test pit locations and elevations should be considered accurate only to the degree implied by the method used.
5. The lines between the materials shown on the test pit logs represent the approximate boundaries between material types and the transitions may be gradual.
6. Free water was not encountered in the test pits at the time of excavation.
7. WC = water content (%);
   DD = dry density (pcf);
   +4 = percent retained on the No. 4 sieve;
   -200 = percent passing No. 200 sieve;
   LL = liquid limit (%);
   PI = plasticity index (%);
   NP = non-plastic;
   MDD = maximum dry density (pcf);
   OMC = optimum moisture content (%);
   CBR = california bearing ratio (%).

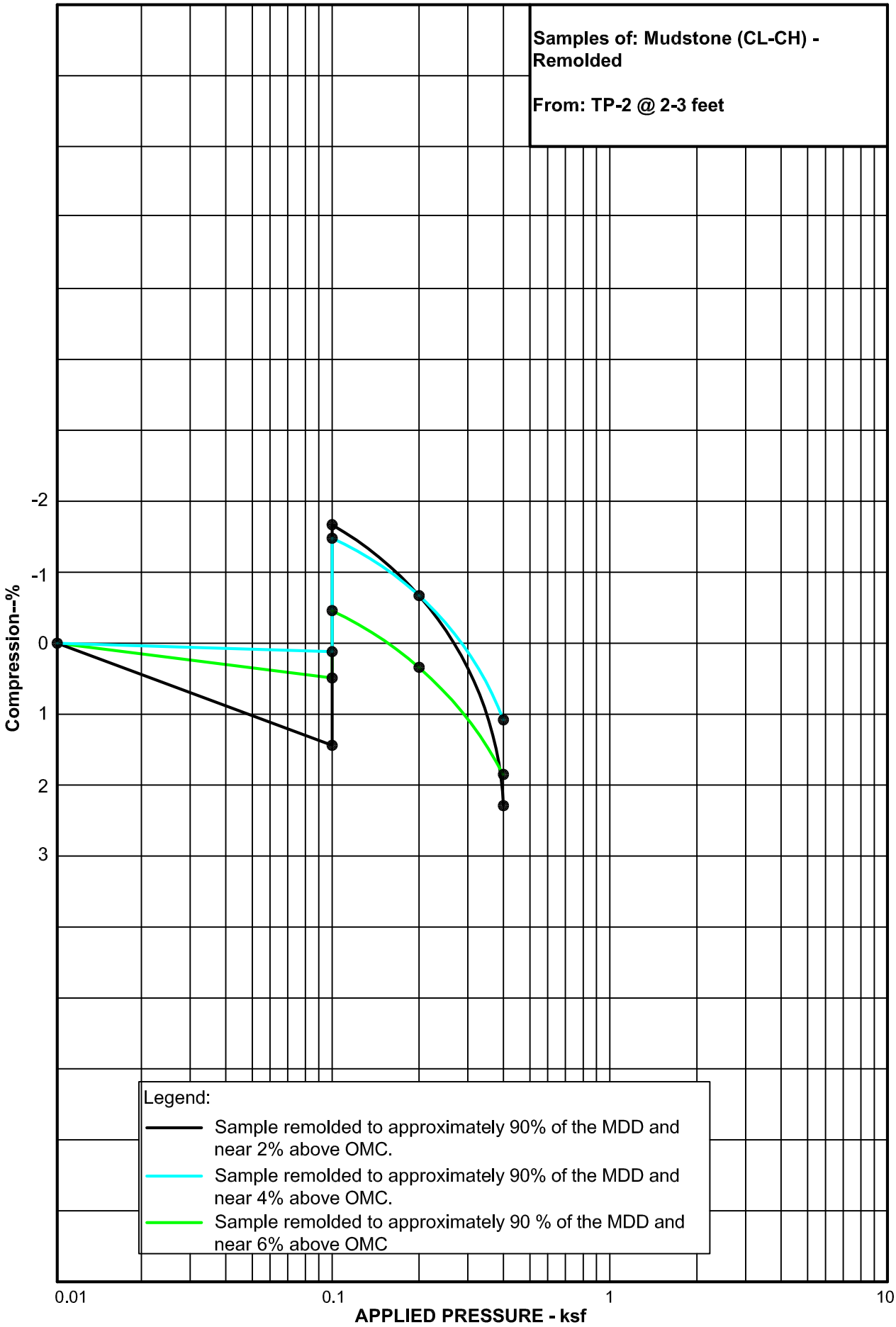
Applied Geotechnical Engineering Consultants, Inc.





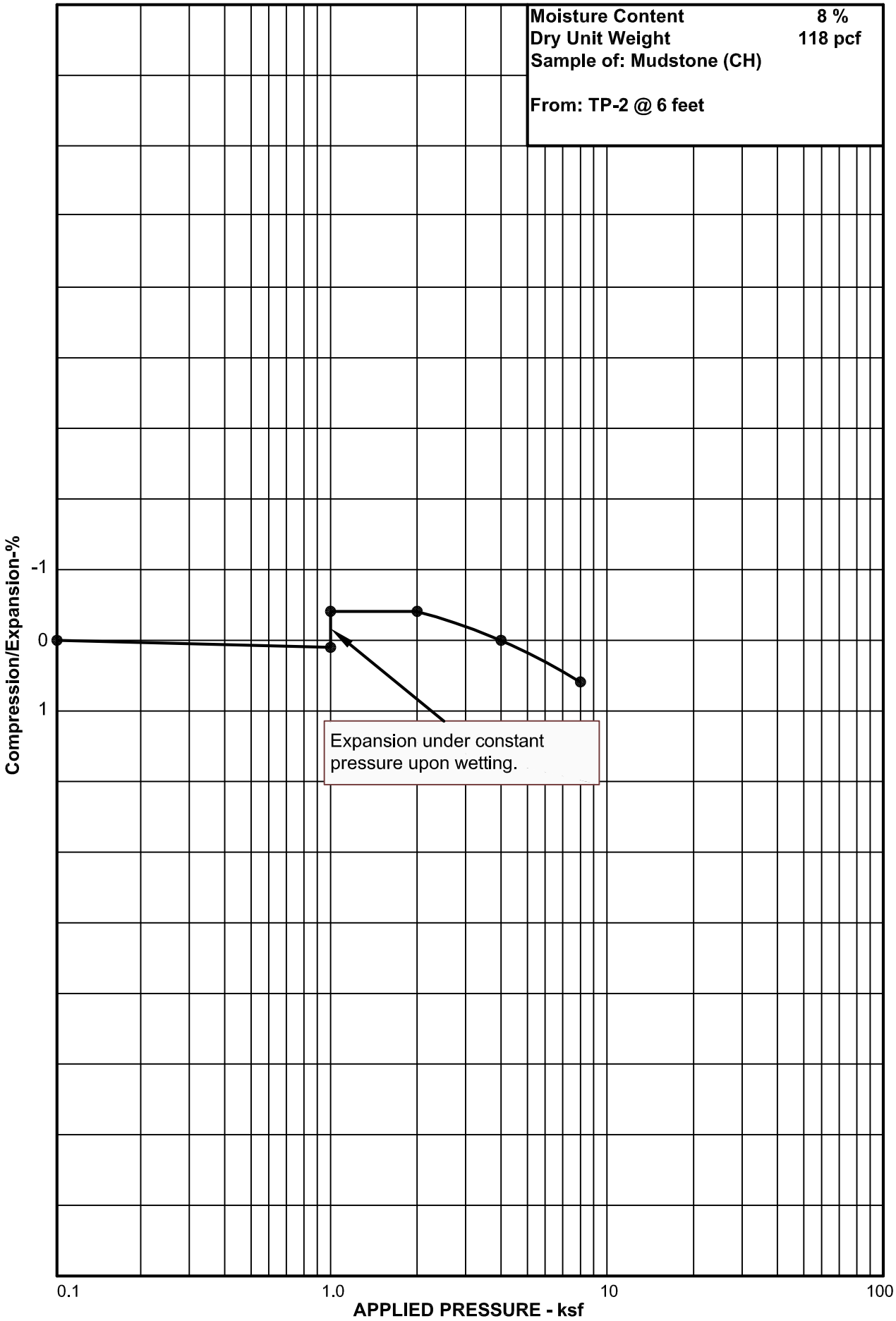
Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 6**

Applied Geotechnical Engineering Consultants, Inc.



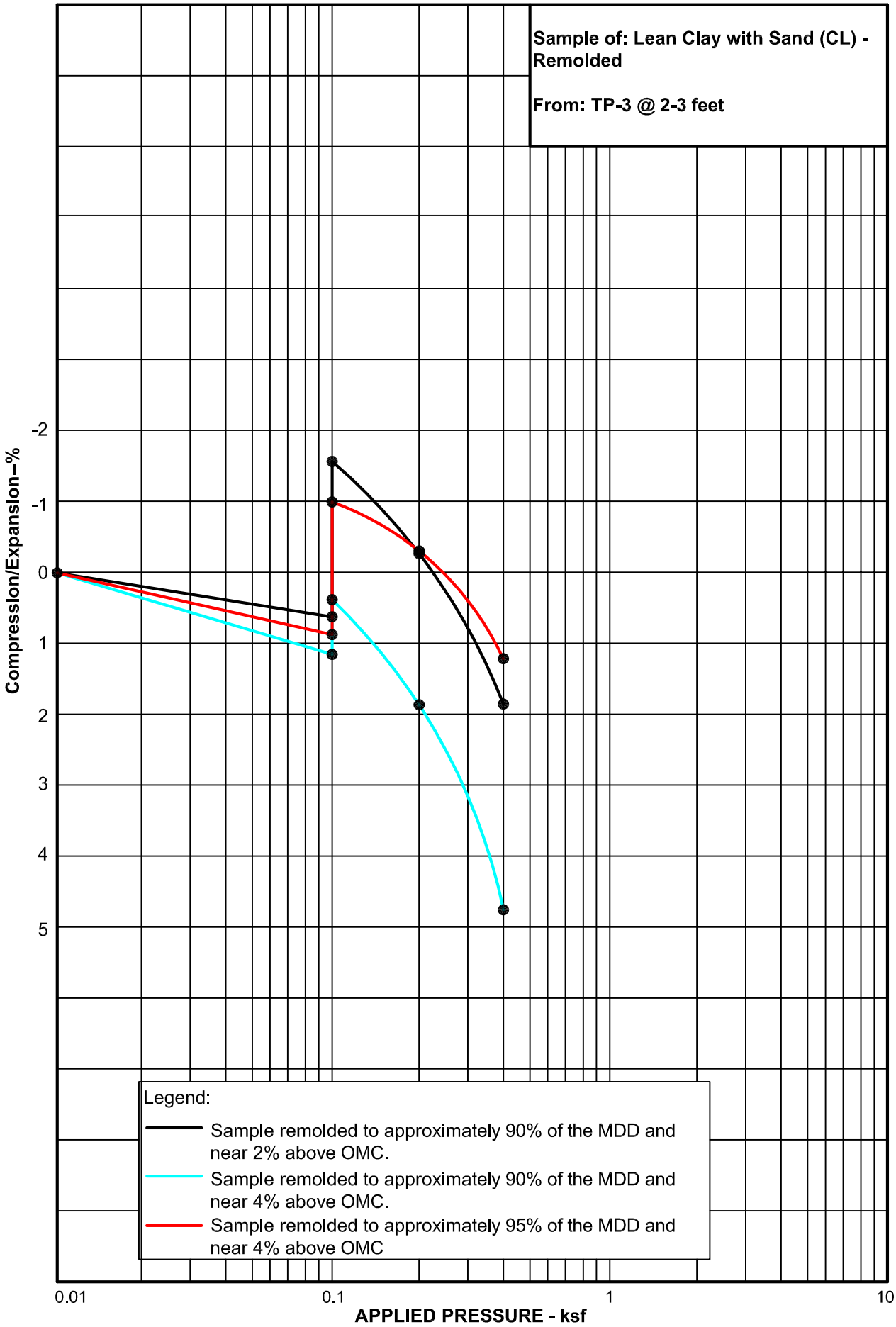
Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 7**

Applied Geotechnical Engineering Consultants, Inc.



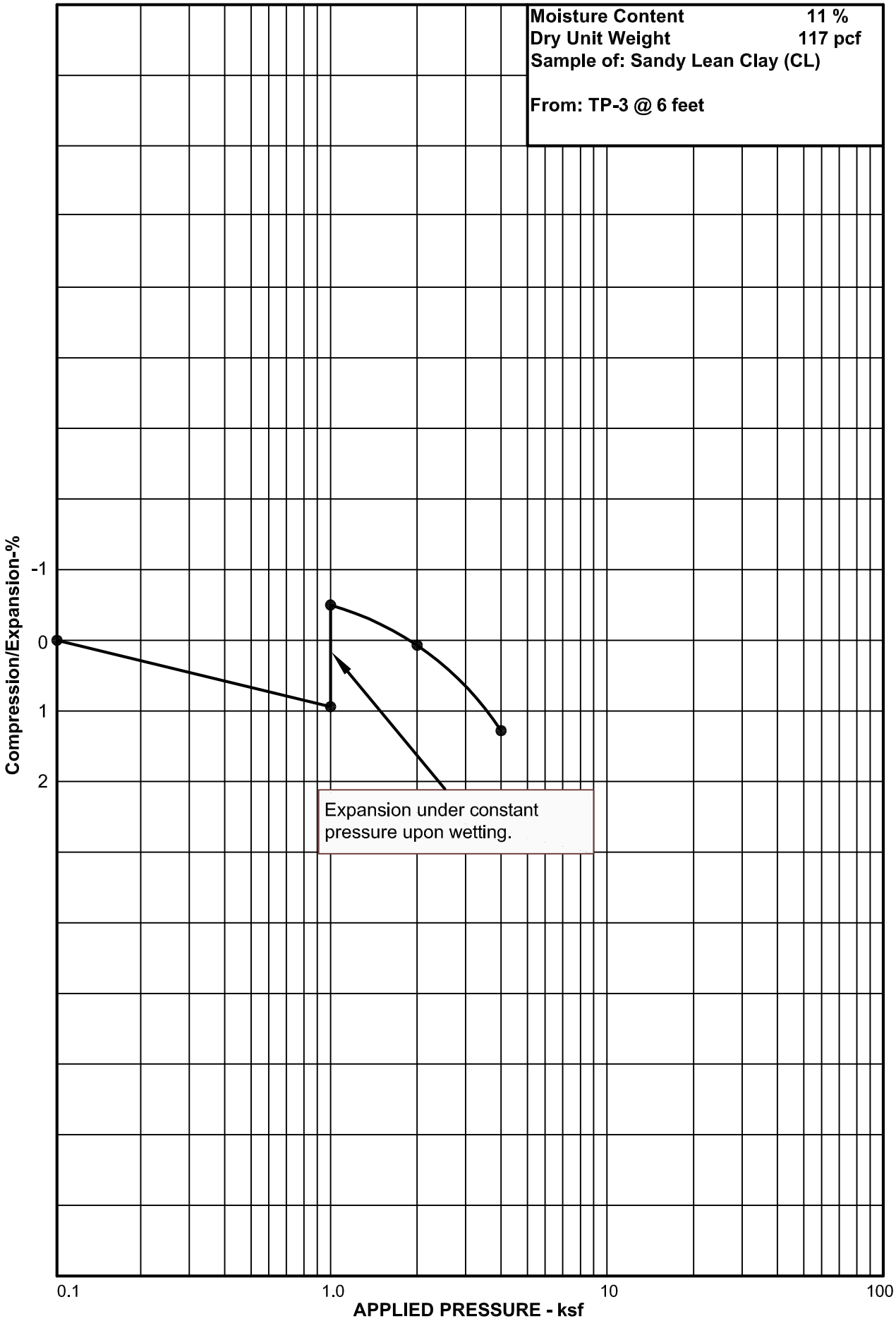
Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 8**

Applied Geotechnical Engineering Consultants, Inc.



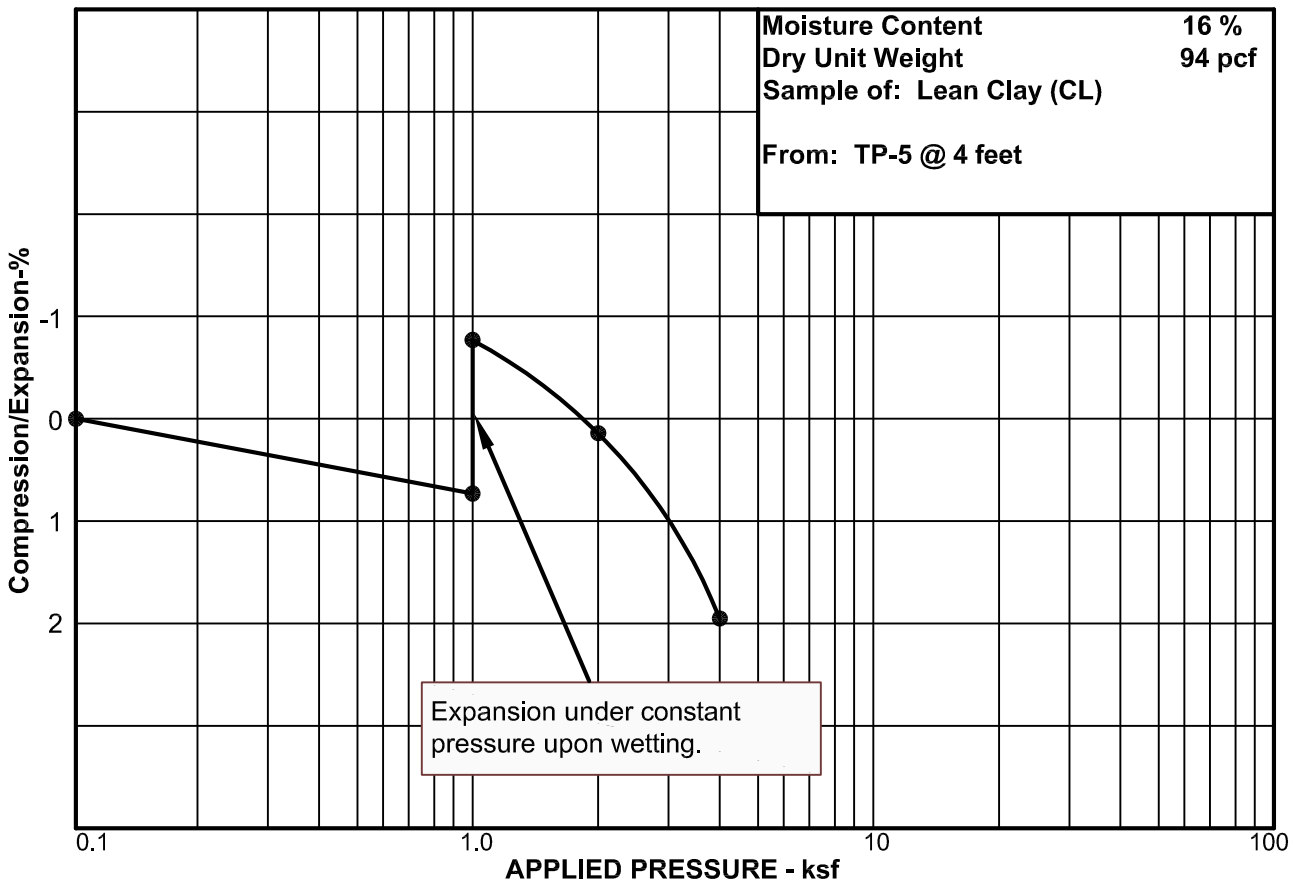
Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 9**

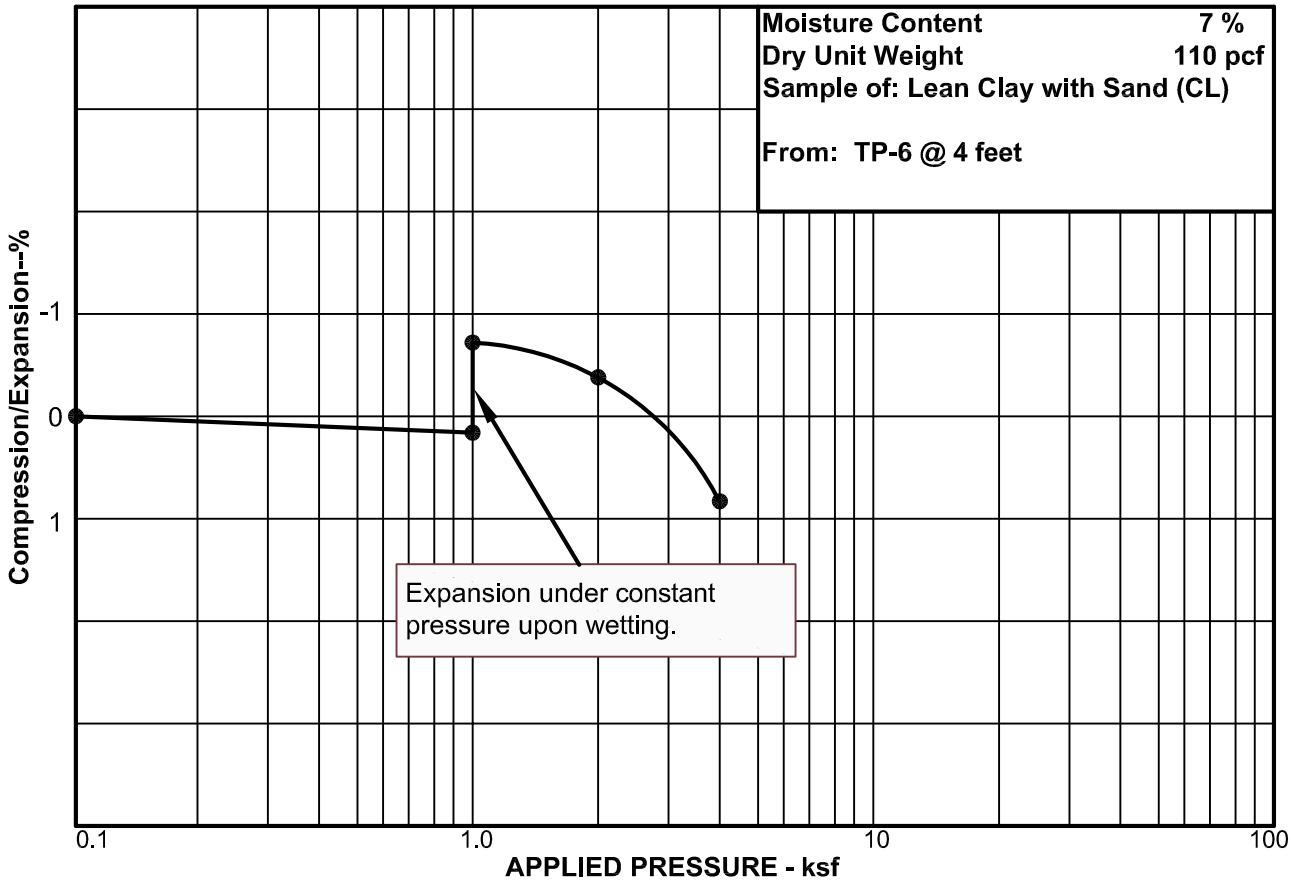
Applied Geotechnical Engineering Consultants, Inc.



Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 10**

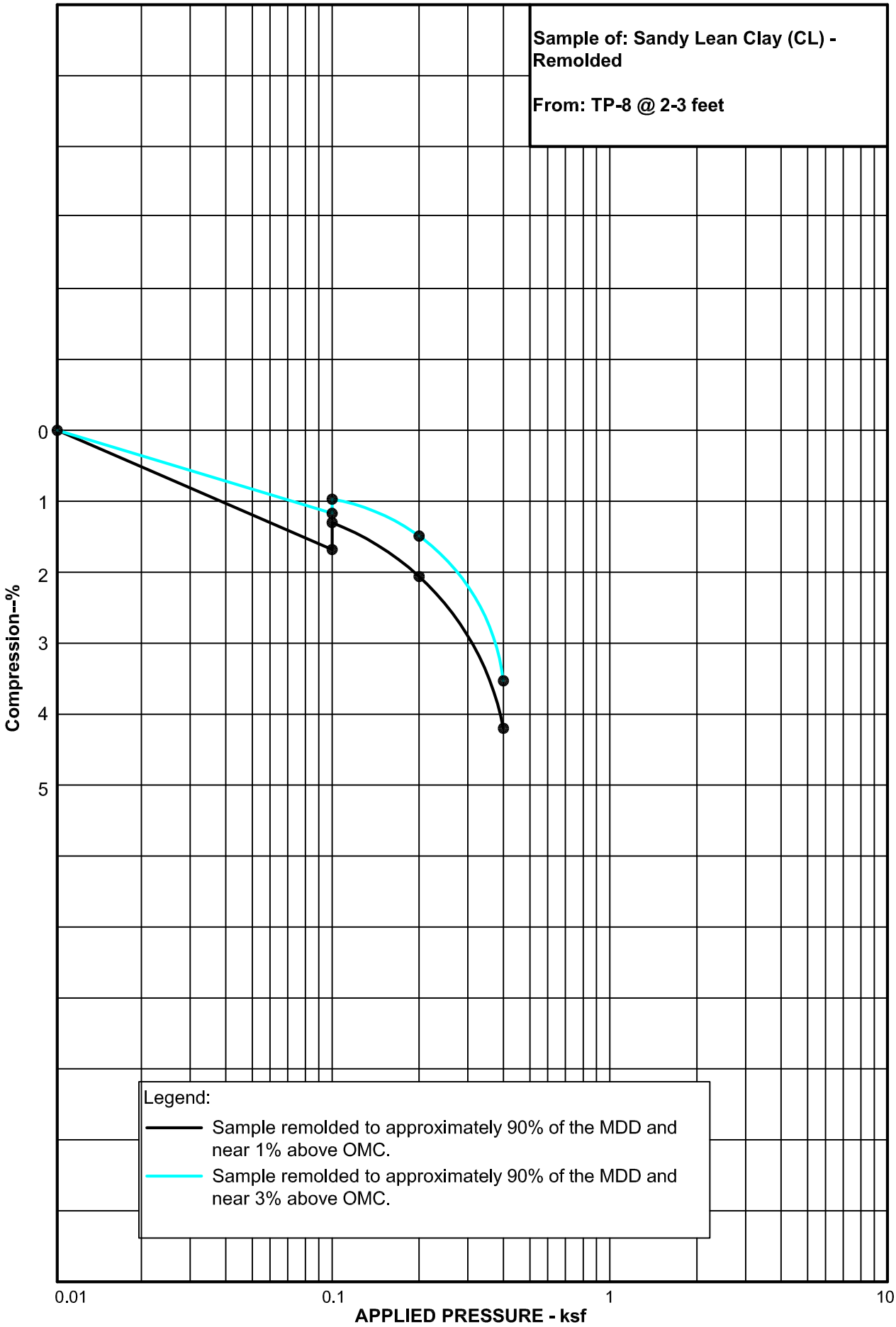
Applied Geotechnical Engineering Consultants, Inc.





Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 11**

Applied Geotechnical Engineering Consultants, Inc.

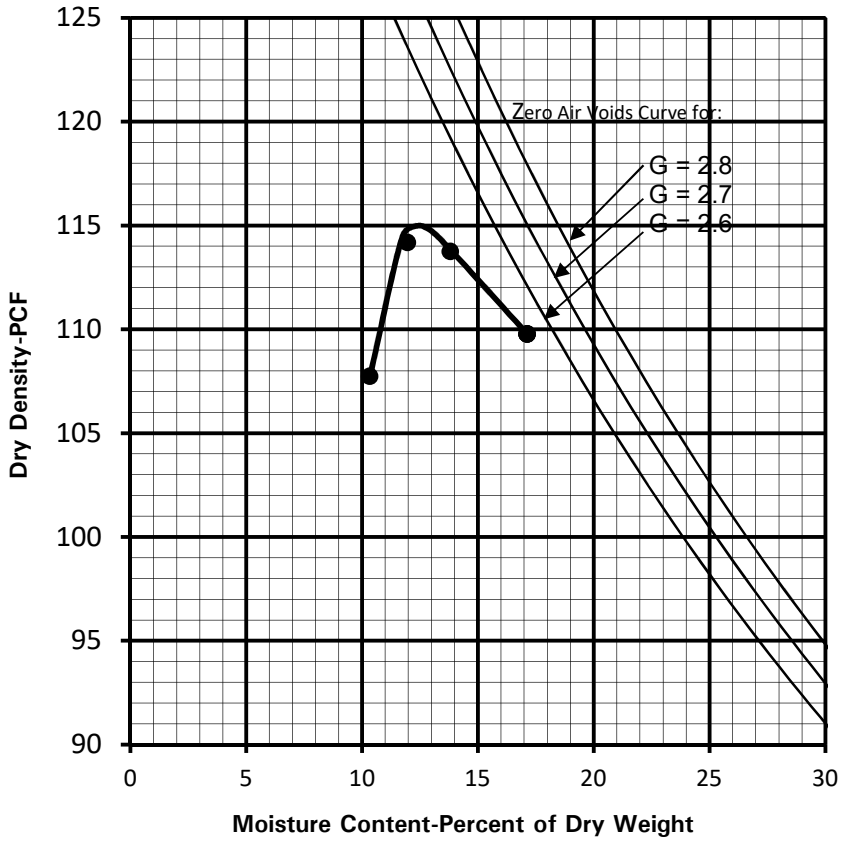


Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 12**

AGEC

Applied GeoTech

Project: 300 West (Tech Ridge South Access Road)



Sample Date:	8/14/18
Sample No.	180815G
Maximum Dry Density:	115.0
Optimum Moisture:	12.5
Atterberg Limits	
Liquid Limit:	45%
Plasticity Index:	24%
Gradation	
Gravel:	0%
Sand:	15%
Silt & Clay:	85%

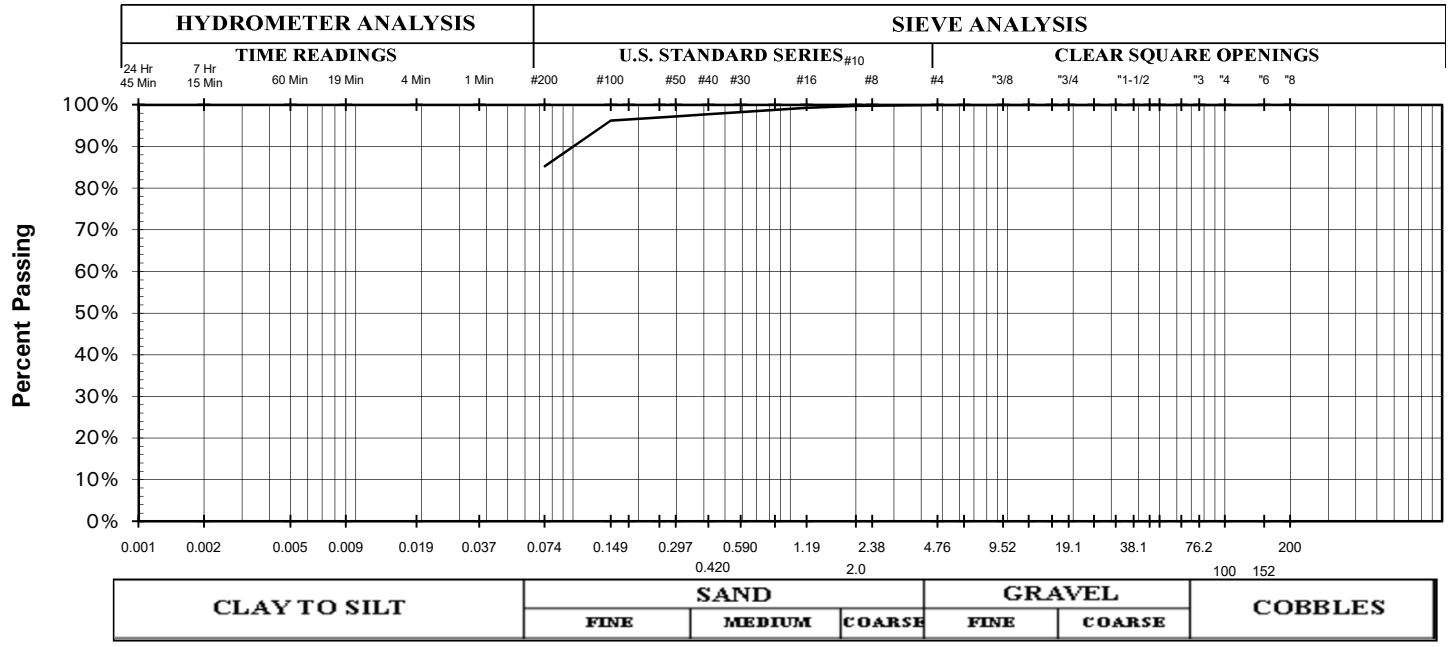
Moisture - Density Relationship Test Procedure: ASTM D-1557 B

Reviewed By: BI

Sample Description: Mudstone - lean clay (CL)

AASHTO Classification: A-7-6

Sample Location: TP-2 @ 2-3'



GRADATION AND MOISTURE-DENSITY RELATIONSHIP RESULTS

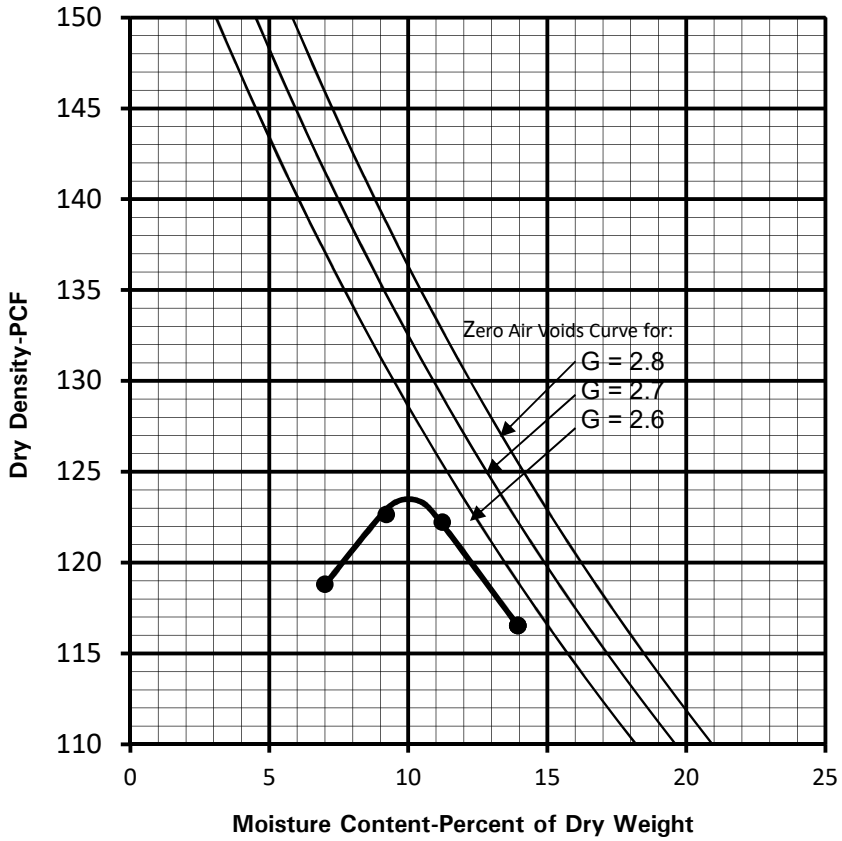
Project No.: 2180295

Figure: 13

AGEC

Applied GeoTech

Project: 300 West (Tech Ridge South Access Road)



Sample Date:	8/14/18
Sample No.	180816A
Maximum Dry Density:	123.5
Optimum Moisture:	10.0
Atterberg Limits	
Liquid Limit:	36%
Plasticity Index:	24%
Gradation	
Gravel:	0%
Sand:	27%
Silt & Clay:	73%

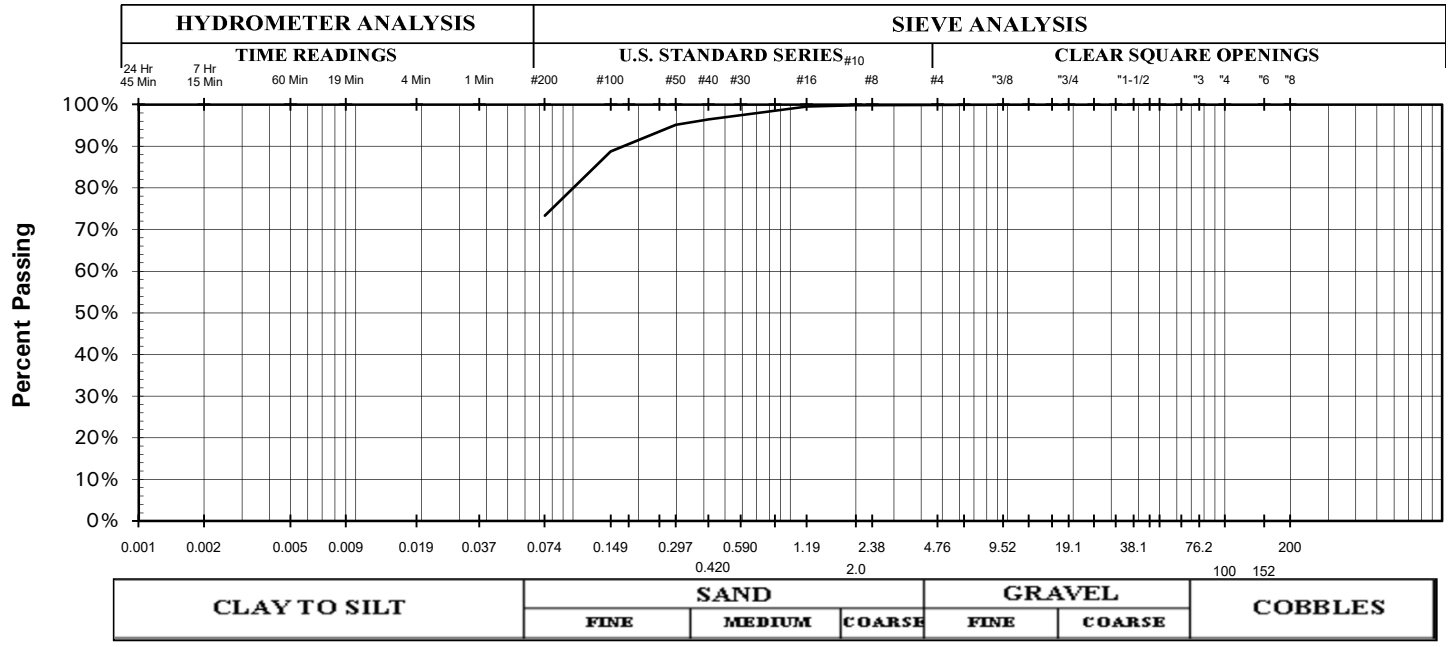
Moisture - Density Relationship Test Procedure: ASTM D-1557 B

Reviewed By: BI

USCS Classification: lean clay with sand (CL)

AASHTO Classification: A-6

Sample Location: TP-3 @ 2-3'



GRADATION AND MOISTURE-DENSITY RELATIONSHIP RESULTS

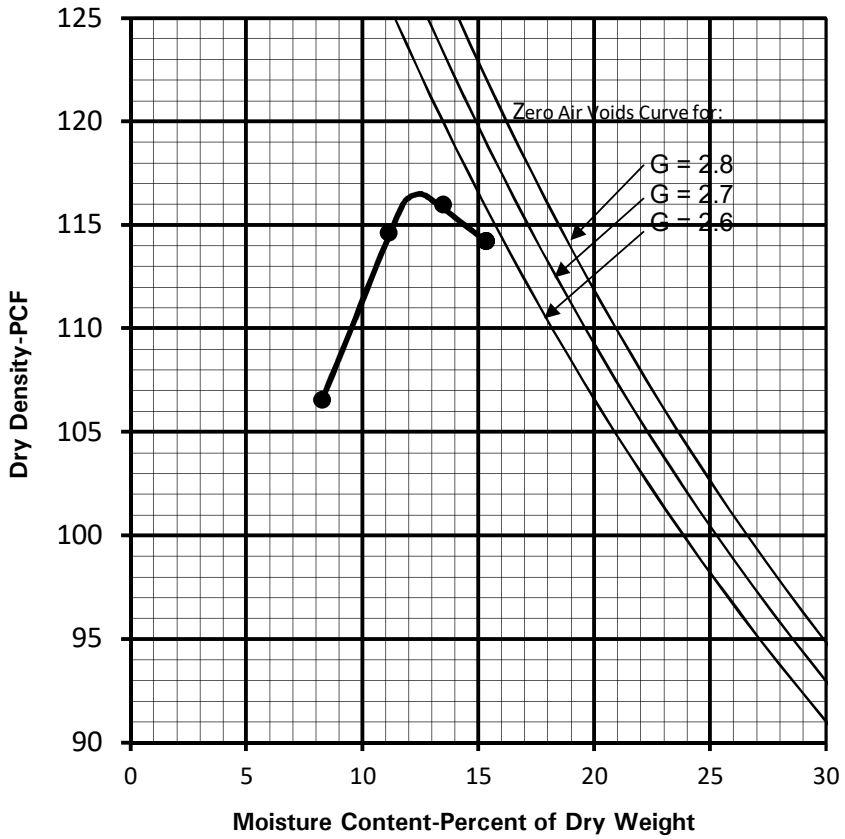
Project No.: 2180295

Figure: 14

AGEC

Applied GeoTech

Project: 300 West (Tech Ridge South Access Road)



Sample Date:	8/14/18
Sample No.	180816b
Maximum Dry Density:	116.5
Optimum Moisture:	12.5
Atterberg Limits	
Liquid Limit:	37%
Plasticity Index:	20%
Gradation	
Gravel:	12%
Sand:	22%
Silt & Clay:	66%

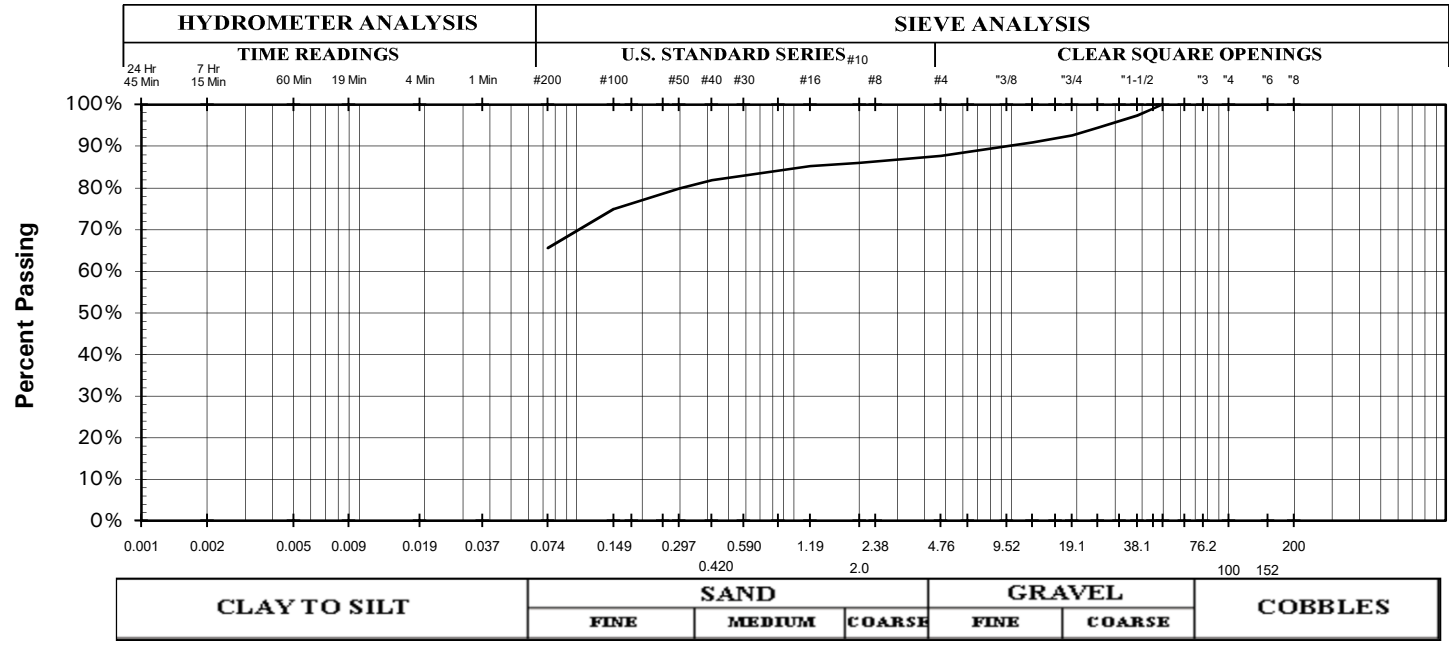
Moisture - Density Relationship Test Procedure: ASTM D-1557 B

Reviewed By: BI

Sample Description: sandy lean clay (CL)

AASHTO Classification: A-6

Sample Location: TP-8 @ 2-3'



GRADATION AND MOISTURE-DENSITY RELATIONSHIP RESULTS

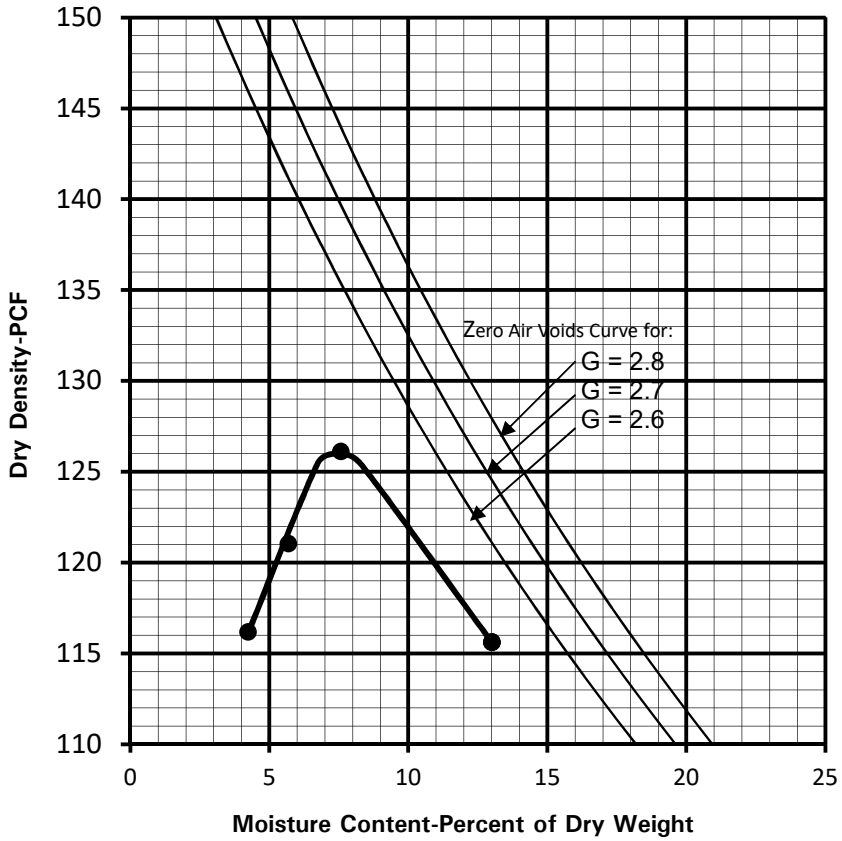
Project No.: 2180295

Figure: 15

AGEC

Applied GeoTech

Project: 300 West (Tech Ridge South Access Road)



Sample Date:	8/14/18
Sample No.	180816E
Maximum Dry Density:	126.0
Optimum Moisture:	7.5

Atterberg Limits

Liquid Limit:	
Plasticity Index:	Non-Plastic

Gradation

Gravel:	2%
Sand:	63%
Silt & Clay:	35%

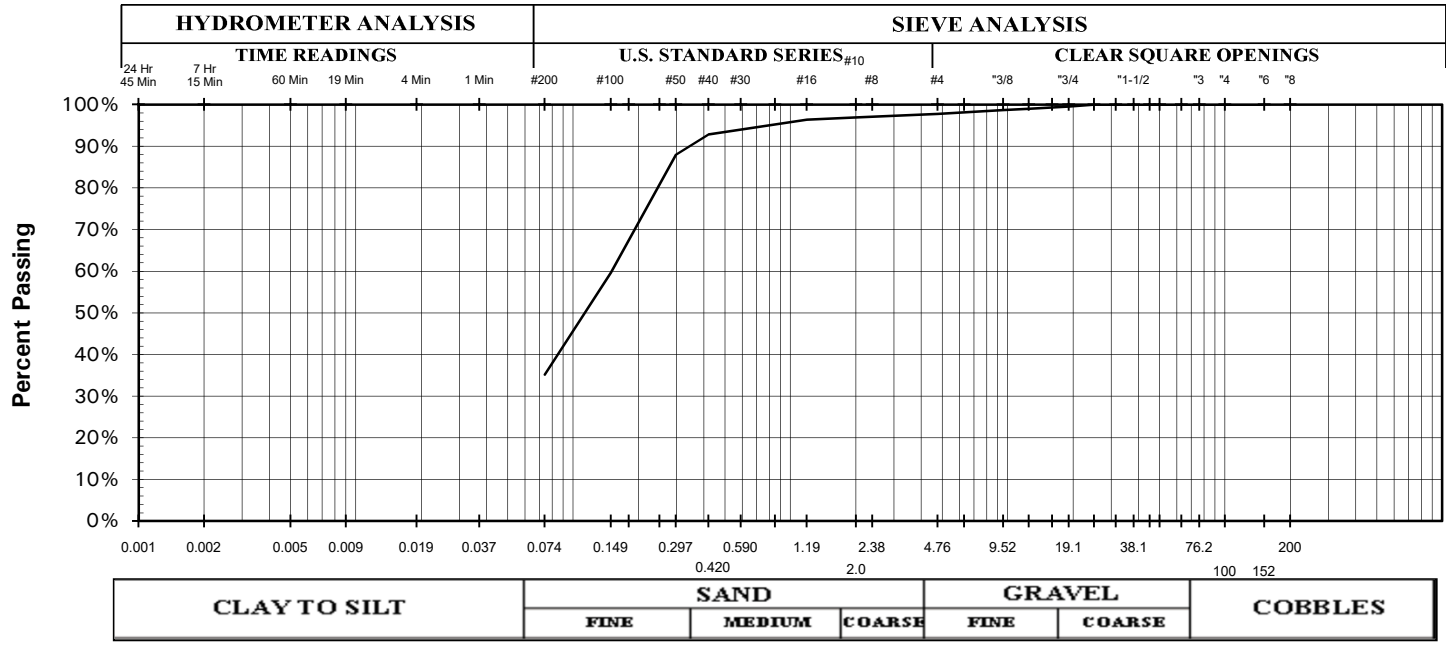
Moisture - Density Relationship Test Procedure: ASTM D-1557 B

Reviewed By: BI

USCS Classification: silty sand (SM)

AASHTO Classification: A-4

Sample Location: TP-10 @ 2-3'



GRADATION AND MOISTURE-DENSITY RELATIONSHIP RESULTS

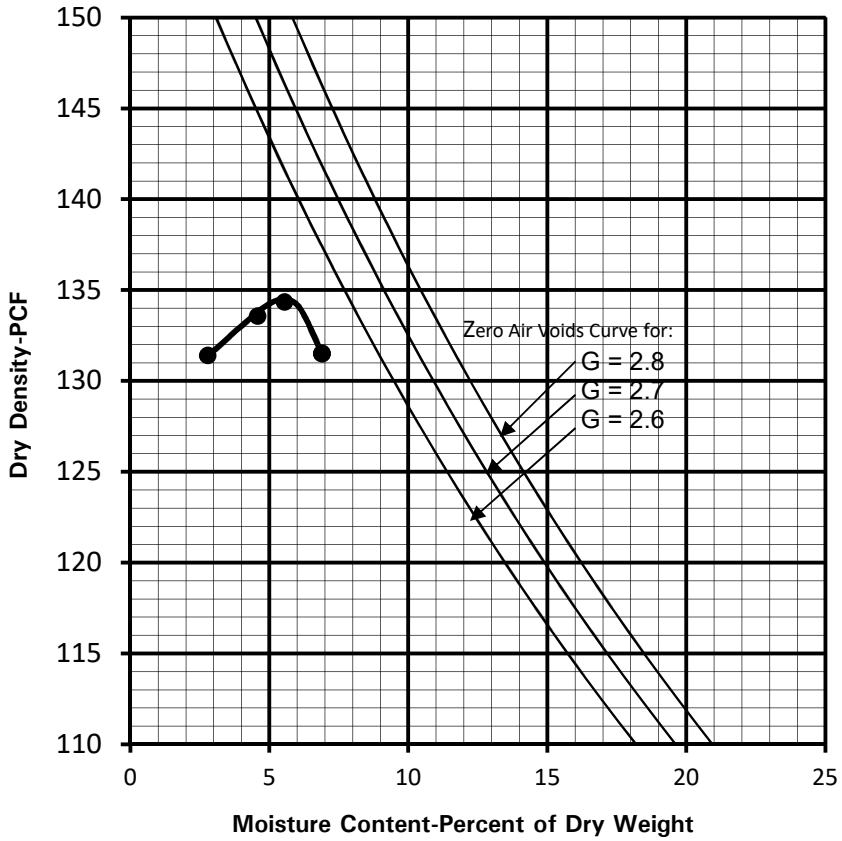
Project No.: 2180295

Figure: 16

AGEC

Applied GeoTech

Project: 300 West



Sample Date:	8/14/18
Sample No.	180816F
Maximum Dry Density:	134.5
Optimum Moisture:	5.5

Atterberg Limits

Liquid Limit:	
Plasticity Index:	Non-Plastic

Gradation

Gravel:	68%
Sand:	16%
Silt & Clay:	16%

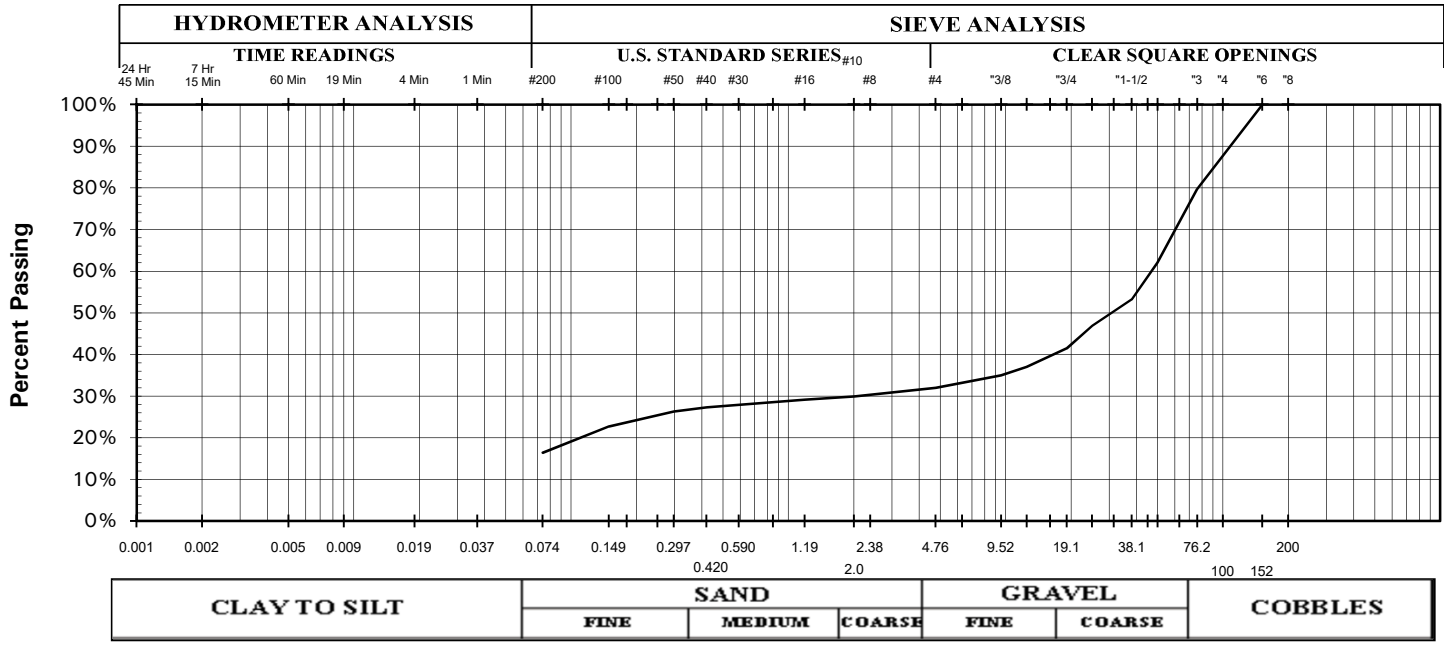
Moisture - Density Relationship Test Procedure: ASTM D-1557 B

Reviewed By: TT

USCS Classification: silty gravel with sand (GM) *Rock Corrected*

AASHTO Classification: A-1-b

Sample Location: TP-11 @ 0-1'

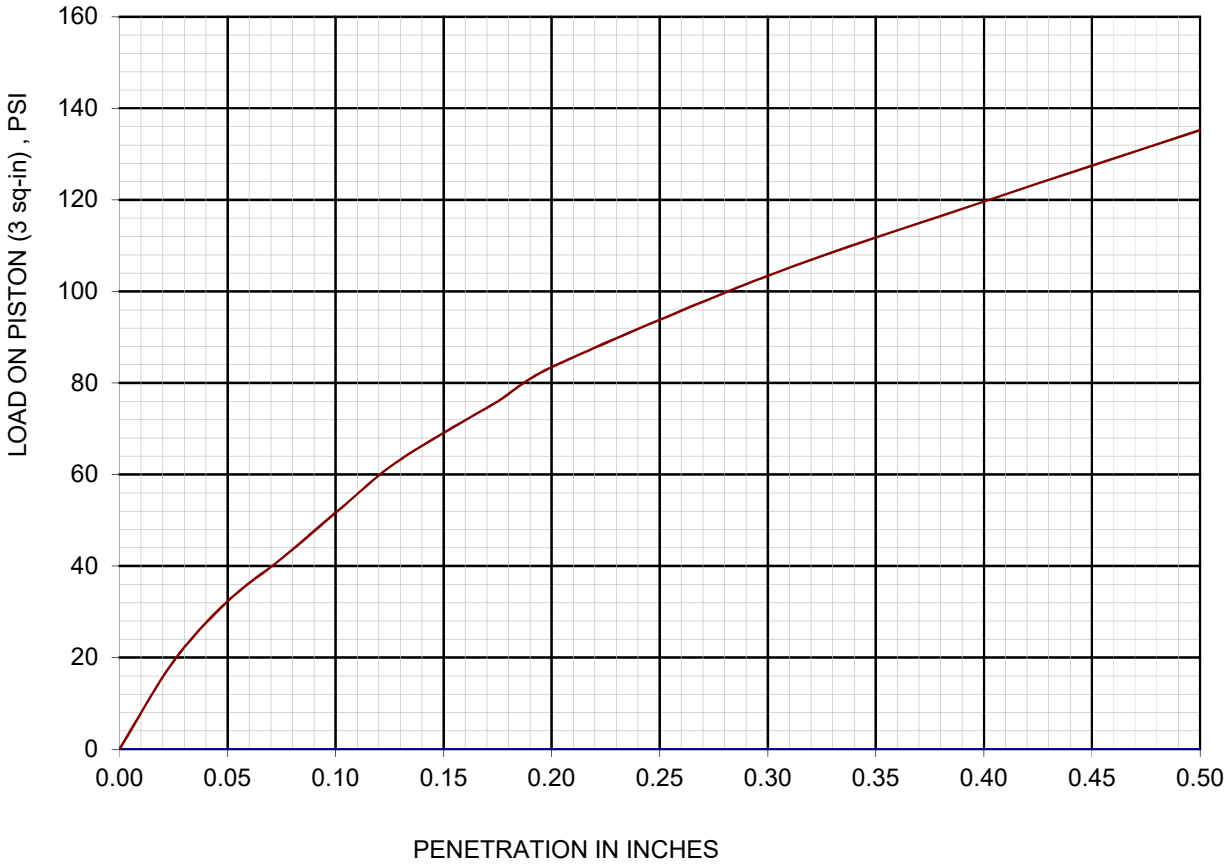


GRADATION AND MOISTURE-DENSITY RELATIONSHIP RESULTS

Project No.: 2180295

Figure: 17

AGEC
Applied GeoTech



Project 300 West **Sample Location** TP-2 @ 2-3'

Sample Classification (CL) lean clay - purple mudstone **AGEC Sample ID No.** A-082718

Method of sample preparation: Remolded to approximately 90% of the maximum dry density at the optimum moisture content +2 as per ASTM D-1557

Sample penetration after soaking for 96 hours

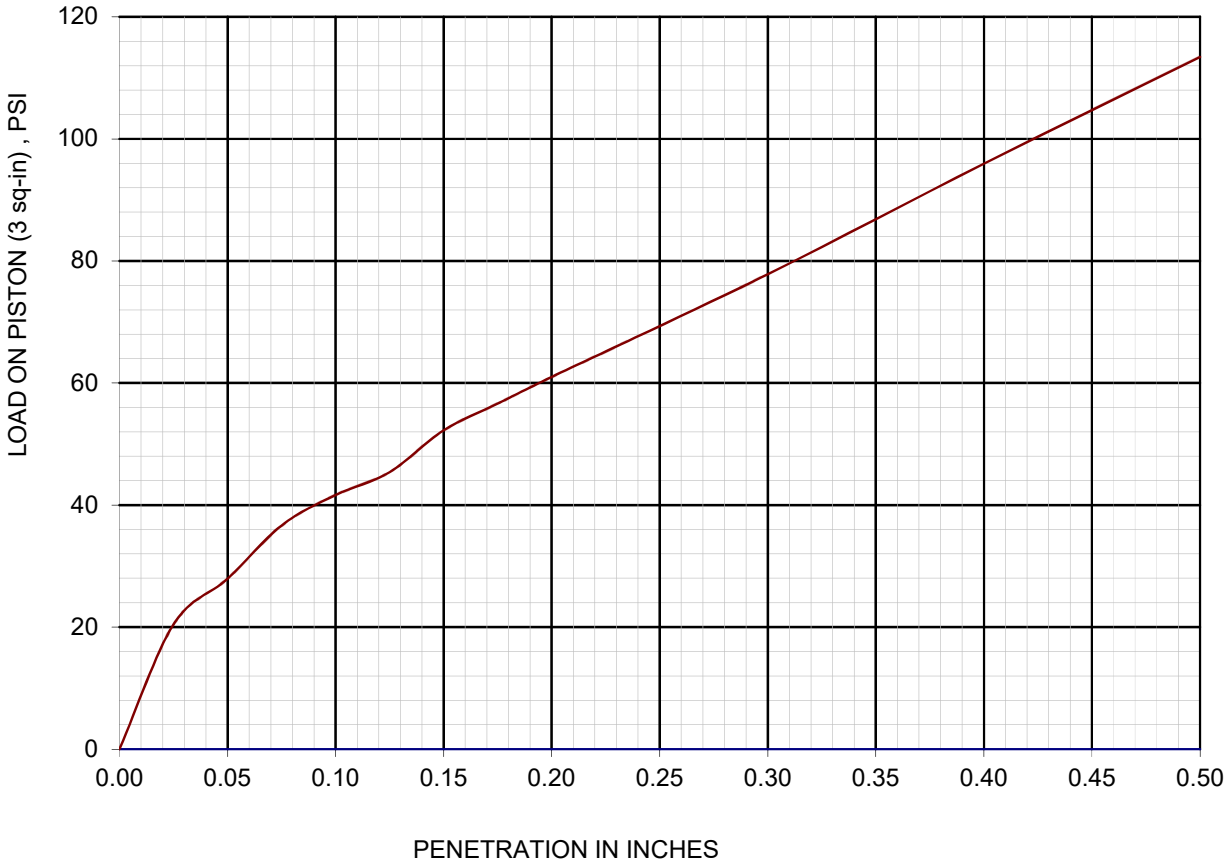
Dry Density:	as molded	103.0	pcf	**Moisture Content:**	as molded	14.1	percent
	after soaking	98.1	pcf		top 1-inch after soaking	26.0	percent
Swell:	after soaking	4.1	percent		average after soaking	25.3	percent

Comments CBR value taken at 0.2 inch penetration

Bearing Ratio of Sample, CBR = **6** percent **Surcharge** 30 lb

Proj. No. 2180295 **CALIFORNIA BEARING RATIO TEST RESULTS** Figure 18

AGEC
Applied GeoTech



Project 300 West **Sample Location** TP-3 @ 2-3'

Sample Classification (CL) lean clay with sand **AGEC Sample ID No.** B-082718

Method of sample preparation: Remolded to approximately 90% of the maximum dry density at the optimum moisture content +2% as per ASTM D-1557

Sample penetration after soaking for 96 hours

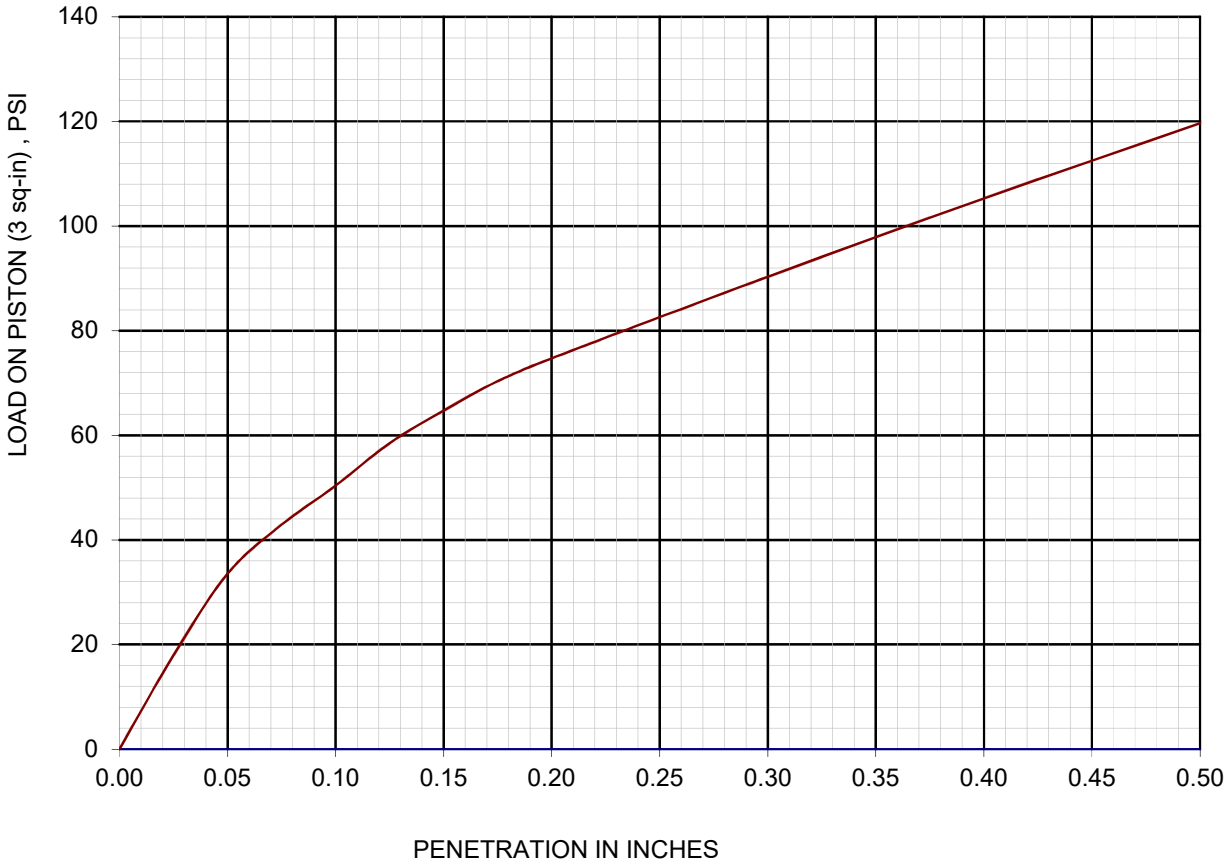
Dry Density:	as molded	113.6	pcf	**Moisture Content:**	as molded	12.0	percent
	after soaking	108.6	pcf		top 1-inch after soaking	23.1	percent
Swell:	after soaking	1.3	percent		average after soaking	20.0	percent

Comments CBR value taken at 0.2 inch penetration

Bearing Ratio of Sample, CBR = **4** percent **Surcharge** 30 lb

Proj. No. 2180295 **CALIFORNIA BEARING RATIO TEST RESULTS** Figure 19

AGEC
Applied GeoTech



Project 300 West **Sample Location** TP-8 @ 2-3'

Sample Classification (CL) sandy lean clay **AGEC Sample ID No.** C-082718

Method of sample preparation: Remolded to approximately 90% of the maximum dry density at the optimum moisture content +2% as per ASTM D-1557

Sample penetration after soaking for 96 hours

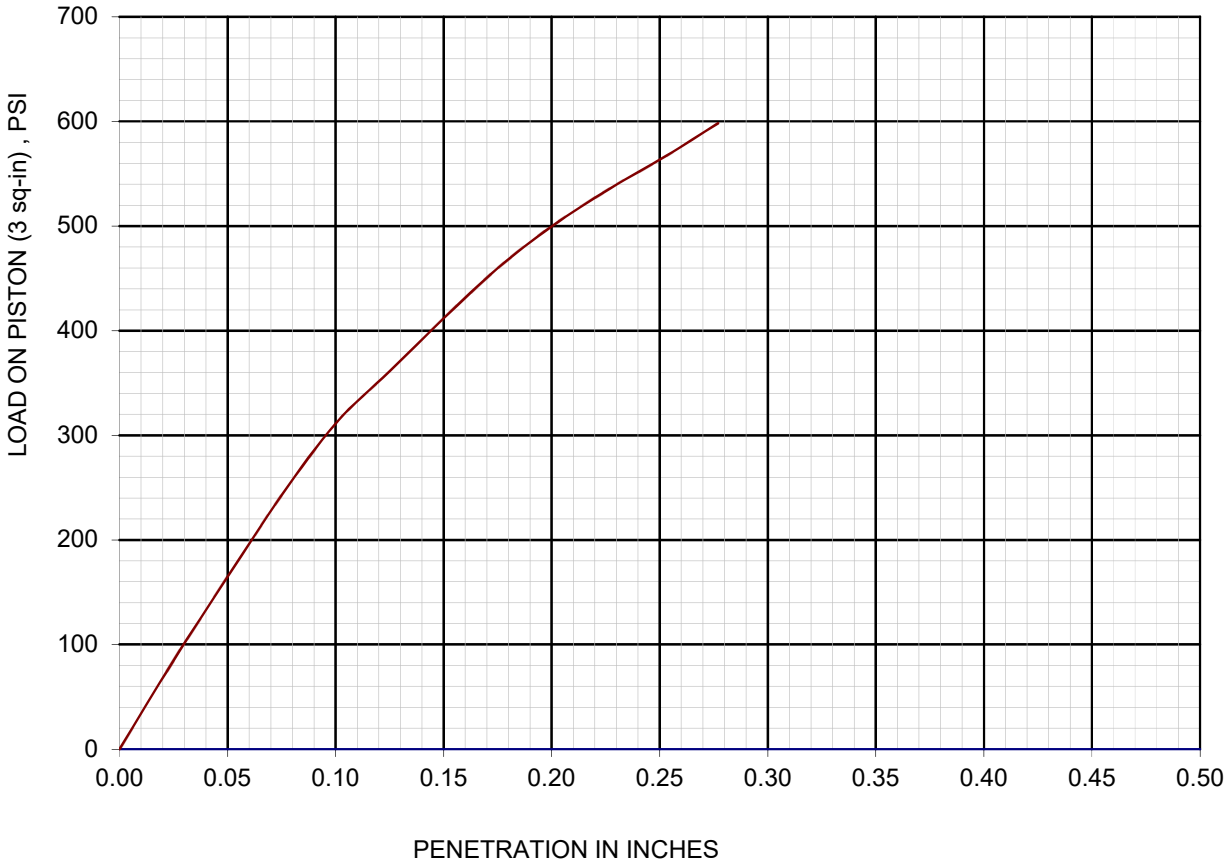
Dry Density:	as molded	104.5	pcf	**Moisture Content:**	as molded	14.5	percent
	after soaking	104.1	pcf		top 1-inch after soaking	21.7	percent
Swell:	after soaking	1.5	percent		average after soaking	18.9	percent

Comments CBR value taken at 0.2 inch penetration

Bearing Ratio of Sample, CBR = **5** percent **Surcharge** 30 lb

Proj. No. 2180295 **CALIFORNIA BEARING RATIO TEST RESULTS** Figure 20

AGEC
Applied GeoTech



Project 300 West **Sample Location** TP-10 @ 2-3'

Sample Classification (SM) Silty sand **AGEC Sample ID No.** D-082718

Method of sample preparation: Remolded to approximately 95% of the maximum dry density at the optimum moisture content as per ASTM D-1557

Sample penetration after soaking for 96 hours

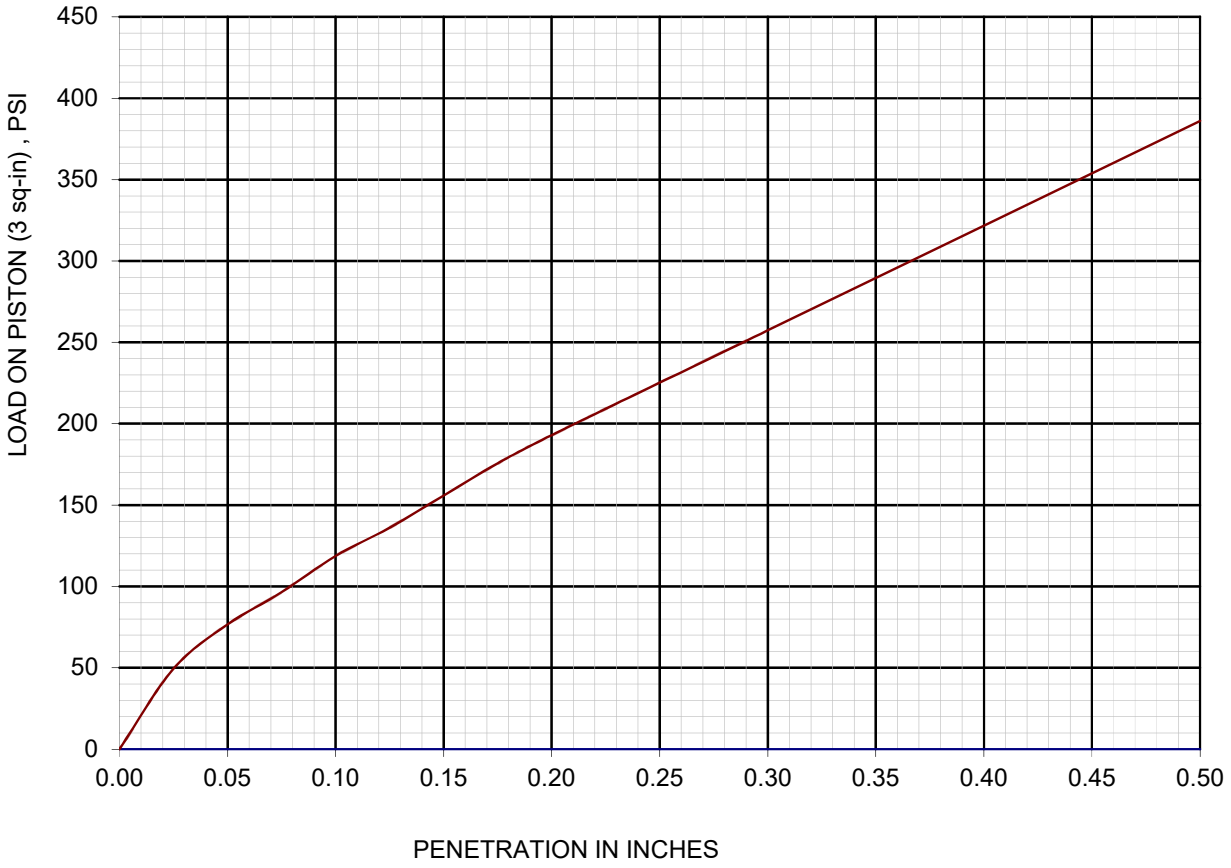
Dry Density:	as molded	122.2	pcf	**Moisture Content:**	as molded	7.4	percent
	after soaking	123.0	pcf		top 1-inch after soaking	10.3	percent
Swell:	after soaking	0.2	percent		average after soaking	10.5	percent

Comments CBR value taken at 0.2 inch penetration

Bearing Ratio of Sample, CBR = **33** percent **Surcharge** 10 lb

Proj. No. 2180295 **CALIFORNIA BEARING RATIO TEST RESULTS** Figure 21

AGEC
Applied GeoTech



Project 300 West **Sample Location** TP-11 @ 0-1'

Sample Classification Silty sand w/gravel - Basalt **AGEC Sample ID No.** E-082718

Method of sample preparation: Remolded to approximately 95% of the maximum dry density at the optimum moisture content as per ASTM D-1557

Sample penetration after soaking for 96 hours

Dry Density:	as molded	127.1	pcf	**Moisture Content:**	as molded	5.1	percent
	after soaking	122.6	pcf		top 1-inch after soaking	18.8	percent
Swell:	after soaking	1.6	percent		average after soaking	16.7	percent

Comments CBR value taken at 0.2 inch penetration

Bearing Ratio of Sample, CBR = 13 percent **Surcharge** 30 lb

Proj. No. 2180295 **CALIFORNIA BEARING RATIO TEST RESULTS** Figure 22

Applied Geotechnical Engineering Consultants, Inc.

Table 1 - Summary of Laboratory Test Results

Tech Ridge South Access Road

Project No. 2180295

Sample Location				Gradation			Atterberg Limits		Moisture-Density Relationship			
Test Pit No.	Depth (ft)	Natural Moisture Content (%)	Natural Dry Density (pcf)	Gravel (%)	Sand (%)	Silt/Clay (%)	Liquid Limit (%)	Plastic Index (%)	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	California Bearing Ratio (%)	Soil Type
TP-1	4	7	124			63	31	19				Sandy Lean Clay (CL)
TP-1	6	7	123			62	27	14				Sandy Lean Clay (CL)
TP-1	13	15	96			84	44	29				Mudstone
TP-2	2	7				71	35	19				Mudstone
TP-2	2-3			0	15	85	45	24	115.0	12.5	6	Mudstone
TP-2	6	8	118			90	52	30				Mudstone
TP-3	2-3			0	27	73	36	24	123.5	10.0	4	Lean Clay with Sand (CL)
TP-3	6	11	117			69	47	35				Sandy Lean Clay (CL)
TP-4	2	11										Silty Gravel with Sand (GM)
TP-4	4	8	108			36						Silty Sand (SM)
TP-4	6	17	101			81						Silt with Sand (ML)
TP-5	2	9	93				39	27				Lean Clay (CL)
TP-5	4	16	94			96	48	33				Lean Clay (CL)
TP-5	6	14				92	36	22				Lean Clay (CL)
TP-6	4	7	110			83	29	18				Lean Clay with Sand (CL)

Applied Geotechnical Engineering Consultants, Inc.

Table 1 - Summary of Laboratory Test Results

Tech Ridge South Access Road

Project No. 2180295

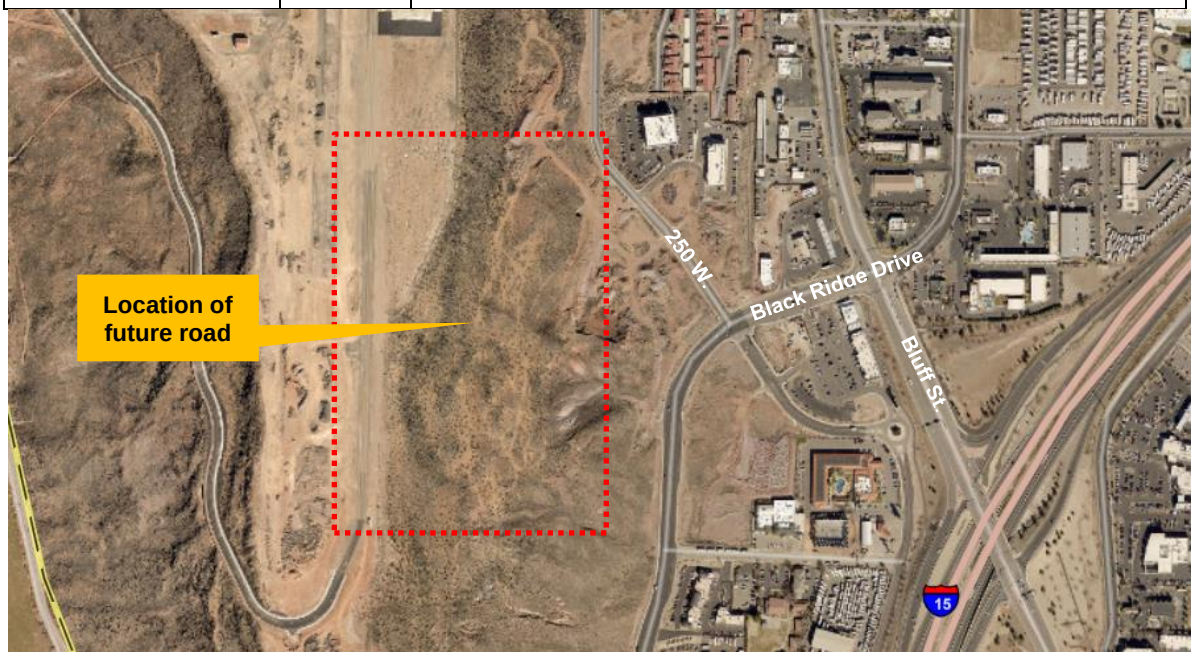
Sample Location				Gradation			Atterberg Limits		Moisture-Density Relationship			
Test Pit No.	Depth (ft)	Natural Moisture Content (%)	Natural Dry Density (pcf)	Gravel (%)	Sand (%)	Silt/Clay (%)	Liquid Limit (%)	Plastic Index (%)	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	California Bearing Ratio (%)	Soil Type
TP-6	6	6	112			94		NP				Silt (ML)
TP-7	3½					81	37	21				Lean Clay with Sand (CL)
TP-8	2	9		3	26	71	41	25				Lean Clay with Sand (CL)
TP-8	2-3			12	22	66	37	20	116.5	12.5	5	Sandy Lean Clay (ML)
TP-8	4	5				77	30	20				Lean Clay with Sand (CL)
TP-10	2	3	88			48						Silty Sand (SM)
TP-10	2-3			2	63	35		NP	126.0	7.5	33	Silty Sand (SM)
TP-10	4	1				6						Well Graded Sand with Silt (SW-SM)
TP-10	9½	10				59	59	37				Mudstone
TP-10	14½					99	52	39				Mudstone
TP-11	0-1			68	16	16		NP	134.5	5.5	13	Silty Gravel with Sand (GM)
TP-15	4					96	77	35				Shale Bedrock
TP-16	10½	5	110			71						Mudstone

St.George
Community Development

ITEM 3
Hillside Permit

HILLSIDE REVIEW BOARD AGENDA REPORT: **01/25/2023**

Tech Ridge Southeast Access Road Hillside Development Permit (Case No. 2023-HS-003)		
Request:	Consider a Hillside Development Permit to construct the southeast access road from 250 West St. to the Tech Ridge Development.	
Applicant:	City of St. George	
Representative:	Mike Bradshaw	
Location:	250 West Street at approximately 1170 South	
General Plan:	COM (Commercial), OS (Open Space), and MDR (Medium Density Residential)	
Existing Zoning:	R-1-10 (Single Family Residential 10,000sf) and PD-MU (Planned Development Mixed use)	
Surrounding Zoning:	North	PD-MU and R-1-10
	South	PD-MU and R-1-10
	East	PD-C
	West	OS, PD-MU



BACKGROUND

This is a request to obtain a hillside development permit to be able to construct the southeast access road from 250 West Street to the Tech Ridge development.

EXHIBITS PROVIDED

1. Exhibit A – Maps
   "Exhibit A" in the packet shows the general plan land use map and the zoning map.

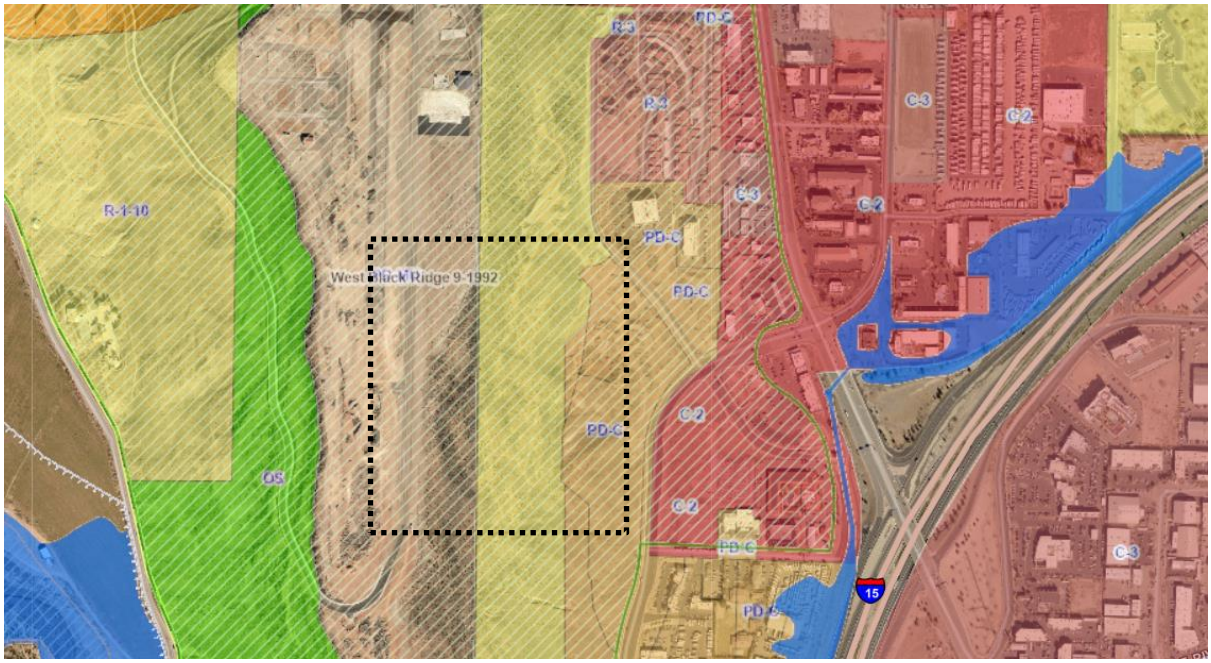
2. Exhibit B – Applicable Ordinances
   "Exhibit B" in the packet lists the applicable zoning regulation that apply to this case found in Title 10, Chapter 13A.

3. Exhibit C – Tech Ridge East Access Road Hillside Protection Plan
   "Exhibit C" in the packet shows the location of the east access road along with grading and slope analysis.

4. Exhibit D – Geotechnical Report
   "Exhibit D" in the packet shows the Geotech report for this proposal.

Exhibit A
MAPS

General Plan - COM



Zoning - R-1-10

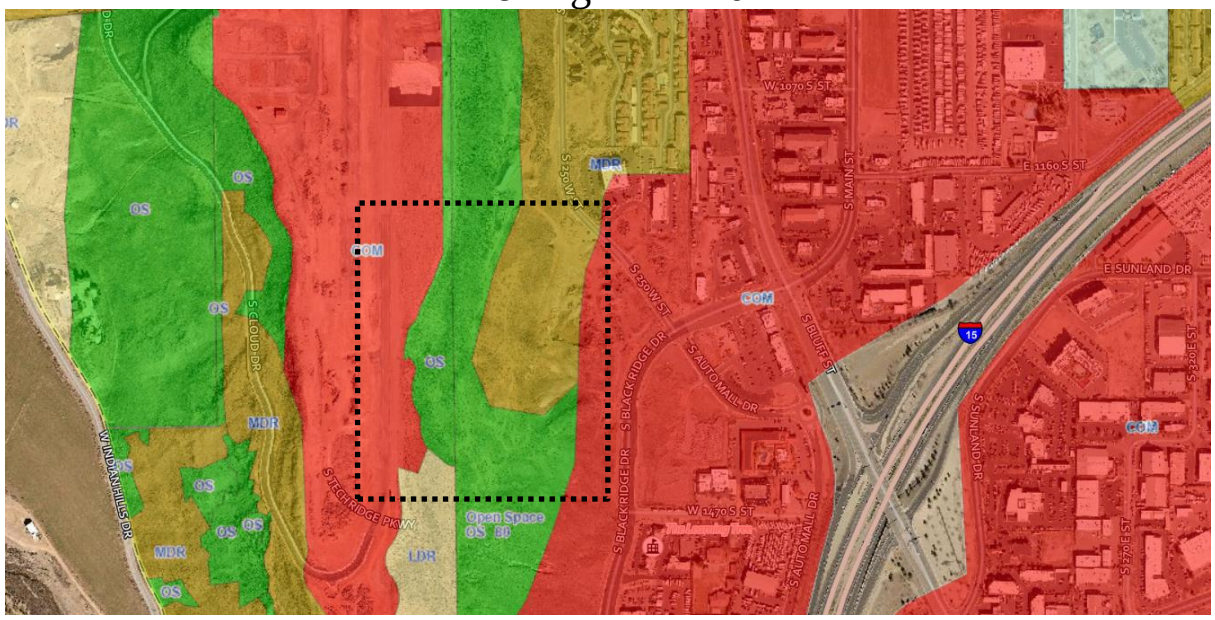


Exhibit B
APPLICABLE ORDINANCES

I. *Density and Disturbance Standards*

A. The hillside development overlay zone (HDOZ) limits development densities and provides specific development incentives to transfer underlying zone densities from hillsides (sending areas), to less steep slopes or more safe development areas (receiving areas), within a development.

B. For those portions of a proposed development with natural slopes twenty percent (20%) or less, development density follows the density and development standards in the underlying zone.

C. For those portions of a proposed development with natural slopes from twenty-one percent (21%) to thirty percent (30%), development activity shall not disturb more than thirty percent (30%) of the parcel within this slope category.

D. For those portions of a proposed development with natural slopes from thirty-one percent (31%) to forty percent (40%), development activity shall not disturb more than five percent (5%) of the area within this slope category.

E. A proposed development may not disturb slopes in excess of forty percent (40%).

F. The applicant may:

1. Transfer all development density from steeper slope categories (sending areas), to areas within the development with natural slopes of twenty percent (20%) or less (receiving areas); and

2. Develop additional bonus density, calculated from each slope category, as follows:

a. Natural slopes twenty percent (20%) or less transferred on a one-to-one (1:1) unit basis; plus

b. One (1) additional density unit for each density unit transferred from natural slopes of twenty-one percent (21%) to thirty percent (30%); plus

c. Two (2) additional density units for each density unit transferred from natural slopes of thirty-one percent (31%) to forty percent (40%).

3. Unit calculation for the receiving area shall be based on the requirements of the sending area zone.

G. Density transfers to the receiving area may occur without a zone change within the receiving area even though the resulting density or configuration may exceed the density limits of the receiving area zone. Other than density, the receiving area's zoning requirements apply to development in the receiving area. For instance, lot sizes may vary, but single-family zoning districts only allow single-family detached dwellings.

H. If the applicant proposes to develop within the twenty-one percent (21%) to forty percent (40%) slope area, the applicant cannot employ partial density transfers from the sending area and must propose a design, site development plans, and a grading plan that blends and harmonizes all aspects of the proposed development into the natural topography, and that minimizes road cuts and fills.

I. Non-disturb areas within a residential lot as shown on the slope analysis map shall not be used to calculate minimum lot size.

J. Disturbance standards do not apply to the city for limited city facilities: trails, parks, and utilities. (Ord. 2019-10-002, 10-10-2019)

II. Slope and Slope Areas Determined

A. Slope shall be determined for each significant portion of a development parcel.

B. Procedure: The applicant shall map the location of the natural slope by using the following procedure:

1. Preparation of Contour Maps: The applicant shall submit an accurate, current contour map, prepared and certified by a licensed professional engineer or surveyor, which shows all land contours at intervals no greater than five feet (5'), drawn at a one inch equals one hundred feet (1" = 100') scale maximum.

2. Verification through Field Surveys: The city engineer or designee may require the applicant to submit a field survey to verify the accuracy of the contour map.

C. Determination of Slope Areas: Using the contour map, natural slopes shall be calculated using points identified as natural slopes of twenty percent (20%), thirty percent (30%), and forty percent (40%), and shall be located on the contour map and connected by a continuous line. That area bounded by said lines and intersecting property lines shall be used for determining project density. Small washes or outcrops, which have slopes distinctly different from surrounding property, and are not part of the contiguous topography, may be excluded from the slope determination. (Ord. 2019-10-002, 10-10-2019)

III. Street Design

The following standards apply to public and private streets within the zone:

A. Street Grades: The maximum allowed street grade is fifteen percent (15%).

B. Intersections: Roads shall intersect at ninety-degree (90°) angles.

C. Intersection Spacing: Intersections should be spaced far enough apart so that the traffic stopped to make left turns at one intersection does not interfere with traffic movements at the adjacent intersections.

1. On low-volume streets such as access roads to minor collectors or minor collectors to minor collectors, the minimum spacing distance is one hundred twenty-five feet (125');

2. For minor collectors to major collectors, the minimum spacing distance is two hundred fifty feet (250').

D. Design Speed: The design of geometric features such as horizontal and vertical alignment will depend on the design speed selected for each street. The design speed is primarily determined by the street function and classification and is the maximum speed for safe and comfortable operation of a vehicle. Other than a major collector, all streets in hillside areas are classified as low speed streets (thirty-five (35) miles per hour or less).

Street Design Classification	Design Speed	Posted Speed
Minor collector	*30*	*30*
Local road	*25 – 30*	*25*
Hillside local	*25*	*25*
Hillside access	*25*	*25*

E. Clear Sight Distance at Intersections: Adequate, clear sight distance is required at intersections, as follows:

Posted Speed of Higher Order Road	Minimum Y	Desired Y
20	*210*	*240*
25	*260*	*300*
30	*310*	*380*
35	*365*	*475*

F. Vertical Curves and Intersection Relationship: The vertical alignment of residential streets shall comply with latest editions of AASHTO geometric design of highways and streets. See table below for listing of pertinent design criteria:

Design Speed	Crest "K" Value	Sag "K" Value
	Minimum Length of Vertical Curves	
20	*10*	*20*
25	*20*	*30*
30	*30*	*40*
35	*40*	*50*

L = KA (for minimum sight distance on a vertical curve).

L = Length of vertical curve for proper sight distance.

A = Algebraic difference in grade.

Vertical alignment with the intersection is also of special nature, and design alternatives may be required. As a guideline, the approach area where vehicles stop while waiting to enter an intersection shall not exceed four (4%) to five percent (5%) from the gutter line of the street being intersected for a distance of fifty feet (50'), though a range of fifty feet (50') to one hundred feet (100') is more desirable. This applies to all intersections, except those intersections where both intersecting streets are minor collectors. The landing area for a minor collector shall be designed for a grade of two percent (2%) to three percent (3%) for a distance of one hundred feet (100').

G. Safe Stopping Sight Distance: The minimum sight distance to be provided before a stop is required is included in the table below:

Design Speed	Computed	Recommended Distance	Add-On for 15% Grade
20	106.7	125	20
25	146.5	150	36
30	195.7	200	64
35	248.4	250	95

H. Horizontal Curves: The minimum centerline radius for horizontal curves on low-speed residential streets is:

Street Classification or Speed	Curve Radius in Feet
Minimum Centerline Radius	
Private streets	50 – 100
20 mph	100 – 150
25 mph	185
30 mph	310

I. Street Cross-Section Standards: The requirements for street cross-section configurations are based on the following factors:

1. Traffic capacity;

2. Design speed;

3. Projected traffic;

4. Designs to reduce scarring.

J. Alternate road cross sections, such as grade separated streets, may be used if applicable safety and traffic standards are met.

K. Elimination of sidewalk on one side of the road may be approved when elimination of one (1) sidewalk can appreciably reduce the amount of hillside disturbance. Other considerations may also warrant its elimination. When one (1) sidewalk is eliminated, the remaining sidewalk shall be increased by one foot (1') in width.

L. The following table sets forth the requirements for street standards for single-family residential development.

Maximum Grade	Street Classification	Width ROW	Width TBC	Pavement Width	Width Sidewalk	ADT
Street Cross-Section Standards for Single-Family Residential						
12%	Minor collector	60'	50'	45'	5'	1,500 – 3,500
15%	Local road	50'	40'	35'	4'	750 – 1,500
15%	Hillside local	45'	35'	30'	4'	150 – 750
15%	Hillside access	41'	31'	26'	4'	0 – 150

(Ord. 2019-10-002, 10-10-2019)

IV. Additional Design Standards

1. *Retaining walls shall be colored to blend into the surrounding natural geology.*

2. *Retaining wall height is limited to the heights set forth in chapter 18 of this title and the standards for rock wall construction.*

3. *Building exterior colors shall be earth tone and blend with the surrounding natural landscape.*

4. *In residential zones, "no disturbance" areas shall be held as the "common area" of a project. Common areas shall be owned and maintained by the homeowners' association or may be deeded to the city when accepted by the city.*

5. *In nonresidential zones, any "no disturbance" area shall be identified on the final site plan or final plat.*

6. *Any required no disturbance area shall be identified on the ground with temporary fencing or other approved means to prevent accidental disturbance of the area during construction and such fencing shall be installed prior to issuance of a grading permit.*

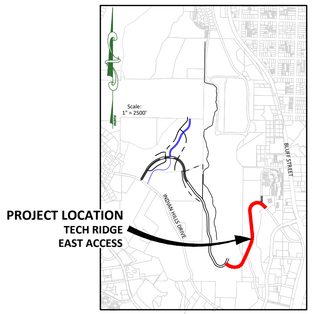
7. *The building site shall be located on the flattest portion of the parcel.*

8. *No structure shall extend over any natural ridgeline. The structure shall be in contact with the ground at all edges. (Ord. 2019-10-002, 10-10-2019)*

Exhibit C

TECH RIDGE EAST ACCESS ROAD HILLSIDE PROTECTION PLAN

TECH RIDGE EAST ACCESS ROAD
HILLSIDE APPLICATION
FOR
TECH RIDGE DEVELOPMENT, LLC
LOCATED IN
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT



VICINITY MAP

SHEET INDEX	
SHEET NO.	DESCRIPTION
C1.0	COVER SHEET
C1.1	SHEET LAYOUT
C1.2	EXISTING GRADE SLOPE ANALYSIS
C1.3	OVERALL CUT AND FILL
C2.0- C2.9	EAST ACCESS ROAD GRADING

CALL 811 BEFORE YOU DIG
811
SAFE DIGGING PARTNER
BLUE STAKES OF UTAH

DEVELOPER

CITY OF ST. GEORGE
ATT: MR. CAMERON CUTLER
175 W 200 N
ST. GEORGE, UT 84770
EMAIL: CAMERON.CUTLER@SGCITY.ORG

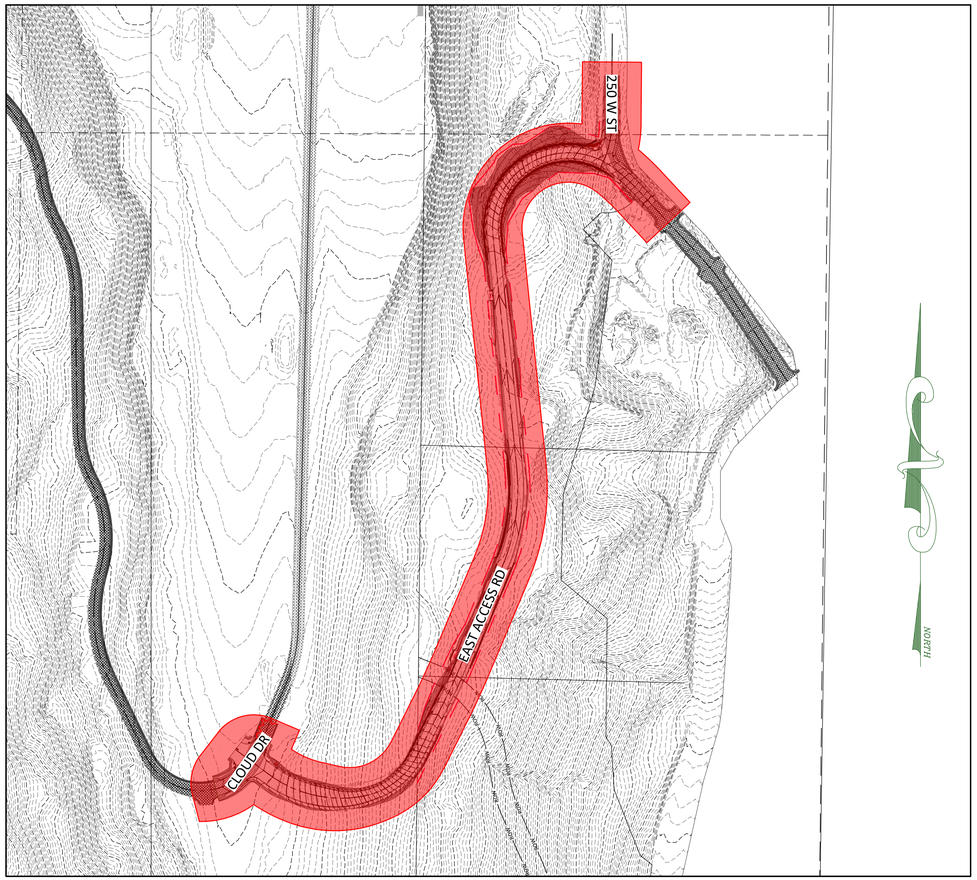
ENGINEER

ALLIANCE CONSULTING
2303 N. CORAL CANYON BLVD. SUITE 201
WASHINGTON, UT 84780-0577
PHONE: (435) 673-8060
FAX: (435) 673-8065
ENGINEER: MR. DELOSS HAMMON P.E.
CONTACT: MR. MIKE BRADSHAW
EMAIL: mwb@allianceconsulting.us

GEOTECHNICAL REPORTS:

The contractor is responsible to read and fully understand the Geotech report and to coordinate with the geotechnical engineer throughout the grading process to ensure that the report's recommendations are implemented from the beginning to the end of the projects construction. The owner will contract with the geotechnical engineer for their representatives to be on site throughout the grading process to ensure full compliance with the geotechnical report's recommendations. Refer to following reports.

1. Applied GeoTech Geotechnical Investigation, Tech Ridge South Access Road, Project No. 2180295, 12-6-2022d: Oct 19, 2018



GRAPHIC SCALE

250 0 125 250 500

(IN FEET)
1 inch = 250 ft.
If Printed 11x17 use Half Scale

GENERAL NOTES:

1. Unless shown otherwise on these plans, all construction shall conform to the codes and ordinances of St. George City, the State of Utah Administrative Codes, "The International Plumbing Code", and the "International Building Code" latest editions as administered by St. George City.
2. The Contractor shall be responsible for the location of and protection of all existing underground utilities and overhead power line during construction.
3. The Benchmark for this Project is the South 1/4 of Section 36, Township 42 South, Range 16 West Salt Lake Base and Meridian - St. George HCN #181 - Elevation: 2667.70
3. Existing contour and finish contour interval is 2 feet.
4. Any necessary design modifications shall be approved by the design engineer.
5. All grading to be within ±0.1' of proposed elevation.
6. Project shall install an information sign on site before construction begins. This sign shall have a minimum size, placement location and content information with the company name, phone & permit number.
7. A mandatory pre-construction meeting shall be required on all projects prior to any grubbing, grading, or construction activities. The permit holder shall be required to notify all Development Services inspectors.
8. Projects shall submit a dust control plan with details on equipment scheduling and reporting of dust control activities.
9. Follow Appendix J standards found in the IBC.
10. All work materials shall meet City of St. George standards.
11. The Developer will Maintain the Temporary Detention Basin until Decommission.

CONSTRUCTION NOTES:

1. All excavations and grading shall be in accordance with the requirements of the City of St. George [phone:435-627-4000], of the "International Building Code", 2018 edition, and the specifications and requirements included in the Tech Ridge Grading Recommendations...
1. All excavation, grading, and fill operations within the building area should be observed by the Field Engineer to verify subsoil conditions and determine adequacy of site preparation, suitability of fill materials and compliance with compaction requirements.
2. The Contractor shall provide suitable equipment to control dust and air pollution caused by construction operations. The Contractor shall also provide suitable mud and dirt containment to maintain clean conditions on the work site, access roadways, and adjacent properties.
3. Project shall submit a Dust Control Plan with details on equipment, scheduling and reporting of dust control activities.
4. Contractor is responsible and required to obtain their own UPDES/NOI permits.
5. It is the contractors responsibility to identify all and any SWPPP requirements.
6. Prior to and during compaction operations, all backfill material shall have the required moisture content uniform throughout each layer.
7. All Rip-Rap rock shall be approved by owner.
8. Contractor must coordinate with other Contractors working in areas.
9. Contractor must protect existing facilities.
10. All rock walls are to match in color and composition with the native basalt lava rock. Rock to be stained black.

Date: 12-30-2022

REVISIONS

No.	Date	by	Description
		ARL	

File Name
East Access Hillside Application.dwg

ALLIANCE CONSULTING
A PLANNING AND ENGINEERING FIRM

UTAH
2303 N CORAL CANYON BLVD
SUITE 201,
WASHINGTON, UT 84780
435-673-8060

NORTH DAKOTA
621 26th STREET W.
WILLISTON, ND 58801
701-572-8100

TECH RIDGE EAST ACCESS ROAD HILLSIDE PROTECTION PLAN

FOR

CITY OF ST. GEORGE

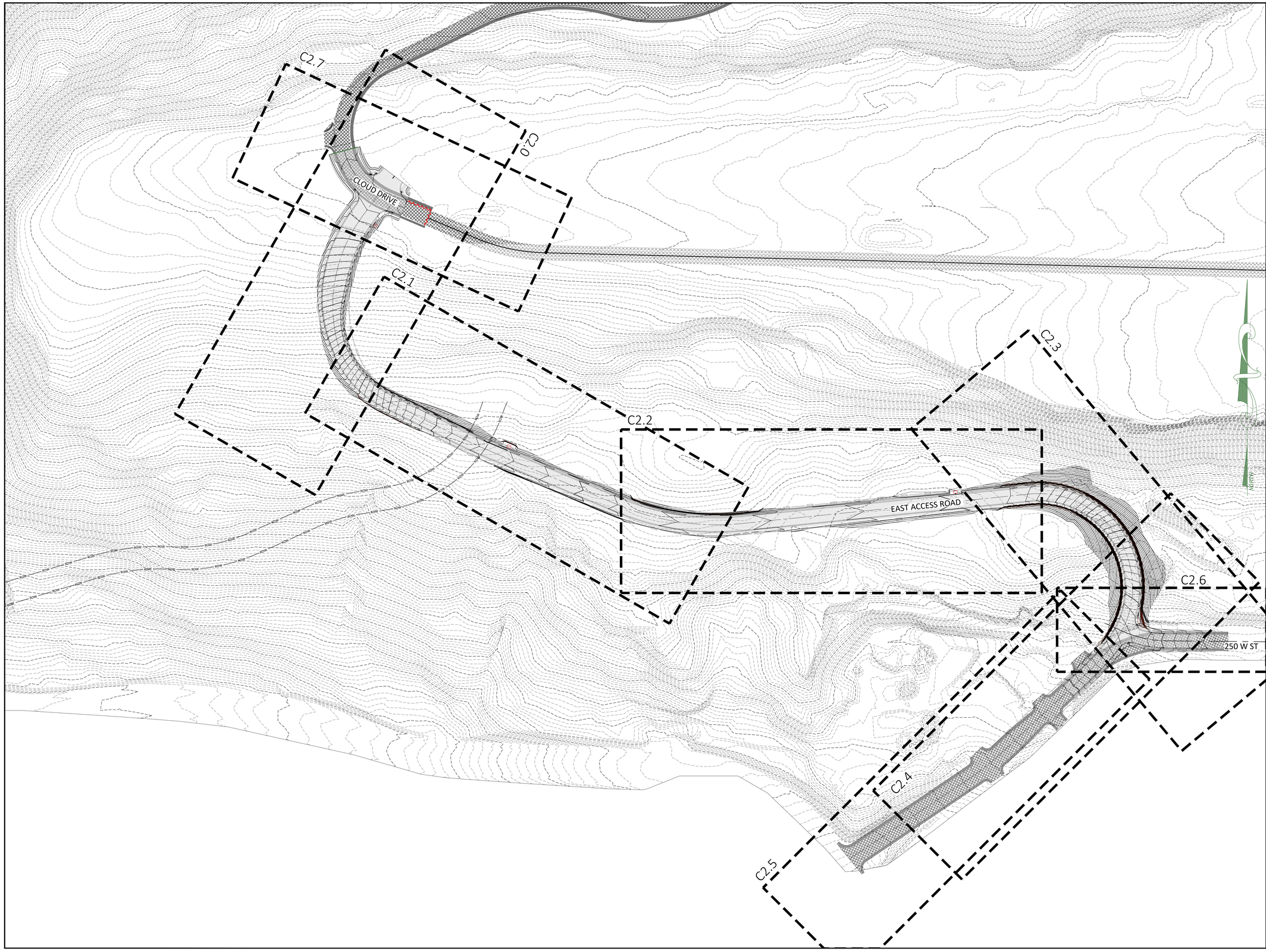
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T 42 SOUTH, R 16 WEST SLB&M
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

NOT FOR CONSTRUCTION REVIEW ONLY

Drawn By: ARL	Scale: 1"=250'
Client No. 4568	Project No. 4568-21

Drawing Sheet
C1.0

Sheet 1 of 14 Sheets



Date:
12-30-2022

REVISIONS

No.	Date	by	Description
		ARL	

File Name
East Access Hillside Application.dwg

GRAPHIC SCALE
120 0 60 120 240
(IN FEET)
1 inch = 120 ft.
If Printed 11x17 use Half Scale

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701-572-8100

TECH RIDGE
EAST ACCESS ROAD
HILLSIDE SHEET LAYOUT

FOR

CITY OF ST. GEORGE

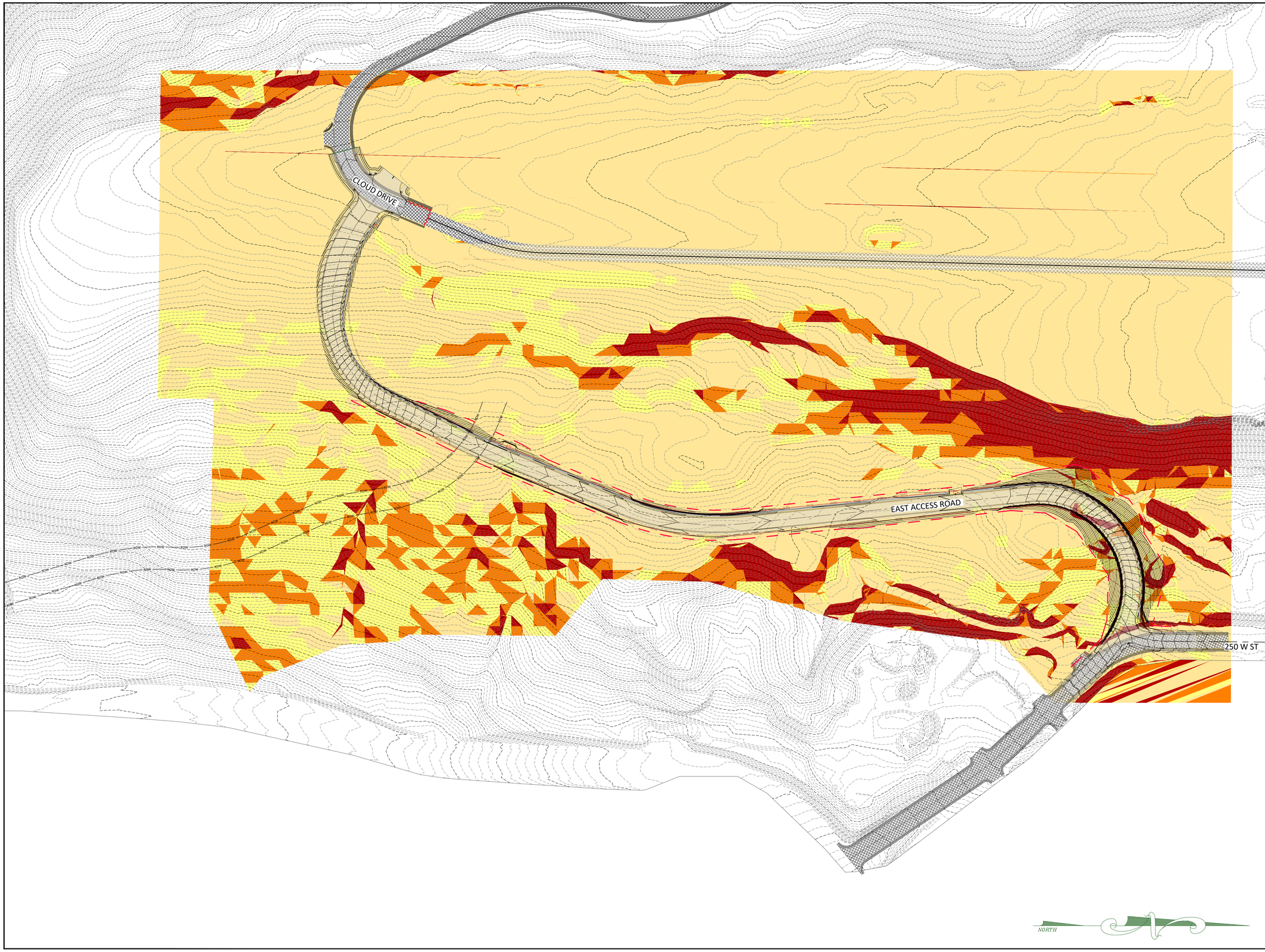
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CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

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REVIEW ONLY

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Client No. 4568	Project No. 4568

Drawing Sheet
C1.1

Sheet 2 of 14 Sheets



Date:
12-30-2022

REVISIONS

No.	Date	by	Description
		ARL	

File Name
East Access Hillside Application.dwg

SLOPE ANALYSIS LEGEND

- 0% to 20%
- 20% to 40%
- 40% to 60%
- 60% +

GRAPHIC SCALE

120 0 60 120 240

(IN FEET)
1 inch = 120 ft.
If Printed 11x17 use Half Scale

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621 26th STREET W.
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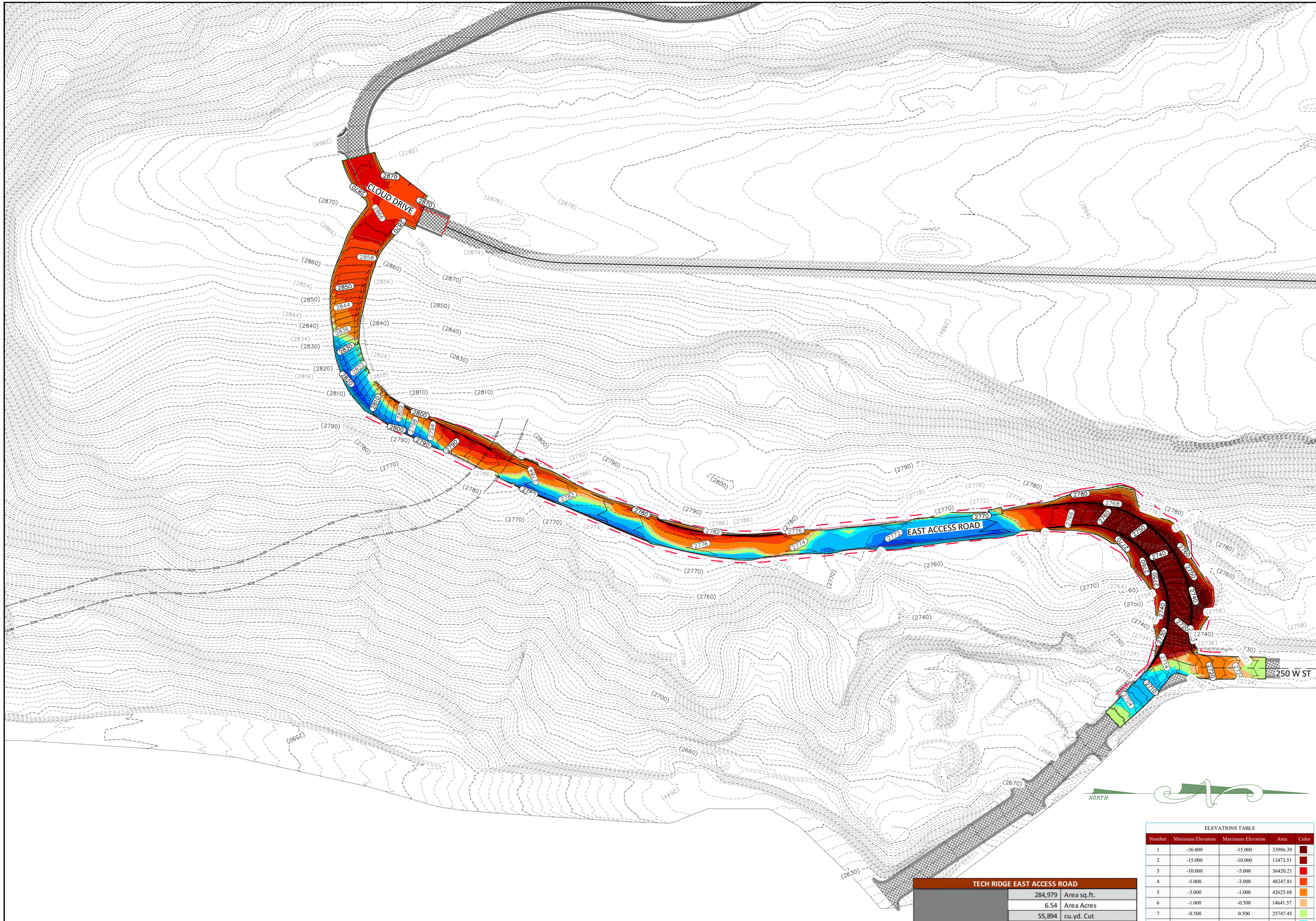
TECH RIDGE
EAST ACCESS ROAD
HILLSIDE SLOPE ANALYSIS
FOR
CITY OF ST. GEORGE
LOCATED IN SEC 36
T 42 SOUTH, R 16 WEST SLB&M
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

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Drawn By:	Scale:
ARL	1"=120'
Client No.	Project No.
4568	4568

Drawing Sheet
C1.2

Sheet 3 of 14 Sheets



TECH RIDGE EAST ACCESS ROAD		
	284,979	Area sq.ft.
	6.54	Area Acres
	55,894	cu.yd. Cut
	6,316	cu.yd. Fill
Shrinkage 15%	947	cu.yd. Shrinkage
Total	**(50,525.40)**	**cu.yd. Material Export**

Cut and Fill volumes shown are based on Digital Terrain Modeling computations. Shrinkage volumes shown are estimated. These volumes are approximate based on the information provided.

ELEVATIONS TABLE

Number	Minimum Elevation	Maximum Elevation	Area	Color
1	-36.000	-15.000	33986.39	
2	-15.000	-10.000	13472.51	
3	-10.000	-5.000	36420.21	
4	-5.000	-3.000	48247.81	
5	-3.000	-1.000	42625.68	
6	-1.000	-0.500	14641.57	
7	-0.500	0.500	25747.45	
8	0.500	1.000	11792.38	
9	1.000	3.000	35077.70	
10	3.000	5.000	20122.57	
11	5.000	7.000	2817.70	
12	7.000	10.000	0.00	
13	10.000	20.000	0.00	

Date: 12-30-2022

REVISIONS

No.	Date	by	Description
		ARL	

File Name
East Access Hillside Application.dwg

LEGEND

- EXISTING ASPHALT
- PROPOSED ASPHALT
- EXISTING CONCRETE
- PROPOSED CONCRETE
- 30" CURB & GUTTER
- SLOPE EASEMENT
- EXISTING CONTOUR
- DESIGN CONTOUR

GRAPHIC SCALE

120 0 60 120 240

(IN FEET)
1 inch = 120 ft.
If Printed 11x17 use Half Scale

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TECH RIDGE
EAST ACCESS ROAD
HILLSIDE CUT/FILL

FOR

CITY OF ST. GEORGE

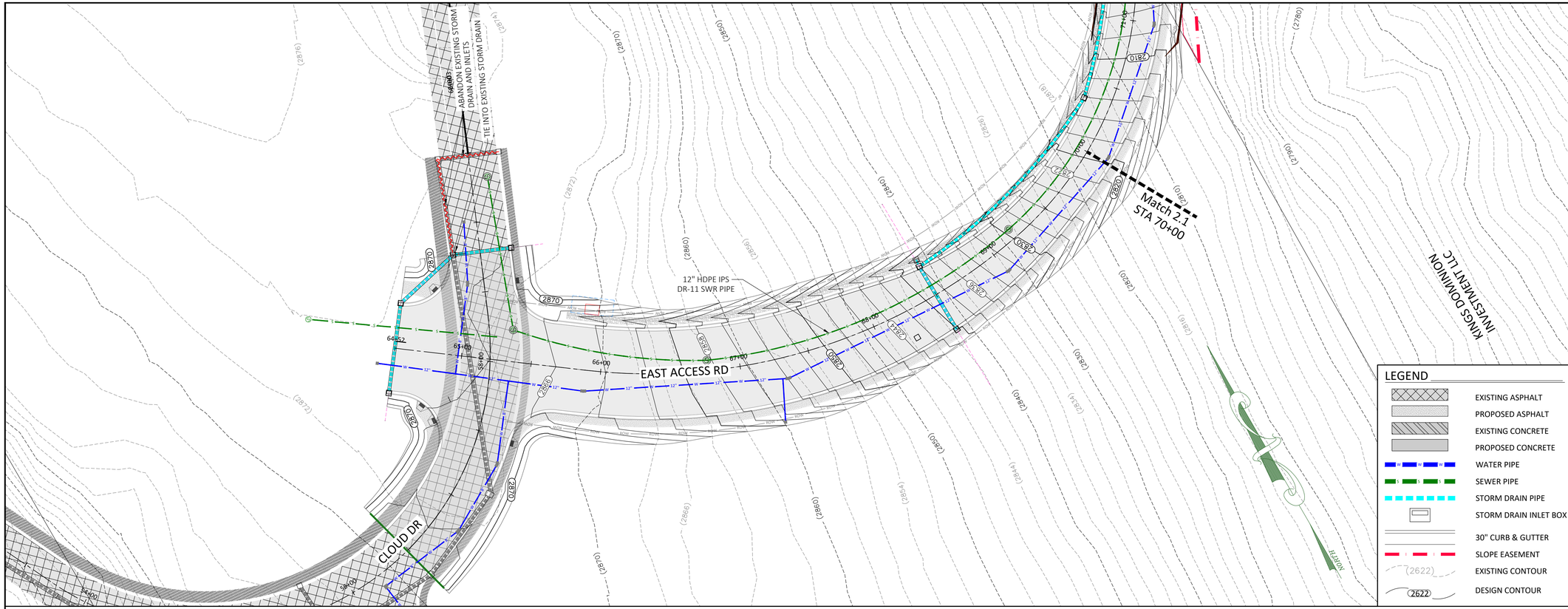
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Client No. 4568	Project No. 4568

Drawing Sheet
C1.3

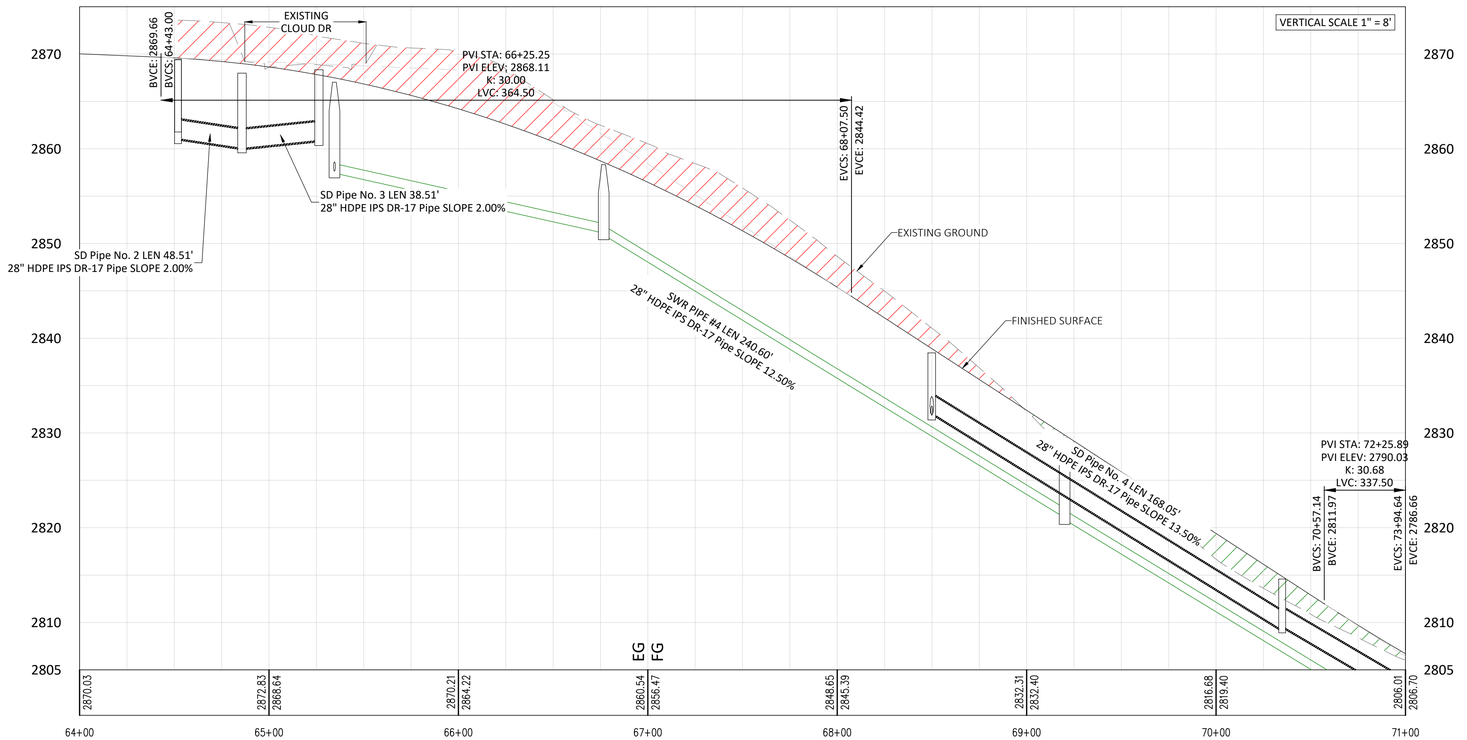
Sheet 3 of 14 Sheets



LEGEND

- EXISTING ASPHALT
- PROPOSED ASPHALT
- EXISTING CONCRETE
- PROPOSED CONCRETE
- WATER PIPE
- SEWER PIPE
- STORM DRAIN PIPE
- STORM DRAIN INLET BOX
- 30" CURB & GUTTER
- SLOPE EASEMENT
- (2622) EXISTING CONTOUR
- 2622 DESIGN CONTOUR

East Access REV 4



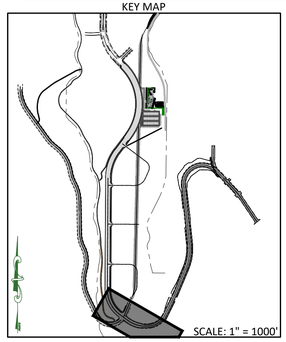
Date: 12-30-2022

REVISIONS

No.	Date	by	Description

File Name
East Access Hillside Application.dwg

KEY MAP



GRAPHIC SCALE

40 0 20 40 80

(IN FEET)
1 inch = 40 ft.
If Printed 11x17 use Half Scale

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TECH RIDGE
EAST ACCESS
GRADING

FOR

CITY OF ST. GEORGE

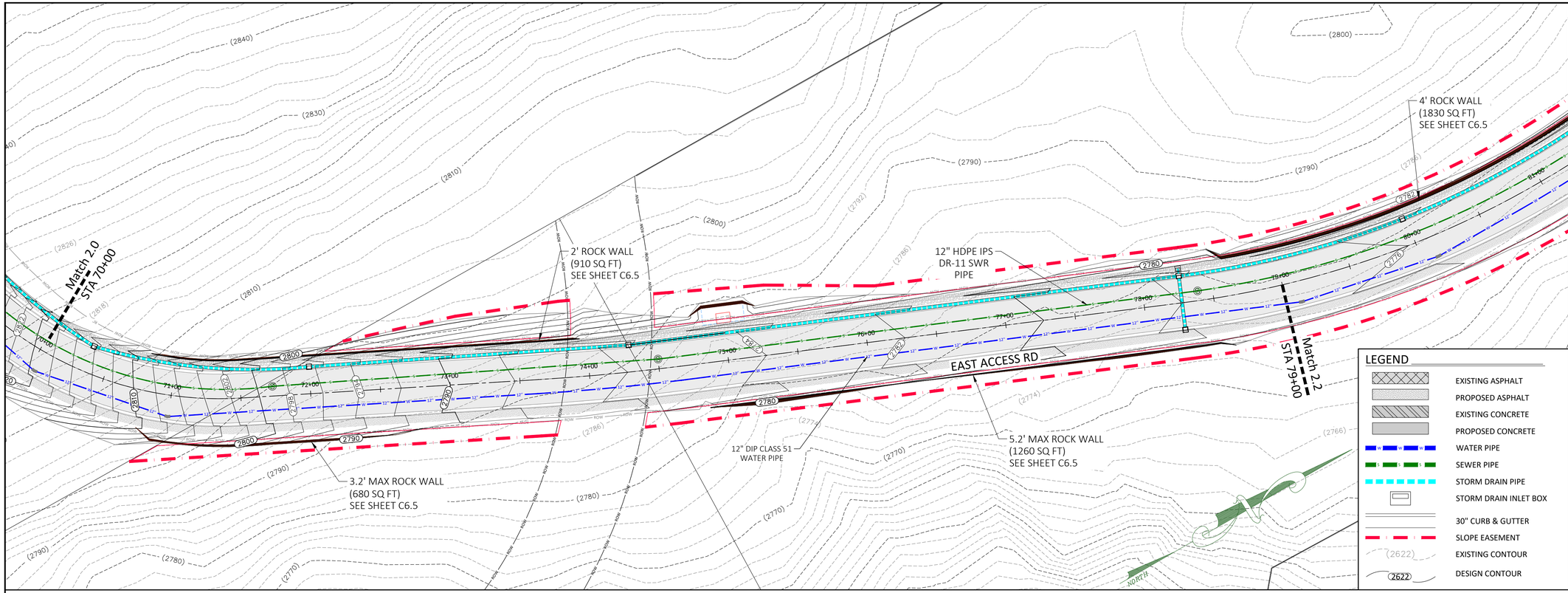
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Drawn By:	Scale:
ARL	1" = 40"
Client No. 4568-21	Project No. 4568-21

Drawing Sheet
C2.0

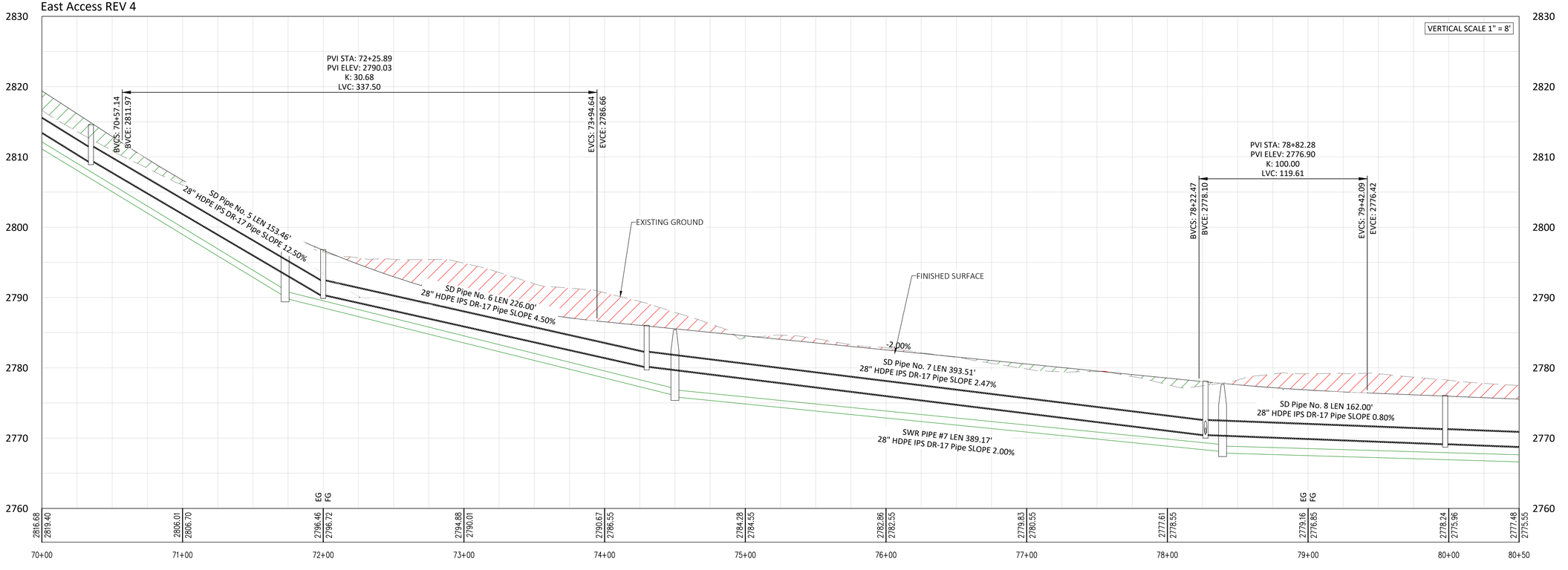
Sheet 5 of 14 Sheets



LEGEND

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- PROPOSED ASPHALT
- EXISTING CONCRETE
- PROPOSED CONCRETE
- WATER PIPE
- SEWER PIPE
- STORM DRAIN PIPE
- STORM DRAIN INLET BOX
- 30" CURB & GUTTER
- SLOPE EASEMENT
- EXISTING CONTOUR
- DESIGN CONTOUR

East Access REV 4



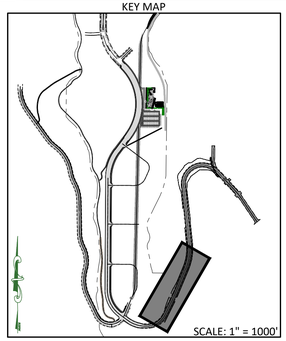
Date: 12-30-2022

REVISIONS

No.	Date	by	Description

File Name
East Access Hillside Application.dwg

KEY MAP



GRAPHIC SCALE

40 0 20 40 80

(IN FEET)
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TECH RIDGE
EAST ACCESS
GRADING

FOR

CITY OF ST. GEORGE

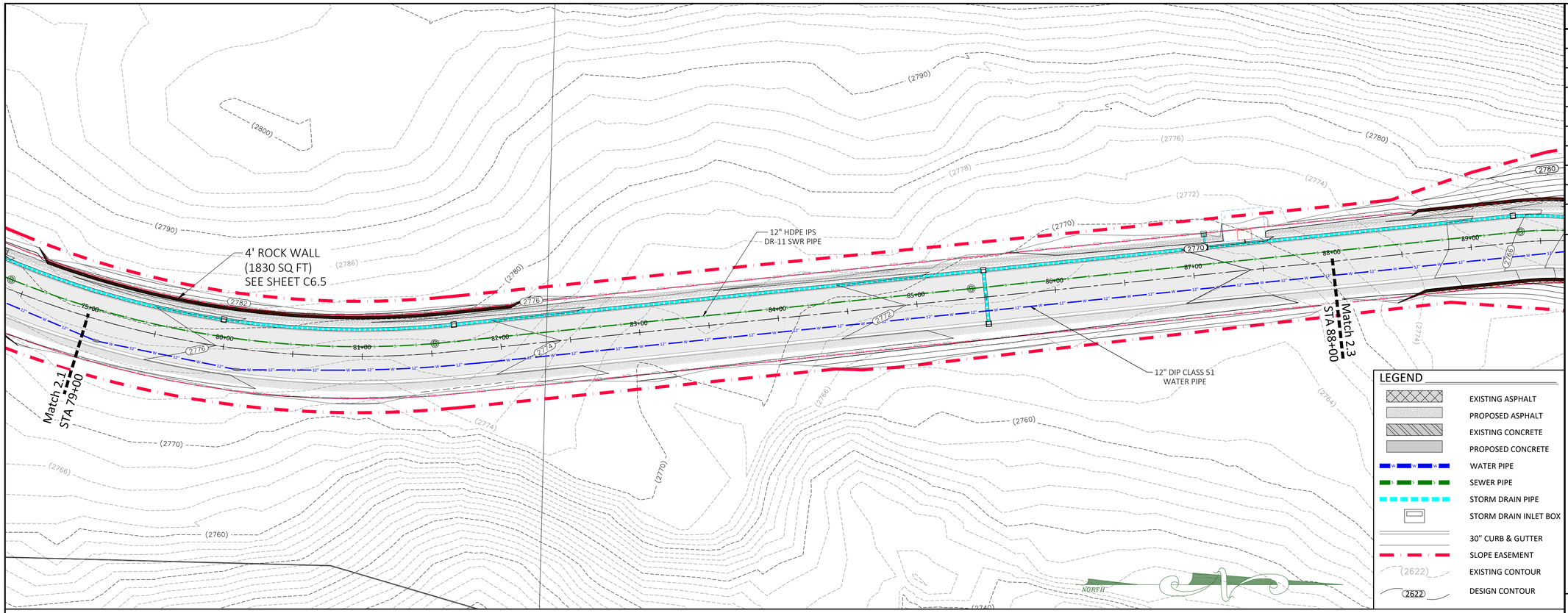
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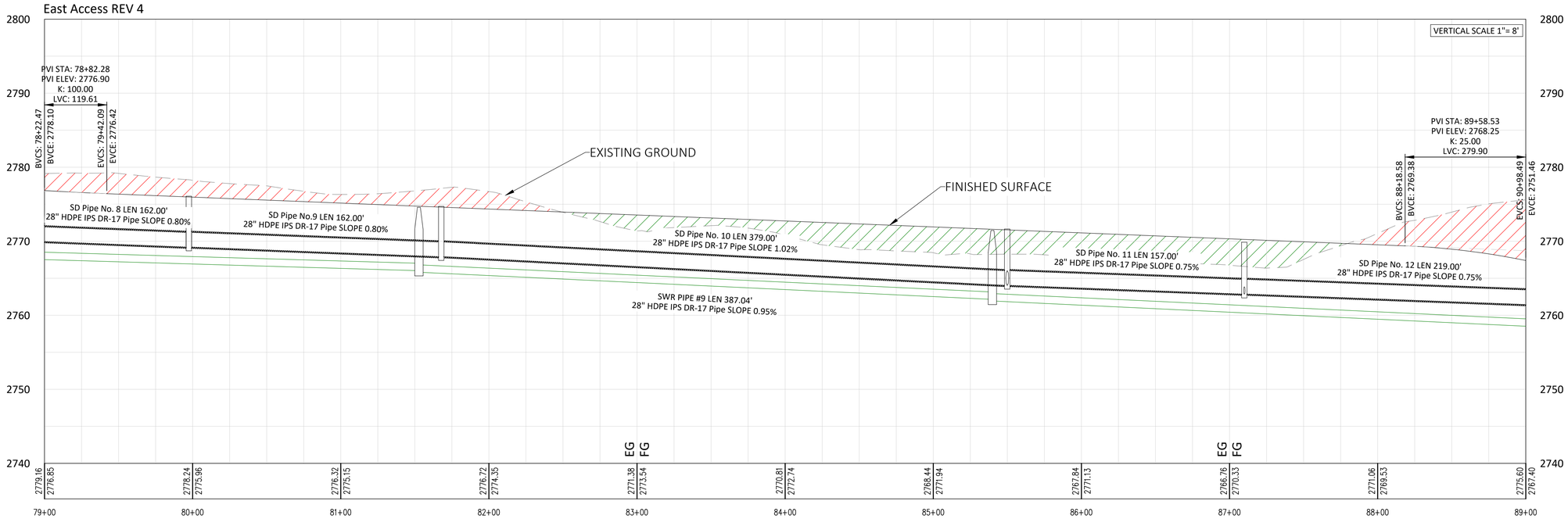
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Drawing Sheet
C2.1

Sheet 6 of 14 Sheets





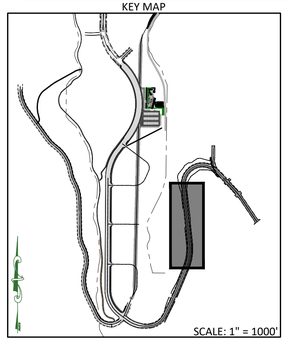
Date: 12-30-2022

REVISIONS

No.	Date	by	Description

File Name
East Access Hillside Application.dwg

KEY MAP



GRAPHIC SCALE

40 0 20 40 80

(IN FEET)
1 inch = 40 ft.
If Printed 11x17 use Half Scale

ALLIANCE CONSULTING
A PLANNING AND ENGINEERING FIRM

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NORTH DAKOTA
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WILLISTON, ND 58801
701-572-8100

TECH RIDGE
EAST ACCESS
GRADING

FOR

CITY OF ST. GEORGE

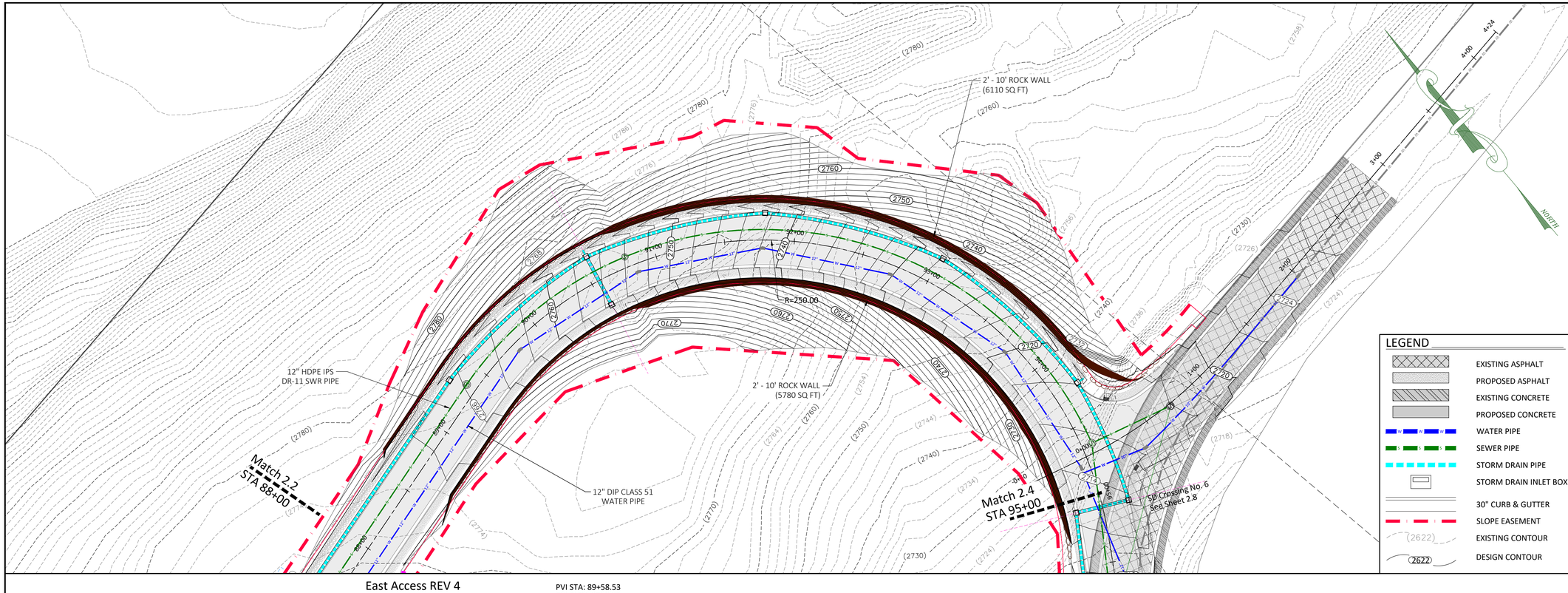
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CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

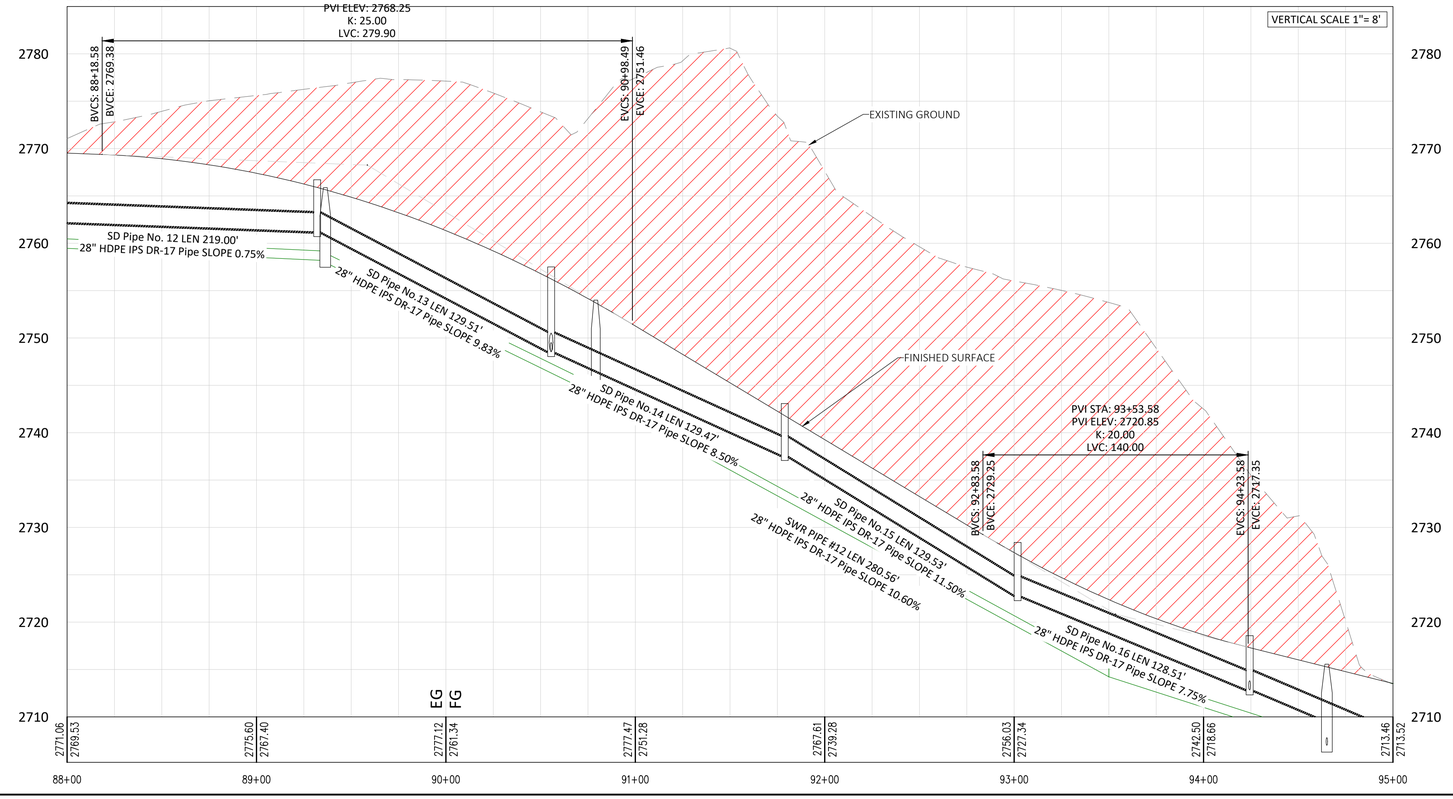
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CONSTRUCTION
REVIEW ONLY

Drawn By:	Scale:
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Client No.	Project No.
4568-21	4568-21

Drawing Sheet
C2.2

Sheet 7 of 14 Sheets





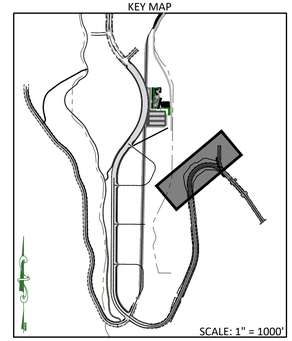
Date: 12-30-2022

REVISIONS

No.	Date	by	Description

File Name
East Access Hillside Application.dwg

KEY MAP



GRAPHIC SCALE

40 0 20 40 80

(IN FEET)
1 inch = 40 ft.
If Printed 11x17 use Half Scale

ALLIANCE CONSULTING
A PLANNING AND ENGINEERING FIRM

UTAH
2303 N CORAL CANYON BLVD
SUITE 201,
WASHINGTON, UT 84780
435-673-8060

NORTH DAKOTA
621 26th STREET W.
WILLISTON, ND 58801
701-572-8100

TECH RIDGE
EAST ACCESS
GRADING

FOR

CITY OF ST. GEORGE

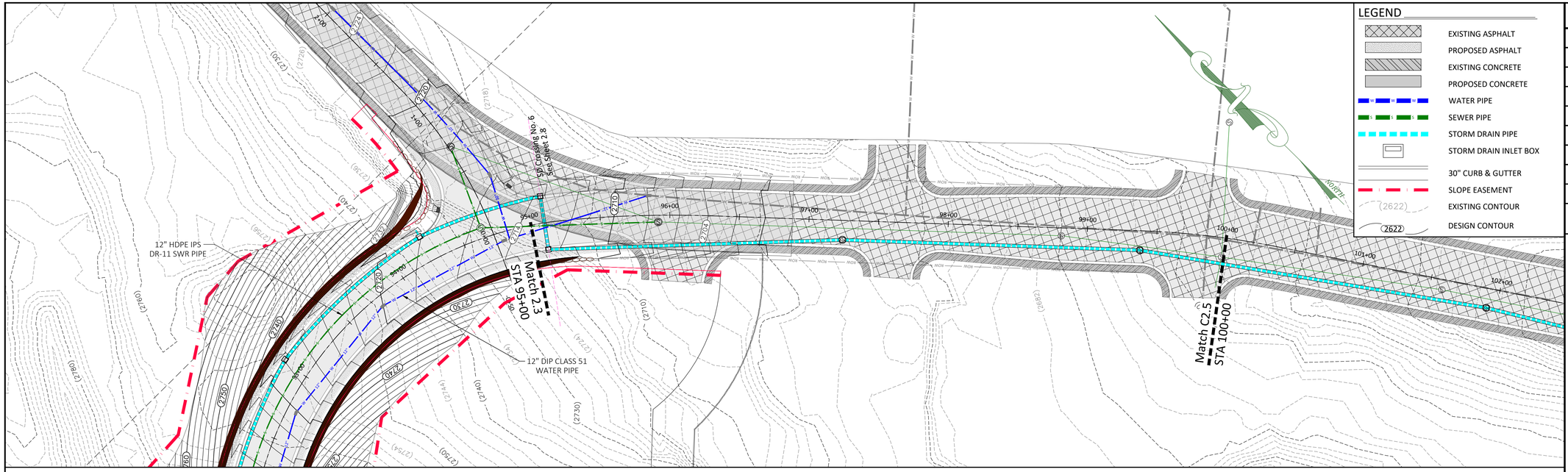
LOCATED IN SEC 36
T 42 SOUTH, R 15 WEST SLB&M
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

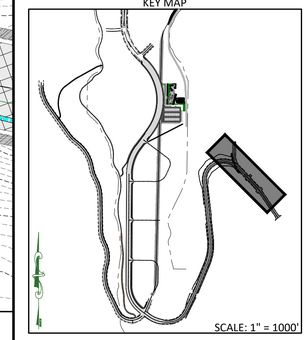
NOT FOR
CONSTRUCTION
REVIEW ONLY

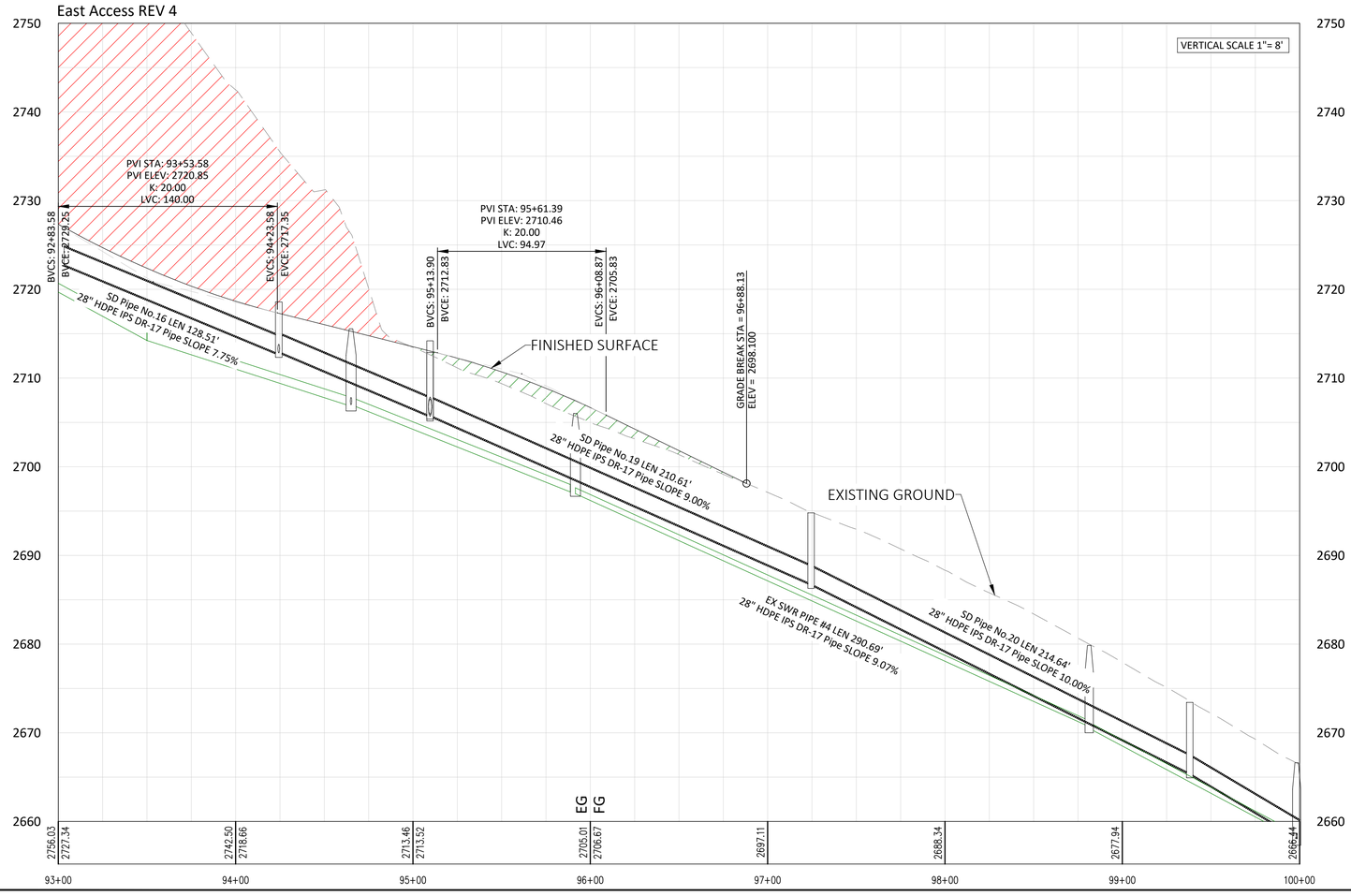
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ARL	1" = 40"
Client No. 4568-21	Project No. 4568-21

Drawing Sheet
C2.3

Sheet 8 of 14 Sheets







LEGEND

- EXISTING ASPHALT
- PROPOSED ASPHALT
- EXISTING CONCRETE
- PROPOSED CONCRETE
- WATER PIPE
- SEWER PIPE
- STORM DRAIN PIPE
- STORM DRAIN INLET BOX
- 30" CURB & GUTTER
- SLOPE EASEMENT
- (2622) EXISTING CONTOUR
- 2622 DESIGN CONTOUR

Date: 12-30-2022

REVISIONS

No.	Date	by	Description

File Name
East Access Hillside Application.dwg

KEY MAP

GRAPHIC SCALE
40 0 20 40 80
(IN FEET)
1 inch = 40 ft.
If Printed 11x17 use Half Scale

ALLIANCE CONSULTING
A PLANNING AND ENGINEERING FIRM

UTAH
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435-673-8060

NORTH DAKOTA
621 26th STREET W.
WILLISTON, ND 58801
701-572-8100

TECH RIDGE
EAST ACCESS
GRADING

FOR

CITY OF ST. GEORGE

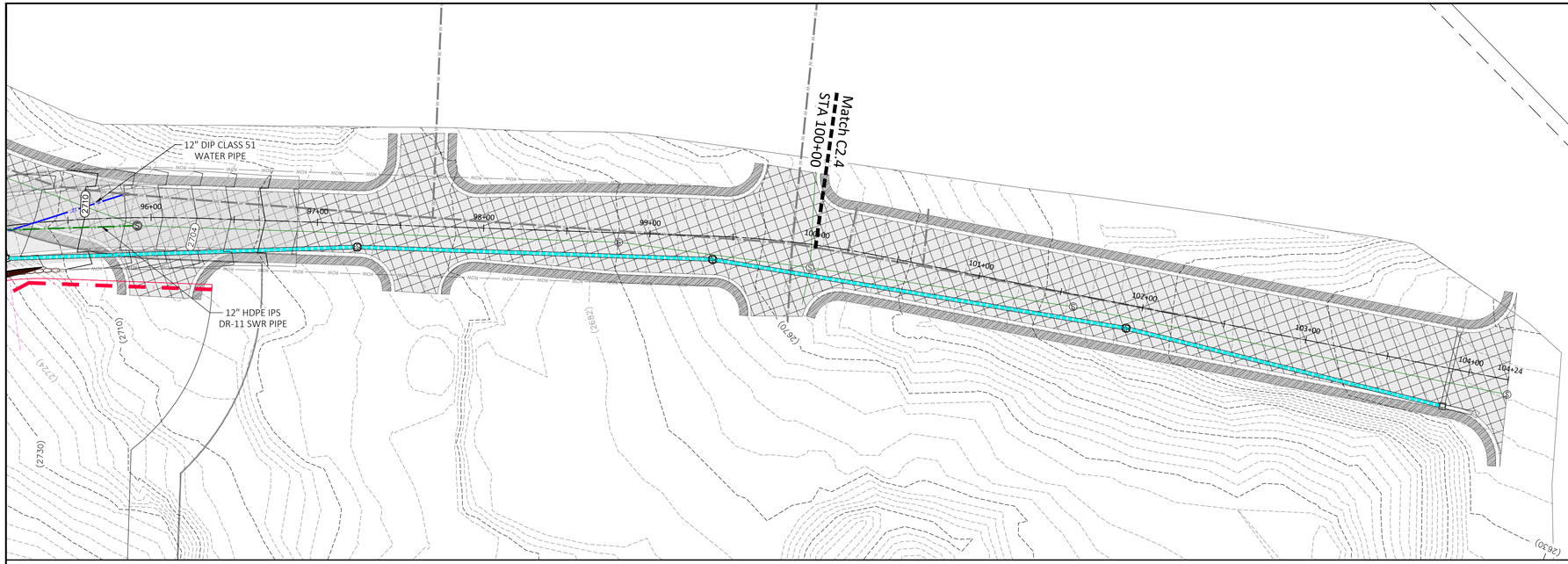
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T 42 SOUTH, R 15 WEST SLB&M
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

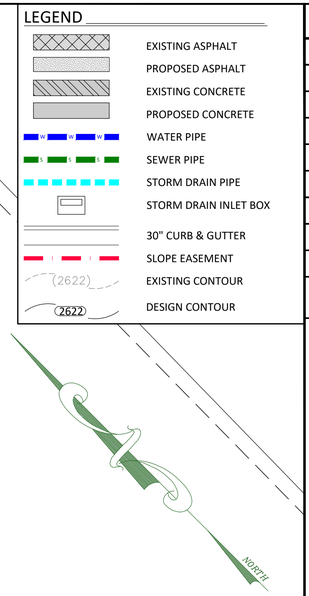
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Client No. 4568-21	Project No. 4568-21

Drawing Sheet
C2.4

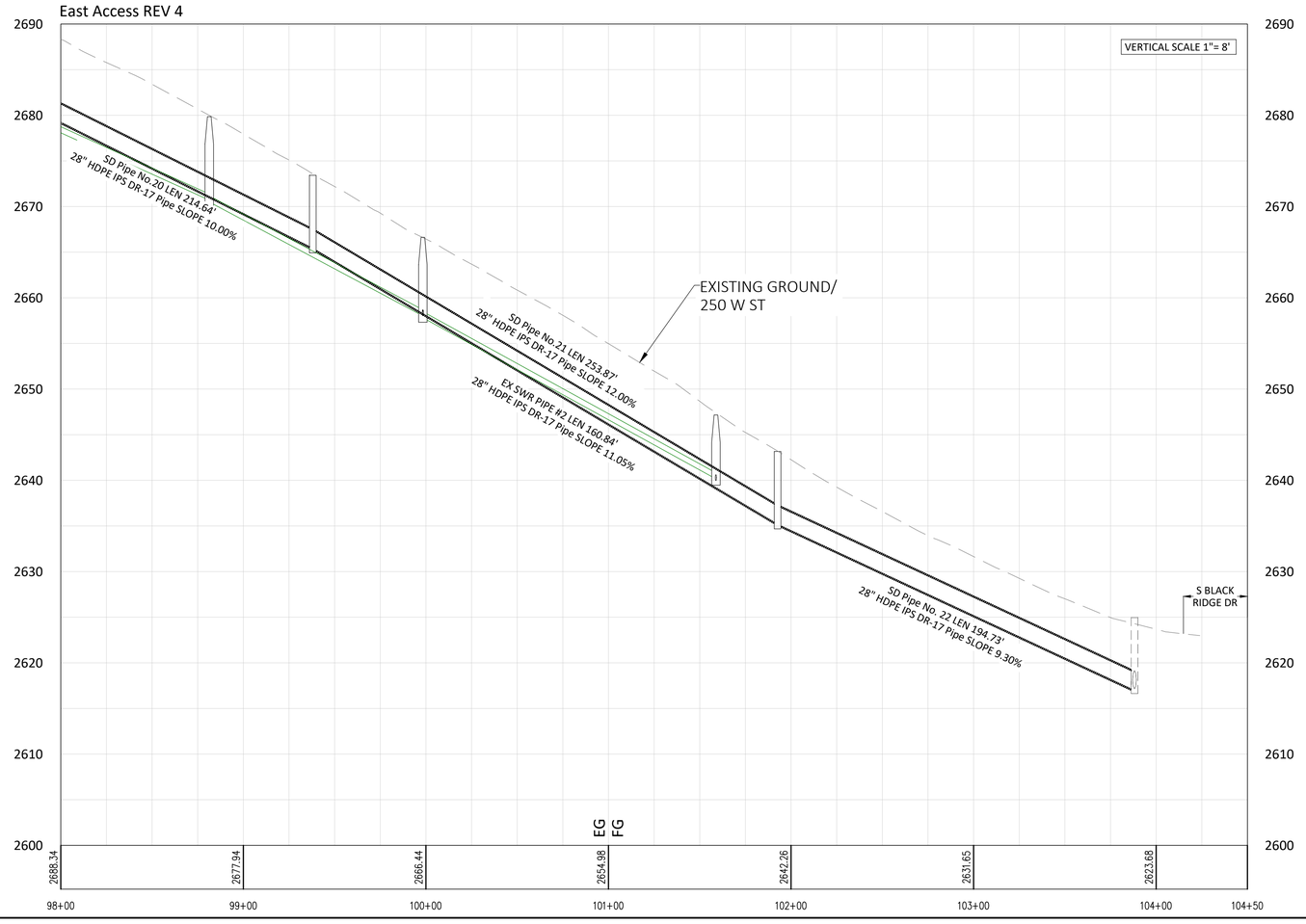
Sheet 9 of 14 Sheets





LEGEND

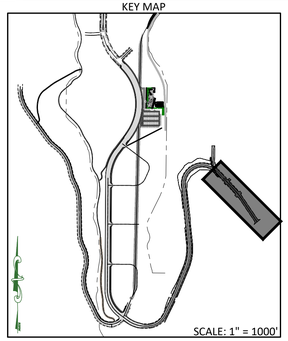
- EXISTING ASPHALT
- PROPOSED ASPHALT
- EXISTING CONCRETE
- PROPOSED CONCRETE
- WATER PIPE
- SEWER PIPE
- STORM DRAIN PIPE
- STORM DRAIN INLET BOX
- 30" CURB & GUTTER
- SLOPE EASEMENT
- EXISTING CONTOUR (2622)
- DESIGN CONTOUR 2622



Date: 12-30-2022			
REVISIONS			
No.	Date	by	Description

File Name
East Access Hillside Application.dwg

KEY MAP



GRAPHIC SCALE

40 0 20 40 80

(IN FEET)
1 inch = 40 ft.
If Printed 11x17 use Half Scale

ALLIANCE CONSULTING
A PLANNING AND ENGINEERING FIRM

UTAH
2303 N CORAL CANYON BLVD
SUITE 201,
WASHINGTON, UT 84780
435-673-8060

NORTH DAKOTA
621 26th STREET W.
WILLISTON, ND 58801
701-572-8100

TECH RIDGE
EAST ACCESS
GRADING

FOR

CITY OF ST. GEORGE

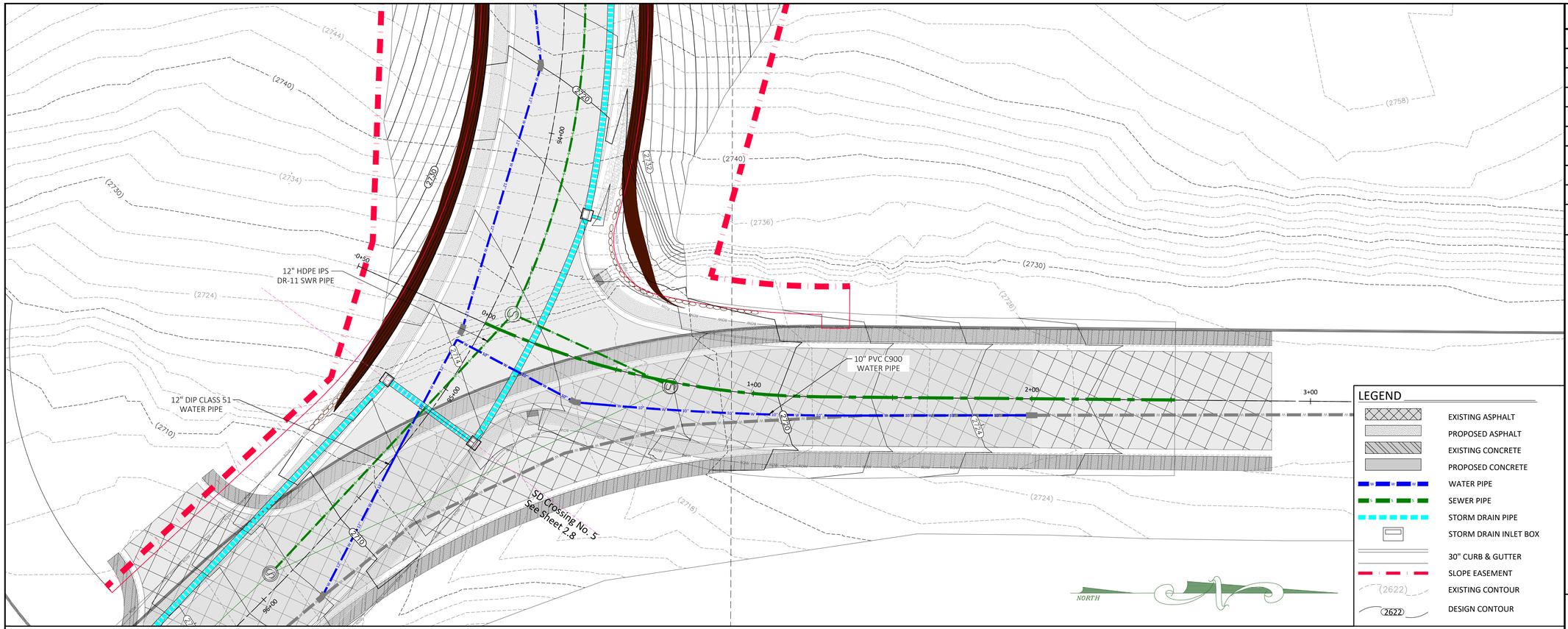
LOCATED IN SEC 36
T 42 SOUTH, R 15 WEST SLB&M
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

NOT FOR
CONSTRUCTION
REVIEW ONLY

Drawn By: ARL	Scale: 1" = 40"
Client No. 4568-21	Project No. 4568-21

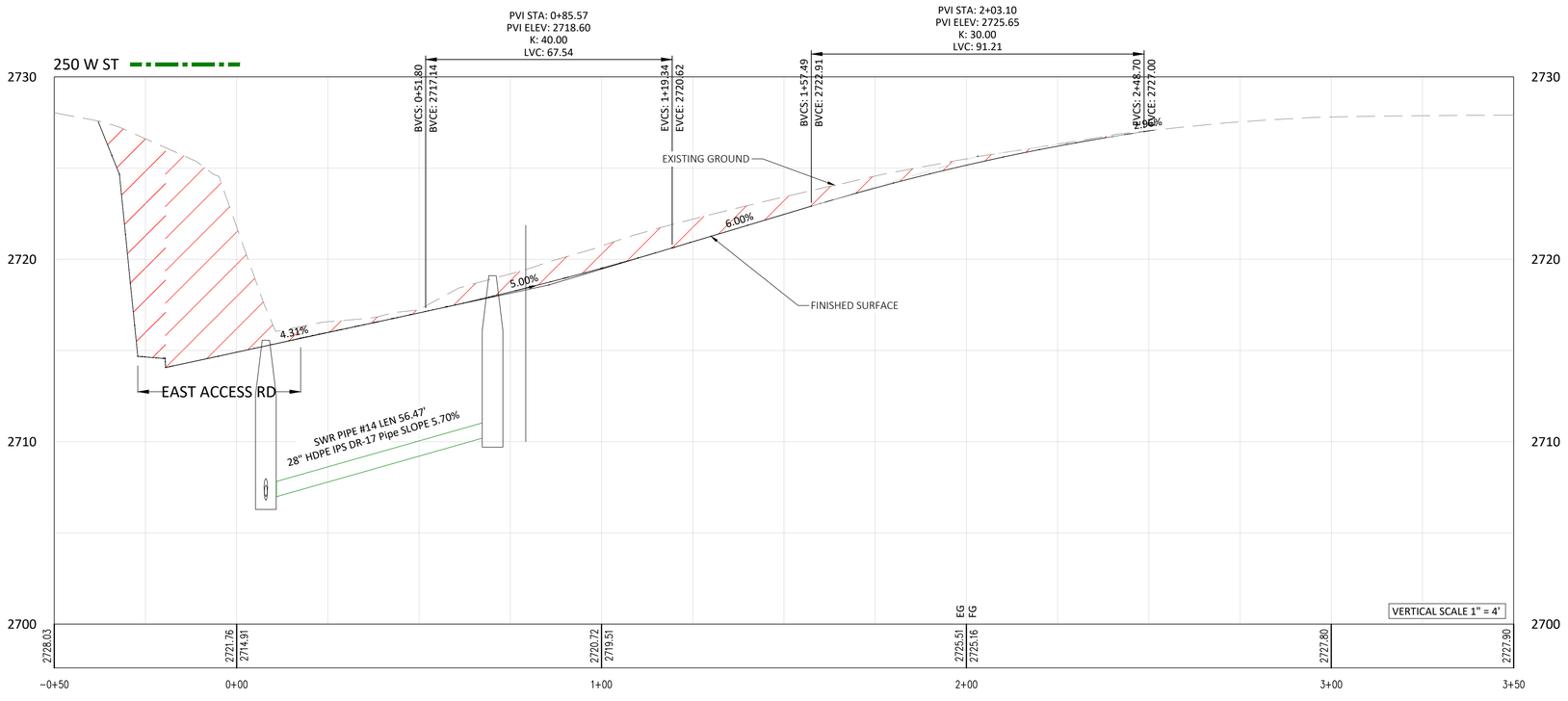
Drawing Sheet
C2.5

Sheet 10 of 14 Sheets



LEGEND

- EXISTING ASPHALT
- PROPOSED ASPHALT
- EXISTING CONCRETE
- PROPOSED CONCRETE
- WATER PIPE
- SEWER PIPE
- STORM DRAIN PIPE
- STORM DRAIN INLET BOX
- 30" CURB & GUTTER
- SLOPE EASEMENT
- (2622) EXISTING CONTOUR
- 2622 DESIGN CONTOUR



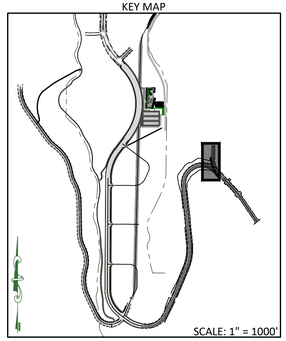
Date: 12-30-2022

REVISIONS

No.	Date	by	Description

File Name
East Access Hillside Application.dwg

KEY MAP



SCALE: 1" = 1000'

GRAPHIC SCALE

20 0 10 20 40

(IN FEET)
1 inch = 20 ft.
If Printed 11x17 use Half Scale

ALLIANCE CONSULTING
A PLANNING AND ENGINEERING FIRM

UTAH
2303 N CORAL CANYON BLVD
SUITE 201,
WASHINGTON, UT 84780
435-673-8060

NORTH DAKOTA
621 26th STREET W.
WILLISTON, ND 58801
701-572-8100

TECH RIDGE
W 250 ST
RE-GRADING

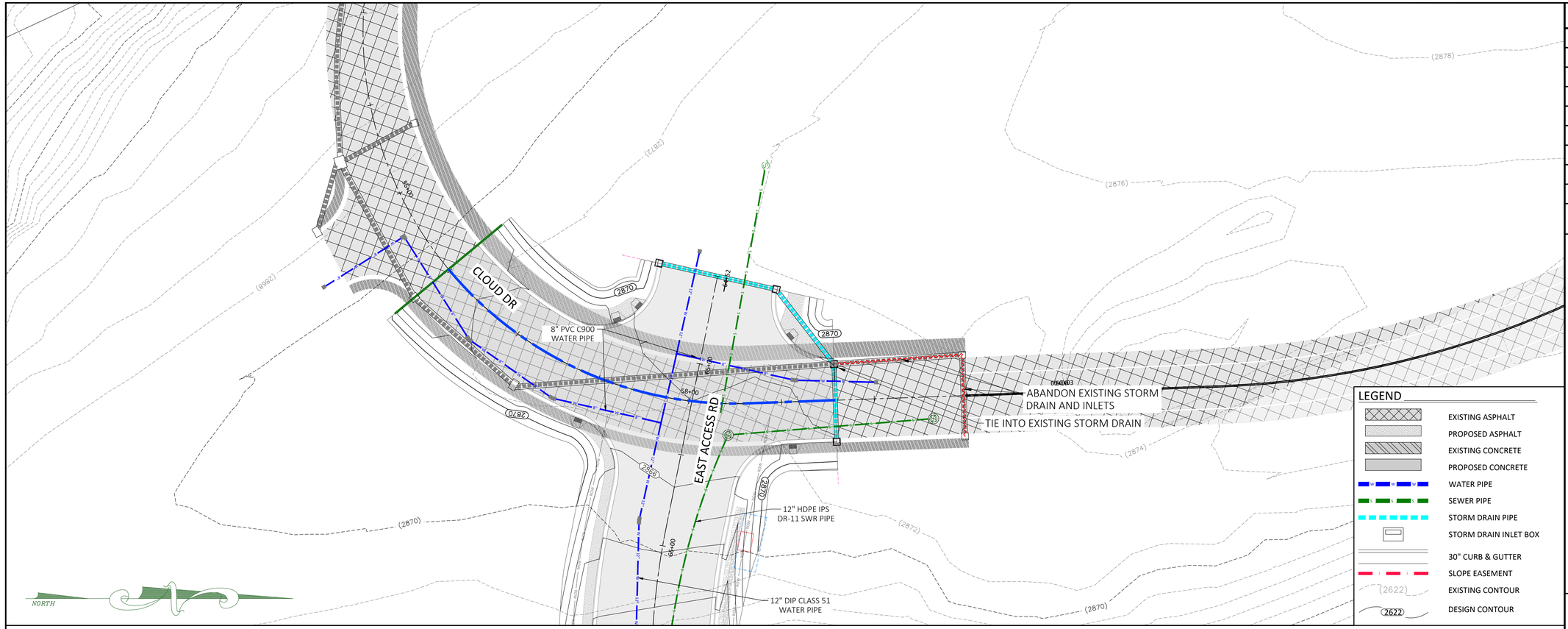
FOR
CITY OF ST. GEORGE
LOCATED IN SEC 36
T 42 SOUTH, R 15 WEST SLB&M
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

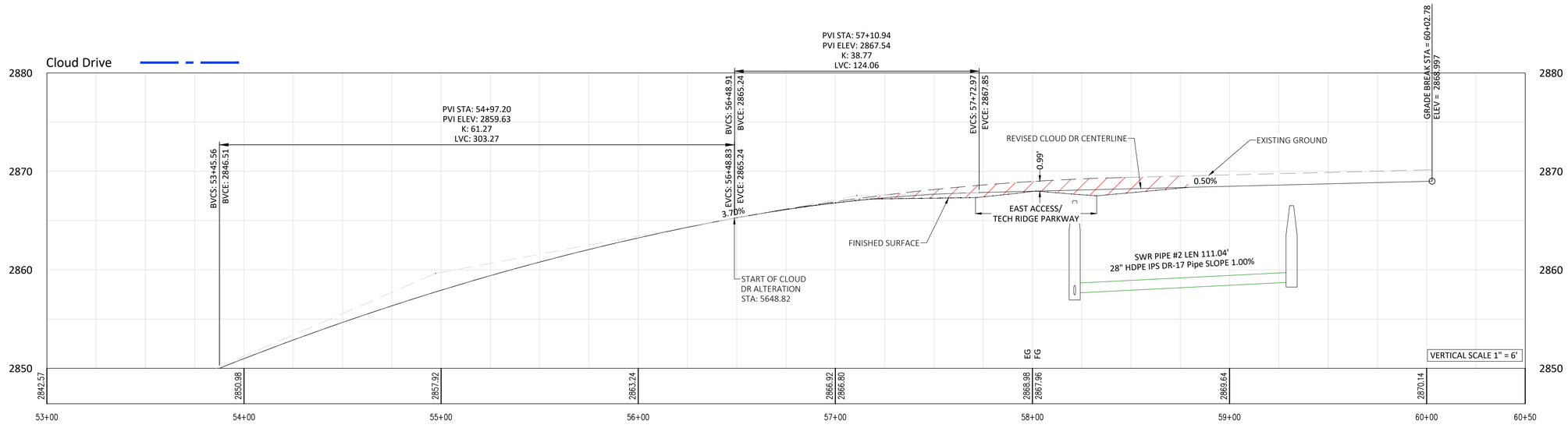
NOT FOR CONSTRUCTION REVIEW ONLY

Drawn By:	Scale:
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Client No.	Project No.
4568-21	4568-21

Drawing Sheet
C2.6

Sheet 11 of 14 Sheets





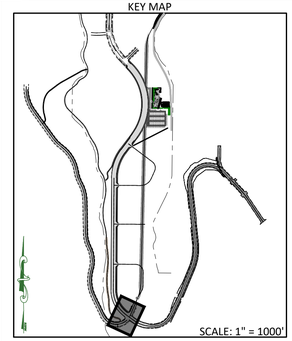
Date: 12-30-2022

REVISIONS

No.	Date	by	Description

File Name
East Access Hillside Application.dwg

KEY MAP



GRAPHIC SCALE

30 0 15 30 60

(IN FEET)
1 inch = 30 ft.
If Printed 11x17 use Half Scale

ALLIANCE CONSULTING
A PLANNING AND ENGINEERING FIRM

UTAH
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SUITE 201,
WASHINGTON, UT 84780
435-673-8060

NORTH DAKOTA
621 26th STREET W.
WILLISTON, ND 58801
701-572-8100

TECH RIDGE
CLOUD DRIVE
ALTERATION

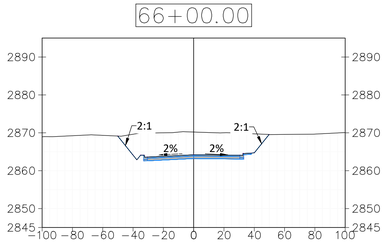
FOR
CITY OF ST. GEORGE
LOCATED IN SEC 36
T 42 SOUTH, R 15 WEST SLB&M
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

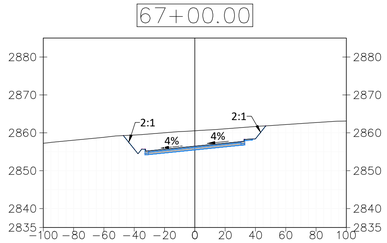
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CONSTRUCTION
REVIEW ONLY

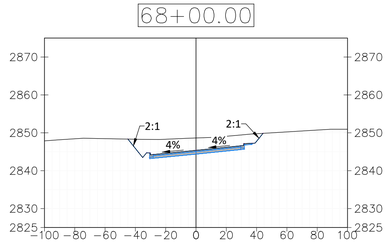
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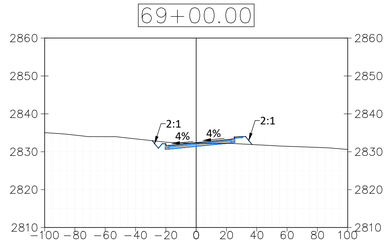
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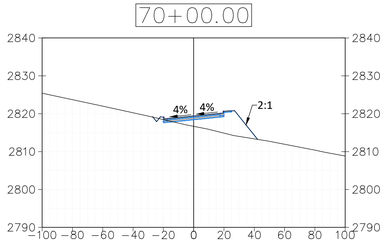
Sheet 12 of 14 Sheets

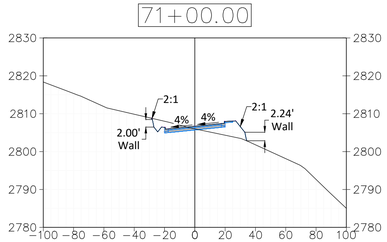


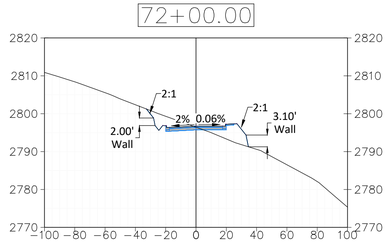


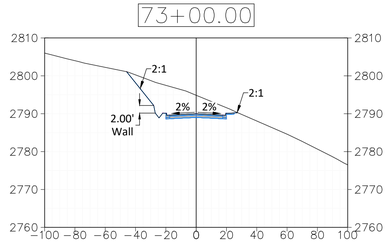


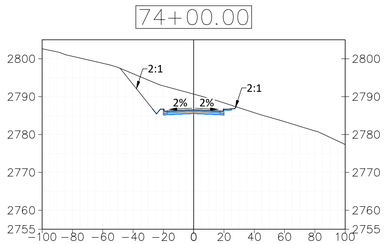


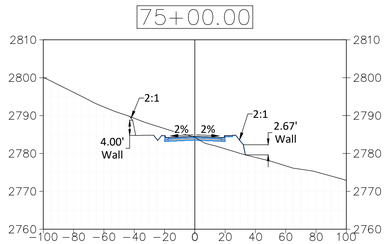


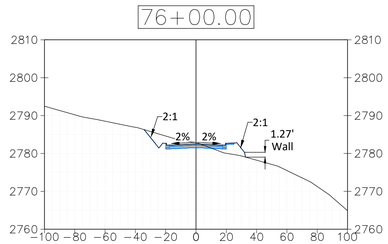


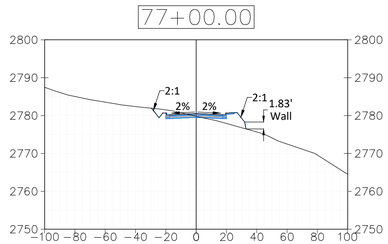


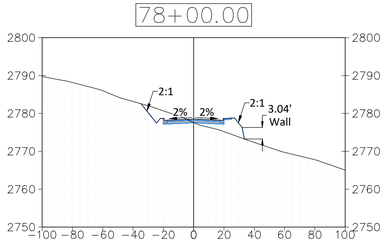


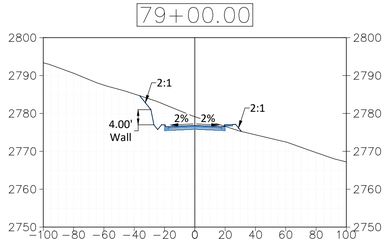


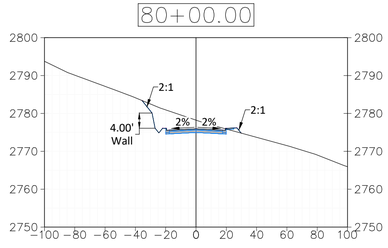


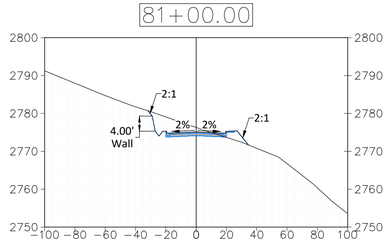












Date:
12-30-2022

REVISIONS

No.	Date	by	Description

File Name
East Access Hillside Application.dwg

ALLIANCE CONSULTING
A PLANNING AND ENGINEERING FIRM

UTAH
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435-673-8060

NORTH DAKOTA
621 26th STREET W.
WILLISTON, ND 58801
701-572-8100

TECH RIDGE
EAST ACCESS
GRADING

FOR

CITY OF ST. GEORGE

LOCATED IN SEC 36
T 42 SOUTH, R 15 WEST SLB&M
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

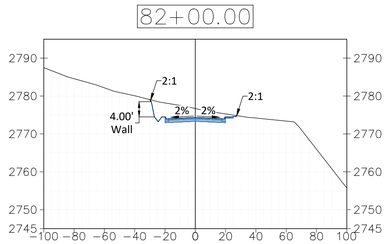
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CONSTRUCTION
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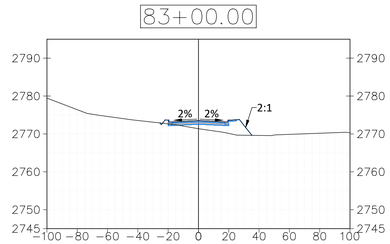
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Client No.	Project No.
4568-21	4568-21

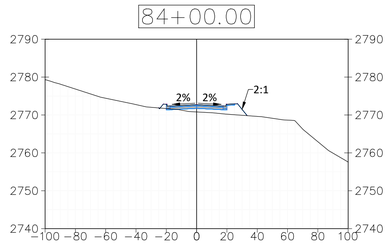
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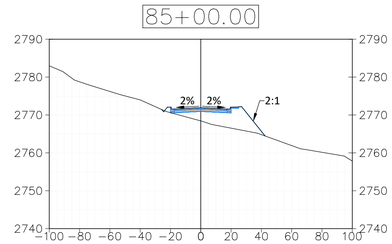
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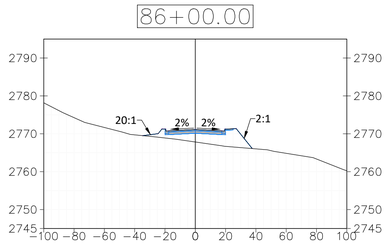
Sheet 13 of 14 Sheets

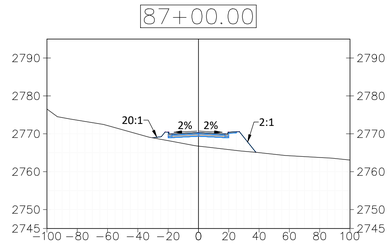


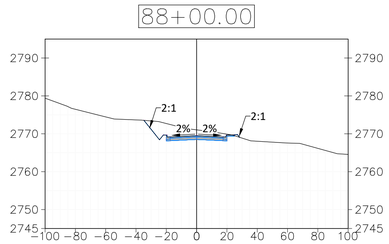


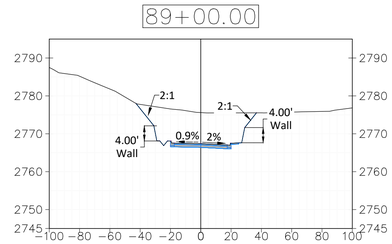


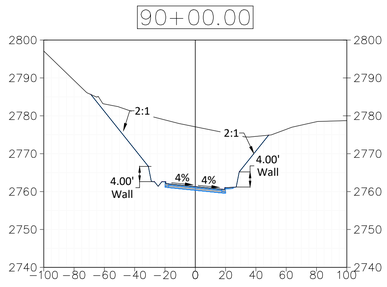


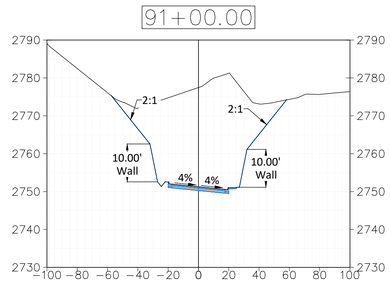


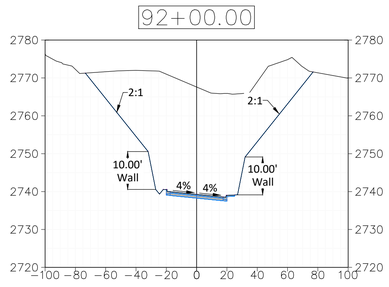


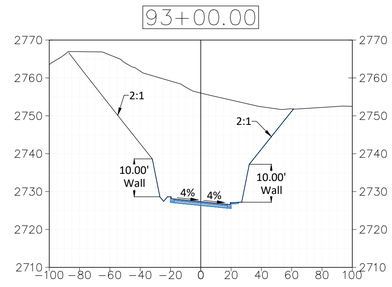


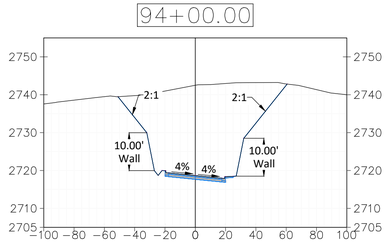


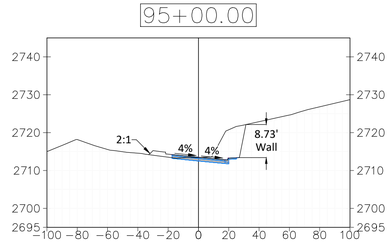


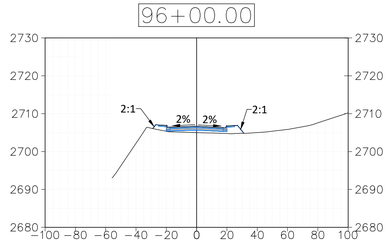


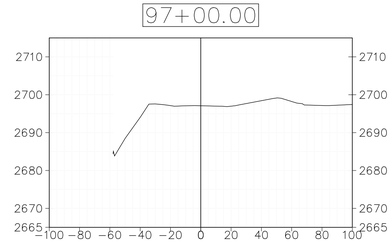












Date:
12-30-2022

REVISIONS

No.	Date	by	Description

File Name
East Access Hillside Application.dwg

ALLIANCE CONSULTING
A PLANNING AND ENGINEERING FIRM

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WILLISTON, ND 58801
701-572-8100

TECH RIDGE
EAST ACCESS
GRADING

FOR

CITY OF ST. GEORGE

LOCATED IN SEC 36
T 42 SOUTH, R 15 WEST SLB&M
CITY OF ST. GEORGE, WASHINGTON COUNTY, UT

NOT FOR
CONSTRUCTION
REVIEW ONLY

Drawn By:	Scale:
ARL	NONE
Client No.	Project No.
4568-21	4568-21

Drawing Sheet
C2.9

Sheet 14 of 14 Sheets

Exhibit D
GEOTECHNICAL REPORT

AGEC
Applied GeoTech

GEOTECHNICAL INVESTIGATION

TECH RIDGE SOUTH ACCESS ROAD
ST. GEORGE, UTAH

PREPARED FOR:

TECH RIDGE, LLC
446 SOUTH MALL DRIVE
ST. GEORGE, UTAH 84790

ATTENTION: ISAAC BARLOW

PROJECT NO. 2180295 **OCTOBER 19, 2018**

1420 South 270 East • St. George, Utah 84790 • (435) 673-6850 • FAX (435) 673-1044

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SUMMARY

A. East Slope Stability

1. Much of the proposed roadway crosses historical landslide deposits.

2. An evaluation of the east slope stability was included in the scope of this investigation.

3. Based on the available information obtained from previous investigations, inclinometer measurements, and past performance of the slope, it is apparent that the east slope for this project is currently maintaining its stability.

   Using the information available from our subsurface exploration, the laboratory test results along with our experience in the area, it is our professional opinion that the stability of the east slope is marginal. Even with the lack of apparent movement, small changes in the slope configuration and/or weakening of the material in the slope could trigger future movement.

   The strength of the slope will be adversely impacted by water infiltration. Therefore, we recommend strict drainage recommendations be followed to reduce the risk of future slope instability.

B. Roadway

If construction of the roadway is to proceed, the following information and recommendations apply.

1. A variety of soil and bedrock types were encountered in the test pits. Lean clay, silt, silty sand, well graded sand with silt, silty gravel with sand, basalt, mudstone, and shale bedrock were encountered. Practical excavator refusal was encountered on stiff clay, boulders, basalt and shale bedrock

2. Potentially expansive mudstone, potentially expansive lean clay and potentially collapsible silty sand were encountered in the test pits.

3. Subsurface water was not encountered in the excavated test pits to the maximum depths investigated. Fluctuation in groundwater level may occur over time. An evaluation of such fluctuations is beyond the scope of this report.

4. The on-site granular soils such as the silty gravel with sand (GM), silty sand (SM), and well graded sand with silt (SW-SM) free of organics, debris, and material greater than 6 inches in size, are suitable for use as site grading fill. Oversized rocks (greater than 6 inches and smaller than 12 inches) may be used as fill at depths greater than 3 feet below finished subgrade. The oversized rock should be placed so that rock to rock contact is minimized to reduce potential for nesting and voids.

5. The on-site fine grained soils range between non-plastic silt to highly plastic mudstone. The silt and portions of the lean clay observed in test pits TP-7 and TP-8 are suitable for use as low permeable fill above expansive subgrade. The mudstone and expansive lean clay similar to that encountered in test pits TP-1, should not be used as fill within 6 feet of the finished roadway subgrade elevation.

6. Consolidation testing of remolded samples of mudstone and lean clay indicate the material remains expansive upon processing and adding moisture. However, the laboratory tests also indicate the expansion potential of the processed and remolded mudstone and lean clay can be reduced with moisture contents of 4 to 6 percent above the optimum moisture content and a compaction of approximately 90 percent of the modified proctor value (ASTM D-1557). Conversely, remolded samples with moisture contents below 4 percent and compaction near or above 95% will likely exhibit higher expansive properties.

7. The proposed roadway may be supported on a properly prepared subgrade as recommended in the Subgrade Preparation section of this report.

   The on-site, potentially expansive mudstone and expansive lean clay should be overexcavated to an appropriate depth beneath the proposed roadway. Overexcavation depths may be determined from the information provided in the Subgrade Preparation section of this report.

   Areas which expose near surface loose, dry, potentially collapsible silty sand should be overexcavated prior to placing fill as recommended in the Subgrade Preparations section of this report.

   Drainage recommendations are also provided in this report to reduce the risk of the underlying expansive subgrade.

   Moisture conditioning and compaction criteria are also included in this report. The calculated asphalt, untreated base course, and borrow thickness vary depending on subgrade and traffic loading.

8. The information provided in this summary should not be used independent of that provided within the body of this report.

SCOPE OF WORK

This report presents the results of a geotechnical investigation for the proposed south access road construction project to Tech Ridge located in St. George, Utah as shown on Figures 1 and 2. The geotechnical investigation includes access from the east and west sides of Tech Ridge. AGEC was requested to perform the following tasks:

1. Conduct a subsurface investigation to determine the subsurface conditions. The subsurface investigation included the excavation of 21 test pits along the roadway alignment. The first 13 test pits which include the west access road (TP-1 through TP-11) and a portion of the east access road (TP-12 and TP-13) were excavated with a track mounted excavator (CAT 336E) equipped with a 30-inch wide bucket. A ripper tooth attachment was also used to loosen boulders encountered during test pit excavations.

2. Log the subsurface soil profile and obtain samples of the subsurface soils to conduct laboratory testing.

3. Conduct a laboratory testing program on the subsurface soils to determine their engineering characteristics and determine the support value of the subsurface soil.

4. Prepare a report which presents the subsurface conditions encountered and recommendations for the geotechnical aspects of the project including slope stability of the eastern facing slope. Our conclusions and recommendations are based on the subsurface investigation, the results of laboratory testing and our engineering analysis.

This report was prepared in accordance with our "Proposal for Professional Geotechnical Services" dated, April 30, 2018.

SITE CONDITIONS

The existing site topography consists of sloping hillsides and relatively flat areas. A dry wash runs through the west side access from the north to the south. The majority of the hillside along the proposed alignment have been mapped geologically as ancient landslide deposits and consists of undulating hummocky terrain with relatively gently benches and steeper sloping areas. Existing vegetation across the site consists of sparse, low brush. Basalt boulders are also exposed at the surface across the site. Various dirt roads traverse the sides of both hill slopes.

PROPOSED CONSTRUCTION

The proposed project consists of constructing a 2 lane roadway to the west and a 4 lane roadway to the east near the south end of Tech Ridge. Detailed roadway cross-sections and grading plans for the east access road were not provided for the preparation of this report.

Based on a review of the plan and profile sheet (dated 03/28/2018) prepared by Alliance Consulting for the west access road, we anticipate cuts of up to 9 feet and fills on the order of 19 feet will be required to grade the proposed roadway. The grading plan also indicates a 12-foot by 12-foot underpass will be constructed over the existing drainage. A flexible pavement section is proposed for the project and we anticipate the project will include curb, gutter and sidewalk.

The Average Daily Traffic (ADT) provided by Alliance Consulting includes 2,500 to 5,000 vehicles for the west access and approximately 15,000 vehicles for the east access road. These ADT values correspond to a Traffic Index of 6 for the west side access road and 7 for the east side as provided by the City of St. George Design Criteria.

GEOLOGY AND GEOLOGIC HAZARDS

Geologic conditions at the site were evaluated by a review of geologic literature and aerial photographs. Aerial photographs used during the investigation were downloaded from the Utah Geological Survey website. They have photograph numbers of 810941 AM-4-1 and 2 and a photograph date of October 23, 1981.

A. Geologic Literature Review

The site is located in the transition zone of the Basin and Range, and Colorado Plateau provinces. Hayden and Willis (2011) map the area to be underlain by the Moenave and Chinle Formations (See Figure 1). The bedrock dips gently down to the north. The bedrock is capped by the Cedar Bench lava flow at the top of the hill. Alluvial and colluvial sediments overlie the bedrock at the northwest end of the road alignment. Landslide deposits are mapped for the south and central portions of the road alignment. A geologist from AGEC visited on September 12, 2018. The geology of the area was found to be consistent with mapping by Hayden and Willis (2011).

Geologic hazards mapped by Lund and others (2008) are mostly limited to landslide and rockfall. Rockfall is not generally a hazard for the road for the current condition of the hillside but could become a hazard depending on how cut slopes are developed for the road. Similarly, landslide is not currently a significant hazard on the slope in its present condition, but could be a concern with added water or steepened slopes. This will be addressed in the geotechnical study for the project.

B. Aerial Photograph Review

Based on review of aerial photographs of the site, faulting and debris flow are not potential hazards at the site. The area of landslide deposits appears to be similar to that mapped by Hayden and Willis (2011). Lineations formed in the landslide deposits and likely representative of intermediate landslide scarps are shown on Figure 1.

C. Seismicity

The property is located in the Intermountain Seismic Zone, which consists of an area of relatively high historical seismic activity. The most intense seismic ground shaking at the site is expected to originate from the Washington fault zone. The Washington fault zone is considered capable of producing earthquakes on the order of 7 to 7.5 magnitude and can result in significant seismic ground shaking at the site. The US Geological Survey data indicate that a peak ground acceleration in bedrock of 0.24g can be expected to have a 2 percent probability of being exceeded in a 50-year time period at this site (IBC, 2015). The St George fault zone may also add to the seismic hazard in the area, although there is no evidence that the fault displaces Holocene sediments, suggesting the fault may not be active. The St George Fault is not included in the Quaternary Fault and Fold Database (Utah Geological Survey, 2018).

ROADWAY SUBSURFACE CONDITIONS

On August 8 and 9, 2018, an engineer from AGEC visited the site and observed the excavation of 13 test pits at the approximate locations shown on Figure 2. The 8 additional test pits (TP-14 to TP-21) were excavated during a previous geotechnical investigation by AGEC in August of 1998. The subsurface profile observed within the excavated test pits at the site is highly variable and consists of lean clay, silt, silty sand with gravel, well graded sand with silt, silty gravel with sand, basalt, mudstone bedrock, and shale bedrock.

Potentially expansive mudstone was encountered in test pits TP-1, TP-2, TP-10, TP-14, and TP-15 as shown on Figures 3-5. Expansive lean clay was encountered in test pits TP-1, TP-3, TP-5, TP-6, TP-7, TP-8, TP-14, TP-16 and TP-20. The shale bedrock encountered in test pits TP-16, TP-19, and TP-21 may also contain expansive layers. The dry loose nature of the near surface silty sand with gravel encountered in test pit TP-10 indicates the material is potentially collapsible if exposed to water.

Practical excavator refusal was encountered on stiff clay and boulders in test pits TP-3, TP-7, TP-8 and TP-20. Practical excavator refusal on basalt was encountered in test pits TP-11, TP-12, TP-13, and TP-17 with refusal on shale bedrock encountered in test pit TP-19. The maximum depth investigated in the test pits was 19 feet.

Detailed descriptions of the bedrock and soil types observed follow.

Lean Clay - The lean clay is medium stiff to very stiff, moist, medium plastic, contains varied amounts of sand, gravel, and boulders (1 to 4 feet in size). The lean clay varies from red-brown to brown with white mottles in color.

Laboratory tests conducted on samples of the lean clay indicate in-place moisture contents ranging from 5 to 16 percent, in-place dry densities ranging from 93 to 124 pounds per cubic foot (pcf), gravel contents (percent retained on the No. 4 sieve) ranging from 0 to 12 percent, and fines contents (percent passing the No. 200 sieve) ranging from 62 to 96 percent. Atterberg Limits tests conducted on samples of the lean clay indicated liquid limits ranging from 27 to 48 percent and plasticity indices ranging from 14 to 35 percent.

Moisture-Density relationship (ASTM D-1557) tests conducted on samples of the lean clay from test pits TP-3 and TP-8 indicate maximum dry densities (MDD) ranging from 116.5 pcf to 123.5 pcf and optimum moisture contents (OMC) ranging from 10.0 to 12.5 percent. California Bearing Ratio (CBR) tests conducted on remolded samples of the lean clay indicate CBR values ranging from 4 to 5 percent. The samples were remolded to near 90 percent of the maximum dry density (ASTM D-1557) and approximately 2% above the optimum moisture content.

One-dimensional consolidation tests conducted on samples of the native lean clay indicate it is slightly moisture sensitive when wetted under a constant pressure of approximately 1,000 pounds per square foot (psf). Swell potentials of 1 to 1½ percent and swell pressures ranging from 2,650 psf to 3,500 psf were measured in the laboratory testing.

Remolded one-dimensional consolidation tests conducted on samples of the lean clay indicate moisture conditioned and remolded samples are still expansive when wetted. The remolded one-dimensional consolidation results indicate a reduction in expansion potential with an increase moisture content during processing.

Silt - The silt is medium stiff to stiff, slightly moist to moist, contains various amount of sand, and is reddish brown in color.

Laboratory tests conducted on samples of the silt indicate in-place moisture contents ranging from 6 to 17 percent, in-place dry densities ranging from 101 to 112 pcf, and a fines content ranging from 81 to 94 percent. Atterberg Limits tests conducted on samples of the silt indicate it is non-plastic.

Silty Sand - The silty sand is loose to medium dense, dry, fine to medium grained, contains occasional gravel, cobbles, and boulders and ranges in color from light reddish brown to brown in color.

Laboratory tests conducted on samples of the silty sand indicate in-place moisture contents ranging from 3 to 8 percent, in-place dry densities ranging from 88 to 108 pcf, a gravel content of 2 percent, and fines contents ranging from 35 to 48 percent. The relatively low dry density and moisture content of the near surface silty sand indicates it is potentially collapsible.

A Moisture-Density relationship (ASTM D-1557) test indicates the silty sand has a maximum dry density of 126.0 pcf and an optimum moisture content of 7.5 percent.

Well Graded Sand with Silt - The well graded sand with silt is medium dense, dry, contains gravel, and brown in color.

Laboratory tests conducted on samples of the silty to clayey gravel with sand indicate an in-place moisture content of 1 percent, and a fines content of 6 percent.

Silty Gravel with Sand - The silty gravel with sand is medium dense to dense, dry to moist, and light brown to brown in color.

Laboratory tests conducted on the silty gravel with sand from test pit TP-4 indicate an in-place moisture content of 11 percent.

Basalt - The basaltic rock is moderately hard to very hard, dry, highly fractured to less fractured, and black in color.

A Moisture-Density relationship (ASTM D-1557) test indicates the fractured basalt with silt and sand has a maximum dry density of 134.5 pcf and an optimum moisture content of 5.5 percent.

Mudstone - The mudstone, known locally as “blue clay” is soft to moderately hard, dry to moist, medium to highly plastic, and grey to purple in color.

Laboratory tests conducted on samples of the mudstone indicate in-place moisture contents ranging from 7 to 15 percent, in-place dry densities ranging from 96 to 118 pcf, and fines contents ranging from 59 to 99 percent. Atterberg Limits tests conducted on samples of the mudstone indicate liquid limits ranging from 35 to 76 percent and plasticity indexes ranging from 19 to 39 percent.

A Moisture-Density relationship (ASTM D-1557) test indicates the mudstone has a maximum dry density of 115.0 pcf and an optimum moisture content of 12.5 percent. A CBR test conducted on a remolded sample of the mudstone indicates a CBR value of 6 percent. The sample was remolded to near 90 percent of the maximum dry density (ASTM D-1557) and approximately 2 percent above the optimum moisture content.

One-dimensional consolidation tests conducted on natural samples of the mudstone indicate it is moisture sensitive (expansive) when wetted under a constant pressure of approximately 1,000 psf. Swell potentials of ½ to 1 percent with swell pressures of 2,170 to 4,000 psf were measured in the laboratory testing.

Remolded one-dimensional consolidation tests conducted on samples of the mudstone indicate moisture conditioned and remolded samples are still expansive when wetted. The remolded one-dimensional consolidation results indicate a reduction in expansion potential with an increase moisture content during processing.

Shale Bedrock - The shale bedrock is soft to hard, dry to slightly moist, interbedded with layers of siltstone and claystone, and dark brown to dark red in color.

Laboratory tests conducted on a sample of the shale bedrock indicate an in-place moisture content of 5 percent, an in-place dry density of 110 pcf, and a fines content of 71 percent.

The Logs, Legend and Notes of Test Pits are shown on Figures 3-5. The results of laboratory testing are also shown on Figures 3 and 4 and are summarized in the Summary of Laboratory Test Results, Table 1. The One-dimensional Consolidation Test Results are shown graphically on Figures 6-12. The Gradation/Soil Classification and Moisture-Density Relationship Test Results are shown graphically on Figures 13-17. The California Bearing Ratio Test Results are shown graphically on Figures 18-22.

ROADWAY SUBSURFACE WATER

Groundwater was not encountered during the subsurface investigation to the maximum depth investigated, approximately 19 feet. Fluctuations in the groundwater level may occur over time. An evaluation of such fluctuations is beyond the scope of this report.

EAST SLOPE STABILITY

AGEC previously investigated the subsurface conditions of the east facing slope by drilling five borings to depths varying from 110 to 250 feet. Inclinometer casings were installed at each of the five locations along with an adjacent boring to facilitate measurements of the groundwater level.

Our findings of the stability analysis are presented without the boring logs, laboratory test results, inclinometer measurements, and our calculations as stipulated in our agreement for this project.

Existing Conditions

As indicated on Figure 1, portions of both arms of the access road are located on landslide deposits. In addition to verifying the geologic mapping presented on Figure 1, the east hillside stability has been evaluated. Site conditions that reflect the material behavior and characteristics of the landslide include:

1. The hummocky nature of the ground surface along with the lineations associated with each of the landslide slumps .

2. Landslide masses will often reach equilibrium at a slope angle close to the internal material strengths. The ground surface slopes from 8 to 18 degrees (3 to 7:1 horizontal to vertical) which are consistent with the internal friction values obtained from our earlier studies and from samples tested in the laboratory.

Contributing Factors

In addition to the surface geology, the following items contribute to the status of the slope stability.

1. The bedding planes in the area generally slope down to the northeast at an angle of approximately 7 to 8 degrees.

2. The weakest clay sample tested from explorations conducted on the east slope has been found to have a residual coefficient of friction of 7.5 degrees. This angle closely matches the dip of the bedding plane. With this strength and bedding plane combination, slippage would occur on 7.5 degree downward slope if the interface strength is less than 7.5 degrees or slippage would also occur if there are areas or zones where the dip angle of the bedding plane is steeper than the 7.5 degrees.

3. Investigation into landslide movements on the east slope indicate a relatively thick deposit that contains layers of this potentially weak clay. Measurements indicate that the hillside movement occurs at multiple depths indicating similar strength characteristics throughout the deposit.

4. Groundwater was encountered in each of the deep borings.

Status of Movement

Inclinometers were installed at five locations to depths of 92 to 258 feet on the east hillside in 2007. Inclinometer Measurements were obtained in 2008, 2011 and April 4, 2018. The 2018 measurements on 4 of the 5 inclinometers are within the accuracy of the equipment indicating no measurable movement.

The inclinometer located immediately west of the vacant restaurant, located at 1090 South Bluff Street, was measured before 2011. Displacement was measured at multiple depths.

Geotechnical Testing Services (GTS) installed an inclinometer on a berm placed behind the restaurant. We understand that recent measurements by GTS indicate lateral movement of approximately 0.7 inches in the last 5 years.

Anticipated Performance

With the lack of measured movement in the 4 inclinometers over the past 10½ years along with the lack of surficial evidence of movement, it is apparent that the portion of the slope for this project is currently maintaining its stability. Using the information available from our subsurface exploration, the laboratory test results along with our experience in the area, it is our professional opinion that the stability of the slope is marginal even with the lack of apparent movement.

With these conditions, small changes in the slope configuration or weakening of the material strengths in the slope could trigger future movement.

As stated in the 1996 Transportation Research Board, Special Report 247, (entitled Landslides, Investigation and Mitigation), "…old landslides are often barely stable, and they may not have significant resistance to new loadings or other changed conditions that tend to reduce their stability. Changing natural drainage patterns on the surfaces of old landslides may significantly influence their stability and cause unwanted movements. Thus, the decision to construct transportation facilities over ancient landslides must be carefully investigated and appropriate consideration given to remedial measures and long-term stability".

It is important to recognize that marginal stability of the slope indicates that:

1. A calculated factor of safety using the parameters selected to characterize the materials in the slope and the existing configuration is near 1.0 and will not meet the standard acceptable level of at least 1.5.

2. Changes in the internal conditions and/or surficial geometry modifications may improve or reduce the ability of the slope to maintain its stability. It may not be practical to quantify with confidence the impact that internal changes may have provided.

3. It is a matter of time before more movement on the slope occurs. Determining a location and/or timing of such an event is not possible with the information currently available.

4. A seismic event could introduce sufficient lateral load to initiate slope movement.

Mitigation

If the decision is made to continue with construction of the roadway on the landslides, we recommend the following items be seriously considered:

1. Introduction of moisture into the subgrade should be minimized if not eliminated. This could be accomplished by:

    a. Collecting and transporting surface drainage off of the slope in watertight catch basins and piping. This is not standard storm drainage procedures therefore, this would require specific attention to verify that the improvements are watertight.

    b. Water ways should be lined to prevent seepage into the ground.

    c. Measures need to be taken to eliminate the potential for water to pond on the slope.

    d. No water bearing utilities should be installed within the landslide area.

2. Cut and fill slopes need to be minimized. Overall impact of potential grade changes should be evaluated and the consequence of the change found to be acceptable before proceeding.

3. Water entering the ground in all areas above the slope (within the Tech Ridge area) should be reduced and ideally eliminated. Some, if not all, of the methods described above should be considered within the Tech Ridge area.

ROADWAY RECOMMENDATIONS

The following recommendations are provided with the assumption that all stakeholders recognize and accept the risk of landslide movement. The recommendations are based on the proposed construction, information obtained from the field and laboratory testing, engineering analysis, and our experience in the area.

A. Site Grading

Based on the subsurface conditions and the proposed grading provided by Alliance Consulting, the following recommendations are provided:

1. Subgrade Preparation

a. *General Subgrade Preparation*: Prior to conducting site grading, vegetation and soil containing significant amounts of roots and organics should be removed. Loose/disturbed soil, debris, deleterious material, previously placed fill, and undiscovered fill should be removed to the full depth.

b. *Expansive Mudstone and Lean Clay Subgrade Areas*: To reduce the potential for wetting and subsequent swelling of the expansive subgrade supporting the proposed roadway, we recommend the expansive mudstone and lean clay areas be overexcavated to remove a portion of the expansive material and it replace with properly compacted, low permeable fill. The low permeable fill is intended to provide a less permeable zone which reduces the potential for infiltration of water to the underlying expansive mudstone and lean clay. If the natural moisture content of the expansive mudstone and lean clay is maintained, distress to the asphalt/sidewalk and curb will be reduced.

Prior to placing the low permeable fill and subsequent to overexcavation, the exposed subgrade should be scarified a minimum of 8 inches, moisture conditioned to 4 to 6 percentage points above the optimum moisture content and compacted to 90 percent of the maximum dry density as determined by ASTM D-1557.

We recommend overexcavation and replacement of the expansive mudstone and lean clay be performed to provide a low permeable zone above expansive materials and reduce the risk of wetting and potential heave. The surface heave estimates are provided in the following table. The estimates are based on an assumed active zone (wetted depth) of 10 feet. The heave estimates should be used to assist in determining the depth of overexcavation and replacement desired based on the associated risk of surface heave.

Depth to Expansive Soil Below Finished Subgrade Elevation (feet)	Estimated Potential Surface Heave (inches)
0	3 to 4½
2	2½ to 4
4	2 to 3
6	1 to 2½

c. *Sand, and Gravel Areas (All Other Subgrades Encountered)*: Subsequent to grubbing and prior to placing fill, base course, or asphalt pavement, the exposed subgrade beneath pavement and fill slope areas should be scarified to a depth of 8 inches, moisture conditioned and properly compacted to at least 95 percent of the maximum dry density as determined by ASTM D-1557.

If the exposed subgrade consists of loose, dry silty sand or silty gravel (potentially collapsible soils), we recommend this soil be overexcavated to remove the full depth of this material. An engineer from AGEC should observe the exposed subgrade to provide guidance regarding the subgrade preparation in these areas.

d. *Potentially Soft Subgrade (Encountered in Area of TP-4):* Potentially soft subgrade conditions may be encountered near TP-4 resulting from heavy equipment and very moist subgrade conditions observed in the test pit. If soft/pumping conditions are encountered subgrade stabilization may be implemented using overexcavation to remove the soft soils or by implementing gravel and geosynthetic reinforcement may be necessary. Additional details may be provided upon request.

2. Excavation/Earthwork

The on-site soils and soft mudstone bedrock may be excavated with conventional excavation equipment. Excavations extending into large boulders, potential cemented zones, basalt and hard shale bedrock will likely require the use of heavy excavation equipment such as a trackhoe equipped with rock teeth or a single ripper tooth. A rock hammer may also be necessary to excavate portions of the basalt or shale bedrock. Difficulty may be particularly evident in confined excavations.

3. Grading Slopes

Review of the grading plan for the west side access road indicates existing slopes along the road alignment of the project will be excavated and cut to construct the roadway. We also anticipate grading along the east side access road will require cuts into hillside. Our experience with soil cut and fill slopes in the area has shown soils will tend to erode over time to their natural angle of repose. The following table provides recommendations for guidance of cut slopes based on the observed onsite soils:

Expected Soil Condition	Grading Recommendations (Horizontal:Vertical)
Basalt	½:1
Lean Clay	¾ :1
Silty Sand and gravel	1:1
Shale and Mudstone Bedrock	½ :1 (if faced) or 1½ :1 (if not faced)

Mudstone and clay slopes cut steeper than 1½ :1 would remain stable, but will dessicate, and likely ravel naturally to approximately a 1½ :1 slope. This process will require long term maintenance to remove the accumulated soils deposited at the toe of the slope. If this process is not acceptable, steep slopes may be flattened or faced to provide protection from weathering and erosion. Stacked rockery facing or reinforced gunnite facing anchored with soil nails may be considered to protect steeper cut slopes. Design and recommendations associated with reinforced/stabilized cut slopes are beyond the scope of AGEC's services.

Additionally, several existing cut slopes are part of a larger ancient landslide deposit. This analysis does not address the potential development, re-activation or stabilization of larger scale slope movement as could be possible due to the site being part of the larger landslide deposit.

We recommend fill slopes constructed with onsite soil not exceed a 2:1 (horizontal:vertical) slope. Fill slopes should be graded by overbuilding and then cutting them back to the desired grade to provide a compacted slope face. Fill placed on existing slopes steeper than 4:1 (horizontal to vertical) should be placed using a benching procedure to "key" the fill into the existing slope. Benches should be of sufficient width to extend fill placement through loose/surficial soils or to meet the criteria given in the following table, whichever is greater.

Approximate Slope Grade (Horizontal:Vertical)	Bench Width (feet)
1:1	2
2:1	4
3:1	6
4:1	8

4. Materials

The on-site granular soils such as the silty gravel with sand (GM), silty sand (SM), and well graded sand with silt (SW-SM) free of organics, debris, and material greater than 6 inches in size, are suitable for use as site grading fill. Oversized rocks (greater than 6 inches and smaller than 12 inches) may be used as fill at depths greater than 3 feet below finished subgrade. The oversized rock should be placed so that rock to rock contact is avoided to reduce potential voids and nesting of rocks.

The on-site fine grained soils range between non-plastic silt to low to medium plastic lean clay and highly plastic mudstone. The silt and portions of the lean clay observed in test pits TP-7 and TP-8 are suitable for use as low permeable fill above expansive subgrade. The on-site expansive soils (mudstone and lean clay) free of organics may be used as site grading fill in areas not supporting the roadway. The mudstone and the expansive lean clay should not be used as fill within 6 feet of the finished roadway subgrade elevation without accepting potential surface heave risks.

Listed below are the materials recommended for fill.

Area	Fill Type	Soil Type
Roadway	Untreated Base Course	CBR > 70%, **200** < 12% Maximum size: 1 inch
Roadway	Site Grading and Embankment Fill	**-200** < 35%, **LL** < 30% Maximum size: 4 inches Solubility < 1%

-200 = Percent Passing the No. 200 Sieve

LL = Liquid Limit

The potential impact of the expansive characteristics of the underlying expansive mudstone and lean clay can be reduced by protecting the expansive material from becoming wet. Placement of relatively low permeable fill above the expansive soil/bedrock can help reduce the possibility of water coming in contact with the expansive material.

Low permeable fill used to replace removed expansive soil should meet at least one of the following options:

Option No.	Liquid Limit (%)	Percent Passing the No. 200 Sieve
1	50+	15-20
2	30-50	20-40
3	0-30	30-100

Based on the above criteria, we anticipate some of the on-site soils will be suitable for use as low permeable fill. Mixing of onsite soils (lean clay and mudstone) with non-expansive fill may be necessary to produce low permeable fill meeting the above requirements. If mixing will be considered, AGEC should be contacted to conduct additional laboratory testing to determine mixing/blending recommendations.

5. Compaction

Compaction of fill materials placed at the site should meet the following moisture content criteria and equal or exceed the following compaction criteria:

Area	Moisture Content	Percent Compaction
Low Permeable Fill	+2% to +4% above OMC	90%
Subgrade - Expansive Materials	+4% to +6% above OMC	90%
Subgrade - Non-expansive Materials	± 2% of OMC	90%
Roadway Fill - Expansive Materials	+4% to+ 6% above OMC	90%
Roadway Fill - Non-expansive Materials	± 2% of OMC	95%
Roadway Base Course	± 2% of OMC	95%

OMC = Optimum moisture content

Fill tested should be compared to the maximum dry density as determined by ASTM D-1557. Soils placed as site grading fill should be moisture conditioned to the above recommendations. Soil at the site was generally below the optimum moisture content and will require moisture conditioning prior to placement to achieve the required compaction.

It is critical that the low permeable fill is moisture conditioned over the optimum moisture content (as recommended) to provide the low permeable properties necessary for the application. If the low permeable fill is placed dry of the optimum moisture content, the permeability or infiltration rate of water will be higher.

Fill should be placed in lift thicknesses which do not exceed the capacity of the compaction equipment used. Generally 6 inch loose lifts are appropriate for heavy rubber-tire compaction equipment. Lift thickness should be reduced to 4 inches for hand compaction equipment. Fill placed at the site should be tested frequently to verify proper compaction.

B. Soil Corrosion

Our experience has shown the on-site soils, bedrock and many import soils may contain sulfates in sufficient concentration to be corrosive to concrete. Therefore, we recommend concrete elements that will be exposed to the on-site soils be designed in accordance with provisions provided in the American Concrete Institute Manual of Concrete Practice (ACI) 318-14 Chapter 19. Tables 19.3.1.1 and 19.3.2.1 of ACI 318-14 should be referenced for design of concrete elements utilizing a Sulfate Exposure Class of S2.

Consideration should also be given to cathodic protection of buried metal pipes. We recommend utilizing PVC pipes where local building codes allow.

C. Pavement Analysis and Design

The following pavement design criteria were used in our pavement design based on the UDOT Pavement Management and Pavement Design Manual dated November, 1998 and updated March, 2008.

- A 20 year design life with ADT values of 2,500 to 5,000 for the west access road and 15,000 for the east access road were provided by Alliance Consulting. These traffic conditions correspond to a Major Collector (TI = 6) for the west access roadway and a Minor Arterial (TI = 7) for the east access roadway according to the St. George City Design Specifications.
- A Standard Deviation of 0.45.
- Initial and Terminal Serviceabilities of 4.2 and 2.5, respectively.
- A Reliability of 90 percent.
- CBR values of 4 and 10 percent for varying on-site soil types.
- A Subgrade Resilient Modulus of 1500*CBR value.
- A Untreated Base Course Resilient Modulus of 27,000 psi.
- A Granular Borrow Resilient Modulus of 15,000 psi.
- Layer Coefficients of 0.4, 0.1, and 0.08 for the hot mix asphalt, untreated base course, and the granular borrow, respectively.
- A Drainage Coefficient of 1 for the untreated base course and the granular borrow.

D. Pavement Support, Section, and Materials

Based on the subsurface conditions encountered, UDOT/AASHTO Design methods, and a 20-year design life, the following recommendations are given. Although the following pavement sections are based on a 20 year design life, the life span of the pavement may be shorter if not properly maintained, drained, and due to the presence of expansive materials, and landslide deposits below the roadway on some portions of the project.

1. Subgrade Support

The subgrade should be prepared as outlined in the Site Grading section of this report. We anticipate the subgrade materials at the site will generally consist of lean clay, mudstone, silty sand and gravel, and silty gravel with sand.

AGEC measured CBR values ranging from 4 to 33 percent from remolded samples of the on-site soils obtained from the test pit excavations. For the purpose of this report, a CBR value of 4 was used for design of pavement supported over the mudstone and lean clay and a CBR value of 10 was used for the design of pavement supported over the remaining subgrade soils encountered at the site.

2. Pavement Thickness

Refer to the following tables for pavement section thicknesses.

East Access Roadway (TI = 7)

Subgrade Type	CBR Value	Asphalt Thickness (in)	Base Course Thickness (in)
Mudstone and Lean Clay	4	4	12
Other Soils	10	3½	8

West Access Roadway (TI = 6)

Subgrade Type	CBR Value	Asphalt Thickness (in)	Base Course Thickness (in)
Mudstone and Lean Clay	4	3½	8
Other Soils	10	3	6

3. Pavement Materials

The pavement materials should meet St. George City specifications for gradation and quality. The pavement thicknesses indicated above assume that the base course is a high quality material with a CBR of at least 50 percent and the asphaltic concrete has a minimum Marshal stability of 1,800 pounds.

Other materials may be considered for use in the pavement section. The use of other materials may result in other pavement material thicknesses.

E. Drainage and Maintenance

The collection and diversion of drainage away from the pavement surface is extremely important to the satisfactory performance and life span of the pavement section and the slope stability. Proper drainage and precautions presented in the stability section should be provided.

Due to the moisture sensitivity of the on-site mudstone and portions of the lean clay, it is critical that infiltration of water be minimized to reduce the potential for future movement of pavement and utilities. Maintaining natural soil moisture conditions of the moisture sensitive soil and bedrock reduces potential for expansion of underlying soil/bedrock and subsequent heave. To reduce infiltration, we recommend the following:

1. Maintain positive site drainage during and following construction. Ponding of water should be eliminated.

2. Surface drainage of streets should be maintained by providing sufficient crown/grade in the road to direct flows into the curb/gutter systems or off of roadway improvements in areas not including curb and gutter. Positive flow of the gutters should be provided and maintained.

3. Seams and joints in the asphalt and concrete should be properly sealed to reduce infiltration of water to the underlying expansive soil/bedrock.

4. Maintenance should be provided to maintain asphalt cracks which may occur over time.

F. Construction Materials Observation and Testing

Construction materials observation and testing should meet St. George City testing requirements. We also recommend the following be conducted during the construction of the roadway.

1. Verify that the subgrade is properly prepared prior to placing fill and the recommended overexcavation depths are achieved to expose the underlying competent basalt.

2. Observe the placement and conduct compaction testing on each foot of site grading fill placed in roadway areas and within utility trenches.

3. Conduct materials testing on road-base, concrete, and asphalt in accordance with St. George City standards.

G. Geotechnical Recommendation Review

The client should familiarize themselves with the information contained in this report. If specific questions arise or if the client does not fully understand the conclusions/recommendations provided, AGEC should be contacted to provide clarification.

LIMITATIONS

This report has been prepared in accordance with generally accepted soil engineering practices in the area for design purposes. The conclusions and recommendations included within the report are based on the information obtained from the borings drilled and the test pits excavated at the locations indicated on the site plan, the results of laboratory testing, the referenced documents and our experience in the area. Variations in the subsurface conditions may not become evident until additional exploration or excavation is conducted. If the subsurface soil or groundwater conditions are found to be different from what is described in this report, we should be notified to reevaluate the recommendations given.

Sincerely,

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.





Jake Erickson, P.E.

James E. Nordquist, P.E.

Reviewed by Arnold DeCastro, P.E.

JE/sd P:\2018 Project Files\2180200\2180295 Tech Ridge Access Road(s)\2180295 Report.wpd

References

Hayden, J.M. and Willis, G.C., 2011; Geologic map of the St George quadrangle, Washington County, Utah, Utah Geological Survey Map 251DM.

International Building Code, 2015; International Code Council, Falls Church, Virginia.

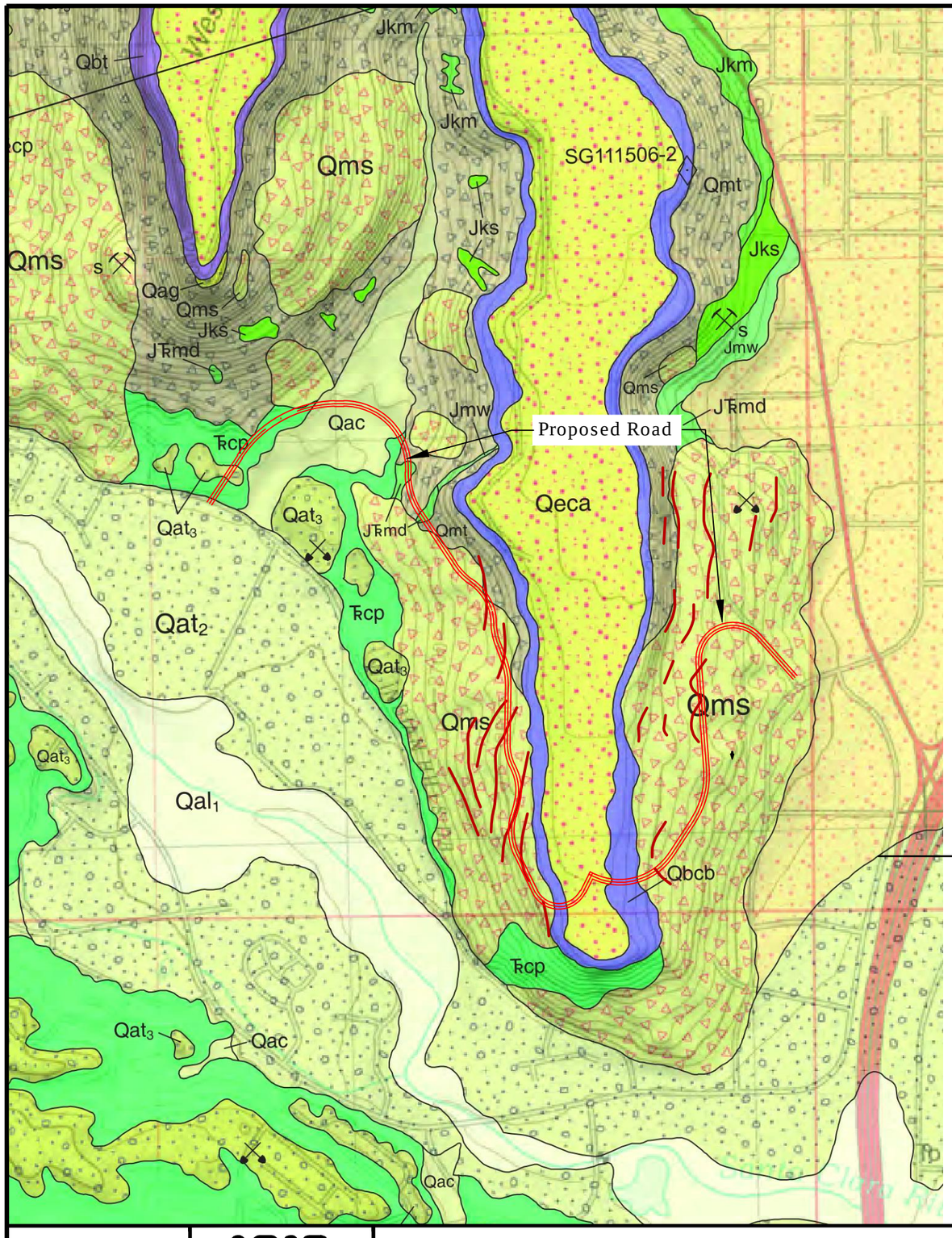
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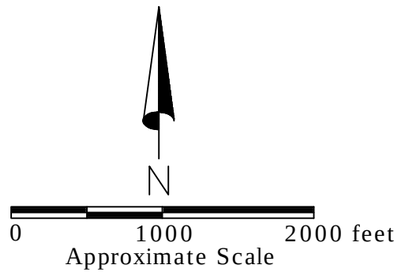
Utah Geological Survey, 2018; Utah Quaternary Fault and Fold Database, http://geology.utah.gov/resources/data-databases/qfaults/ Accessed September 24, 2018.

"Pavement Management and Pavement Design Manual", Utah Department of Transportation, November 1998, updated March 2008.

"Landslide-Hazard Map for the St. George-Hurricane Metropolitan Area", Utah Geological Survey, 2008.

"St. George Geologic Map Overlay", Utah Geological Survey, 2013.





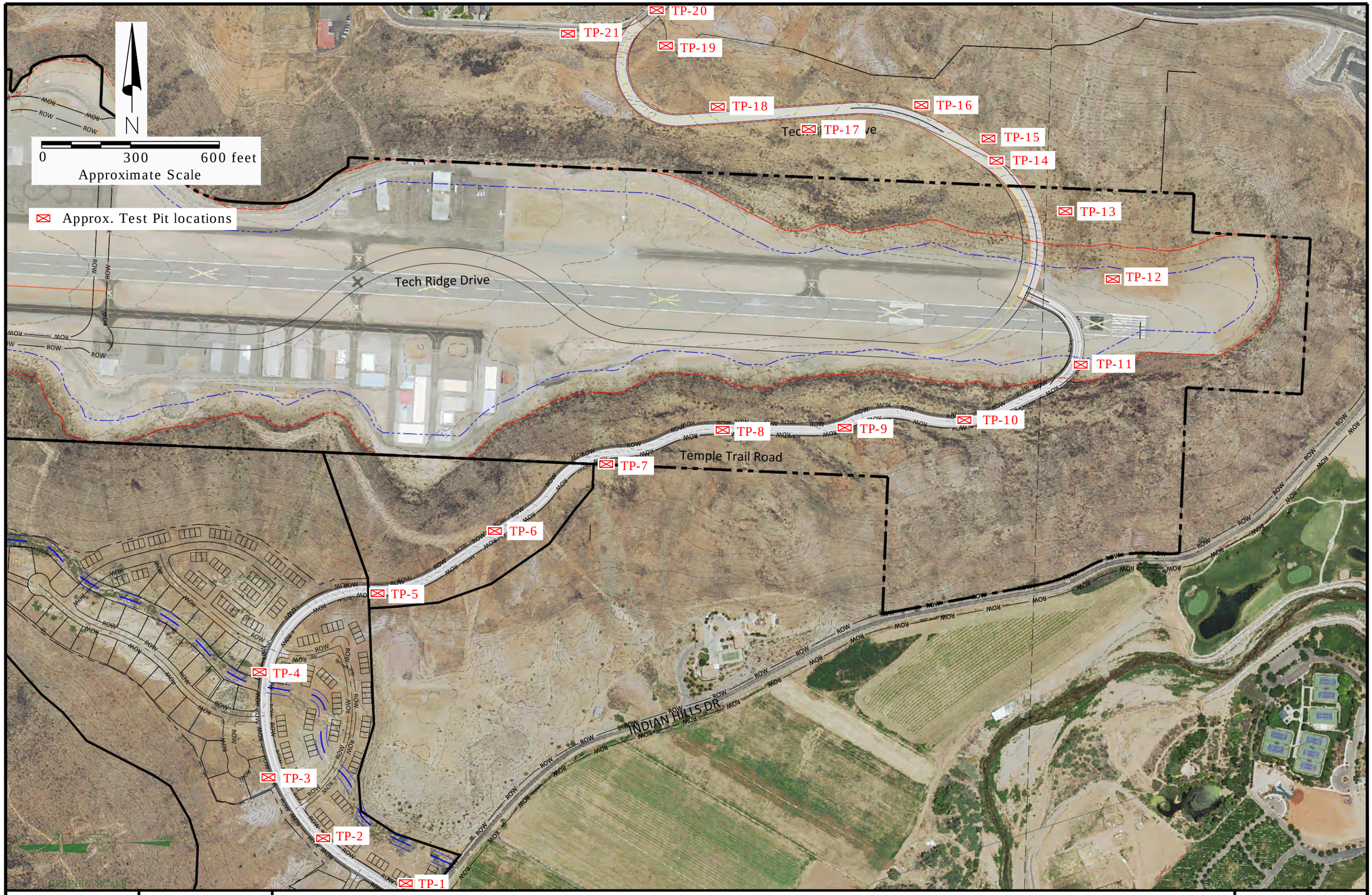
Explanation of Symbols and Geologic Units in Area of Proposed Road

Qal_1	-	Stream alluvium (Holocene)
Qac	-	Mixed alluvial and colluvial deposits (Holocene to upper Pleistocene)
Qeca	-	Eolian and alluvial deposits (Holocene to lower Pleistocene)
Qat_2	-	Alluvial-terrace deposits (Holocene)
Qat_3	-	Alluvial-terrace deposits (late Pleistocene)
Qmt	-	Talus deposits (Holocene to upper Pleistocene)
Qms	-	Landslide deposits (Holocene to middle Pleistocene)
Qbcb	-	Cedar Bench lava flow (lower Pleistocene)
Jmw	-	Whitmore Point Member of the Moenave Formation (Lower Jurassic)
JTrmd	-	Dinosaur Canyon Member of the Moenave Formation (Lower Jurassic)
Trcp	-	Petrified Forest Member of the Chinle Formation (Upper Triassic)
		Lineation within the landslide deposits
		Approximate location of proposed access roads

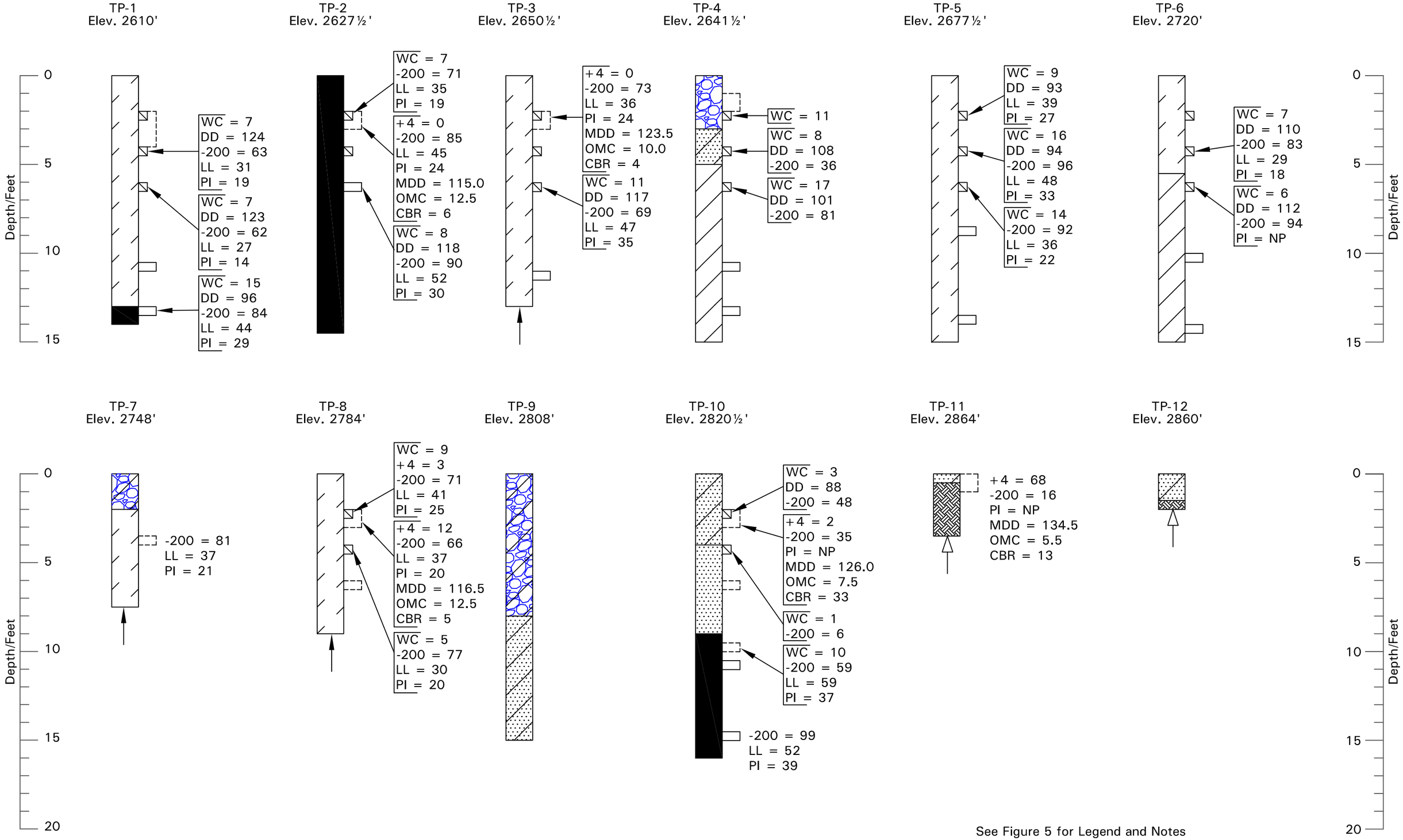
TECH RIDGE SOUTH ACCESS ROAD
ST. GEORGE, UTAH

Map taken from Hayden, J.M. and Willis, G.C., 2011; Geologic map of the St George quadrangle, Washington County, Utah, Utah Geological Survey Map 251DM.

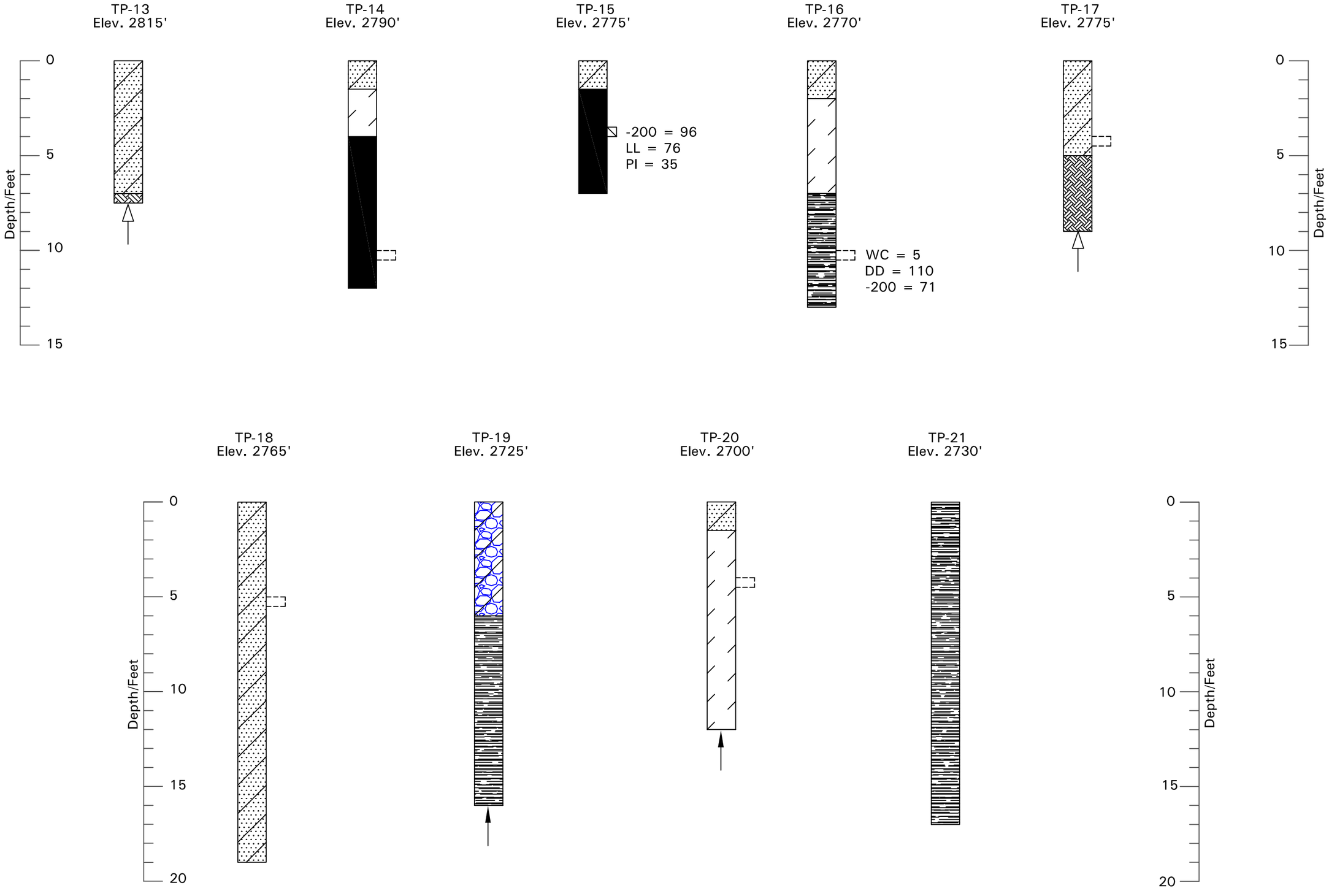
2180295	AGEC	Vicinity and Geologic Map	Figure 1



2180295	AGEC	Test Pit Locations	Figure 2



See Figure 5 for Legend and Notes



See Figure 5 for Legend and Notes

LEGEND:

Lean Clay (CL); medium stiff to very stiff, moist, medium plastic, contains varied amounts of sand, gravel, and boulders (1 to 4 feet in size), red-brown to brown with white mottles.

Silt (ML); medium stiff to stiff, slightly moist to moist, contains various amounts of sand, reddish brown.

Silty Sand (SM); loose to medium dense, dry, fine to medium grained, contains occasional gravel, cobbles and boulders (1 to 4 feet in size), light reddish brown to brown.

Well Graded Sand with Silt (SW-SM); medium dense, dry, contains gravel, brown.

Silty Gravel with Sand (GM); medium dense to dense, dry to moist, light brown to brown.

Basalt; moderately hard to very hard, dry, highly fractured near surface, black.

Mudstone; soft to moderately hard, dry to moist, medium to highly plastic, grey to purple.

Shale Bedrock; soft to hard, dry to slightly moist, interbedded with layers of siltstone and claystone, dark brown to dark red.

Indicates relatively undisturbed hand drive sample taken.

Indicates relatively undisturbed block sample taken.

Indicates disturbed sample taken.

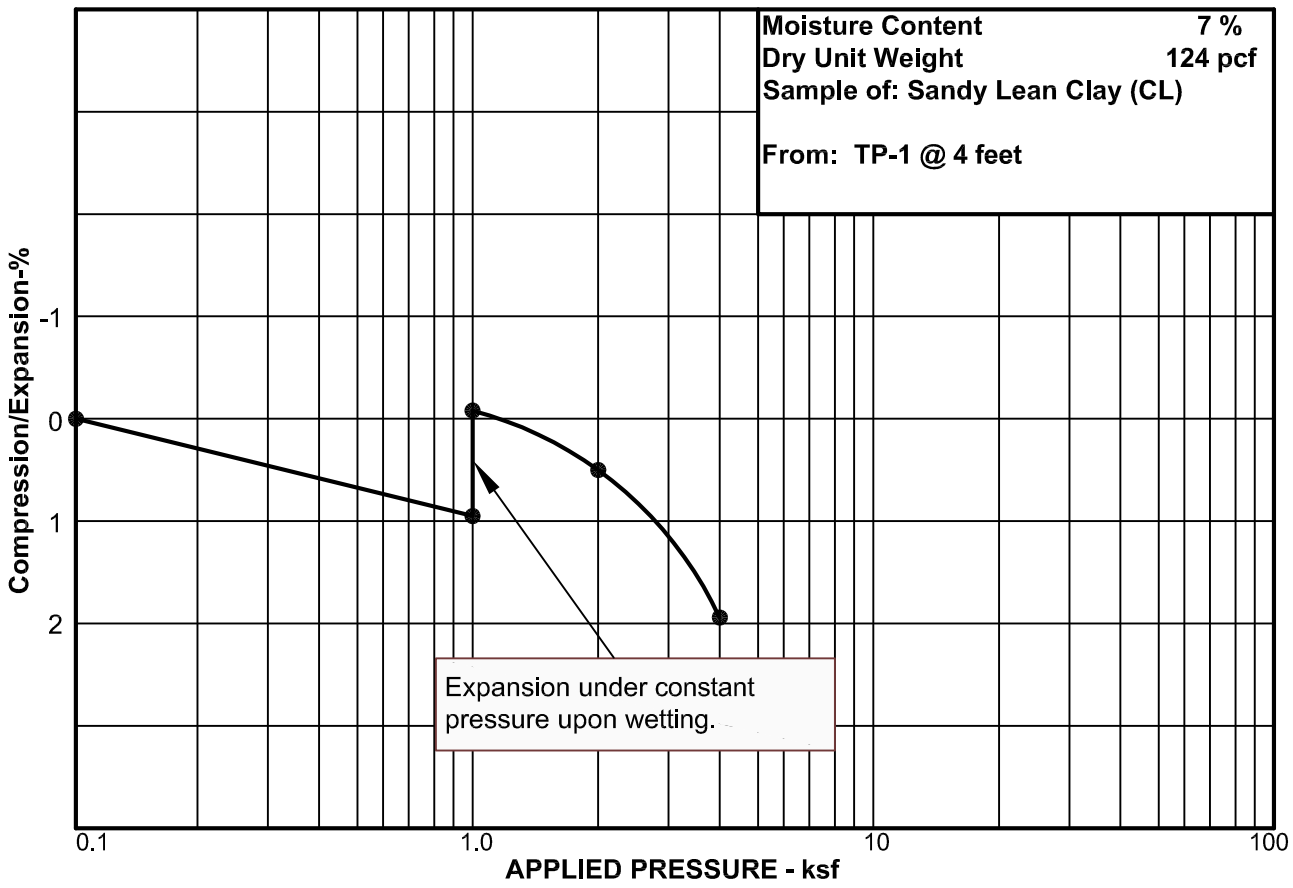
Indicates practical backhoe refusal on stiff clay and boulders or shale bedrock.

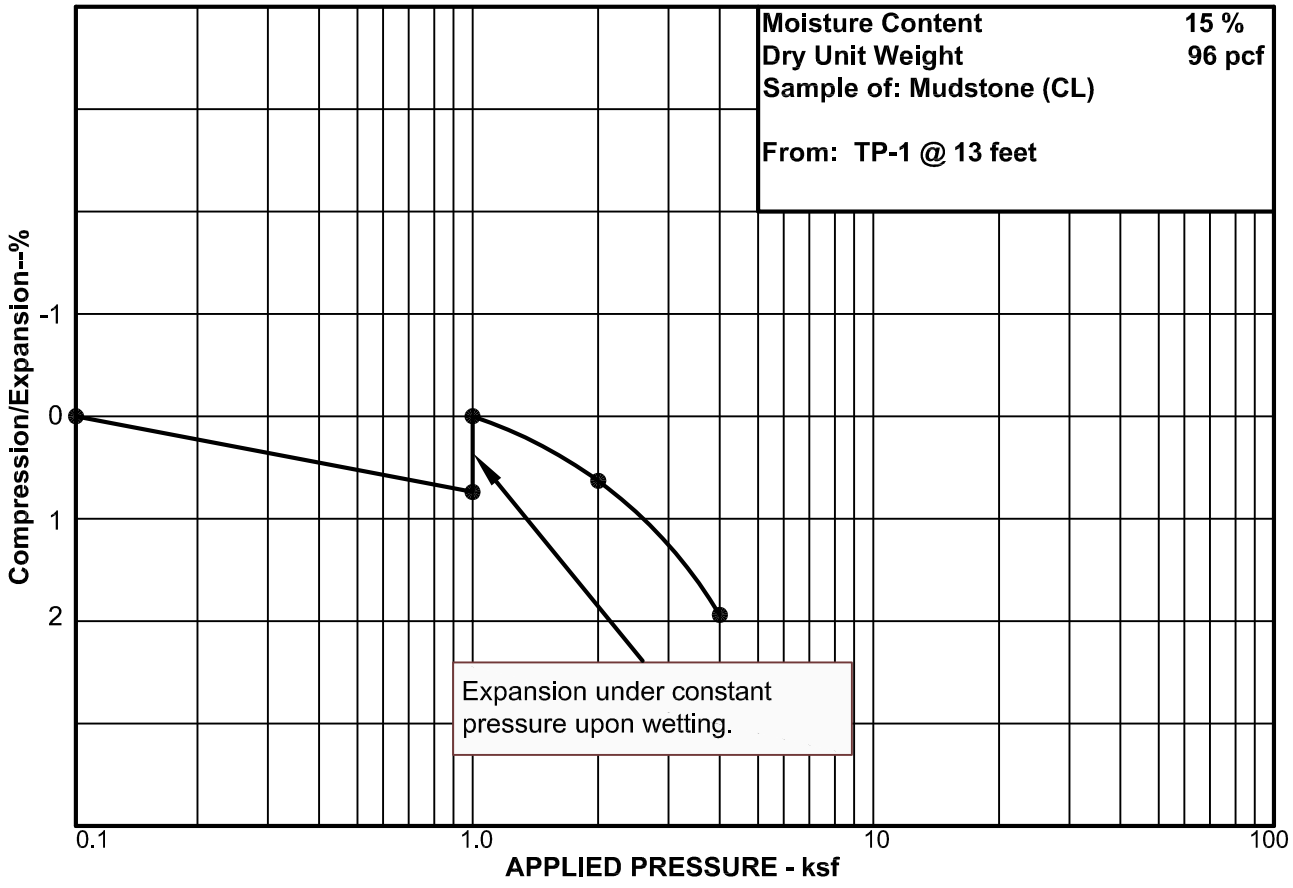
Indicates practical backhoe refusal on basalt.

NOTES:

1. Test pits TP-1 through TP-13 were excavated on August 8 and 9, 2018 and test pits TP-14 through TP-21 were excavated on August of 1998 with a trackhoe.
2. The locations and elevations of test pits TP-1 through TP-11 were measured using roadway centerline stakes, which were located using GPS by others.
3. The locations of test pits TP-12 through TP-21 were located by pacing from features shown on Figure 2. The elevations of test pits TP-12 through TP-21 were interpolated between contours shown on Figure 2.
4. The test pit locations and elevations should be considered accurate only to the degree implied by the method used.
5. The lines between the materials shown on the test pit logs represent the approximate boundaries between material types and the transitions may be gradual.
6. Free water was not encountered in the test pits at the time of excavation.
7. WC = water content (%);
   DD = dry density (pcf);
   +4 = percent retained on the No. 4 sieve;
   -200 = percent passing No. 200 sieve;
   LL = liquid limit (%);
   PI = plasticity index (%);
   NP = non-plastic;
   MDD = maximum dry density (pcf);
   OMC = optimum moisture content (%);
   CBR = california bearing ratio (%).

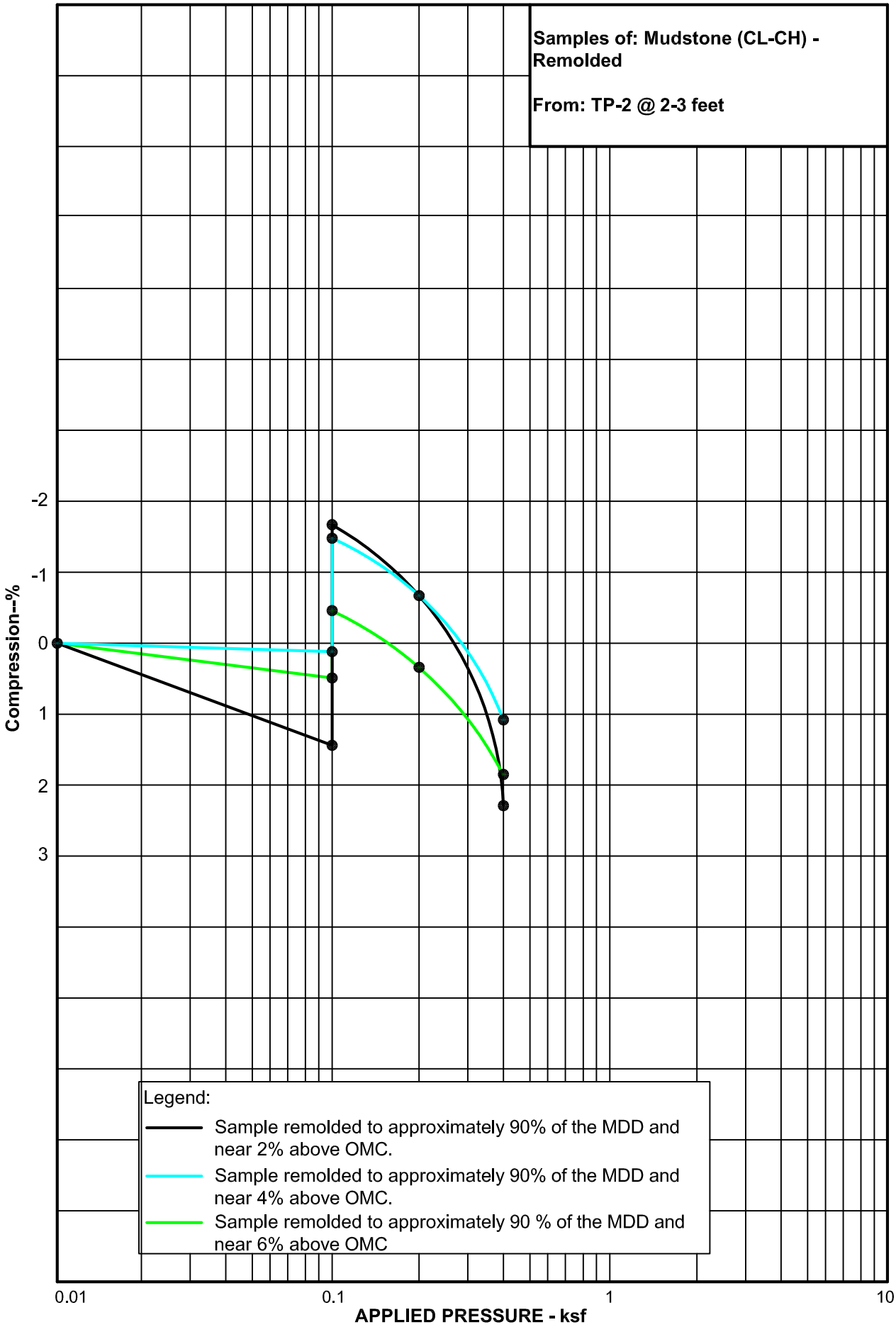
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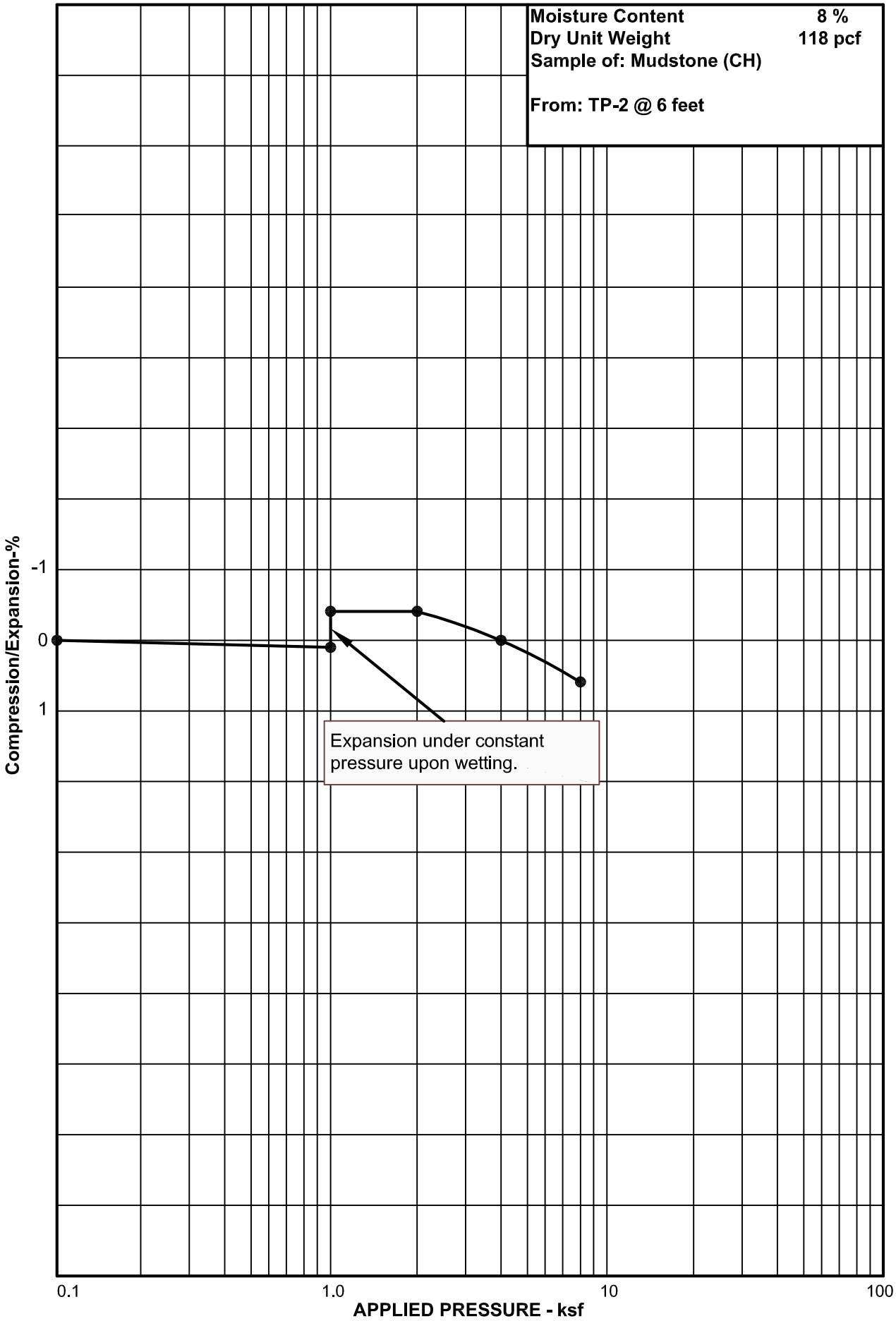
Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 6**

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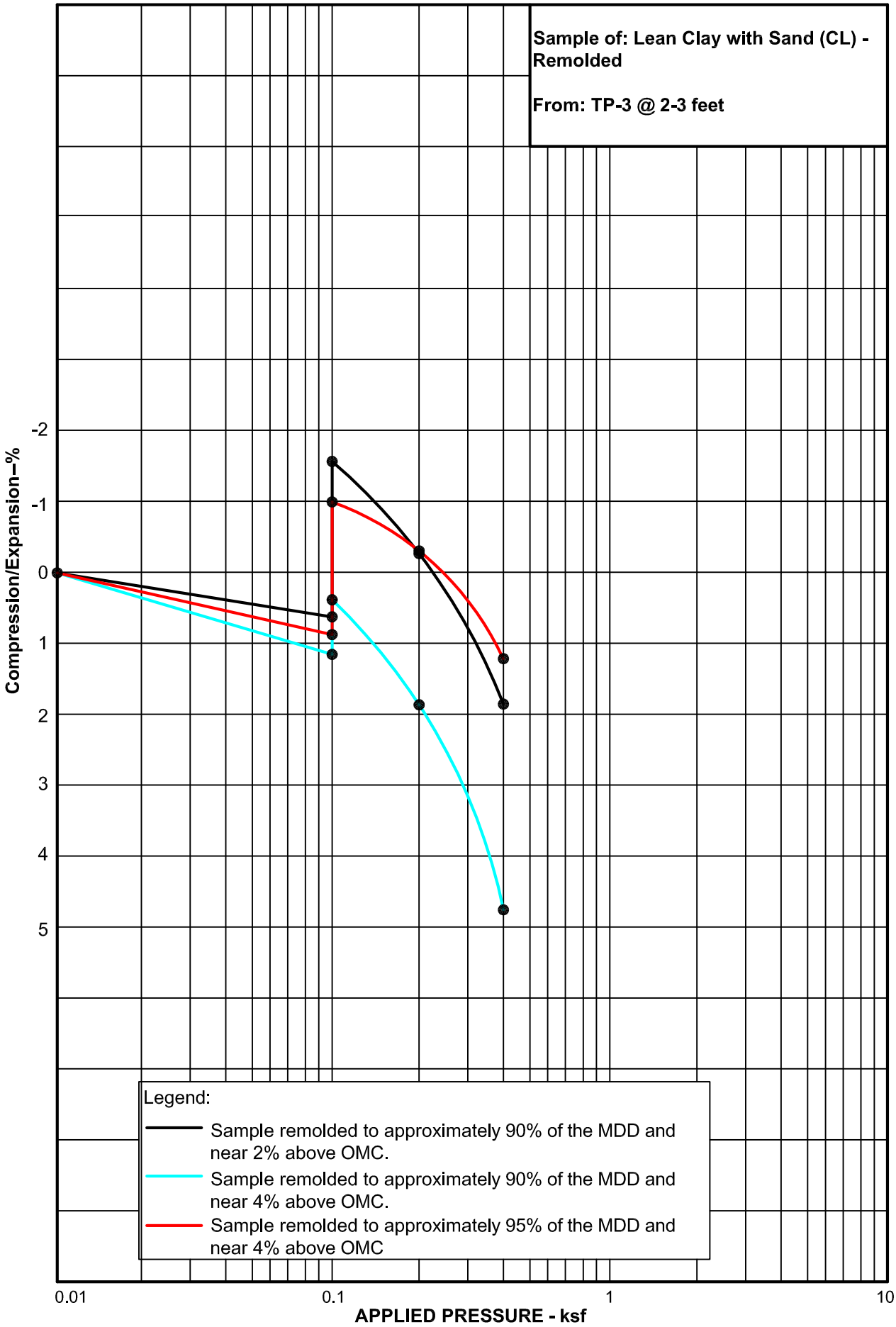
Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 7**

Applied Geotechnical Engineering Consultants, Inc.



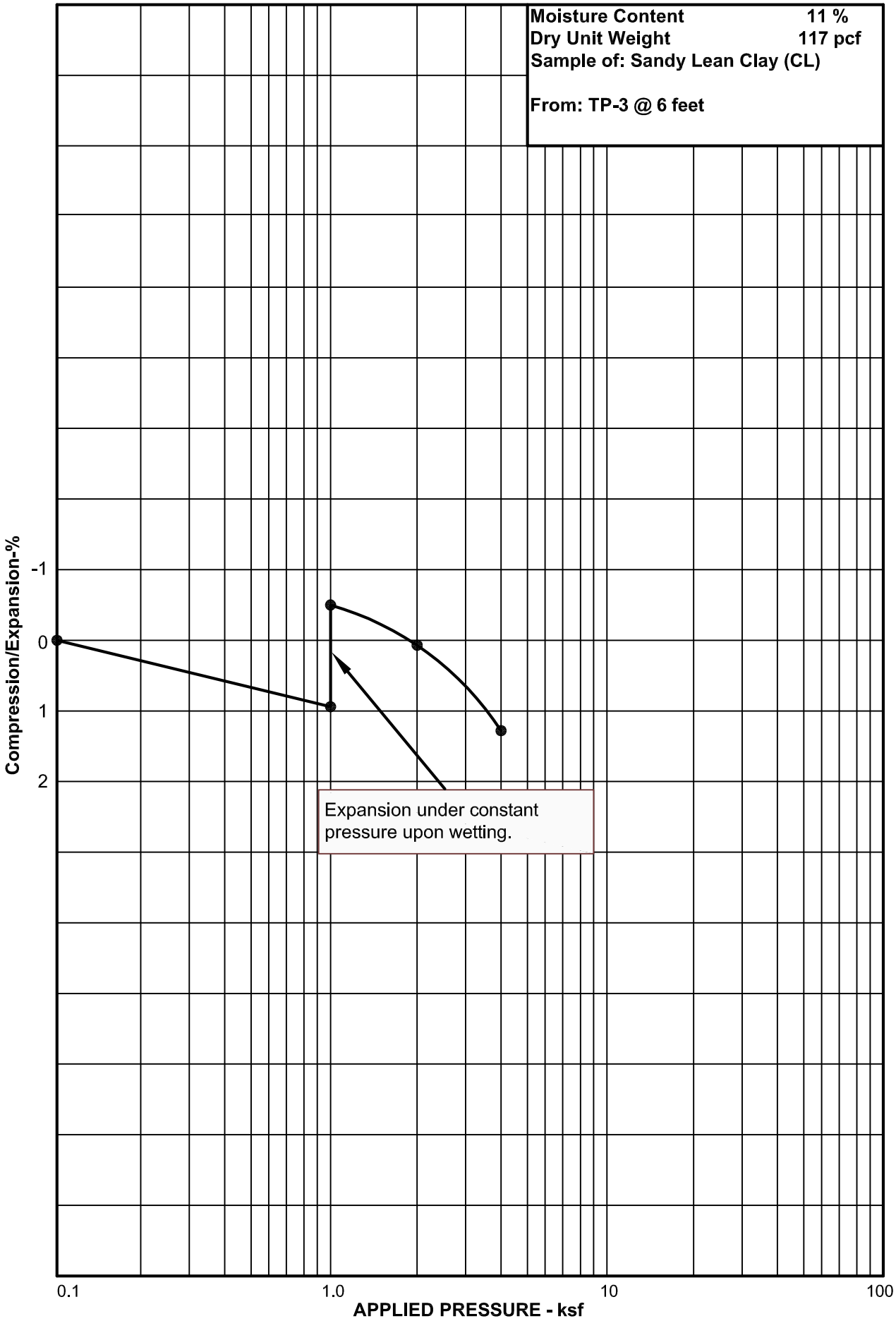
Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 8**

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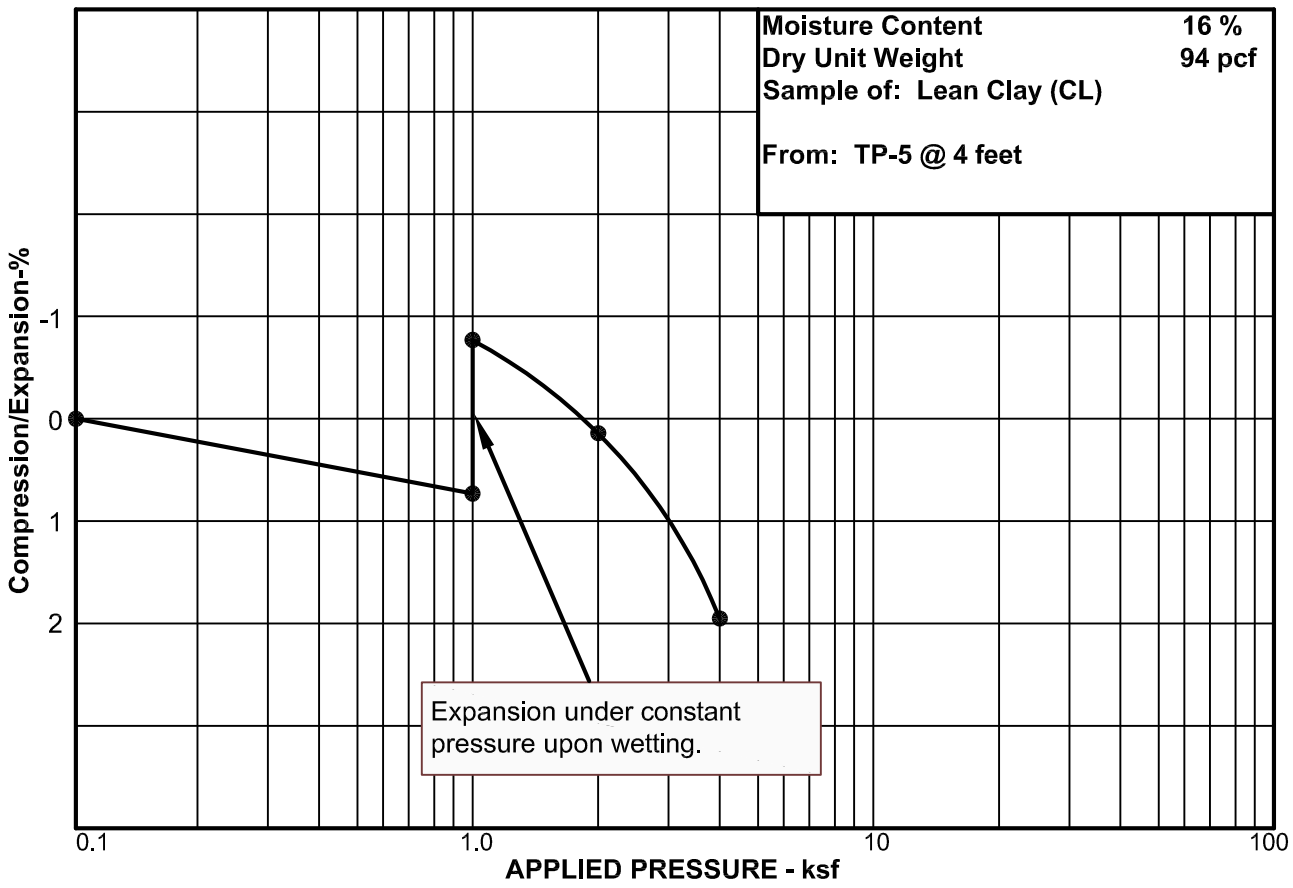
Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 9**

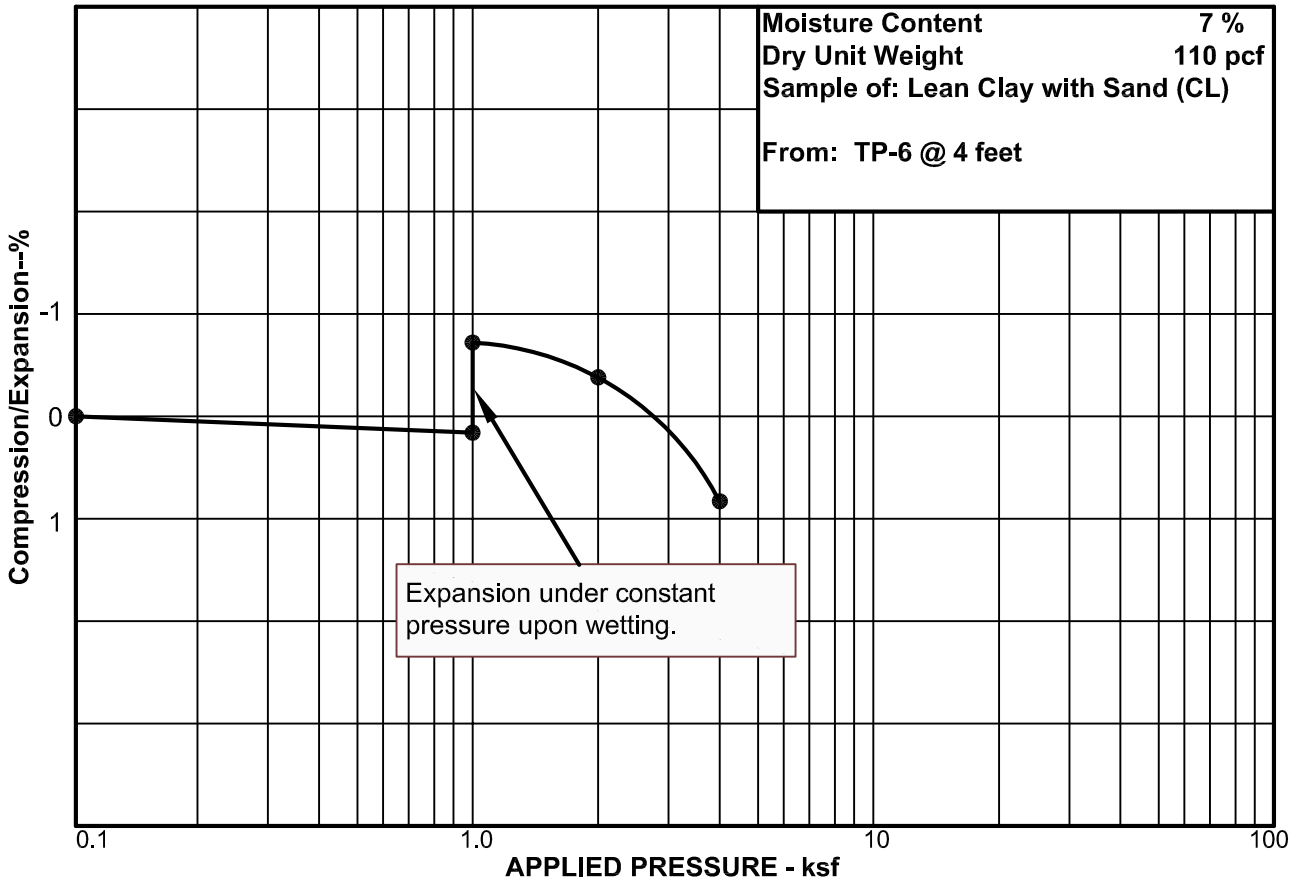
Applied Geotechnical Engineering Consultants, Inc.



Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 10**

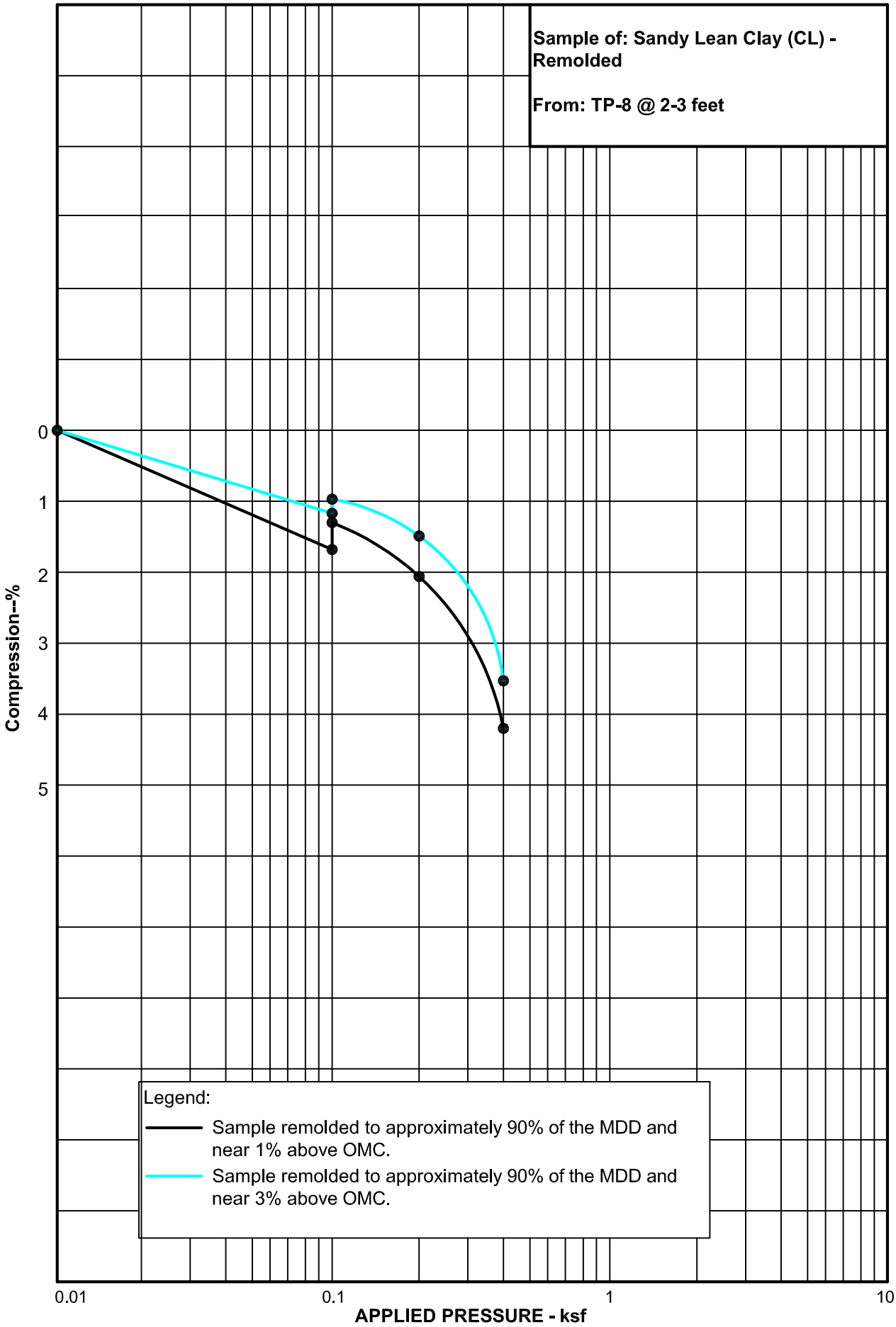
Applied Geotechnical Engineering Consultants, Inc.





Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 11**

Applied Geotechnical Engineering Consultants, Inc.

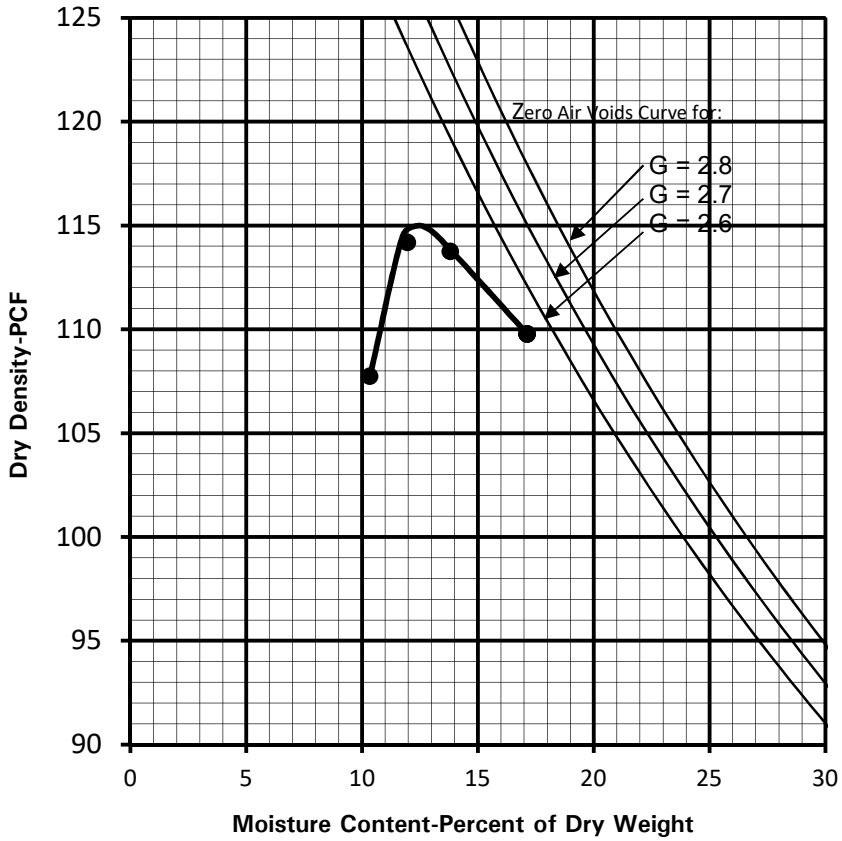


Project No. 2180295 **CONSOLIDATION TEST RESULTS** **Figure 12**

AGEC

Applied GeoTech

Project: 300 West (Tech Ridge South Access Road)



Sample Date:	8/14/18
Sample No.	180815G
Maximum Dry Density:	115.0
Optimum Moisture:	12.5
Atterberg Limits	
Liquid Limit:	45%
Plasticity Index:	24%
Gradation	
Gravel:	0%
Sand:	15%
Silt & Clay:	85%

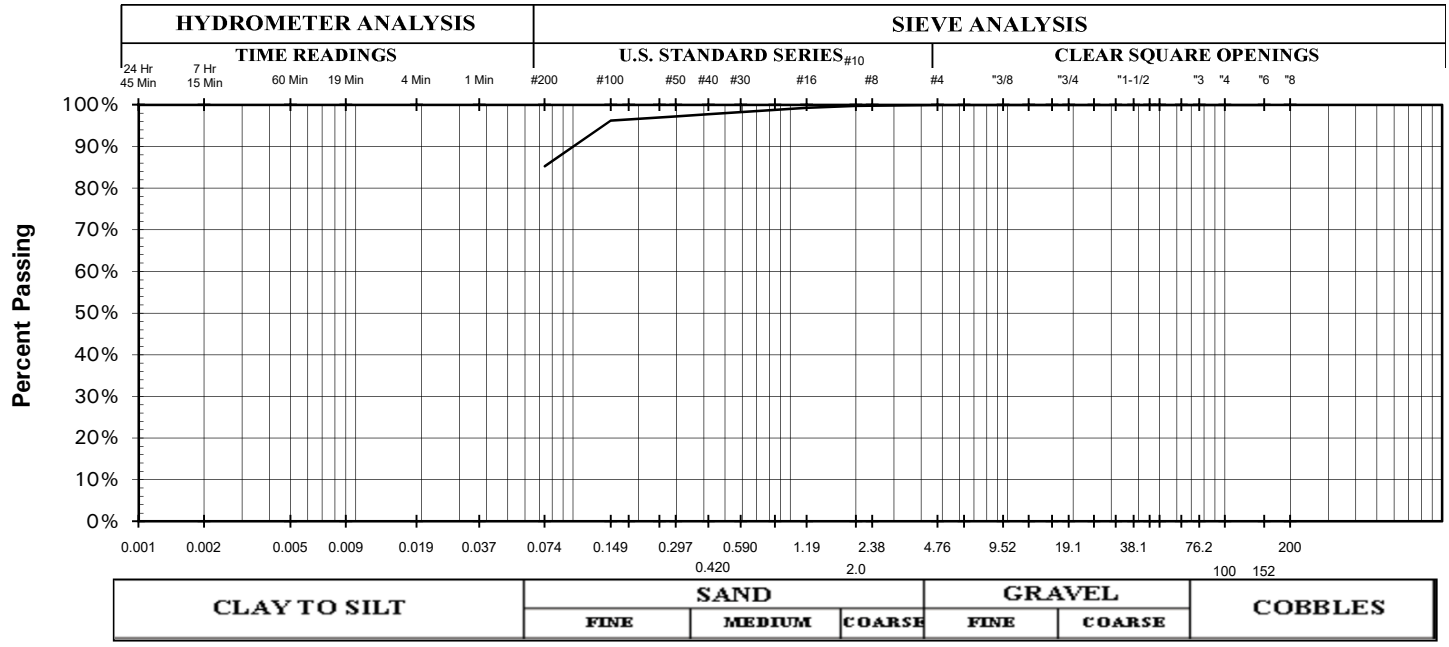
Moisture - Density Relationship Test Procedure: ASTM D-1557 B

Reviewed By: BI

Sample Description: Mudstone - lean clay (CL)

AASHTO Classification: A-7-6

Sample Location: TP-2 @ 2-3'



GRADATION AND MOISTURE-DENSITY RELATIONSHIP RESULTS

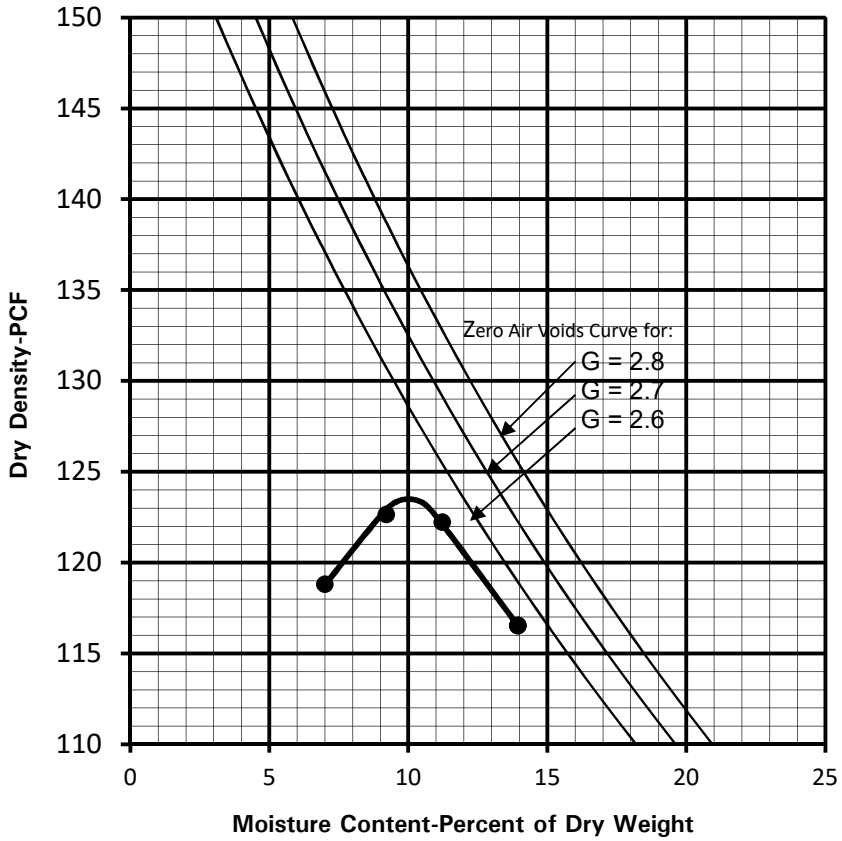
Project No.: 2180295

Figure: 13

AGEC

Applied GeoTech

Project: 300 West (Tech Ridge South Access Road)



Sample Date:	8/14/18
Sample No.	180816A
Maximum Dry Density:	123.5
Optimum Moisture:	10.0
Atterberg Limits	
Liquid Limit:	36%
Plasticity Index:	24%
Gradation	
Gravel:	0%
Sand:	27%
Silt & Clay:	73%

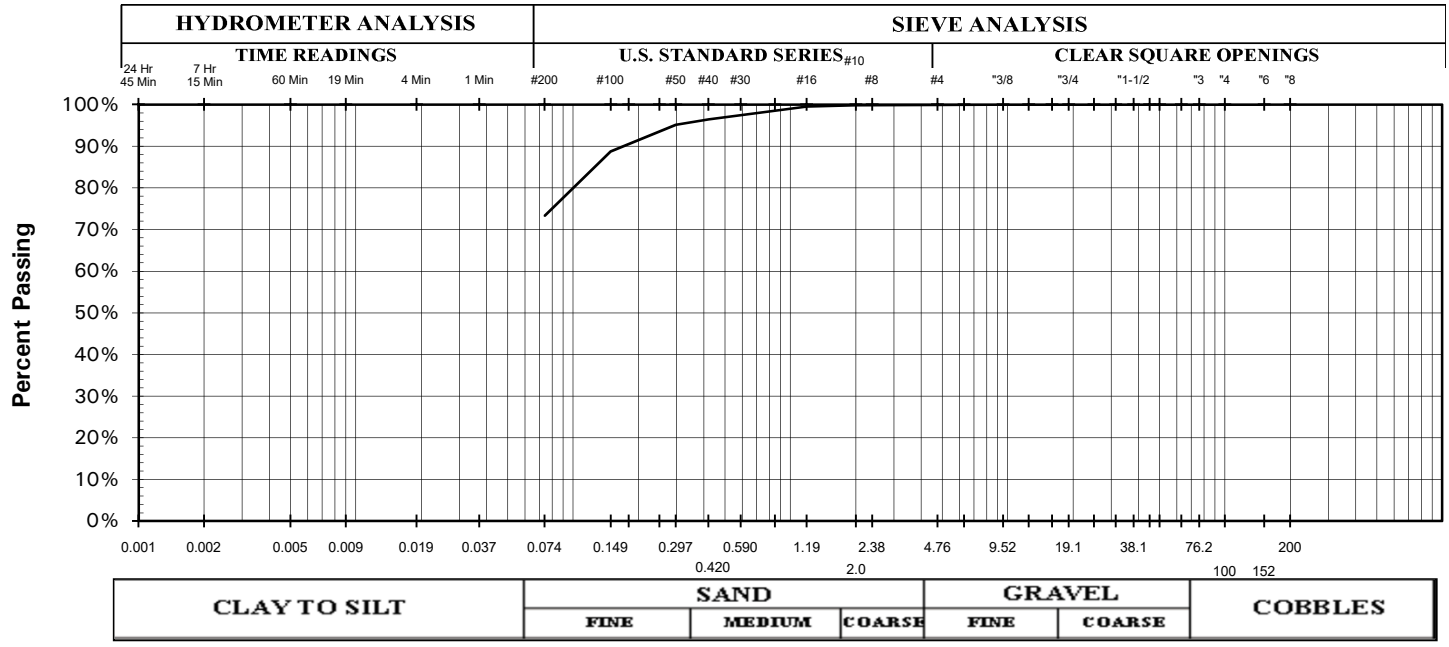
Moisture - Density Relationship Test Procedure: ASTM D-1557 B

Reviewed By: BI

USCS Classification: lean clay with sand (CL)

AASHTO Classification: A-6

Sample Location: TP-3 @ 2-3'



GRADATION AND MOISTURE-DENSITY RELATIONSHIP RESULTS

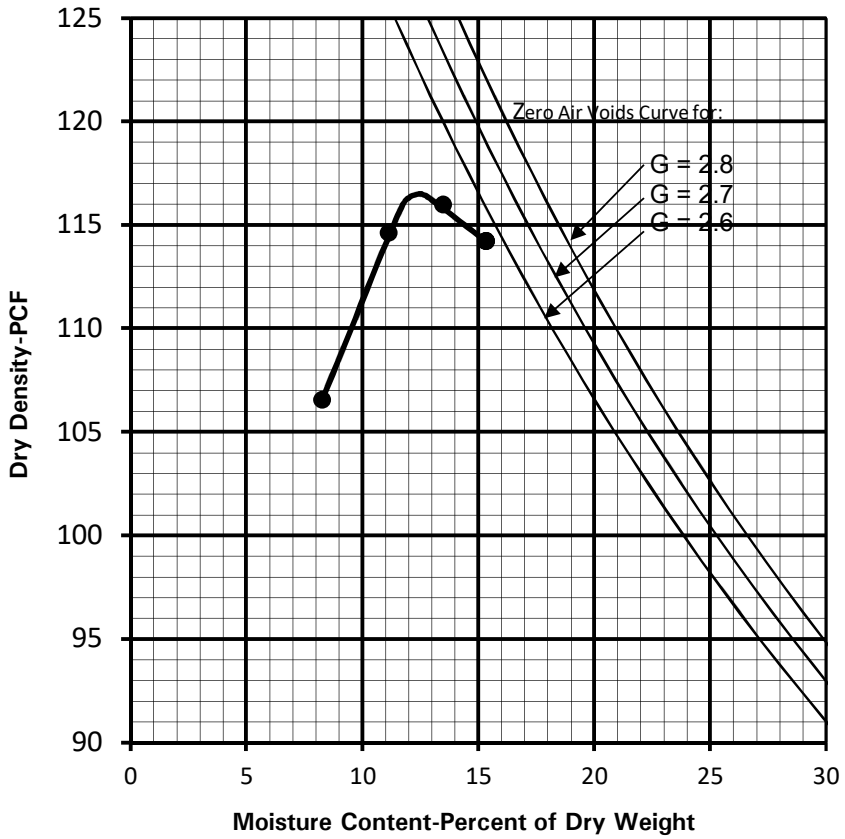
Project No.: 2180295

Figure: 14

AGEC

Applied GeoTech

Project: 300 West (Tech Ridge South Access Road)



Sample Date:	8/14/18
Sample No.	180816b
Maximum Dry Density:	116.5
Optimum Moisture:	12.5
Atterberg Limits	
Liquid Limit:	37%
Plasticity Index:	20%
Gradation	
Gravel:	12%
Sand:	22%
Silt & Clay:	66%

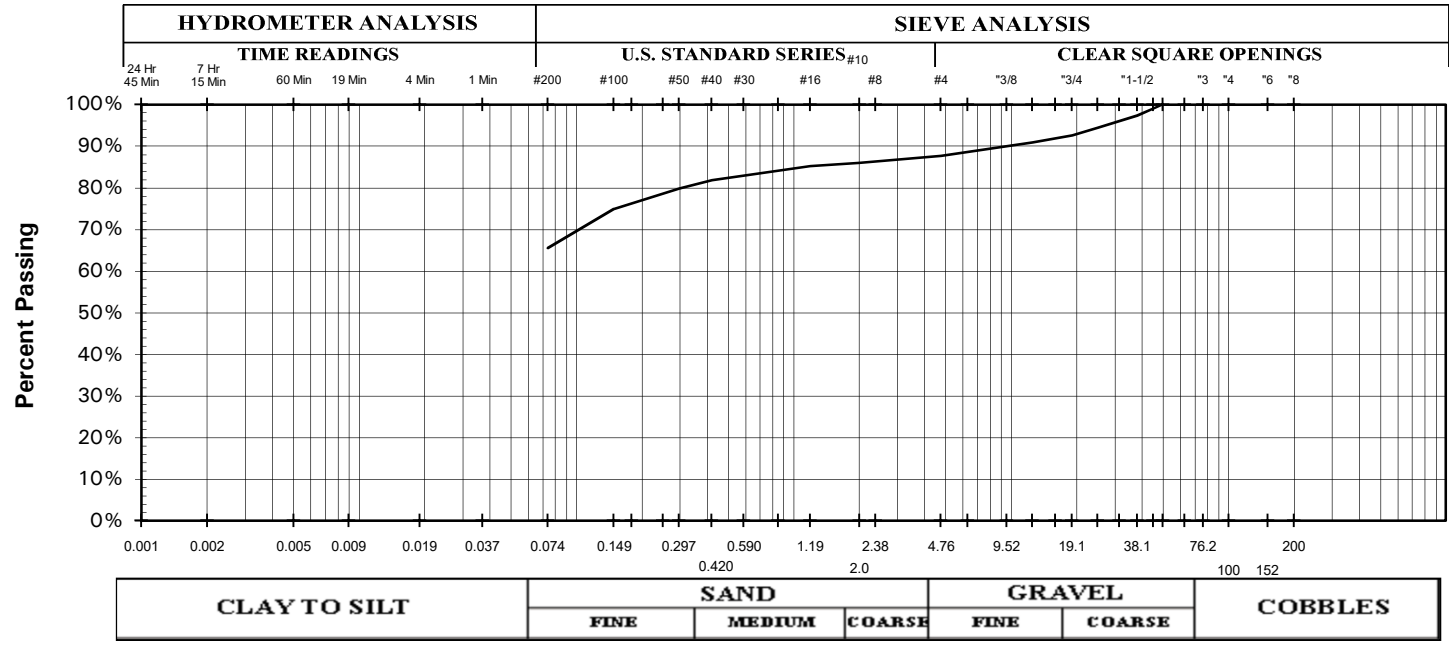
Moisture - Density Relationship Test Procedure: ASTM D-1557 B

Reviewed By: BI

Sample Description: sandy lean clay (CL)

AASHTO Classification: A-6

Sample Location: TP-8 @ 2-3'



GRADATION AND MOISTURE-DENSITY RELATIONSHIP RESULTS

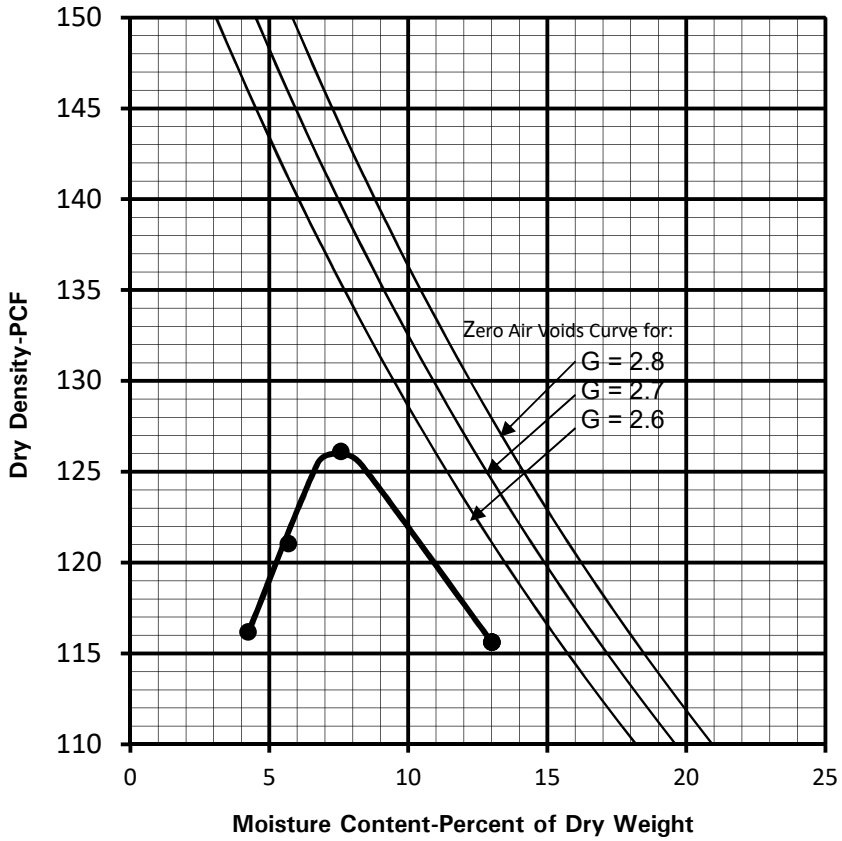
Project No.: 2180295

Figure: 15

AGEC

Applied GeoTech

Project: 300 West (Tech Ridge South Access Road)



Sample Date:	8/14/18
Sample No.	180816E
Maximum Dry Density:	126.0
Optimum Moisture:	7.5

Atterberg Limits

Liquid Limit:	
Plasticity Index:	Non-Plastic

Gradation

Gravel:	2%
Sand:	63%
Silt & Clay:	35%

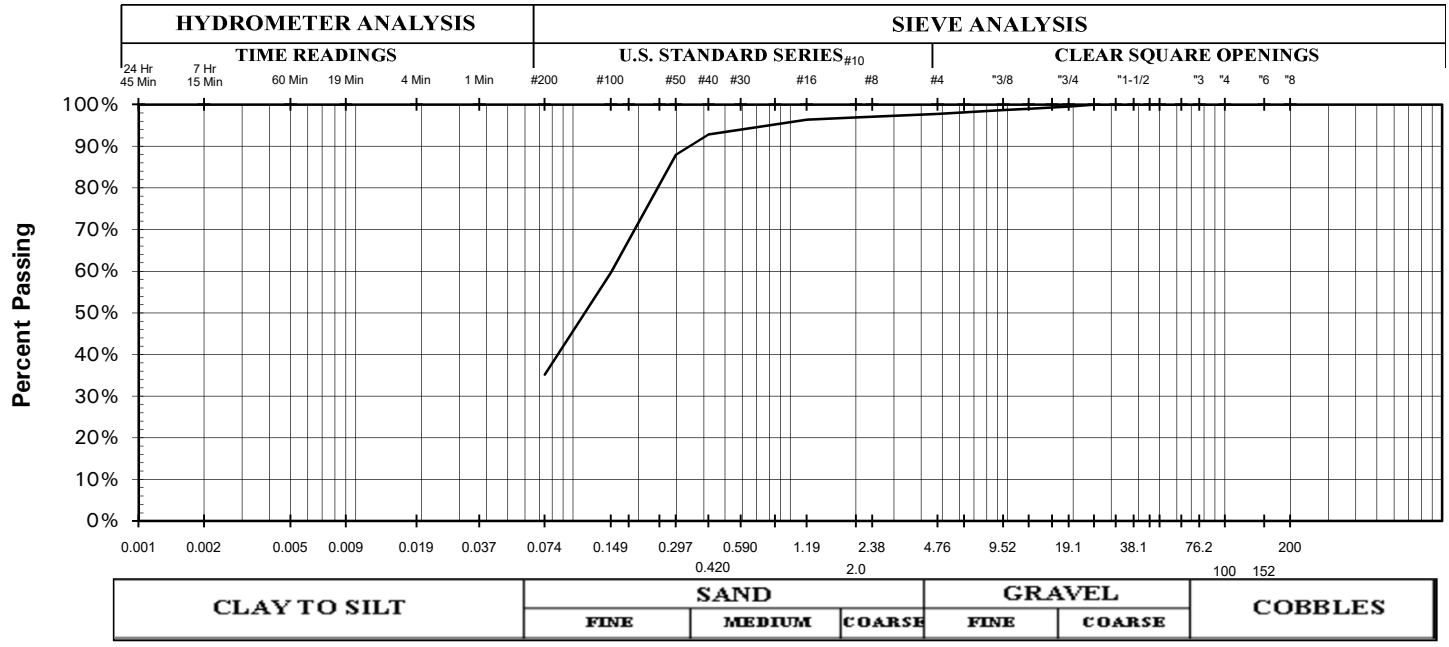
Moisture - Density Relationship Test Procedure: ASTM D-1557 B

Reviewed By: BI

USCS Classification: silty sand (SM)

AASHTO Classification: A-4

Sample Location: TP-10 @ 2-3'



GRADATION AND MOISTURE-DENSITY RELATIONSHIP RESULTS

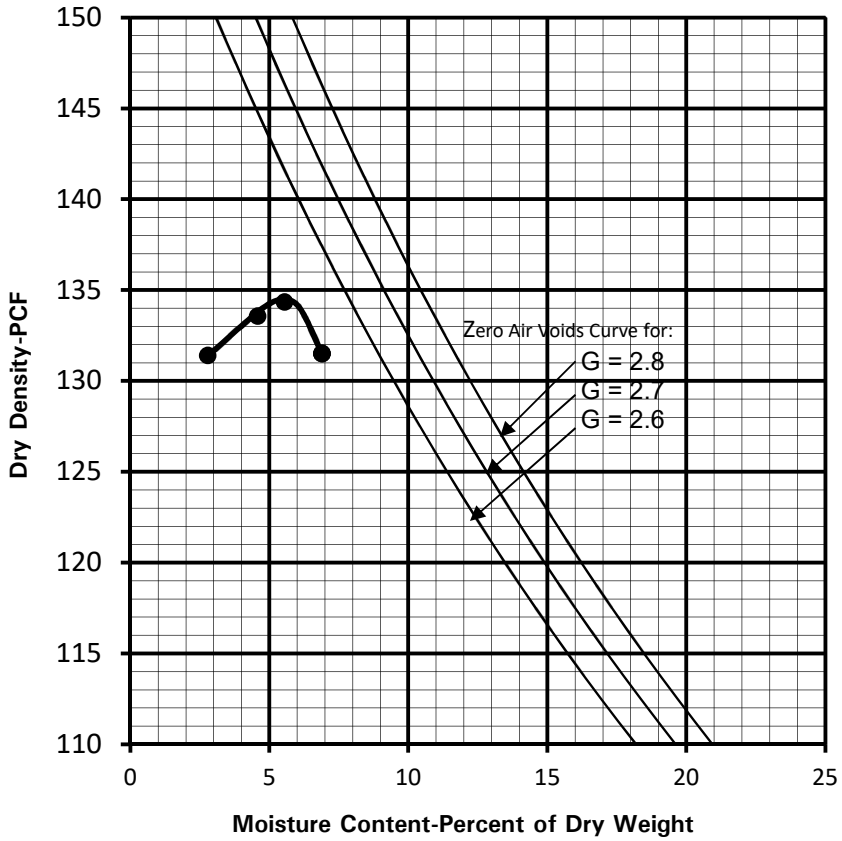
Project No.: 2180295

Figure: 16

AGEC

Applied GeoTech

Project: 300 West



Sample Date:	8/14/18
Sample No.	180816F
Maximum Dry Density:	134.5
Optimum Moisture:	5.5

Atterberg Limits

Liquid Limit:	
Plasticity Index:	Non-Plastic

Gradation

Gravel:	68%
Sand:	16%
Silt & Clay:	16%

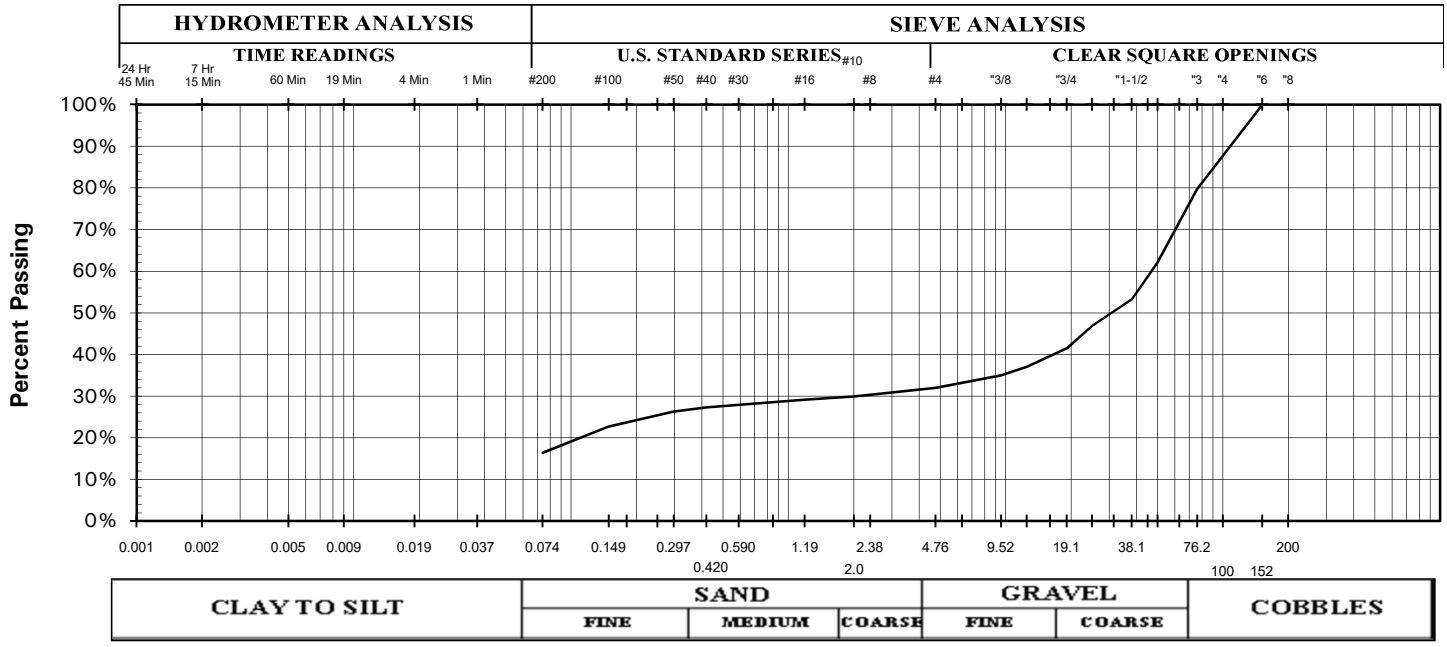
Moisture - Density Relationship Test Procedure: ASTM D-1557 B

Reviewed By: TT

USCS Classification: silty gravel with sand (GM) *Rock Corrected*

AASHTO Classification: A-1-b

Sample Location: TP-11 @ 0-1'

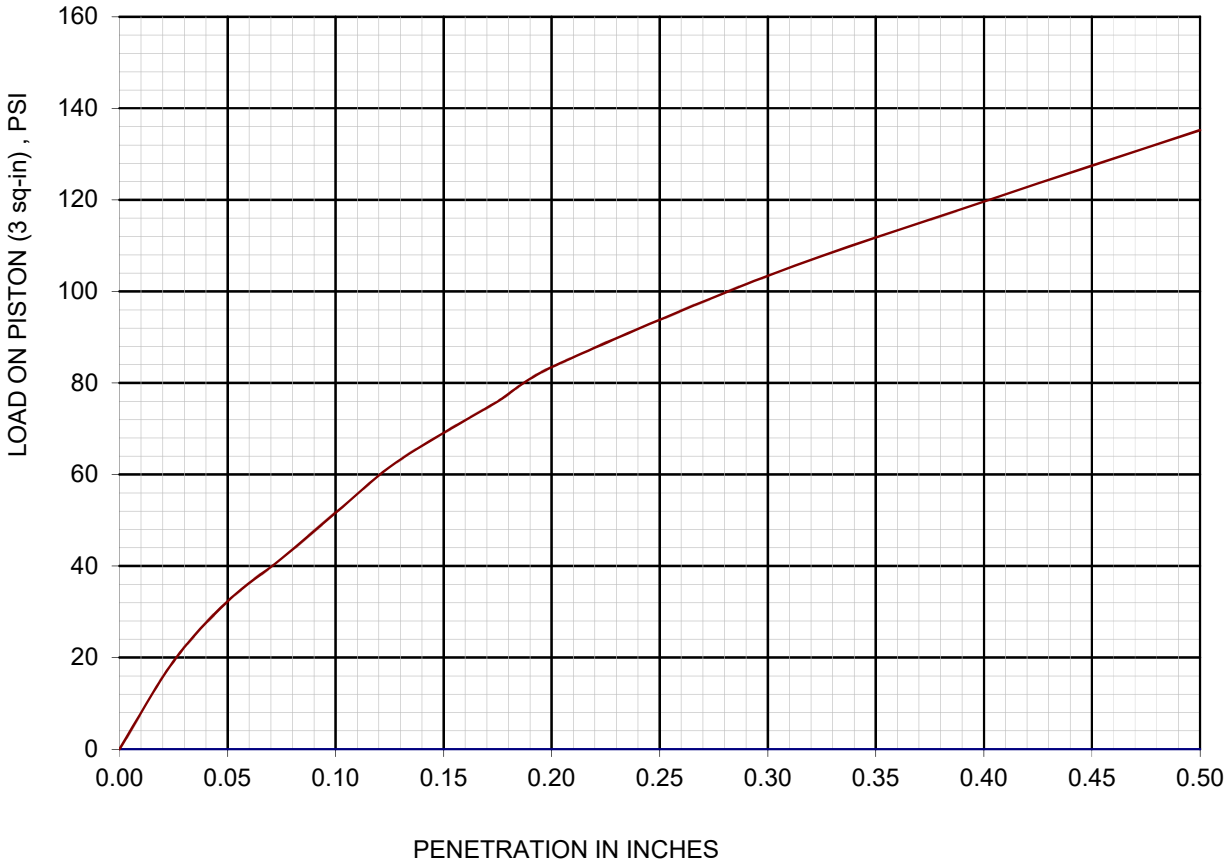


GRADATION AND MOISTURE-DENSITY RELATIONSHIP RESULTS

Project No.: 2180295

Figure: 17

AGEC
Applied GeoTech



Project 300 West **Sample Location** TP-2 @ 2-3'

Sample Classification (CL) lean clay - purple mudstone **AGEC Sample ID No.** A-082718

Method of sample preparation: Remolded to approximately 90% of the maximum dry density at the optimum moisture content +2 as per ASTM D-1557

Sample penetration after soaking for 96 hours

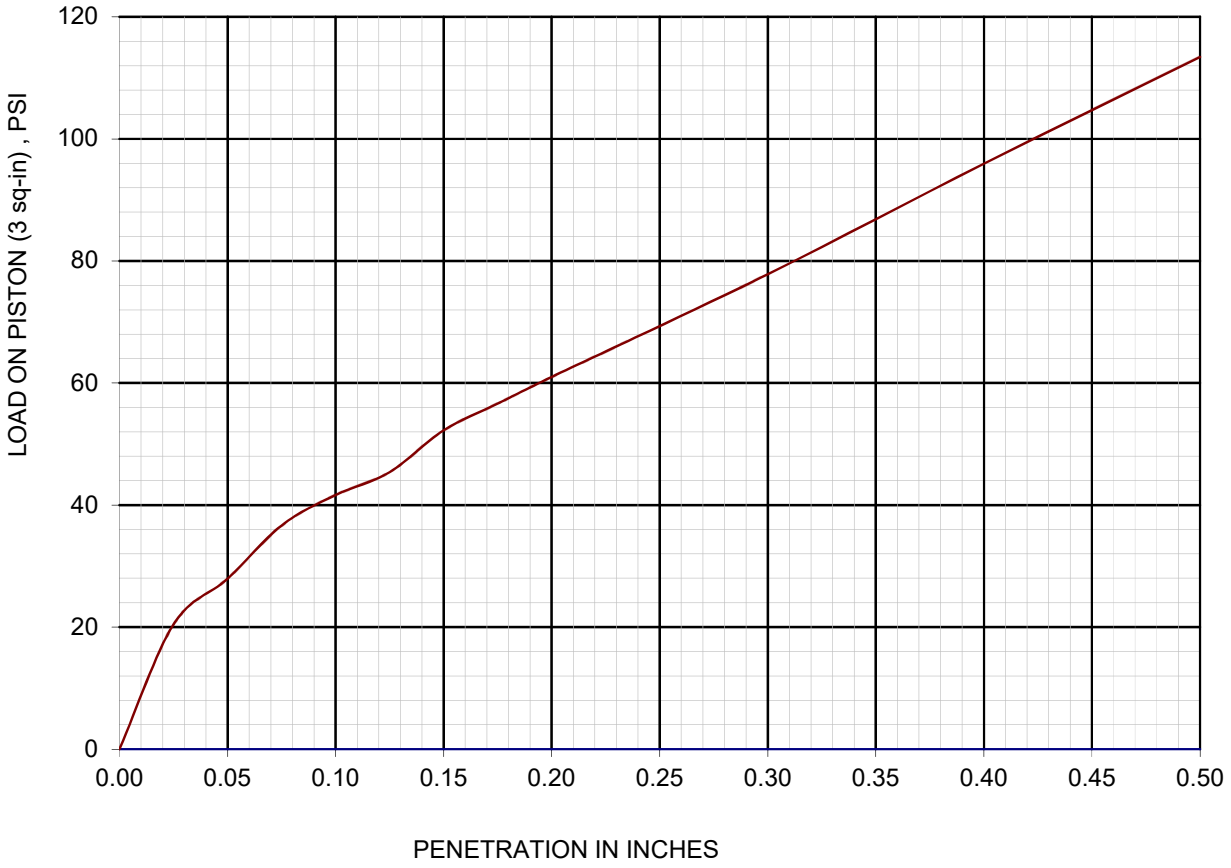
Dry Density:	as molded	103.0	pcf	**Moisture Content:**	as molded	14.1	percent
	after soaking	98.1	pcf		top 1-inch after soaking	26.0	percent
Swell:	after soaking	4.1	percent		average after soaking	25.3	percent

Comments CBR value taken at 0.2 inch penetration

Bearing Ratio of Sample, CBR = **6** percent **Surcharge** 30 lb

Proj. No. 2180295 **CALIFORNIA BEARING RATIO TEST RESULTS** Figure 18

AGEC
Applied GeoTech



Project 300 West **Sample Location** TP-3 @ 2-3'

Sample Classification (CL) lean clay with sand **AGEC Sample ID No.** B-082718

Method of sample preparation: Remolded to approximately 90% of the maximum dry density at the optimum moisture content +2% as per ASTM D-1557

Sample penetration after soaking for 96 hours

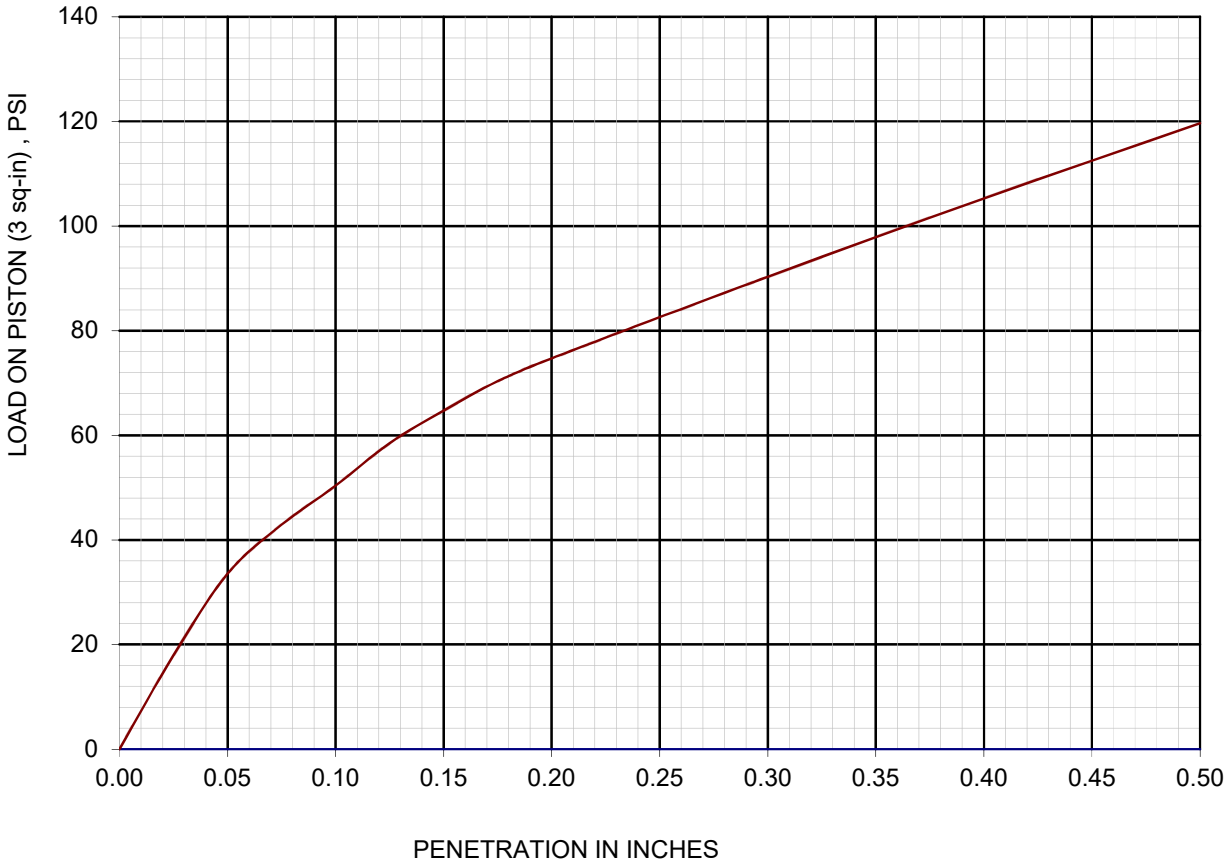
Dry Density:	as molded	113.6	pcf	**Moisture Content:**	as molded	12.0	percent
	after soaking	108.6	pcf		top 1-inch after soaking	23.1	percent
Swell:	after soaking	1.3	percent		average after soaking	20.0	percent

Comments CBR value taken at 0.2 inch penetration

Bearing Ratio of Sample, CBR = **4** percent **Surcharge** 30 lb

Proj. No. 2180295 **CALIFORNIA BEARING RATIO TEST RESULTS** Figure 19

AGEC
Applied GeoTech



Project 300 West **Sample Location** TP-8 @ 2-3'

Sample Classification (CL) sandy lean clay **AGEC Sample ID No.** C-082718

Method of sample preparation: Remolded to approximately 90% of the maximum dry density at the optimum moisture content +2% as per ASTM D-1557

Sample penetration after soaking for 96 hours

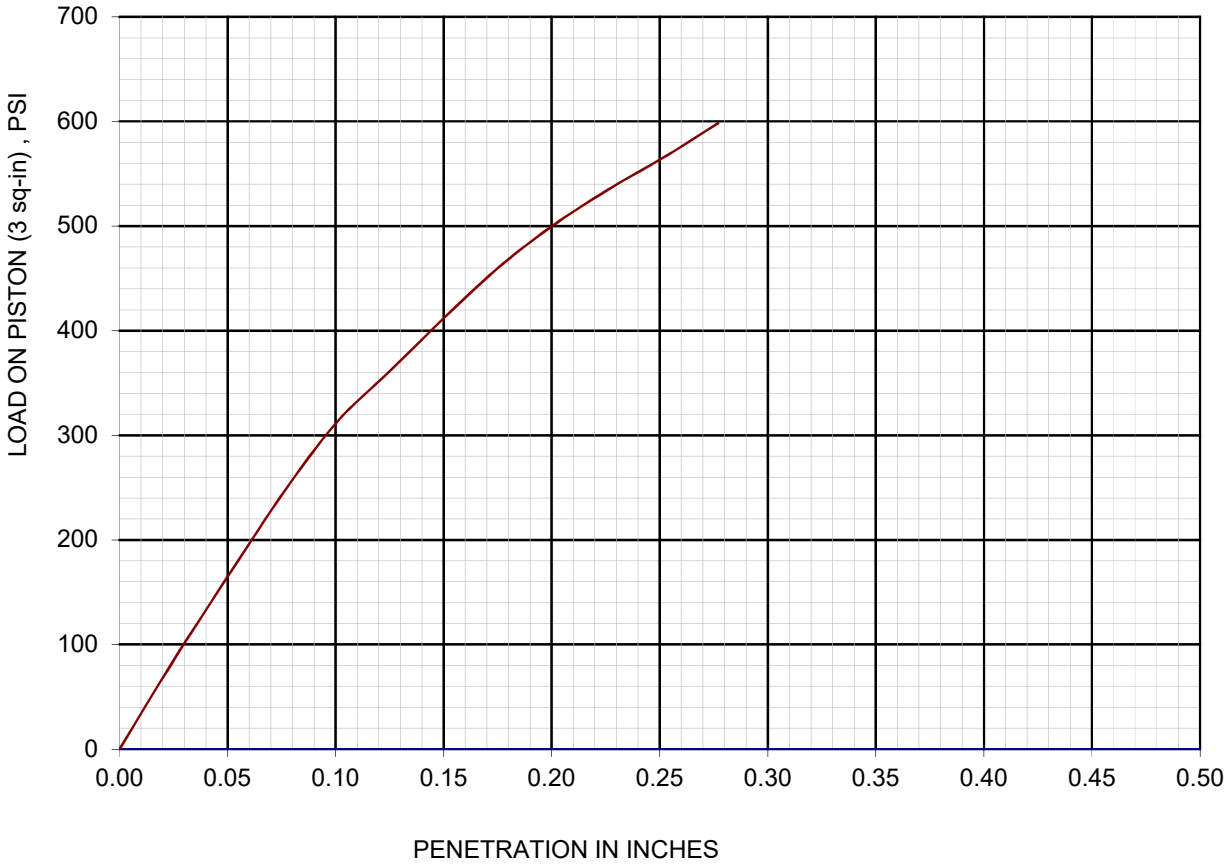
Dry Density:	as molded	104.5	pcf	**Moisture Content:**	as molded	14.5	percent
	after soaking	104.1	pcf		top 1-inch after soaking	21.7	percent
Swell:	after soaking	1.5	percent		average after soaking	18.9	percent

Comments CBR value taken at 0.2 inch penetration

Bearing Ratio of Sample, CBR = **5** percent **Surcharge** 30 lb

Proj. No. 2180295 **CALIFORNIA BEARING RATIO TEST RESULTS** Figure 20

AGEC
Applied GeoTech



Project 300 West **Sample Location** TP-10 @ 2-3'

Sample Classification (SM) Silty sand **AGEC Sample ID No.** D-082718

Method of sample preparation: Remolded to approximately 95% of the maximum dry density at the optimum moisture content as per ASTM D-1557

Sample penetration after soaking for 96 hours

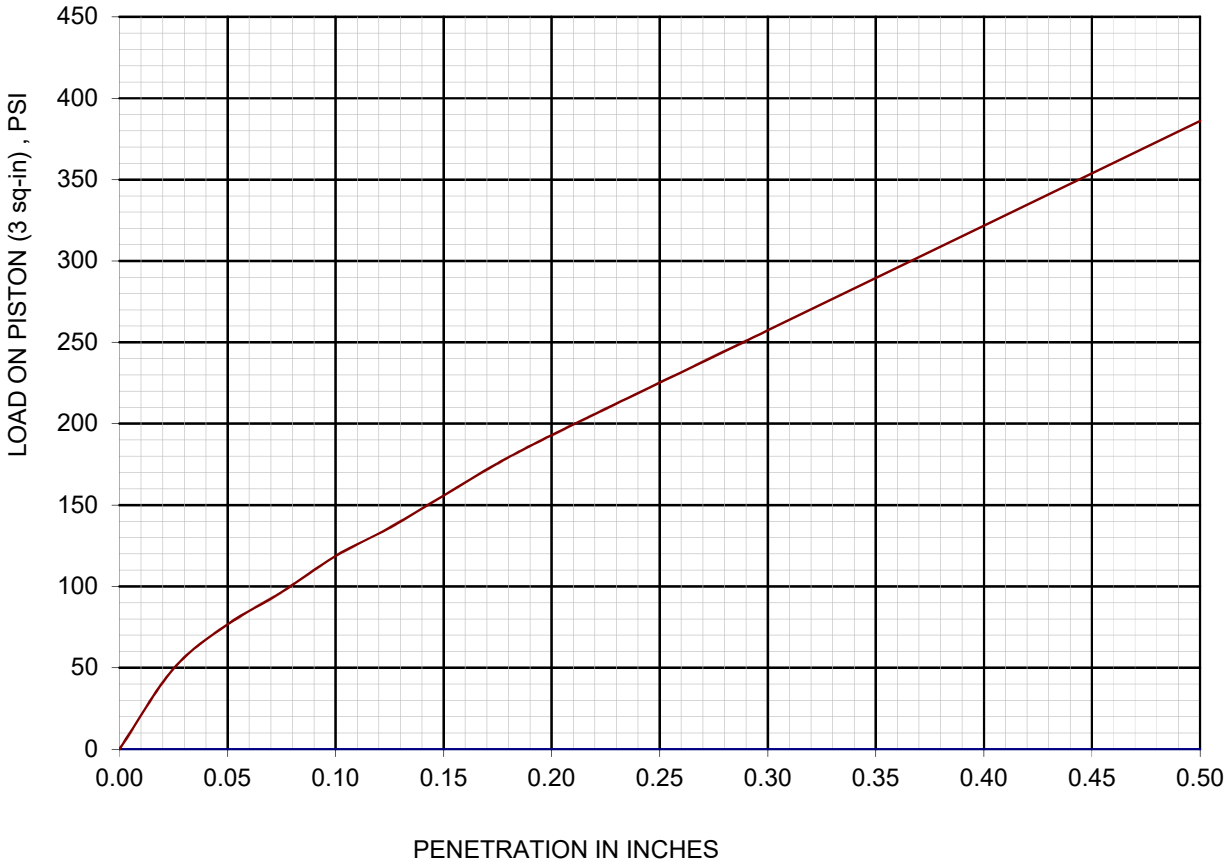
Dry Density:	as molded	122.2	pcf	**Moisture Content:**	as molded	7.4	percent
	after soaking	123.0	pcf		top 1-inch after soaking	10.3	percent
Swell:	after soaking	0.2	percent		average after soaking	10.5	percent

Comments CBR value taken at 0.2 inch penetration

Bearing Ratio of Sample, CBR = **33** percent **Surcharge** 10 lb

Proj. No. 2180295 **CALIFORNIA BEARING RATIO TEST RESULTS** Figure 21

AGEC
Applied GeoTech



Project 300 West **Sample Location** TP-11 @ 0-1'

Sample Classification Silty sand w/gravel - Basalt **AGEC Sample ID No.** E-082718

Method of sample preparation: Remolded to approximately 95% of the maximum dry density at the optimum moisture content as per ASTM D-1557

Sample penetration after soaking for 96 hours

Dry Density:	as molded	127.1	pcf	**Moisture Content:**	as molded	5.1	percent
	after soaking	122.6	pcf		top 1-inch after soaking	18.8	percent
Swell:	after soaking	1.6	percent		average after soaking	16.7	percent

Comments CBR value taken at 0.2 inch penetration

Bearing Ratio of Sample, CBR = 13 percent **Surcharge** 30 lb

Proj. No. 2180295 **CALIFORNIA BEARING RATIO TEST RESULTS** Figure 22

Applied Geotechnical Engineering Consultants, Inc.

Table 1 - Summary of Laboratory Test Results

Tech Ridge South Access Road

Project No. 2180295

Sample Location				Gradation			Atterberg Limits		Moisture-Density Relationship			
Test Pit No.	Depth (ft)	Natural Moisture Content (%)	Natural Dry Density (pcf)	Gravel (%)	Sand (%)	Silt/Clay (%)	Liquid Limit (%)	Plastic Index (%)	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	California Bearing Ratio (%)	Soil Type
TP-1	4	7	124			63	31	19				Sandy Lean Clay (CL)
TP-1	6	7	123			62	27	14				Sandy Lean Clay (CL)
TP-1	13	15	96			84	44	29				Mudstone
TP-2	2	7				71	35	19				Mudstone
TP-2	2-3			0	15	85	45	24	115.0	12.5	6	Mudstone
TP-2	6	8	118			90	52	30				Mudstone
TP-3	2-3			0	27	73	36	24	123.5	10.0	4	Lean Clay with Sand (CL)
TP-3	6	11	117			69	47	35				Sandy Lean Clay (CL)
TP-4	2	11										Silty Gravel with Sand (GM)
TP-4	4	8	108			36						Silty Sand (SM)
TP-4	6	17	101			81						Silt with Sand (ML)
TP-5	2	9	93				39	27				Lean Clay (CL)
TP-5	4	16	94			96	48	33				Lean Clay (CL)
TP-5	6	14				92	36	22				Lean Clay (CL)
TP-6	4	7	110			83	29	18				Lean Clay with Sand (CL)

Applied Geotechnical Engineering Consultants, Inc.

Table 1 - Summary of Laboratory Test Results

Tech Ridge South Access Road

Project No. 2180295

Sample Location				Gradation			Atterberg Limits		Moisture-Density Relationship			
Test Pit No.	Depth (ft)	Natural Moisture Content (%)	Natural Dry Density (pcf)	Gravel (%)	Sand (%)	Silt/Clay (%)	Liquid Limit (%)	Plastic Index (%)	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	California Bearing Ratio (%)	Soil Type
TP-6	6	6	112			94		NP				Silt (ML)
TP-7	3½					81	37	21				Lean Clay with Sand (CL)
TP-8	2	9		3	26	71	41	25				Lean Clay with Sand (CL)
TP-8	2-3			12	22	66	37	20	116.5	12.5	5	Sandy Lean Clay (ML)
TP-8	4	5				77	30	20				Lean Clay with Sand (CL)
TP-10	2	3	88			48						Silty Sand (SM)
TP-10	2-3			2	63	35		NP	126.0	7.5	33	Silty Sand (SM)
TP-10	4	1				6						Well Graded Sand with Silt (SW-SM)
TP-10	9½	10				59	59	37				Mudstone
TP-10	14½					99	52	39				Mudstone
TP-11	0-1			68	16	16		NP	134.5	5.5	13	Silty Gravel with Sand (GM)
TP-15	4					96	77	35				Shale Bedrock
TP-16	10½	5	110			71						Mudstone

NOTICE OF MEETING
HILLSIDE REVIEW BOARD
CITY OF ST. GEORGE
WASHINGTON COUNTY, UTAH

Public Notice

Notice is hereby given that the Hillside Review Board of the City of St. George, Washington County, Utah, will hold meetings at the referenced site on **Wednesday, November 30, 2022,** commencing on-site at approximately 9:00 a.m.

PRESENT:
James Sullivan
Dave Black
James Dotson
Russ Owens

EXCUSED:
Jeff Mathis

CITY STAFF:
Assistant Public Works Director, Wes Jenkins
Planner III, Carol Davidson
Development Office Supervisor, Brenda Hatch

The agenda for the meeting is as follows:

James Sullivan called the meeting to order.

1. Consider a request for a hillside development permit for a residential retaining wall. The applicant is requesting that the Hillside Review Board consider the structural stability and mitigate the appearance and location of this retaining wall. The property is currently zoned R-1-8 (Single Family Residential, minimum lot size 8,000sf). The site is located at 150 N. Donlee Drive. The applicant is Ryan and Martina Davis. Case No. 2022-HS-018. **Meeting time is approx. 9:00 am**

Dave Black – I guess I'm not convinced that they have demonstrated that the wall is stable yet. First of all they need to run a stability calc for seismic as well, it needs to meet a seismic requirement as well. Typically stacked block walls that high and in their situation without geogrid really have a hard time meeting the factors of safety. I am surprised they had as high as they did in their calculations. This might be one that you want to get a copy of their results and look at their profile because it should be analyzed as a terraced wall and not two single walls, you need to look at the total height. There is a good chance that the minimum stability factors of safety under seismic condition wouldn't meet the requirements. They at least need to demonstrate that. In my opinion the conclusions in their report don't match their data. They did some compaction testing, they didn't do a proctor so they don't give you anything in percent compaction. Their density tests range by 20 lbs per cubic foot. Which indicates to me a lack of uniform compaction. They did some DCP testing and they said that supports their data that it was uniformly compacted. But, if you look at the DCP testing one of them the results are all

over like their density tests. The other DCP test shows a decrease in density. That would maybe indicate a lack of compaction as well. I don't think they have adequately demonstrated that it meets the requirements. They need to do some more analysis to show it meets the requirements. If it meets the requirements, my thought is looking at the data you provided us that at a minimum the block base should be colored.

Ryan Davis – We are actually going to stain them with a chocolate mocha stain to match the colors.

Russ Owens – Can you tell us about the construction on it?

Ryan Davis – So at the bottom, the blocks are actually up against the basalt. We actually excavated down to where we were touching the basalt and then did a wet set with the concrete. For the first two blocks on the bottom we had a jumping jack compactor. That was the biggest compactor we could get in. There isn't much dirt in it. So we put those in and then starting about the second block on up then it was wide enough we could get a full compactor in. We had the remote one that drives. We compacted as we went, made sure we were watering and mixing the soil up so we had the right water content. As the cliff comes up, there isn't much dirt to put in there. The higher we got we put the gravel in there for drainage. The idea is that we will stain that to match the hillside as close as possible.

Russ Owens – It's 42 inches wide, right?

Ryan Davis – 40 inches and 40 inches deep.

Russ Owens – So with that you could probably do a 10 ft wall without grid as long as you've got the compaction and things. I guess my concern is the color, 2, if it's approved do a hold harmless saying it was done without City approval and if it fails then it's your fault and you will take full responsibility. And then maybe something on the plat so if you sell it then at least the people who buy it know that it was an unapproved wall and that it was suspect when you build it.

James Dotson – Does the pool go in-between the two terraces?

Ryan Davis – No the pool is on the upper level in the center.

Russ Owens – You could get a mini-ex back there if they want to go up and test compaction on it.

Ryan Davis – Oh yeah, that's what they did, when they came down we had the excavator there and they dug a hole on the outside wall and then they dug two holes on the inside wall, the upper wall. As well as three spots in the ground. That's what Landmark did.

Dave Black – So they did 5 density tests, and they range from 123.2 lbs. to 103 lbs.

Russ Owens – And did Bryce Christensen give a number?

Dave Black – They didn't give a number, no density, but Bryce Christensen pit silty sanded gravel.

Ryan Davis – We actually hauled in the dirt. We told Bryce Christensen that it was for compaction, that it had to be compactible soil. So that's what they sent us.

Dave Black – So one test is 123, so the proctor is at least 123, and it's likely that they didn't put it in at 100%. So let's say it's 125, 128 lbs. per cubic ft. or something. These other tests would then not meet compaction except for 1. Without a proctor the 103 is 80%. The other thing that bothered me is that they referenced their DCP test and one of the tests shows lower density and it just keeps getting lower and lower and they said it's consistent. The other one, their proctor test is interpreted as density, they got low densities and high densities. This one starts off at the top and then it gets less compact less dense with depth. There is no level of confidence in that. If you assume the proctor is 125, they did their analysis for stability with the density of the backfill of 120 lbs. moist. It probably ought to be 130 lbs. moist if your proctor is really 125. And they need to demonstrate that it meets the seismic factor of safety, which they didn't report. It's not just a 10ft high wall, it's a terraced wall, the upper wall is closer than your setback requirement. That means the whole wall needs to be analyzed as a system, not based on the stability of a 10 ft wall. Structurally the setback should be one and a half times the lower wall. The City's requirement to be considered right now is the setback should be at least the height of the lower wall and it's not. Regardless of the two, it's a system, a terraced wall and you need to make sure it was analyzed as a terraced wall and if it does meet the factors of safety then we're good. I don't think that they demonstrate that. I don't know if they analyzed it as a single wall or a terraced wall.

Wes Jenkins – And you're saying on a gravity wall it's usually one and a half times the height of the wall that the terraced wall should be setback?

Dave Black – Yes.

Ryan Davis – And my understanding was that the height was the same width. When it's finished it will be and 8 ft exposed wall, so there is 8 ft between the two walls. We know it can't be higher than the 8 ft, so we have to put the dirt we excavated back.

James Sullivan – You're going to put dirt back on the front of the wall?

Ryan Davis – Yes, the lower wall.

Discussion continued regarding the height of the wall and the setback.

Dave Black – We don't want you to put dirt back on that side of the wall.

Discussion on what needs to be tested.

James Sullivan – My other big concern is the pool. I assume you don't have a permit yet.

Ryan Davis – No, we don't have any of that yet.

James Sullivan – On the pool permit side, work with Landmark and an engineer on it. I would want that pool to be drawn and designed as such that if that wall does fail, the pool is not going anywhere.

Discussion on pools next to block walls.

MOTION: Dave Black made a motion we table this item until they provide additional data on the stability of the rock wall.
SECOND: James Dotson
AYES (5)
James Sullivan
Dave Black
James Dotson
Russ Owens
NAYS (0)
Motion carries

Discussion on what tests should be done.

2. Adjourn

MOTION: Russ Owens made a motion to adjourn.

NOTICE OF MEETING
HILLSIDE REVIEW BOARD
CITY OF ST. GEORGE
WASHINGTON COUNTY, UTAH

Public Notice

Notice is hereby given that the Hillside Review Board of the City of St. George, Washington County, Utah, will hold meetings at the referenced site on **Wednesday, December 14, 2022,** commencing on-site at approximately 9:00 a.m.

James Sullivan
Dave Black
Jeff Mathis
James Dotson
Russ Owens

EXCUSED:

CITY STAFF:
Assistant Public Works Director, Wes Jenkins
Planner III, Dan Boles
Development Office Supervisor, Brenda Hatch

The agenda for the meeting is as follows:

James Sullivan called the meeting to order.

1. Consider a request for a hillside development permit to determine the ridgeline on lot 29 of South Rim at Formaster Ridge for the construction of an infinity pool. The property is currently zoned R-1-10 (Single Family Residential, minimum lot size 10,000sf). The site is located at 1682 E. Howard Lane. The applicant is Ryan Andrews and Tonya Shepard. Case No. 2022-HS-019.

Ryan Andrews and Loren Orvin.

Loren Orvin – The pool was permitted but there was a mistake on the address. We found out when we called on an inspection.

Wes Jenkins – This is somewhat similar to the other Foremaster ones we have done where the ridgeline basically just follows the property line, they did the 30 ft setback from the property line. So, the question is, is that the ridgeline, or is it further to the south. The ordinance now allows that you can do pools within the 30 ft setback as long as they are below grade and you can do landscaping, but no solid walls.

Carol Davidson – This plat does say that you can't have a pool in the 30 ft setback.

Wes Jenkins – Yes, this plat was before the ordinance change. The question is though is the pool within the 30 ft setback of the ridgeline?

Jeff Mathis – Are the corners marked?

Carol Davidson – Yes.

Everyone walked out to the back to see where the ridgeline actually is located. Wes showed pictures from below and referenced what areas the pictures were showing.

James Sullivan – The ridgeline is out here, this obviously isn't following the ridgeline. What do you think Dave?

Discussion on what was shown on the building permit and what is shown on the plat regarding the surrounding area.

Dave Black – My thought is we don't want to make them take the pool down, but maybe we have an opportunity to address this.

Ryan Andrews – This is after the fact, but we are making the pool blend in with the lava, black and this was all going to be black lava rock in the desert. Even the pool water isn't going to be blue water, we are going to make it dark. Just so you know we are dealing with the aesthetics of making it blend in.

Dave Black – And there is some stuff here that was probably done by the developer that would be nice to make it blend in as well with color.

James Sullivan – What do you have in mind for the face of the pool?

Ryan Andrews – It will be black.

Discussion on what it will aesthetically look like, what products are a possibility.

MOTION: Dave Black made a motion to recommend that the ridgeline shown on the drawing be moved out beyond the property line to match the natural ridgeline of the hillside, the pool does meet the minimum setback requirements and that the construction and disturbed soil around be mitigated with natural colors to blend into the hillside.
SECOND: Jeff Mathis
AYES (5)
James Sullivan
Dave Black
Jeff Mathis
James Dotson
Russ Owens
NAYS (0)
Motion carries

2. Approval of the meeting minutes from the November 2, 2022, meeting.

MOTION: Jeff Mathis made a motion that the minutes be approved.
SECOND: James Dotson

AYES (5)
James Sullivan
Dave Black
Jeff Mathis
James Dotson
Russ Owens
NAYS (0)
Motion carries

3. Adjourn

MOTION: James Sullivan made a motion to adjourn.

Meeting Location

Item #1 – 1682 E Howard Lane


Foremaster Dr
Howard Lane
Meeting Location
Riverside Dr