

**GEOTECHNICAL INVESTIGATION REPORT  
HIGH SIERRA SUBDIVISION  
34 LOTS IN 6TH AND 9TH FILINGS  
BILLINGS, MONTANA**

**PREPARED FOR:**

Mr. Landy Leep  
High Sierra II, Inc.  
175 North 27<sup>th</sup> Street, Suite 940  
Billings, MT 59101



November 1, 2018

Mr. Landy Leep  
High Sierra II, Inc.  
175 North 27<sup>th</sup> Street, Suite 940  
Billings, MT 59101

**SUBJECT: Geotechnical Investigation Report  
High Sierra Subdivision, 6<sup>th</sup> and 9<sup>th</sup> Filings  
Billings, Montana**

Dear Mr. Leep:

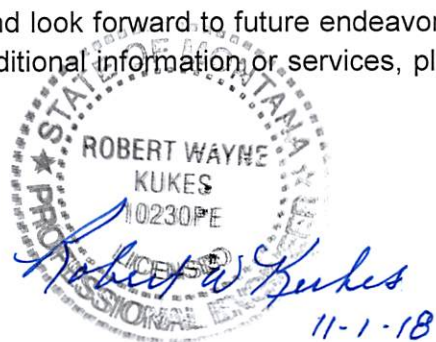
This report presents the results of our geotechnical investigation for the High Sierra Subdivision Project. The site location and boring locations are shown on the Vicinity/Site Map shown on Plate 1 at the end of this report. The projects consists of 34 residential lots in the 6<sup>th</sup> and 9<sup>th</sup> Filings. The borings in the 9<sup>th</sup> filing were drilled in 2014.

Our recommendations contained in this report are based on exploratory borings, laboratory testing, engineering analysis and preparation of this report. The recommendations required to design residential foundations and complete utility and street construction are contained in the attached report. These conclusions and recommendations, along with restrictions and limitations on these conclusions, are discussed in the attached report.

We appreciate this opportunity to be of service to you, and look forward to future endeavors. If you have any questions regarding this report or need additional information or services, please feel free to call the undersigned.

Sincerely,  
**RAWHIDE ENGINEERING, INC.**

Jason A. Frank  
Principal



Robert W. Kukes, P.E.  
Principal

Enclosures: Report (1 hard copy, 1 pdf)

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**GEOTECHNICAL INVESTIGATION REPORT  
HIGH SIERRA SUBDIVISION  
34 LOTS IN 6th AND 9th FILINGS  
BILLINGS, MONTANA**

**INTRODUCTION**

**Project Description**

This residential subdivision development consists of 34 residential lots located in the High Sierra Subdivision in Billings, Montana. This project consists of the 21 Lots in High Sierra 6<sup>th</sup> Filing and 13 Lots in the 9<sup>th</sup> Filing as shown on the site map and in the following table. The vicinity and site maps are shown on Plates 1 of this report. The site currently has the streets and utilities installed in both filings.

**LOTS INVESTIGATED FOR THIS REPORT**

<b>Filing, Block No.</b>	<b>Lots, (Totals)</b>
6 <sup>th</sup> Filing – Block 14	1 (1)
6 <sup>th</sup> Filing – Block 15	1-8 (8)
6 <sup>th</sup> Filing – Block 16	1-12 (12)
9 <sup>th</sup> Filing – Block 14	2-5 (4)
9 <sup>th</sup> Filing – Block 16	13-18 (6)
9 <sup>th</sup> Filing – Block 17	1-3 (3)

**Scope of Services**

Our scope of services for this project consisted of the following:

1. Drilling 7 exploratory borings to a depth of 15 feet below existing site grades.
2. Laboratory testing to determine the characteristics of the site soils for use in engineering design.
3. Engineering analysis to aid in the design of structure foundations, utility installation and asphalt pavement structural sections.
4. Provide information as to the existing groundwater conditions at the time of our exploration.
5. Provide recommendations for earthwork and construction on the site.

This study did not include evaluations of site seismicity, liquefaction, faulting, or other potential geologic or environmental hazards. This study did not include a groundwater study or the design of a dewatering system.

### **Authorization**

Authorization to proceed with our work on this project was provided on October 22, 2018.

### **Professional Statements and Limitations**

Recommendations presented in this report are governed by the physical properties of the soils encountered in the exploratory borings, laboratory testing, current groundwater conditions, the project layout and design data described in the following proposed construction section.

The recommendations presented in this report are based on exploratory boring locations shown on the site map. Variations in soils may exist between the explored locations and the nature and extent of soil variations may not be evident until construction occurs. If subsurface conditions other than those described in this report are encountered and if project design and layout is substantially altered from the information in this report, Rawhide Engineering should be notified so that recommendations can be reviewed and amended, if necessary.

This report has been prepared for design purposes for our client and specifically for this project in accordance with the generally accepted standards of practice at the time the report was written. No warranty, either expressed or implied, are intended or made.

Other standards or documents referenced in any given standard cited in this report, or otherwise relied upon by the authors of this report, are only mentioned in the given standard; they are not incorporated into it or "included by reference," as that latter term is used relative to contracts or other matters of law.

### **PROPOSED CONSTRUCTION**

It is our understanding that this project will include the construction of 34 residential structures which are anticipated to be one to two story wood framed structures with concrete basements, crawl spaces or conventional stemwall foundations. Exact information on each structure was not available at the time of this report. Rawhide Engineering has estimated that the structural loads for these structures will have continuous footings loads of 2 to 3 kips per lineal foot for long term loading conditions based on experience with similar projects. The project will also include installation of utilities and interior streets.

## **FIELD INVESTIGATION**

In order to determine and evaluate the subsurface conditions across the site, 7 exploratory borings were completed using a truck mounted drill rig equipped with hollow stem and solid stem augers. Boring depths were 15 feet below the existing ground surface. The location of the borings shown on the Site Map were dimensioned from property corners with the site map provided. This location should be considered accurate only to the degree implied by the method used.

The field investigation was under the direct control of an experienced member of our geotechnical staff who logged the soil conditions for each boring. Samples were obtained from driving a 2-inch Standard Penetration Sampler 18 inches using a 140 pound hammer falling 30 inches. The blow counts recorded on the boring logs were determined by counting the number of blows for the last 12 inches of the drive sample. Bulk auger cuttings were also obtained for further testing. The SPT and bulk samples were examined by field personnel, logged and sealed to prevent moisture loss prior to laboratory testing. After completion, the groundwater level in the boring was recorded and the borings were backfilled using drill cuttings.

The boring logs included at the end of this report are labelled B-1 through B-7. A boring log legend and a description of the Unified Soil Classification System used to identify the soils is included with the boring logs.

## **LABORATORY TESTING**

A laboratory testing program was utilized to provide the necessary data for engineering analysis of this project. The testing was used to evaluate the index and engineering properties specifically for the conditions encountered during our field exploration. The following program was used for this project.

### **Moisture Content Tests – ASTM D2216**

Moisture content tests were conducted on selected samples obtained from the site. These tests were used to aid in identifying the current soil conditions and aid in classifying the soils. Moisture content tests are shown on the boring logs.

### **Soil Classification Tests – ASTM D422, D1140, D4318, D2487 and D2488**

In order to classify the soils according to the Unified Classification System, soil gradations and Atterberg Limits test were conducted on selected samples. The results of this testing is shown below and on the boring logs.

### Gradations and Atterberg Limits Tests

Percent Passing		
Sieve Size	B-2 @ 4.5 – 6.0'	B-1 @ 9.5 – 11.0'
3/8	100	100
No. 4	100	91
No. 10	91	84
No. 20	83	78
No. 40	75	72
No. 80	62	66
No. 200	51	55
Plastic Index	6.2	9.4
Unified Classification	Sandy, Silty Clay (CL-ML)	Sandy Lean Clay (CL)

### SITE CONDITIONS

The site is located within the High Sierra Subdivision. The site currently has been stripped and the utilities and streets have been constructed. The site generally slopes to the east and south, but has some significant elevation changes from a ridge that runs through the project.

The site is bordered by developed and undeveloped residential property on all four sides. Drainage on the site consists of infiltration and runoff to the east.

### SUBSURFACE SOILS AND GROUNDWATER

The soil conditions encountered on the site generally consist of a layer of topsoil and vegetated topsoil with organics extending to a depth of 0.5 feet below the existing surface. Beneath the topsoil we encountered sandy, silty clay to depths ranging from 4 to 7 feet below existing site grades. The sandy, silty clay soils were generally medium stiff and we underlain by weathered sandstone or weathered sandy shale to the depths explored. The highly weathered sandy shale is lean clay with sand when mechanically broken down. The sandy shale has a low to moderate swell potential. Groundwater was not encountered in the borings at the depths explored of 15 feet below existing site grades.

## RECOMMENDATIONS

Prior to construction, surface soils should be removed from the site or stockpiled for use in non-structural areas. It appears about 0.5 feet can be used as a reasonable estimate for average depth of stripping. All undocumented fills, trash, vegetation and all abandoned underground utilities, wells, and foundations should be removed from the site if they are present. Excavations resulting from removal operations should be cleaned of all loose material and widened as necessary to permit access to compaction equipment.

### Excavations

The contractor is ultimately responsible for the safety of workers and should strictly observe federal and local OSHA requirements for excavation shoring and safety. All temporary slopes should comply with OSHA requirements for Type A soils in the upper soils and Type B in the lower shale and sandstone layers. During wet weather, runoff water should be prevented from entering excavations.

It appears that excavation for footings and utility trenches can be readily made with either a conventional backhoe or excavator in the native soil materials. We expect the walls of the footing trenches in the near surface fine grained soils or weathered bedrock to stand near vertically without significant sloughing. If trenches are extended deeper than five feet or are allowed to dry out, the excavations may become unstable and should be evaluated to verify their stability prior to occupation by construction personnel. Shoring or sloping of any deep trench walls may be necessary to protect personnel and provide temporary stability. All excavations should comply with current OSHA safety requirements for Type A or Type B soils. (Federal Register 29 CFR, Part 1926).

We recommend all backfill be compacted to a minimum compaction of 97% of the maximum dry density as determined by ASTM D698. The moisture content of compacted backfill soils should be within 2% of the optimum. Poor compaction in utility trench backfill may cause excessive settlements resulting in damage to the pavement structural section or other overlying improvements. Compaction of trench backfill outside of improvement areas should be a minimum of 90% relative compaction.

**Material** - Pipe bedding shall be defined as all material within six inches of the perimeter of the pipe. Backfill shall be classified as all material within the remainder of the trench. Material for use as bedding shall consist of clean, granular materials, and shall conform to requirements for bedding material listed in Section 02221 of the Standard Specifications.

**Placement and Compaction** - Pipe bedding shall be placed in thin layers not exceeding eight inches in loose thickness, and conditioned to the proper moisture content for compaction.



All other trench backfill shall be placed in thin layers not exceeding eight inches in loose thickness, conditioned to the proper moisture content, and compacted as required for adjacent fill. If not specified, backfill should be compacted to at least 97% relative compaction in areas under structures, utilities, roadways, parking areas, concrete flatwork, and to 90% relative compaction in undeveloped areas.

## **Foundations**

This site has sandy, silty clay in the top 4 to 7 feet. The majority of the foundations will be located on weathered sandstone or weathered shale bedrock. We are providing two alternative foundation recommendations for this project.

Shallow foundations may be constructed directly on the weathered sandstone bedrock. If the sandstone encountered is competent and hard, it may be advisable to over excavate the building envelope by 1 foot to install plumbing and utilities. If the foundation elevation is in the sandy, silty clay or weathered shale bedrock, the entire building envelope should be over excavated 1 foot in depth and extend laterally 1 foot beyond the edge of the footing. The over excavated material should be replaced with compacted structural fill. Utilizing the structural loads estimated for residential construction, and an allowable bearing pressure of 2,500 pounds per square for compacted structural fill or foundations placed on sandstone bedrock, a settlement of less than ½ inch was estimated.

Structural fill under foundations shall be placed in layers, moisture conditioned, and compacted to 98% of ASTM D698. Exterior continuous foundations should be embedded a minimum of 3.5 feet below lowest adjacent exterior finish grade for frost protection and confinement. Interior footings should be bottomed at least 12 inches below lowest adjacent finish grade for confinement. Wall foundation dimensions should satisfy the requirements listed in the latest edition of the International Residential Code. Reinforcing steel requirements for foundations should be provided by the design engineer.

The allowable bearing pressures, indicated above, are net values, therefore, the weight of the foundation and backfill may be neglected when computing dead loads. Allowable bearing pressures may be increased by one-third for short-term loading such as wind or seismic. Resistance to lateral loads in the upper sandy lean clay or silty sand soils may be calculated using an allowable passive equivalent fluid unit weight of 220 pounds per cubic foot and an allowable coefficient of friction of 0.37 applied to vertical dead loads. Both passive and frictional resistances may be assumed to act concurrently. An allowable active equivalent fluid pressure of 38 pounds per cubic foot may be used.

The International Building Code (IBC) site class for this project is Class C.

## Structural Fill

Structural fill will be used beneath the entire building envelope and should consist of dense gravel with sand and conforming to the following gradation and plastic index.

Sieve Size	Percent Passing
3 Inch	100%
No. 4	25-65%
No. 200	<20%
Plastic Index	12 or less

All structural fill shall be placed in eight inch loose lifts and uniformly moisture conditioned to within +/-2% of optimum moisture content. The contractor shall provide and use sufficient equipment of a type and weight suitable for the conditions encountered in the field. The equipment shall be capable of obtaining the required compaction in all areas, including those that are inaccessible to ordinary rolling equipment.

## Compaction Requirements

The following table lists the compaction requirements for structural fill, foundation backfill, utility trench backfill and street subgrade preparation.

COMPACTION REQUIREMENTS	
Structural Fill Beneath Foundations	98% of ASTM D698
Backfill Against Foundations	95% of ASTM D698
Utility Trench Backfill	97% of ASTM D698

## Concrete Slab-on-Grade Construction

Prior to constructing concrete slabs, the upper six inches of slab subgrade should be scarified, moisture conditioned to within 2% of optimum, and uniformly compacted to at least 95% of maximum dry density as determined by ASTM D698. Scarification and compaction will not be required if floor slabs are to be placed directly on undisturbed compacted structural fill.

All concrete floor slabs should have a minimum thickness of four inches. Slab thickness and structural reinforcing requirements within the slab should be determined by the design engineer. At least six inches of crushed base aggregate should be placed beneath slab-on-grade floors to provide uniform support. The aggregate base should be compacted to a minimum of 95% relative compaction.

We recommend that the base course be placed within three to five days (depending on the time of year) after moisture conditioning and compaction of the subgrade soil. The subgrade should be protected against drying until the concrete slab is placed.

In floor slab areas where moisture sensitive floor coverings are planned, an impermeable membrane (e.g. 10-mil thick polyethylene) should be placed over the base course to reduce the migration of moisture vapor through the concrete slabs. The impermeable membrane should be installed as required by the flooring manufacturer. Current literature from the American Concrete Institute and the Portland Cement Association recommend that the impermeable membrane is placed on top of the base course directly below the concrete slab.

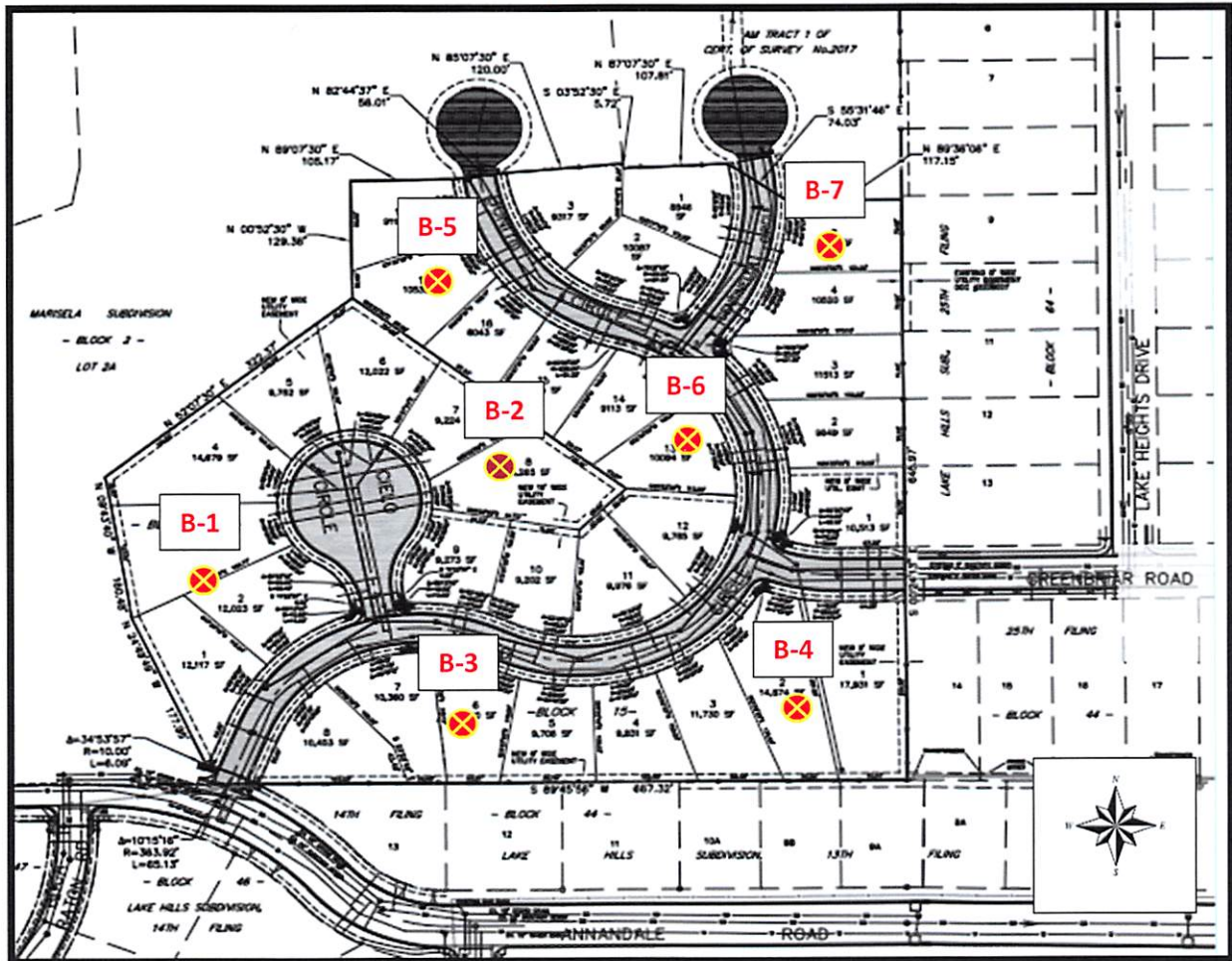
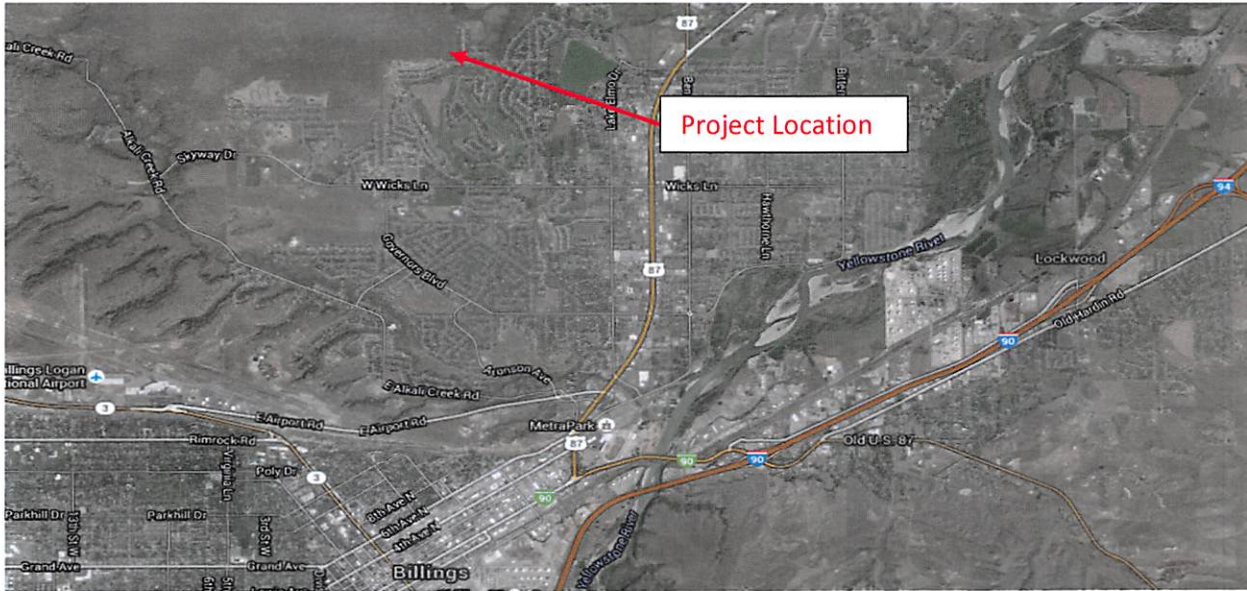
### **Site Drainage**

Final elevations at the site should be planned so that drainage is directed away from all foundations and concrete slabs. Parking areas should be designed to drain surface water off the sight and away from structures. In accordance with the International Residential Code, downspouts with 6 foot extensions should be used. Positive drainage away from all foundations should have 6 inches of fall in the first 10 feet away from the foundations. If sufficient room is not available to construct the 10 foot slope, drainage swales should be constructed as far from the foundations as possible.

# **APPENDIX A**

## **Plates**

# Site / Vicinity Map



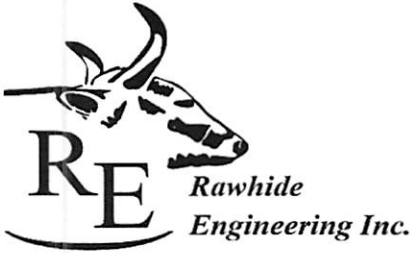


# Boring Log

PROJECT: High Sierra Subdivision  
6th and 9th Filings  
 CLIENT: High Sierra II  
 LOCATION: Billings, Montana

LOGGED BY: J. Frank  
 DRILL METHOD: Hollow Stem  
 DRILLER: R. Kukes  
 DATE: 10/29/18  
 ELEVATION: \_\_\_\_\_

Depth (ft)	SAMPLES			USCS Symbol	BORING NUMBER: 1	Consistency	LABORATORY TESTING			
	Sample Type	Blows / 6 in.	Soil Pattern				Water Content (%)	Plastic Index (PI)	Minus #200 (%)	Sample Recovery
MATERIAL DESCRIPTION AND COMMENTS										
					Topsoil					
1				CL-ML	Sandy Silty Clay - Brown, Moist, Medium Stiff, Low/Medium Plastic Index					
2										
3										
4										
5		16		PCEM	Weathered Sandstone - Brown/Red, Moist, Dense, Granular Non-Plastic	D				1.2
6		17								
7		19								
8				PCEM	Highly Weathered Sandy Shale - Brown/Gray/Red, Moist, Medium Stiff, Medium Plastic Index					
9					When Mechanically Broken Down - Classifies as (CL) - Lean Clay with Sand					
10		21				S	14.8	9.4	54.6	1.4
11		21								
12		23								
13										
14										
15					Boring Ends at Approximately 15 Feet Depth					
16					Groundwater Was Not Encountered					
17										
18										
19										
20										



# Boring Log

PROJECT: High Sierra Subdivision  
6th and 9th Filings  
 CLIENT: High Sierra II  
 LOCATION: Billings, Montana

LOGGED BY: J. Frank  
 DRILL METHOD: Hollow Stem  
 DRILLER: R. Kukes  
 DATE: 10/29/18  
 ELEVATION: \_\_\_\_\_

Depth (ft)	SAMPLES			USCS Symbol	BORING NUMBER: 2	Consistency	LABORATORY TESTING			
	Sample Type	Blows / 6 in.	Soil Pattern				Water Content (%)	Plastic Index (PI)	Minus #200 (%)	Sample Recovery
MATERIAL DESCRIPTION AND COMMENTS										
					Topsoil					
1				CL-ML	Sandy Silty Clay - Brown, Moist, Medium Stiff, Low/Medium Plastic Index					
2										
3										
4										
5		6				F	17.4	6.2	51.3	1.5
6		5								
7		7								
8				PCEM	Weathered Sandstone - Brown/Red, Moist, Dense, Granular Non-Plastic					
9										
10		18				S				1.0
11		18								
12		22		PCEM	Highly Weathered Sandy Shale - Brown/Gray/Red, Moist, Medium Stiff, Medium Plastic Index When Mechanically Broken Down - Classifies as (CL) - Lean Clay with Sand					
13										
14										
15					Boring Ends at Approximately 15 Feet Depth					
16					Groundwater Was Not Encountered					
17										
18										
19										
20										



# Boring Log

PROJECT: High Sierra Subdivision  
6th and 9th Filings  
 CLIENT: High Sierra II  
 LOCATION: Billings, Montana

LOGGED BY: J. Frank  
 DRILL METHOD: Hollow Stem  
 DRILLER: R. Kukes  
 DATE: 10/29/18  
 ELEVATION: \_\_\_\_\_

Depth (ft)	SAMPLES			USCS Symbol	BORING NUMBER: 3	Consistency	LABORATORY TESTING			
	Sample Type	Blows / 6 in.	Soil Pattern				Water Content (%)	Plastic Index (PI)	Minus #200 (%)	Sample Recovery
MATERIAL DESCRIPTION AND COMMENTS										
					Topsoil					
1				CL-ML	Sandy Silty Clay - Brown, Moist, Medium Stiff, Low/Medium Plastic Index					
2										
3										
4										
5		7								
6		9		PCEM	Weathered Sandstone - Brown/Red, Moist, Dense, Granular Non-Plastic	D				1.2
7		12								
8										
9										
10		17								
11		19		PCEM	Highly Weathered Sandy Shale - Brown/Gray/Red, Moist, Medium Stiff, Medium Plastic Index When Mechanically Broken Down - Classifies as (CL) - Lean Clay with Sand	D				0.8
12		20								
13										
14										
15					Boring Ends at Approximately 15 Feet Depth Groundwater Was Not Encountered					
16										
17										
18										
19										
20										





# Boring Log

PROJECT: High Sierra Subdivision  
6th and 9th Filings  
 CLIENT: High Sierra II  
 LOCATION: Billings, Montana

LOGGED BY: J. Frank  
 DRILL METHOD: Hollow Stem  
 DRILLER: R. Kukes  
 DATE: 10/29/18  
 ELEVATION: \_\_\_\_\_

Depth (ft)	SAMPLES			USCS Symbol	BORING NUMBER: 4	Consistency	LABORATORY TESTING			
	Sample Type	Blows / 6 in.	Soil Pattern				MATERIAL DESCRIPTION AND COMMENTS	Water Content (%)	Plastic Index (PI)	Minus #200 (%)
					Topsoil					
1				CL-ML	Sandy Silty Clay - Brown, Moist, Medium Stiff, Low/Medium Plastic Index					
2										
3										
4										
5		9		PCEM	Weathered Sandstone - Brown/Red, Moist, Dense, Granular Non-Plastic	D				1.0
6		10								
7		11								
8										
9										
10		20		PCEM	Highly Weathered Sandy Shale - Brown/Gray/Red, Moist, Medium Stiff, Medium Plastic Index	D				1.2
11		21			When Mechanically Broken Down - Classifies as (CL) - Lean Clay with Sand					
12		21								
13										
14										
15					Boring Ends at Approximately 15 Feet Depth					
16					Groundwater Was Not Encountered					
17										
18										
19										
20										



# Boring Log

PROJECT: High Sierra Subdivision  
6th and 9th Filings  
 CLIENT: High Sierra II  
 LOCATION: Billings, Montana

LOGGED BY: J. Frank  
 DRILL METHOD: Hollow Stem  
 DRILLER: R. Kukes  
 DATE: 6/4/14  
 ELEVATION: \_\_\_\_\_

Depth (ft)	SAMPLES			USCS Symbol	BORING NUMBER: 5	Consistency	LABORATORY TESTING			
	Sample Type	Blows / 6 in.	Soil Pattern				Water Content (%)	Plastic Index (PI)	Minus #200 (%)	Sample Recovery
MATERIAL DESCRIPTION AND COMMENTS										
1					Topsoil with Vegetation					
2				CL-ML	Sandy Silty Clay - Brown, Moist, Medium Stiff, Low/Medium Plastic Index					
3										
4										
5		7								
6		7								
7		9								
8				PCEM	Highly Weathered Sandy Shale - Brown/Gray, Moist, Medium Stiff, Medium Plastic Index When mechanically Broken Down - Classifies as (CL) - Lean Clay with Sand					
9										
10		15								
11		19								
12		19								
13										
14										
15										
16					Boring Ends at Approximately 15 Feet Depth Groundwater Was Not Encountered					
17										
18										
19										
20										



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PROJECT: High Sierra Subdivision  
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 CLIENT: High Sierra II  
 LOCATION: Billings, Montana

LOGGED BY: J. Frank  
 DRILL METHOD: Hollow Stem  
 DRILLER: R. Kukes  
 DATE: 6/4/14  
 ELEVATION: \_\_\_\_\_

Depth (ft)	SAMPLES			USCS Symbol	BORING NUMBER: 6	Consistency	LABORATORY TESTING			
	Sample Type	Blows / 6 in.	Soil Pattern				MATERIAL DESCRIPTION AND COMMENTS	Water Content (%)	Plastic Index (PI)	Minus #200 (%)
1					Topsoil with Vegetation					
2				CL-ML	Sandy Silty Clay - Brown, Moist, Medium Stiff, Low/Medium Plastic Index					
3										
4										
5		6								
6		9								
7		11								
8				PCEM	Weathered Sandstone - Brown/Red, Moist, Dense, Granular Non-Plastic					
9										
10		22								
11		25								
12		24								
13				PCEM	Highly Weathered Sandy Shale - Brown/Gray, Moist, Medium Stiff, Medium PI - (CL) Lean Clay with Sand					
14										
15					Boring Ends at Approximately 15 Feet Depth					
16					Groundwater Was Not Encountered					
17										
18										
19										
20										



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PROJECT: High Sierra Subdivision  
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 LOCATION: Billings, Montana

LOGGED BY: J. Frank  
 DRILL METHOD: Hollow Stem  
 DRILLER: R. Kukes  
 DATE: 6/4/14  
 ELEVATION: \_\_\_\_\_

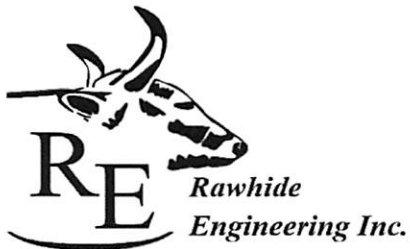
Depth (ft)	SAMPLES			USCS Symbol	BORING NUMBER: 7	Consistency	LABORATORY TESTING			
	Sample Type	Blows / 6 in.	Soil Pattern				Water Content (%)	Plastic Index (PI)	Minus #200 (%)	Sample Recovery
MATERIAL DESCRIPTION AND COMMENTS										
1					Topsoil with Vegetation					
2				CL-ML	Sandy Silty Clay - Light Brown/ Brown, Moist, Medium Stiff, Low/Medium Plastic Index PI					
3										
4										
5		7			Highly Weathered Sandy Shale - Brown/Gray, Moist, Medium Stiff to Stiff to Hard at 10.0', Medium PI When mechanically Broken Down - Classifies as (CL) - Lean Clay with Sand					
6		7								
7		9								
8										
9										
10		15			Boring Ends at Approximately 15 Feet Depth Groundwater Was Not Encountered					
11		19								
12		19								
13										
14										
15										
16										
17										
18										
19										
20										

# BORING LOG LEGEND

MATERIAL DESCRIPTION		
Soil Pattern	USCS Symbol	USCS Classification
	FILL	Artificial Fill
	GP or GW	Poorly/Well graded GRAVEL
	GM	Silty GRAVEL
	GC	Clayey GRAVEL
	GP-GM	Poorly graded GRAVEL with Silt
	GP-GC	Poorly graded GRAVEL with Clay
	SP or SW	Poorly/Well graded SAND
	SM	Silty SAND
	SC	Clayey SAND
	SP-SM	Poorly graded SAND with Silt
	SP-SC	Poorly graded SAND with Clay
	SC-SM	Silty Clayey SAND
	ML	SILT
	MH	Elastic SILT
	CL-ML	Silty CLAY
	CL	Lean CLAY
	CH	Fat CLAY
	PCEM	PARTIALLY CEMENTED
	CEM	CEMENTED
	BDR	BEDROCK

CONSISTENCY					
Cohesionless Soils		Cohesive Soils		Cementation	
VL	Very Loose	So	Soft	MH	Moderately Hard
L	Loose	F	Firm	H	Hard
MD	Medium Dense	S	Stiff	VH	Very Hard
D	Dense	VS	Very Stiff		
VD	Very Dense				

SAMPLING	
	SPT
	Shelby Tube
	No Recovery
	Bulk Sample
	Water Table



# UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests<sup>a</sup>

			Soil Classification			
			Group Symbol	Group Name <sup>b</sup>		
Coarse Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines <sup>c</sup>	$Cu \geq 4$ and $1 \leq Cc \leq 3^d$	GW	Well-graded gravel <sup>f</sup>	
			$Cu < 4$ and/or $1 > Cc > 3^d$	GP	Poorly graded gravel <sup>f</sup>	
	Sands 50% or more of coarse fraction passes No. 4 sieve	Gravels with Fines More than 12% fines <sup>c</sup>		Fines classify as ML or MH	GM	Silty gravel <sup>f, A, M</sup>
				Fines classify as CL or CH	GC	Clayey gravel <sup>f, A, M</sup>
		Clean Sands Less than 5% fines <sup>c</sup>		$Cu \geq 6$ and $1 \leq Cc \leq 3^d$	SW	Well-graded sand <sup>f</sup>
				$Cu < 6$ and/or $1 > Cc > 3^d$	SP	Poorly graded sand <sup>f</sup>
Sands with Fines More than 12% fines <sup>c</sup>		Fines classify as ML or MH	SM	Silty sand <sup>f, M, U</sup>		
		Fines classify as CL or CH	SC	Clayey sand <sup>f, M, U</sup>		
Fine-Grained Soils 50% or more passes the No. 200 sieve	Silt and Clays Liquid limit less than 50	Inorganic	$Pi > 7$ and plots on or above "A" line <sup>e</sup>	CL	Lean clay <sup>f, M, U</sup>	
			$Pi < 4$ or plots below "A" line <sup>e</sup>	ML	Silt <sup>f, M, U</sup>	
		organic	Liquid limit - oven dried	$< 0.75$	OL	Organic clay <sup>f, M, U</sup>
			Liquid limit - not dried		Organic silt <sup>f, M, U</sup>	
		Silt and Clays Liquid limit 50 or more	Inorganic	$Pi$ plots on or above "A" line	CH	Fat clay <sup>f, M, U</sup>
				$Pi$ plots below "A" line	MH	Elastic Silt <sup>f, M, U</sup>
	organic		Liquid limit - oven dried	$< 0.75$	OH	Organic clay <sup>f, M, U</sup>
			Liquid limit - not dried		Organic silt <sup>f, M, U</sup>	
	Highly organic soils	Primarily organic matter, dark in color, and organic odor		PT	Peat	

<sup>a</sup>Based on the material passing the 3-in. (75-mm) sieve

<sup>b</sup>If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

<sup>c</sup>Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

<sup>d</sup>Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC poorly graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

$$e \text{ } Cu = D_{60}/D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

<sup>f</sup>If soil contains  $\geq 15\%$  sand, add "with sand" to group name.

<sup>g</sup>If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

<sup>h</sup>If fines are organic, add "with organic fines" to group name.

<sup>i</sup>If soil contains  $\geq 15\%$  gravel, add "with gravel" to group name.

<sup>j</sup>If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

<sup>k</sup>If soil contains 15 to 20% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

<sup>l</sup>If soil contains  $\geq 30\%$  plus No. 200 predominantly sand, add "sandy" to group name.

<sup>m</sup>If soil contains  $\geq 30\%$  plus No. 200, predominantly gravel, add "gravelly" to group name.

<sup>n</sup> $Pi \geq 4$  and plots on or above "A" line.

<sup>o</sup> $Pi < 4$  or plots below "A" line.

<sup>p</sup> $Pi$  plots on or above "A" line.

<sup>q</sup> $Pi$  plots below "A" line.

