Mcnett Flats Subdivision

Major Subdivision Application

Section 21: Hydrogeologic Evaluation

Revision	*Date*
1st Element Review Copy	August 25, 2020
1st Sufficiency Review Copy	September 1, 2020
2nd Sufficiency Review Copy	October 16, 2020
Governing Body Review	December 4, 2020

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TECHNICAL MEMORANDUM

DATE:	August 21, 2020	**PROJECT NO.**	350.0523
TO:	Kody Swartz; Woith Engineering Nate Tollefson; Tollefson Properties, LLC		
FROM:	Gary Andres, Cam Stringer; NewFields		
SUBJECT:	Hydrogeologic Evaluation, McNett Flats Missoula, Montana		

This technical memorandum presents an analysis of the potential effect of using sumps at the proposed McNett Flats subdivision (Site) on groundwater levels, and an evaluation of depth to groundwater. Work was completed for Woith Engineering on behalf of Tollefson Properties, LLC (Tollefson).

An existing groundwater flow model was used to simulate changes in groundwater elevations near the Site associated with expected stormwater management. The model was also used to assess depth to groundwater to evaluate potential risks to basements and crawlspaces on-site and on surrounding properties.

SITE DESCRIPTION AND BACKGROUND

Tollefson plans to develop a subdivision on the west side of the Missoula Valley in the Grant Creek watershed (**Figure 1**). The site is located about two miles west of the intersection of Mullan Road and Reserve Street in Missoula within the south ½ of Section 13, Township 12N, Range 20W. Grant Creek lies west of the site and the Flynn-Lowney ditch runs to the south.

The Site covers roughly 871,200 square feet or 20 acres. An approximate layout of the subdivision is shown on **Figure 2.** The Site is surrounded by residential development to the south (44 Ranch Estates subdivision) and to the west (Remington Flats subdivision under development), and agricultural land to the east and north. Preliminary design of the subdivision includes dry wells (commonly referred to as sumps) to manage storm water. Structures will be constructed with slabs on grade and will not include full basements.

City of Missoula (City) engineering staff have expressed concerns regarding the use of sumps in the area to manage storm water and the potential impact of sumps on groundwater levels and quality. City staff have also indicated that a hydrogeologic evaluation must be completed to permit the Site.

In 2005, a study was completed to support an environmental restoration and flood control project for Grant Creek (HDR/Maxim 2005), located west of the Site. The study included a hydrogeologic investigation of the shallow aquifer in the Grant Creek Area. A numerical groundwater flow model was developed as part of the 2005 study. Model development was documented (HDR/Maxim 2005), but an electronic version of the model is not available.

A groundwater flow model was developed by NewFields to simulate groundwater flow in the Grant Creek watershed. The model uses MODFLOW for groundwater flow. Model construction and calibration was described by NewFields (2019a) and based on previous modeling completed by HDR/Maxim (2005) and Geomatrix (2006, 2008). The model has been used to support permitting for the Heron's Landing subdivision (NewFields, 2019a, 2020) south of the site, and for the Remington Flats subdivision immediately west of the Site (NewFields, 2019b).

The evaluation presented in this memorandum is designed to assess:

- The potential for groundwater to inundate crawl spaces during high groundwater conditions; and
- The effect of sumps on water table elevations and the potential for infiltration of runoff via sumps to flood crawl spaces or basements in the surrounding area.

HYDROGEOLOGIC SETTING

The Site lies above the Missoula Aquifer, a highly conductive, unconfined, shallow sand and gravel aquifer. Municipal supply wells completed in the Missoula Aquifer commonly produce several thousand gallons of water per minute. The Missoula Aquifer delineated by Clark (1986) is within the Quaternary-age valley fill and possibly the Sixmile Creek Equivalent. The saturated aquifer thickness commonly ranges from 50 to 120 feet (Woessner 1988). Morgan (1986) describes three hydrostratigraphic units of the Missoula Aquifer:

- Unit I: upper coarse-grained unit comprised of boulders, cobbles, gravels, sand, and some clay, ranging from 10 to 30 feet thick;
- Unit 2: silty sandy clay with coarse sand and gravel averaging 40 feet thick in the center of the valley; and
- Unit 3: lower unit, consisting of interbedded gravel, sand, silt, and clay; coarsens toward the bottom; thickness varies from 50 to 100 feet.

HDR/Maxim (2005) divided the groundwater system into two major water-bearing zones: shallow local aquifer and deeper regional Missoula Aquifer. The regional Missoula Aquifer underlies the shallow aquifer, with the two being separated by a thick sequence of fine-grained sediments. The hydrostratigraphy encountered at the Site generally agrees with the sequences described above, with the exception that the material corresponding to Unit 2 in the Site vicinity is comprised of clay with very little sand and no gravel. As a result, hydraulic communication between the two aquifers (Unit I and Unit 2) appears to be minimal in the Site area.

Groundwater in the local shallow aquifer eventually discharges to alluvium associated with the Clark Fork River and then into the river south and southwest of the Site (HDR/Maxim 2005). Groundwater in the deeper regional aquifer generally flows east to west beneath the Site.

Grant Creek is a major source of recharge to the shallow aquifer (HDR/Maxim 2005). Leakage from irrigation ditches and infiltration is another source of recharge to the shallow aquifer.

SITE CONDITIONS

Lorenzen Soil Mechanics (2020) excavated and logged a total of six test pits on February 25, 2020 to evaluate soil conditions in the upper 10.5-11.8 feet beneath the Site. A map showing test pit locations and lithologic logs of the excavations are included in **Attachment A**. A general summary of the test pits is provided in **Table 1**.

Table 1. Summary of McNett Flats Test Pits

Pit	Date	Total Depth	Sandy Silt/Silt		Silty Sand		Gravel		Water Depth
			Depth	Thickness	Depth	Thickness	Depth	Thickness	
TP-01	2/25/2020	11.5	1 - 7	6	-----	-----	7 - 11.5	>4.5	None
TP-02	2/25/2020	10.5	-----	-----	1.1 - 7	5.9	7 - 10.5	>3.5	None
TP-03	2/25/2020	11	1 - 7	6	-----	-----	7 - 11	>4	None
TP-04	2/25/2020	11.5	-----	-----	1-7	6	7 - 11.5	>4.5	None
TP-05	2/25/2020	11.8	-----	-----	1 - 11.8	>10.8	-----	-----	None
TP-06	2/25/2020	11.5	-----	-----	1 - 5.5	4.5	5.5 - 11.5	>6	None

all numbers in feet

The upper foot of material in each test pit was topsoil. Sandy silt or silt was observed from depths of 1 to 7 feet in TP-01 and TP-03, located in the west and north central part of the site. The 1 to 7-foot depth interval in the other test pits ranged from silty sand to sand with gravel. Gravel was observed in the bottom 4 to 6 feet of all test pits except TP-05, which had silty sand. Groundwater was not encountered in any of the test pits.

Grant Creek is a major source of recharge to the shallow aquifer (HDR/Maxim 2005). Leakage from irrigation ditches and infiltration is another source of recharge to the shallow aquifer. Creek and irrigation ditch seepage results in seasonal fluctuations of groundwater levels. The nearest well with a long-term static water level data is, WQD-4 (W131907C Hellgate Elementary) about half a mile to the east. The Missoula Water Quality district periodically measured depth to groundwater this well from July 1994 through June 2008. Depth to groundwater in this well ranged from about 19 to 31 feet with the highest water levels measured during summer months.

Groundwater in the shallow aquifer in the Grant Creek area generally flows from northeast to southwest (NewFields, 2019a). Groundwater in the local shallow aquifer eventually discharges to alluvium associated with the Clark Fork River and then into the river south and southwest of the Site (HDR/Maxim 2005). Groundwater in the deeper regional aquifer generally flows east to west beneath the Site.

GROUNDWATER FLOW MODEL

A groundwater flow model was developed by NewFields to simulate groundwater flow in the Grant Creek watershed. The model uses MODFLOW for groundwater flow. Model construction and calibration was described by NewFields (2019a) and based on previous modeling completed by HDR/Maxim (2005) and Geomatrix (2006,2008). The calibrated model simulates steady-state low water conditions, and transient conditions during a period in 2005 when weekly groundwater monitoring was performed. The model was subsequently used to simulate mounding and nitrate concentrations for Heron's Landing subdivision (NewFields, 2019a, 2020) south of the site, and for the Remington Flats subdivision immediately west of the Site (NewFields, 2019b).

The groundwater flow model described in NewFields (2019a) was used for this analysis to simulate groundwater mounding from storm water discharge at the Site, and to evaluate depth to groundwater at the Site under "typical seasonal high-water elevations." Modifications to the model included increasing hydraulic conductivity values in the model Layer 1 to reflect test pit observations where silt was absent beneath the Site. The revised hydraulic conductivity distribution for Layer 1 is shown on **Figure B-1** (**Attachment B**).

PREDICTIVE SIMULATIONS

Groundwater flow simulations were developed to help evaluate the potential effect of the use of sumps at the Site on groundwater elevations, and to evaluate depth to groundwater for typical seasonal high groundwater levels.

Woith Engineering provided anticipated storm water sump location (shown on **Figure 2**) and estimated the volume of that would infiltrate through these sumps for a 2-year storm event (presented in **Attachment C)**. Specified flux boundary conditions (MODFLOW's Well Package cells) were added to the model to simulate storm water sumps. Well Package cell location are shown on **Figure B-2** (**Attachment B**). In some cases, more than one storm water sump falls within a given model cell, and the injection rates were adjusted accordingly. **Table 2** summarizes input rates for Well Package cells in model.

The simulations were completed using the transient model that replicates the period of high flows in Grant Creek and associated high groundwater levels during 2005. The high flow period was extended, 35 days and 2-year storm event sump discharge was simulated over a 24-hour period to predict the degree of mounding due to the sumps.

Table 2. Model Storm Water Sump Injection Wells Summary

Well	Model Cell Row	Model Cell Column	Number of Sumps	2-Year Flood Rate (ft^3/d)
1	48	25	1	1000
2	48	26	3	3000
3	48	27	6	4843
4	48	28	2	1622
5	49	23	2	2000
6	49	24	2	2000
7	49	25	4	3538
8	49	26	4	3611
9	49	27	3	2613
10	49	28	5	3804
11	49	29	1	1000
12	50	22	1	1000
13	50	23	5	4790
14	50	24	4	3631
15	50	25	4	3513
16	50	26	4	3661
17	50	27	6	6000
18	50	28	1	1000
19	50	29	1	1000
20	51	23	2	2000
21	51	24	2	1626
22	51	25	3	3000
23	51	26	2	2000
24*	51	27	1	0
25	52	23	1	1000
26	52	24	5	4780
27	52	25	2	2000
28	47	27	3	3000

* Infiltration gallery, no discharge for 2-year event

Mounding Analysis

A transient flow simulation was developed evaluate the potential effect of sumps on groundwater elevations near the site. The steady-state simulation based on 2004 seasonal low groundwater conditions (NewFields 2019a) served as initial conditions for the simulation. Flow volumes for during a 2-year storm event representing zones of storm water sumps (shown in **Attachment B**) were imported and translated into Well Package cells. A transient simulation was set up with a 1-day stress period with well package flow rates indicated in **Table 2**, followed by a 9-day period with no flow from the sumps.

Figure 3 is a map showing the maximum increase in water table elevations predicted by the model from infiltration of the 2-year storm event at sumps located at the Site. This map shows that the maximum increase in the elevation of the water table is approximately 0.6 feet beneath the middle of the Site and generally less than 0.5 feet beyond the Site boundary.

Depth to Groundwater

An analysis was also conducted to evaluate depth to groundwater beneath the site during seasonal high-water conditions. Typical seasonal high groundwater elevations were determined by taking the model predicted groundwater elevations for June 2004 (model stress period 8) and adding 2.85 feet to the elevations. This approach is what has been requested most recently by the City for the Heron's Landing subdivision. Typical seasonal high groundwater elevations are shown on **Figure 4**.

Final grade elevations for the McNett Flats subdivision were provided by Woith Engineering. Site depth to groundwater was calculated by subtracting the typical seasonal high groundwater elevations (**Figure 4**) from the final site grade elevations. The resulting depth to groundwater is shown on **Figure 5**. Groundwater depths beneath the Site for the typical seasonal high scenario range from 14.5 to 15.5 feet in places of the west and central portions of the subdivision to greater than 19 feet along the eastern boundary and portions of the north-central and south-central areas. The model results indicate that groundwater levels under typical seasonal high groundwater elevations would be greater than 10 feet beneath the entire subdivision.

SUMMARY AND CONCLUSIONS

Predicted mounding of the groundwater table from use of sumps at the Site during a 2-year storm event will be minimal, with 0.6 feet or less of increased groundwater levels on the Site, and generally less than 0.5 feet beyond the Site boundary (**Figure 3**). Therefore, such mounding would not pose a risk of flooding to basements surrounding the Site.

Depth to groundwater beneath the Site is predicted to range from 14.5 to 19.5 feet under typical seasonal high groundwater conditions. The model results indicate that groundwater levels under the typical seasonal high conditions, will not reach slabs at the subdivision.

REFERENCES

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Woessner, W.W., 1988. Missoula Valley Aquifer Study; Hydrology of the Eastern Portion of the Missoula Aquifer, Missoula County Montana, v1 and v2, Water Development Bureau, Montana Department of Natural Resources and Conservation, Helena, MT.

Attachments: A – Test Pit Logs
B – Groundwater Flow Model Modifications
C – Storm Water Discharge Calculations

Figures

NewFields

Location Map
McNett Flats Subdivision
Missoula, Montana
FIGURE 1

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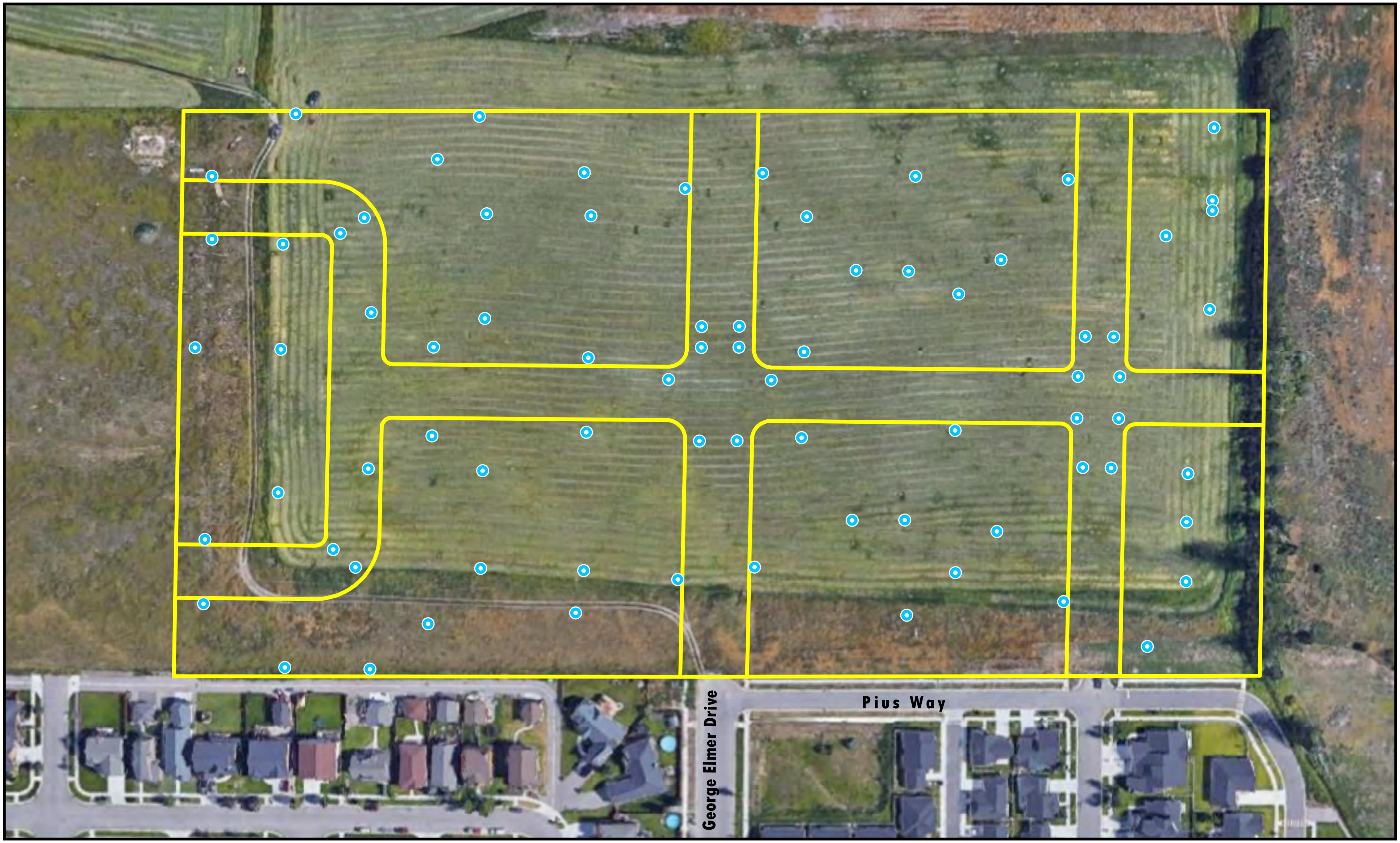

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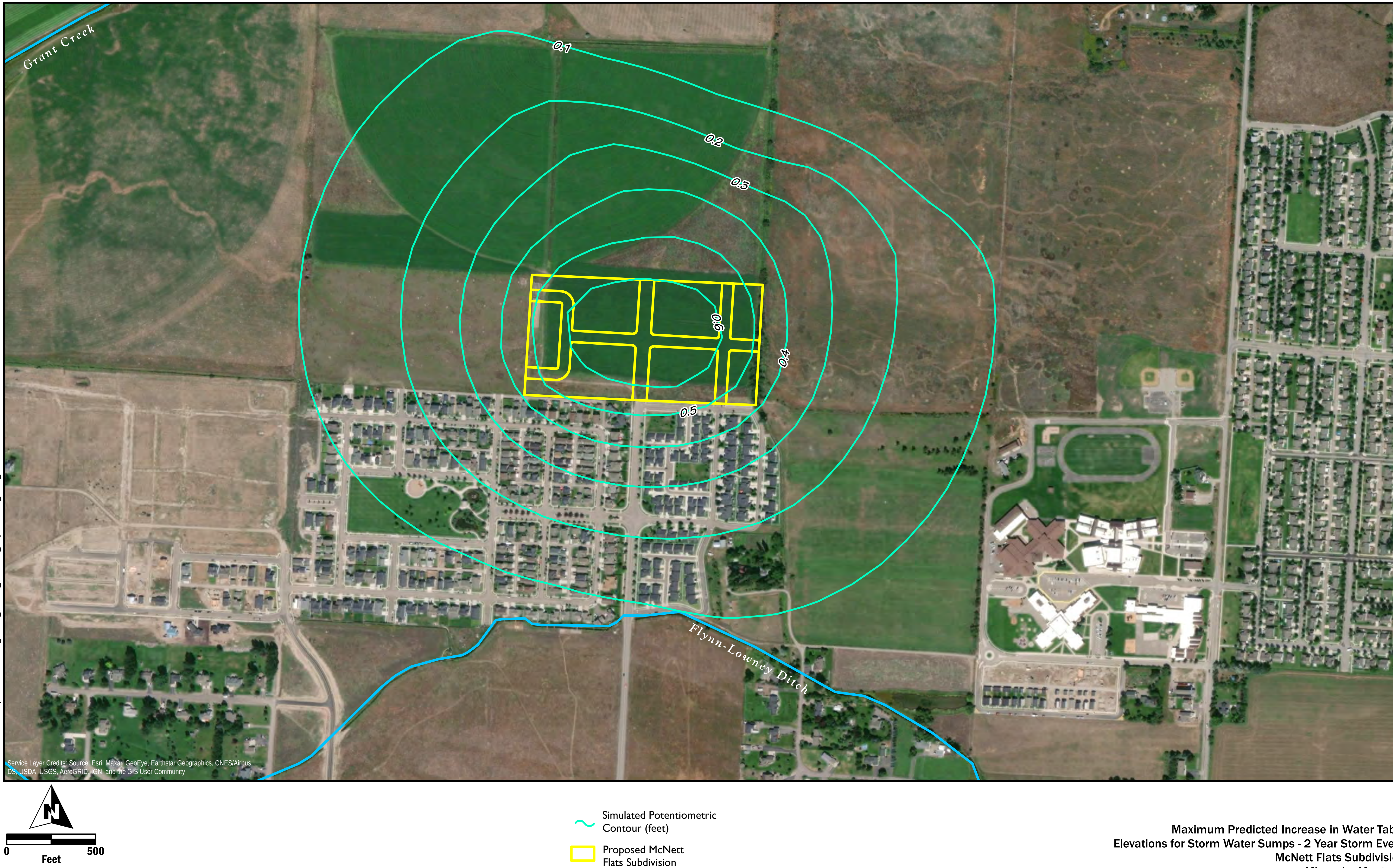
NewFields

Proposed McNett Flats Subdivision

Storm Water Sumps

Storm Water Sumps
McNett Flats Subdivision
Missoula, Montana
FIGURE 2



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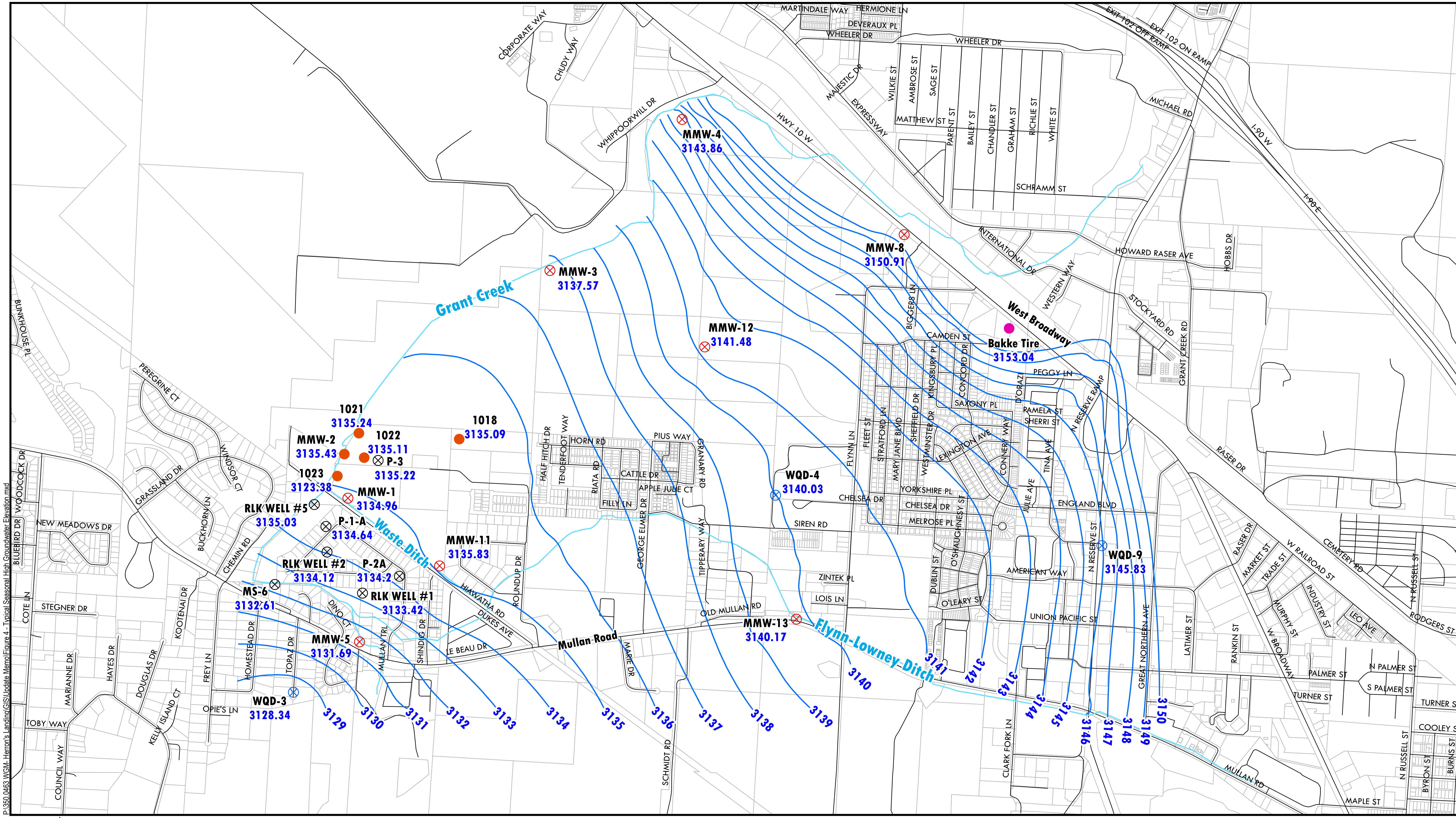
NewFields

Maximum Predicted Increase in Water Table Elevations for Storm Water Sumps - 2 Year Storm Event
McNett Flats Subdivision
Missoula, Montana
FIGURE 3



N

0 Feet 1,500

NewFields

Note:
Data are from June 2004 +2.85 feet

- Monitoring Well
- Previous Investigation Well
- Water Quality District Well
- Private Supply Well
- Test Pit Piezometer
- 3130 Water Table Elevation Contour (feet amsl)
- Heron's Landing

Typical Seasonal High Groundwater Elevation
McNett Flats Subdivision
Missoula, Montana
FIGURE 4

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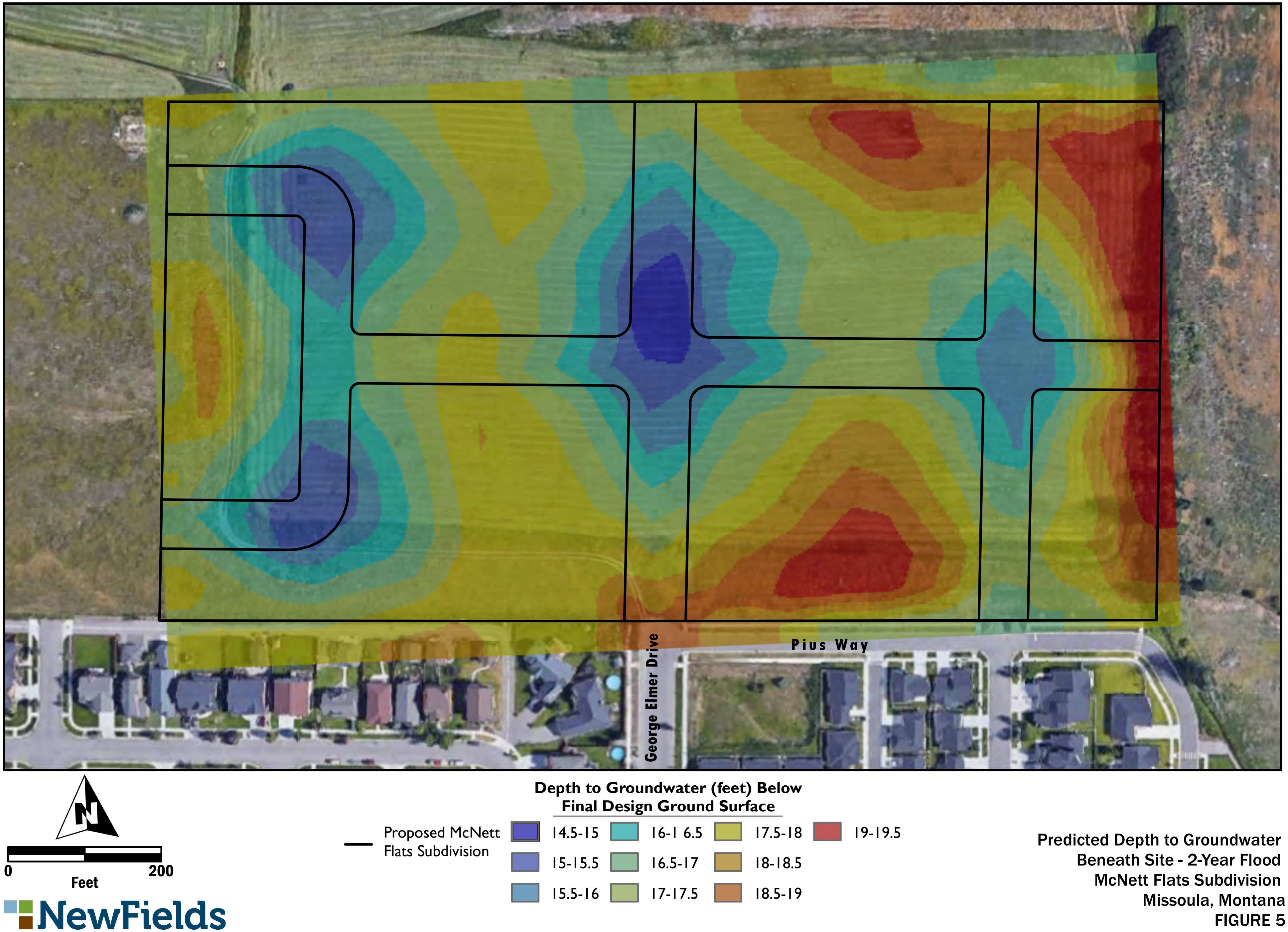


NewFields

Predicted Depth to Groundwater
Beneath Site - 2-Year Flood
McNett Flats Subdivision
Missoula, Montana
FIGURE 5

Attachment A
Test Pit Logs

Figure A-1. Map of Test Pit Locations

GENERAL NOTES

DRILLING & SAMPLING SYMBOLS:

SS:	Split Spoon - 1-3/8" I.D., 2" O.D., unless otherwise noted	CA:	Casing Advancer
ST:	Thin-Walled Tube - 2" O.D., unless otherwise noted	DA:	Drill Auger
CB:	California Sampler - 2" I.D., 2.5" O.D., unless otherwise noted	HA:	Hand Auger
DB:	Diamond Bit Coring - 4", NX, unless otherwise noted	RB:	Rock Bit
BS:	Bulk Sample or Auger Sample	GS:	Grab Sample

The number of blows required to advance a standard 2-inch O.D. split-spoon sampler (SS) the last 12 inches of the total 18-inch penetration with a 140-pound hammer falling 30 inches is considered the "Standard Penetration" or "N-value". The field blow counts are reported for each 6-inch interval, or portion thereof if greater than 50 blows are required to advance the full 6-inch interval. For over-sized split spoon samplers, non-standard hammers, or non-standard drop heights, the field penetration values are reported on the bore log. The values must be corrected to obtain the N-value.

WL:	Water Level	WS:	While Sampling	NE:	Not Encountered
WCI:	Wet Cave-In	WD:	While Drilling		
DCI:	Dry Cave-In	BCR:	Before Casing Removal		
AB:	After Boring	ACR:	After Casing Removal		

Groundwater table levels indicated on the boring logs are the levels measured in the borings at the times indicated. Groundwater table levels at other times and other locations across the site could vary. In pervious soils, the indicated levels may reflect the location of groundwater. In low permeability soils, the accurate determination of groundwater table levels may not be possible with only short-term observations.

DESCRIPTIVE SOIL CLASSIFICATION: Soil classification is based on the Unified Soil Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: gravel or sand. Cobbles and boulders are not part of the USCS system but are included, when present, as percentages. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; depending on their plasticity, they are described as clay or silt. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils are defined on the basis of their consistency.

CONSISTENCY OF FINE-GRAINED SOILS

Unconfined Compressive Strength, Qu, psf	Standard Penetration or N-value (SS) Blows/Ft.	Consistency
< 500	0 - 1	Very Soft
500 - 1,000	2 - 4	Soft
1,001 - 2,000	5 - 8	Medium Stiff
2,001 - 4,000	9 - 15	Stiff
4,001 - 8,000	16 - 30	Very Stiff
8,000 +	30 +	Hard

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Standard Penetration or N-value (SS) Blows/Ft.	California Barrel (CB) Blows/Ft.	Relative Density
0 - 4	0 - 6	Very Loose
5 - 10	7 - 18	Loose
11 - 30	19 - 58	Medium Dense
31 - 50	59 - 98	Dense
50 +	99 +	Very Dense

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term(s) of Other Constituents	Percent of Dry Weight
Trace	< 15
With	15 - 30
Modifier	> 30

USCS* GRAIN SIZE TERMINOLOGY

Major Component of Sample	Particle Size
Boulders	Over 12 in. (300mm)
Cobbles	12 in. to 3 in. (300mm to 75 mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm to 0.075mm)
Silt or Clay	Passing #200 Sieve (0.075mm)

*For AASHTO grain size the #4 sieve is replaced with the #10 sieve

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of Other Constituents	Percent of Dry Weight
Trace	< 5
With	5 - 12
Modifiers	> 12

PLASTICITY DESCRIPTION

Term	Plasticity_Index
Non-Plastic	0
Slightly	1 - 5
Low	6 - 10
Medium	11 - 20
Highly	21 - 40
Very Highly	> 40

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]				Soil Classification: Group Symbol	Soil Classification: Group Name [B]
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	$Cu \geq 4$ and $1 \leq Cc \leq 3$	GW	Well-graded Gravel [F]
			$Cu < 4$ and/or $1 > Cc > 3$	GP	Poorly graded gravel [F]
		Gravels with Fines More than 12% fines	Fines classify as ML or MH	GM	Silty Gravel [F,G,H]
			Fines classify as CL or CH	GC	Clayey Gravel [F,G,H]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines	$Cu \geq 6$ and $1 \leq Cc \leq 3$	SW	Well-graded Sand [I]
			$Cu < 6$ and/or $1 > Cc > 3$	SP	Poorly graded Sand [I]
		Sands with Fines More than 12% fines	Fines classify as ML or MH	SM	Silty Sand [G,H,I]
			Fines classify as CL or CH	SC	Clayey Sand [G,H,I]
Fine-Grained Soils 50% or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	inorganic	PI > 7 and plots on or above "A" line	CL	Lean Clay [K,L,M]
			PI < 4 or plots below "A" line	ML	Silt [K,L,M]
		organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OL	Organic Clay [K,L,M,N]
					Organic Silt [K,L,M,O]
	Silts and Clays Liquid Limit 50 or more	inorganic	PI plots on or above "A" Line	CH	Fat Clay [K,L,M]
			PI plots below "A" line	MH	Elastic Silt [K,L,M]
		organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OH	Organic Clay [K,L,M,P]
					Organic Silt [K,L,M,Q]
Highly organic soils	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-in. (75-mm) sieve

[B] If field sample contains cobbles and/or boulders, add "with cobbles or boulders, or both" as necessary to group name.

[C] 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.

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay.

[E] $$Cu = D_{60} / D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

[F] If soil contains ≥ 15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ≥ 30% plus No. 200, predominantly sand, add "sandy" to group name.

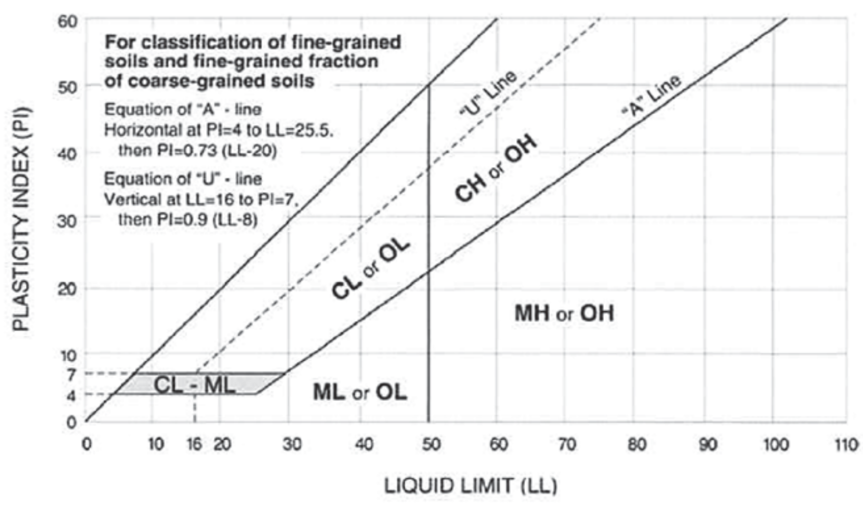
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

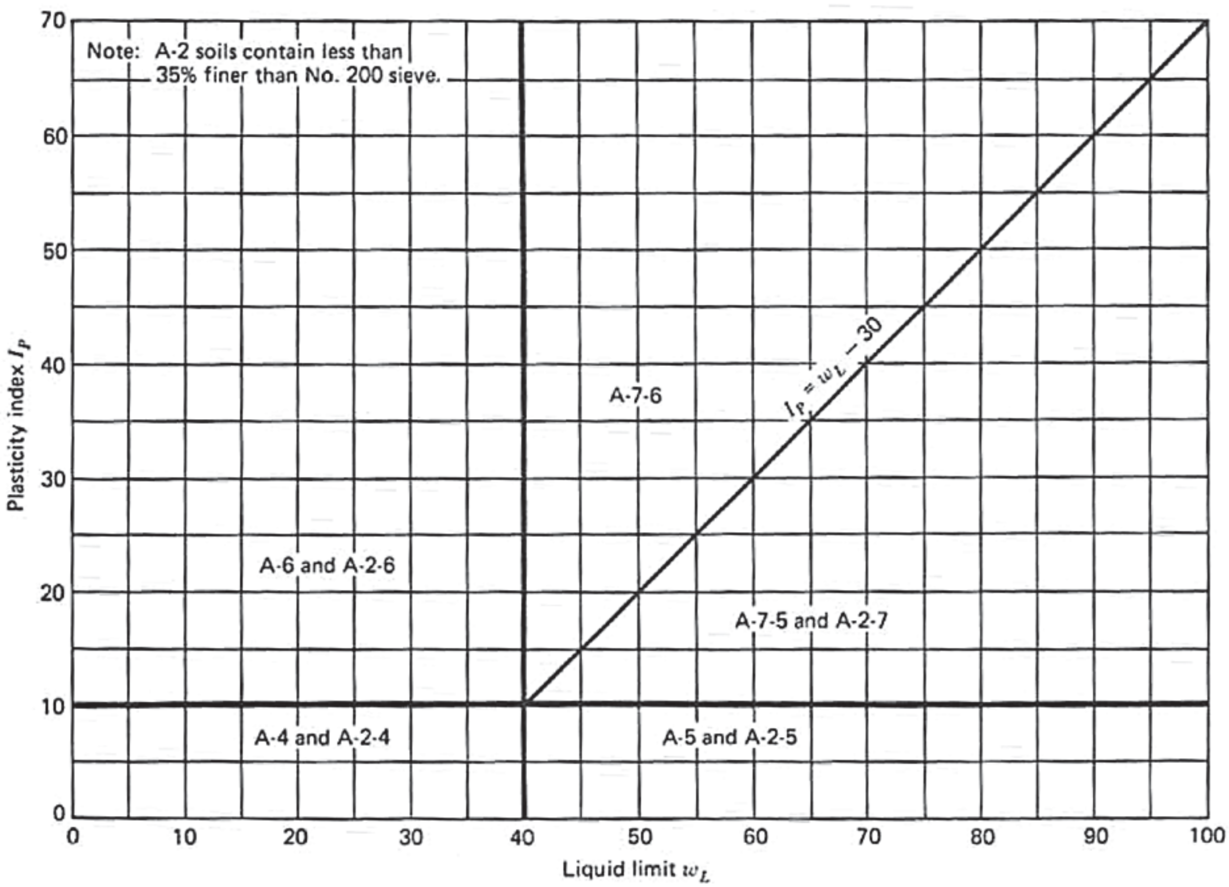
[Q] PI plots below "A" line.



AASHTO SOIL CLASSIFICATION SYSTEM

General classification	Granular materials (35 percent or less of total sample passing No. 200)							Silt-clay material (More than 35 percent of total sample passing No. 200)			
Group classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7 [1]
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve analysis percent passing											
No. 10	50 max										
No. 40	30 max	50 max	51 max								
No. 200	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing No. 40											
Liquid limit, w_L				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plastic Index, I_P	6 max		NP	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min
Significant constituent materials	gravel and sand		fine sand	silty and clayey gravel and sand				silty soils		clayey soils	

[1] Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30.



Lorenzen Soil Mechanics, Inc.
2720 Palmer Street, Unit C
Missoula, MT 59808
Telephone: 406-830-0633

TEST PIT NUMBER TP-01

CLIENT Tollefson Construction
PROJECT NAME George Elmer Drive
PROJECT NUMBER P2020
PROJECT LOCATION Missoula
DATE STARTED 2/25/20 **COMPLETED** 2/25/20
GROUND ELEVATION 3153.7 ft **TEST PIT SIZE** 36 inches
EXCAVATION CONTRACTOR Owner
GROUND WATER LEVELS:
EXCAVATION METHOD CASE 580M Turbo Backhoe
AT TIME OF EXCAVATION --- GW table was not encountered.
LOGGED BY Lorenzen **CHECKED BY** Lorenzen
AT END OF EXCAVATION --- GW table was not encountered.
NOTES N46° 53' 48.6": W114° 04' 14.1"
69 days AFTER EXCAVATION --- GW table was not encountered.

DEPTH (ft)	SAMPLE TYPE NUMBER	TESTS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	Elevation
0.0			ML	1.0	(ML) TOPSOIL, Silty Loam with Vegetative Organics; damp; very dark brown (10YR 2/2); no reaction to 10% HCl solution; slightly plastic; low dry strength.	3152.7
	GB	MC = 16% LL = NP PL = NP Fines = 56%	ML		(ML) Sandy SILT [A-4]; damp to dry; dark yellowish brown (10YR 4/4); no reaction to 10% HCl solution; non-plastic; low dry strength, friable. USDA Soil Texture = LOAM.	
2.5					Army Corps of Engineers Cone Penetrometer was pushed 6 inches under a 320 psi loading at 3 feet.	
	GB	MC = 7%		5.0		3148.7
5.0	GB	MC = 11%	ML		(ML) SILT with Sand [A-4]; dry; yellowish brown (10YR 6/4); light yellowish brown; no reaction to 10% HCl solution; slightly plastic; low dry strength. USDA Soil Texture = SILTY LOAM.	
	GB	MC = 6% LL = NP PL = NP Fines = 85%		7.0		3146.7
	GB	MC = 2%	GW-GM		(GW-GM) Well-Graded GRAVEL with Silt and Sand [A-1-a], frequent Cobbles; rounded to subrounded, flat; damp; yellowish brown (10YR 5/4) to dark yellowish brown (10YR 3/6) matrices; no reaction to 10% HCl solution.	
7.5	GB	LL = NP PL = NP Fines = 6%				
10.0	GB	MC = 2%				
	GB	MC = 3%		11.5		3142.2

Bottom of test pit at 11.5 feet.

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TEST PIT NUMBER TP-02

CLIENT Tollefson Construction
PROJECT NAME George Elmer Drive
PROJECT NUMBER P2020
PROJECT LOCATION Missoula
DATE STARTED 2/25/20 **COMPLETED** 2/25/20
GROUND ELEVATION 3156.4 ft **TEST PIT SIZE** 36 inches
EXCAVATION CONTRACTOR Owner
GROUND WATER LEVELS:
EXCAVATION METHOD CASE 580M Turbo Backhoe
AT TIME OF EXCAVATION --- GW table was not encountered.
LOGGED BY Lorenzen **CHECKED BY** Lorenzen
AT END OF EXCAVATION --- GW table was not encountered.
NOTES N46° 53' 49.1": W114° 04' 06.5
69 days AFTER EXCAVATION --- GW table was not encountered.

DEPTH (ft)	SAMPLE TYPE NUMBER	TESTS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	
0.0	GB	MC = 15%	ML		(ML) TOPSOIL, Silty Loam with Vegetative Organics; damp; very dark brown (10YR 2/2); no reaction to 10% HCl solution; slightly plastic; low dry strength.	
1.1						3155.3
	GB	MC = 12%	SM		(SM) Silty SAND [A-4]; damp; brown (10YR 4/3); strong reaction to 10% HCl solution; low dry strength, friable. Fines are slightly to non-plastic.	
2.5	GB	MC = 10%			Army Corps of Engineers Cone Penetrometer was pushed its full 21 inches under a 260 psi loading at 3 feet.	
5.0						3151.4
	GB	MC = 11%	SM		(SM) Silty SAND [A-4]; damp; dark yellowish brown (10YR 4/6); no reaction to 10% HCl solution; low dry strength, friable. Fines are slightly to non-plastic.	
7.0						3149.4
7.5	GB	MC = 4%	GW-GM		(GW-GM) Well-Graded GRAVEL with Silt and Sand [A-1-a], frequent Cobbles; rounded to subrounded, flat; damp; yellowish brown (10YR 5/6) to dark yellowish brown (10YR 3/6) matrices; strong to no reaction to 10% HCl solution.	
10.0	GB	MC = 5%				
	GB	MC = 3%				
10.5						3145.9

Bottom of test pit at 10.5 feet.

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TEST PIT NUMBER TP-03

CLIENT Tollefson Construction
PROJECT NAME George Elmer Drive
PROJECT NUMBER P2020
PROJECT LOCATION Missoula
DATE STARTED 2/25/20 **COMPLETED** 2/25/20
GROUND ELEVATION 3256.5 ft **TEST PIT SIZE** 36 inches
EXCAVATION CONTRACTOR Owner
GROUND WATER LEVELS:
EXCAVATION METHOD CASE 580M Turbo Backhoe
AT TIME OF EXCAVATION --- GW table was not encountered.
LOGGED BY Lorenzen **CHECKED BY** Lorenzen
AT END OF EXCAVATION --- GW table was not encountered.
NOTES N46° 53' 50.8": W114° 04' 06.8"
69 days AFTER EXCAVATION --- GW table was not encountered.

DEPTH (ft)	SAMPLE TYPE NUMBER	TESTS	U.S.C.S.	MATERIAL DESCRIPTION	Elevation
0.0			ML	(ML) TOPSOIL, Silty Loam with Vegetative Organics; frozen to 1 foot; very dark brown (10YR 2/2); no reaction to 10% HCl solution; slightly plastic; low dry strength.	
1.0	GB	MC = 12% LL = NP PL = NP Fines = 51%	ML	(ML) Sandy SILT [A-4]; damp to dry; dark yellowish brown (10YR 4/4) to yellowish brown (10YR 5/4); strong to weak reaction to 10% HCl solution; non-plastic; low dry strength, friable. USDA Soil Texture = SANDY LOAM.	3255.5
2.5	GB	MC = 10%		Army Corps of Engineers Cone Penetrometer was pushed 2.5 inches under a 320 psi loading at 3 feet.	
4.0			ML	(ML) Sandy SILT [A-4]; damp to dry; brown (10YR 4/3) to yellowish brown (10YR 5/4); strong to weak reaction to 10% HCl solution; non-plastic; low dry strenth, friable.	3252.5
5.0	GB	MC = 9%			
7.0			GP-GM	(GP-GM) Poorly Graded GRAVEL with Silt and Sand [A-1-a], frequent Cobbles; rounded to subrounded, flat; damp; yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/6) matrices; no reaction to 10% HCl solution. Fines are non-plastic.	3249.5
7.5	GB	MC = 3%			
	GB	LL = 18 PL = 18 Fines = 10%			
10.0	GB	MC = 3%			
11.0				Bottom of test pit at 11.0 feet.	3245.5

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TEST PIT NUMBER TP-04

CLIENT Tollefson Construction
PROJECT NAME George Elmer Drive
PROJECT NUMBER P2020
PROJECT LOCATION Missoula
DATE STARTED 2/25/20 **COMPLETED** 2/25/20
GROUND ELEVATION 3156.9 ft **TEST PIT SIZE** 36 inches
EXCAVATION CONTRACTOR Owner
GROUND WATER LEVELS:
EXCAVATION METHOD CASE 580M Turbo Backhoe
AT TIME OF EXCAVATION --- GW table was not encountered.
LOGGED BY Lorenzen **CHECKED BY** Lorenzen
AT END OF EXCAVATION --- GW table was not encountered.
NOTES N46° 53' 51.4": W114° 03' 59.8"
69 days AFTER EXCAVATION --- GW table was not encountered.

DEPTH (ft)	SAMPLE TYPE NUMBER	TESTS	U.S.C.S.	MATERIAL DESCRIPTION	Elevation
0.0			ML	(ML) TOPSOIL, Silty Loam with Vegetative Organics; damp; very dark brown (10YR 2/2); no reaction to 10% HCl solution; slightly plastic; low dry strength.	
1.0	GB	MC = 10% LL = NP PL = NP Fines = 45%	SM	(SM) Silty SAND [A-4]; damp; dark yellowish brown (10YR 4/4); no reaction to 10% HCl solution; non-plastic; low dry strength, friable. USDA Soil Texture = SANDY LOAM.	3155.9
2.0			SP	(SP) Pooly Graded SAND with Gravel [A-1-a]; damp; dark yellowish brown (10YR 4/4); no reaction to 10% HCl solution. Gravels are fine-grained and rounded to subrounded, flat. Fines are non-plastic. Army Corps of Engineers Cone Penetrometer was pushed 7.25 inches under a 320 psi loading at 2.4 feet.	3154.9
2.5	GB GB	MC = 4% LL = NP PL = NP Fines = 1%			
4.0			SP-SM	(SP-SM) Poorly Graded SAND with Silt and Gravel [A-1-a]; damp; dark yellowish brown (10YR 3/6); no reaction to 10% HCl solution. Fines are non-plastic.	3152.9
5.0					
7.0	GB	MC = 7%	GP-GM	(GP-GM) Poorly Graded GRAVEL with Silt and Sand [A-1-a], frequent Cobbles; rounded to subrounded, flat; damp; dark yellowish brown (10YR 4/6) matrix; no reaction to 10% HCl solution. Fines are non-plastic.	3149.9
7.5					
10.0					
11.5	GB	MC = 3%			3145.4

Bottom of test pit at 11.0 feet.

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TEST PIT NUMBER TP-05

CLIENT Tollefson Construction
PROJECT NAME George Elmer Drive
PROJECT NUMBER P2020
PROJECT LOCATION Missoula
DATE STARTED 2/25/20 **COMPLETED** 2/25/20
GROUND ELEVATION 3157.1 ft **TEST PIT SIZE** 36 inches
EXCAVATION CONTRACTOR Owner
GROUND WATER LEVELS:
EXCAVATION METHOD CASE 580M Turbo Backhoe
AT TIME OF EXCAVATION --- GW table was not encountered.
LOGGED BY Lorenzen **CHECKED BY** Lorenzen
AT END OF EXCAVATION --- GW table was not encountered.
NOTES N46° 53' 49.4": W114° 04' 00.0"
69 days AFTER EXCAVATION --- GW table was not encountered.

DEPTH (ft)	SAMPLE TYPE NUMBER	TESTS	U.S.C.S.	MATERIAL DESCRIPTION
0.0	GB	MC = 16%, LL = NP, PL = NP, Fines = 47%	SM	(SM) TOPSOIL, Sandy Loam with Vegetative Organics; damp; very dark grayish brown (10YR 3/2); no reaction to 10% HCl solution; slightly plastic; low dry strength. USDA Soil Texture = SANDY LOAM. (1.0 / 3156.1)
1.0	GB	MC = 15%	SM	(SM) Silty SAND [A-4]; damp; brown (10YR 4/3) to yellowish brown (10YR 5/8); no reaction to 10% HCl solution; non-plastic; low dry strength, friable. Fines are non-plastic. USDA Soil Texture = SANDY LOAM.
2.5	GB	MC = 13%, LL = NP, PL = NP, Fines = 43%		Army Corps of Engineers Cone Penetrometer was pushed its full 21 inches under a 240 psi loading at 3 feet.
5.0	GB	MC = 13%		(7.0 / 3150.1)
7.0	GB	MC = 6%	SP-SM	(SP-SM) Poorly Graded SAND with Silt and Gravel [A-1-a]; damp; dark yellowish brown (10YR 4/6); no reaction to 10% HCl solution. Gravels are rounded to subrounded, flat. Fines are non-plastic.
7.5				
10.0	GB	MC = 3%		(11.8 / 3145.4)

Bottom of test pit at 11.8 feet.

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TEST PIT NUMBER TP-06

CLIENT Tollefson Construction
PROJECT NAME George Elmer Drive
PROJECT NUMBER P2020
PROJECT LOCATION Missoula
DATE STARTED 2/25/20 **COMPLETED** 2/25/20
GROUND ELEVATION 3151.6 ft **TEST PIT SIZE** 36 inches
EXCAVATION CONTRACTOR Owner
GROUND WATER LEVELS:
EXCAVATION METHOD CASE 580M Turbo Backhoe
AT TIME OF EXCAVATION --- GW table was not encountered.
LOGGED BY Lorenzen **CHECKED BY** Lorenzen
AT END OF EXCAVATION --- GW table was not encountered.
NOTES N46° 53' 46.6": W114° 04' 06.3"
69 days AFTER EXCAVATION --- GW table was not encountered.

DEPTH (ft)	SAMPLE TYPE NUMBER	TESTS	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	Elevation
0.0			SM		(SM) FILL, Sandy Loam with Vegetative Organics; damp; very dark grayish brown (10YR 3/2); no reaction to 10% HCl solution; slightly plastic; low dry strength.	
1.0			SM		(SM) Silty SAND [A-4]; damp; brown (10YR 5/3); no reaction to 10% HCl solution; non-plastic; low dry strength, friable. Fines are non-plastic.	3150.6
1.6	GB	MC = 8%	SP-SM		(SP-SM) Poorly Graded SAND with Silt and Gravel [A-1-a]; damp; dark yellowish brown (10YR 4/6); no reaction to 10% HCl solution. Fines are non-plastic. Gravels are rounded to subrounded, flat.	3150.0
2.5	GB	MC = 3%			Army Corps of Engineers Cone Penetrometer was pushed 6 inches under a 320 psi loading at 3 feet.	
	GB	LL = NP PL = NP Fines = 7%				
5.0	GB	MC = 5%				
5.5	GB	MC = 5%	GP-GM		(GP-GM) Poorly Graded GRAVEL with Silt and Sand [A-1-a], frequent Cobbles; rounded to subrounded, flat; damp; dark yellowish brown (10YR 4/4) matrix; no reaction to 10% HCl solution. Fines are non-plastic.	3146.1
7.5						
10.0						
11.5	GB	MC = 3%			Bottom of test pit at 11.5 feet.	3140.1

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GRAIN SIZE DISTRIBUTION

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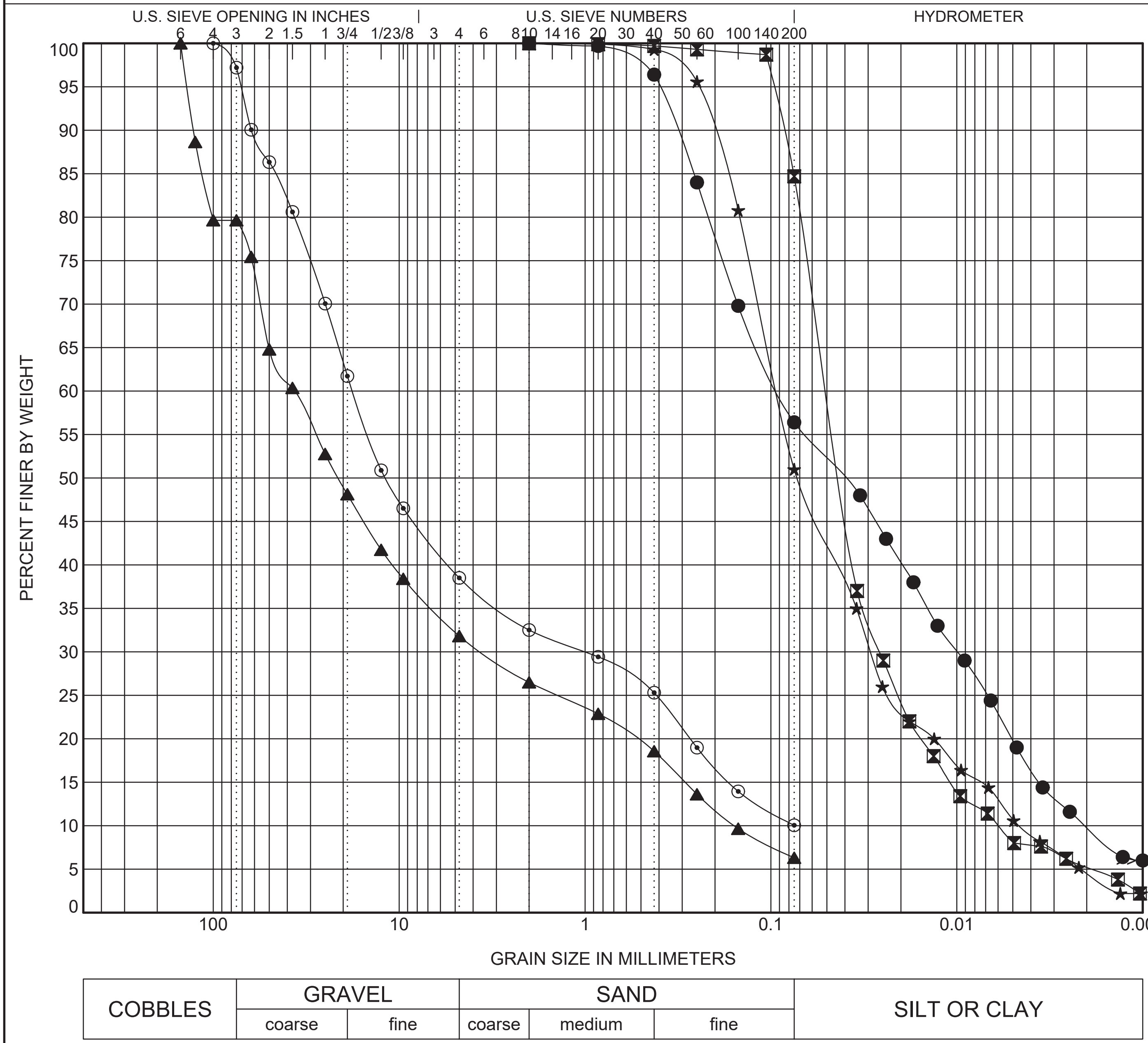
PROJECT NUMBER P2020 **PROJECT LOCATION** Missoula



	BOREHOLE	DEPTH	Classification	LL	PL	PI	Cc	Cu
●	**TP-01**	**1.0**	**SANDY SILT(ML)**	**NP**	**NP**	**NP**	**0.54**	**44.80**
⧗	**TP-01**	**6.0**	**SILT with SAND(ML)**	**NP**	**NP**	**NP**	**2.24**	**8.39**
▲	**TP-01**	**8.0**	**WELL-GRADED GRAVEL with SILT and SAND(GW-GM)**	**NP**	**NP**	**NP**	**2.17**	**234.51**
★	**TP-03**	**1.5**	**SANDY SILT(ML)**	**NP**	**NP**	**NP**	**1.99**	**20.25**
⊙	**TP-03**	**9.0**	**POORLY GRADED GRAVEL with SILT and SAND(GP-GM)**	**18**	**18**	**NP**	**0.75**	**239.21**

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**TP-01**	**1.0**	**2**	**0.09**	**0.01**	**0.002**	**0.0**	**43.6**	**36.6**	**19.8**
⧗	**TP-01**	**6.0**	**2**	**0.05**	**0.026**	**0.006**	**0.0**	**15.3**	**76.5**	**8.2**
▲	**TP-01**	**8.0**	**150**	**36.794**	**3.536**	**0.157**	**47.8**	**25.5**	**6.3**	
★	**TP-03**	**1.5**	**2**	**0.092**	**0.029**	**0.005**	**0.0**	**49.0**	**40.3**	**10.7**
⊙	**TP-03**	**9.0**	**100**	**17.779**	**0.996**		**58.7**	**28.5**	**10.1**	

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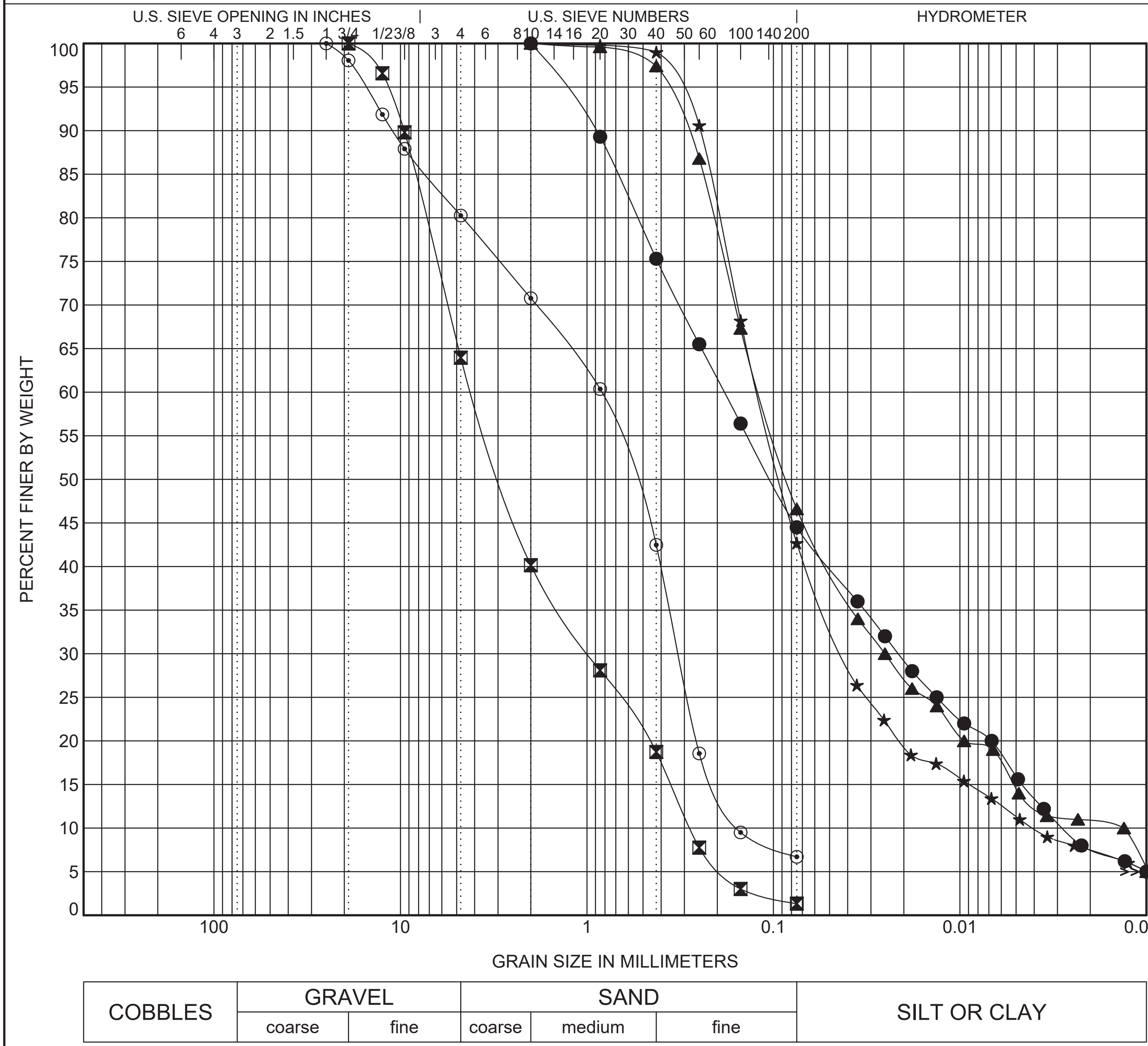
GRAIN SIZE DISTRIBUTION

CLIENT Tollefson Construction
PROJECT NAME George Elmer Drive
PROJECT NUMBER P2020
PROJECT LOCATION Missoula



	BOREHOLE	DEPTH	Classification	LL	PL	PI	Cc	Cu
●	**TP-04**	**1.0**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**	**0.89**	**65.98**
⊠	**TP-04**	**2.5**	**POORLY GRADED SAND with GRAVEL(SP)**	**NP**	**NP**	**NP**	**0.83**	**14.77**
▲	**TP-05**	**0.5**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**	**4.11**	**89.06**
★	**TP-05**	**3.0**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**	**3.66**	**29.77**
⊙	**TP-06**	**3.5**	**POORLY GRADED SAND with SILT and GRAVEL(SP-SM)**	**NP**	**NP**	**NP**	**0.80**	**5.43**

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**TP-04**	**1.0**	**2**	**0.184**	**0.021**	**0.003**	**0.0**	**55.5**	**28.6**	**15.9**
⊠	**TP-04**	**2.5**	**19**	**4.114**	**0.973**	**0.279**	**36.0**	**62.6**	**1.3**	
▲	**TP-05**	**0.5**	**2**	**0.117**	**0.025**	**0.001**	**0.0**	**53.4**	**32.1**	**14.5**
★	**TP-05**	**3.0**	**2**	**0.12**	**0.042**	**0.004**	**0.0**	**57.3**	**31.4**	**11.3**
⊙	**TP-06**	**3.5**	**25**	**0.838**	**0.322**	**0.154**	**19.7**	**73.6**	**6.7**	

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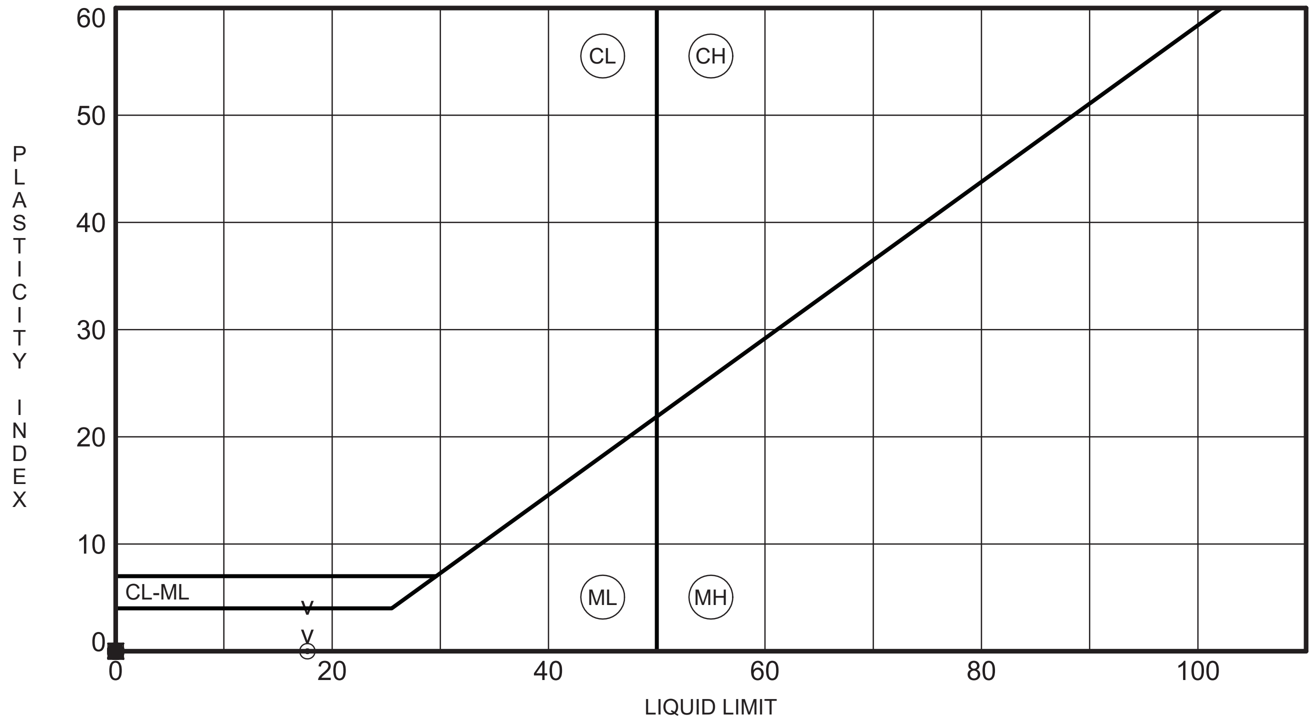
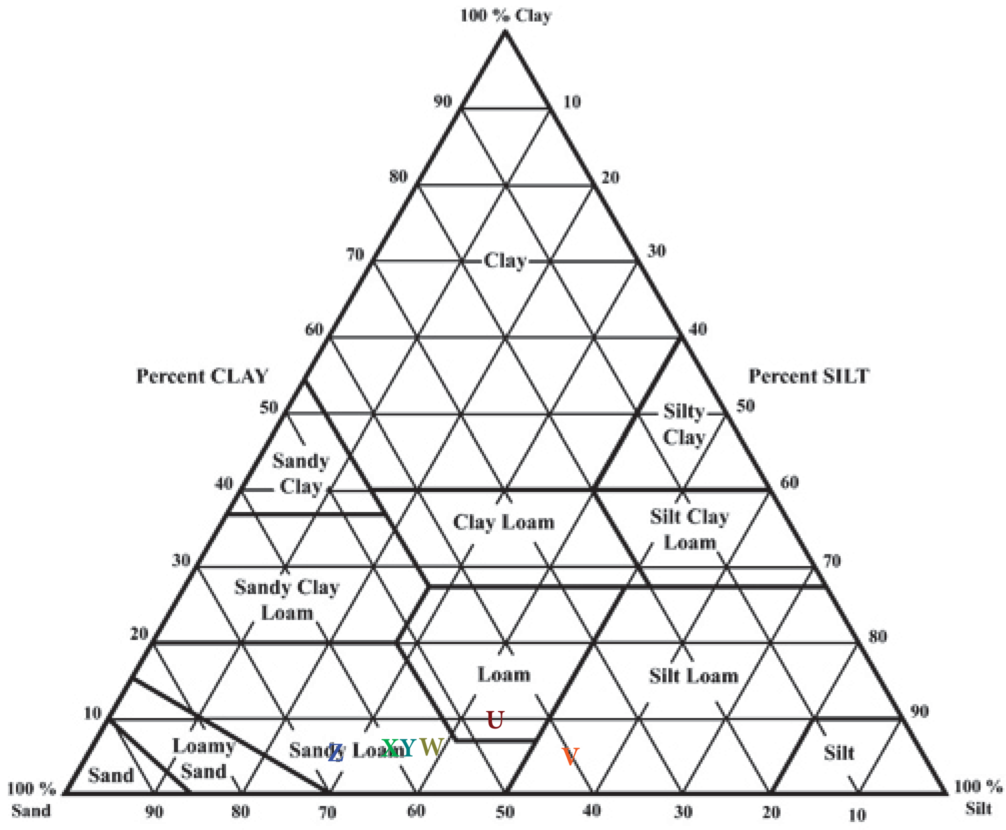
ATTERBERG LIMITS' RESULTS

CLIENT Tollefson Construction **PROJECT NAME** George Elmer Drive
PROJECT NUMBER P2020 **PROJECT LOCATION** Missoula



	BOREHOLE	DEPTH	LL	PL	PI	Fines	Classification
●	**TP-01**	**1.0**	**NP**	**NP**	**NP**	**56**	**SANDY SILT(ML)**
⊠	**TP-01**	**6.0**	**NP**	**NP**	**NP**	**85**	**SILT with SAND(ML)**
▲	**TP-01**	**8.0**	**NP**	**NP**	**NP**	**6**	**WELL-GRADED GRAVEL with SILT and SAND(GW-GM)**
★	**TP-03**	**1.5**	**NP**	**NP**	**NP**	**51**	**SANDY SILT(ML)**
⊙	**TP-03**	**9.0**	**18**	**18**	**NP**	**10**	**POORLY GRADED GRAVEL with SILT and SAND(GP-GM)**
✿	**TP-04**	**1.0**	**NP**	**NP**	**NP**	**45**	**SILTY SAND(SM)**
○	**TP-04**	**2.5**	**NP**	**NP**	**NP**	**1**	**POORLY GRADED SAND with GRAVEL(SP)**
△	**TP-05**	**0.5**	**NP**	**NP**	**NP**	**47**	**SILTY SAND(SM)**
⊗	**TP-05**	**3.0**	**NP**	**NP**	**NP**	**43**	**SILTY SAND(SM)**
⊕	**TP-06**	**3.5**	**NP**	**NP**	**NP**	**7**	**POORLY GRADED SAND with SILT and GRAVEL(SP-SM)**

George Elmer Drive Extension



U = TP-01 @ 1 foot

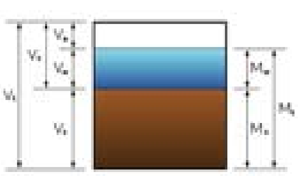
V = TP-01 @ 6 feet

W= TP-03 @ 1.5 feet

X = TP-04 @ 2.5 feet

Y = TP-05 @ 0.5 feet

Z = TP-05 @ 3 feet



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U.S.D.A. Textural Classification

Attachment B
Groundwater Flow Model Modifications

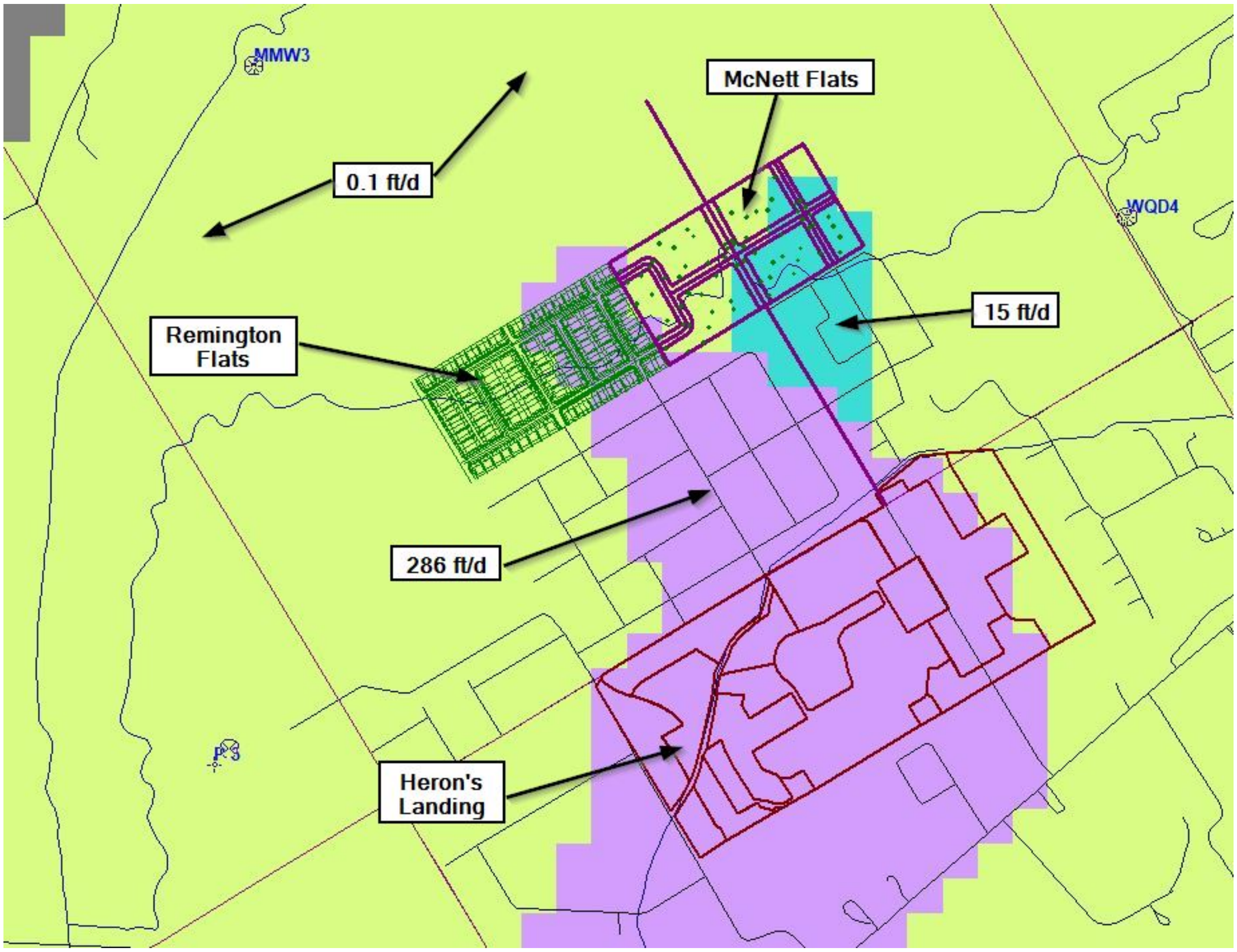


Figure B-1. Model Hydraulic Conductivity Zones – Layer 1

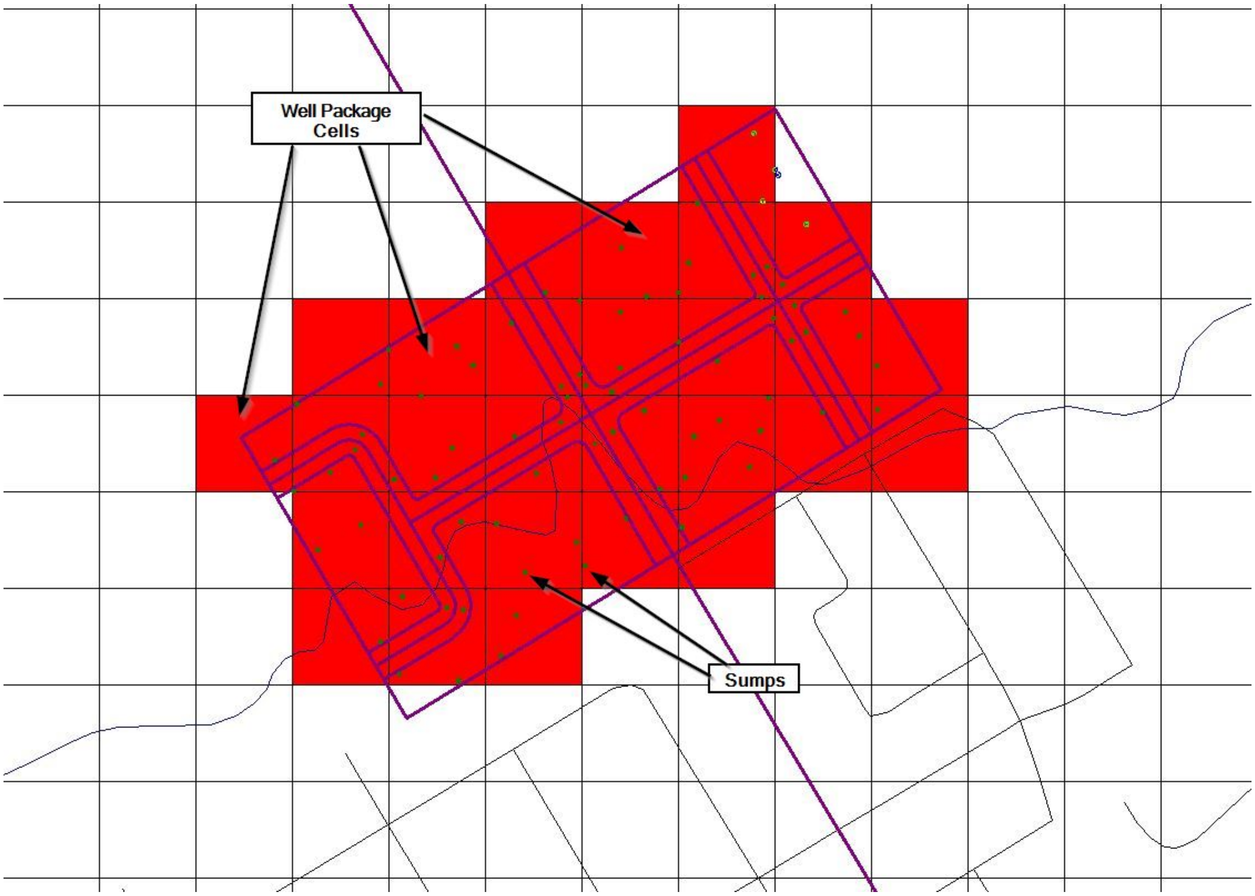


Figure B-2. Location of Well Package Cells Simulating Storm Water Sumps.

Attachment C
Storm Water Discharge Calculations

Description	Northing	Easting	2-yr Discharge FT^3	100-Yr Discharge FT^3	Model ID	Model Well No.
Future Sump	998504.5	827752.879	1000	2250	FS-39	1
Future Sump	998492.928	827935.813	1000	2250	FS-40	2
Future Sump	998379.538	827922.572	1000	2250	FS-43	2
Future Sump	998349.77	827981.309	1000	2250	FS-46	2
Sump	998244.996	828119.874	570.54	1274.22	S-05	3
Sump	998292.482	828130.868	638.59	1426.21	S-21	3
Sump	998290.316	828164.799	633.46	1414.74	S-22	3
Future Sump	998481.356	828118.748	1000	2250	FS-41	3
Future Sump	998388.453	828033.666	1000	2250	FS-42	3
Future Sump	998408.6	828232.5	1000	2250	FS-56	3
Sump	998242.593	828169.937	622.08	1389.32	S-06	4
Future Sump	998318.4	828280.9	1000	2250	FS-57	4
Future Sump	998587.217	827416.836	1000	2250	FS-09	5
Future Sump	998538.092	827364.301	1000	2250	FS-15	5
Future Sump	998514.472	827539.449	1000	2250	FS-10	6
Future Sump	998462.488	827545.392	1000	2250	FS-12	6
Sump	998324.166	827672.093	784.57	1752.23	S-13	7
Sump	998322.655	827717.088	753.19	1682.14	S-14	7
Future Sump	998490.263	827659.651	1000	2250	FS-11	7
Future Sump	998450.209	827803.295	1000	2250	FS-47	7
Sump	998297.706	827715.495	1118.5	2498.05	S-11	8
Sump	998256.298	827752.353	492.41	1099.72	S-18	8
Future Sump	998383.515	827859.697	1000	2250	FS-44	8
Future Sump	998288.532	827793.068	1000	2250	FS-48	8
Sump	998195.001	828116.457	612.66	1368.29	S-08	9
Future Sump	998186.813	827970.058	1000	2250	FS-32	9
Future Sump	998264.167	827924.792	1000	2250	FS-45	9
Sump	998192.598	828166.52	626.05	1398.2	S-07	10
Sump	998135.865	828120.867	583.63	1303.46	S-19	10
Sump	998133.699	828154.798	594.05	1326.72	S-20	10
Future Sump	998122.912	828246.535	1000	2250	FS-49	10
Future Sump	998065.118	828242.299	1000	2250	FS-52	10
Future Sump	997993.702	828238.586	1000	2250	FS-50	11
Future Sump	998529.707	827093.717	1000	2250	FS-07	12
Sump	998454.69	827244.403	959.27	2142.39	S-01	13
Sump	998472.026	827273.651	831.13	1856.22	S-02	13
Future Sump	998444.612	827174.959	1000	2250	FS-01	13
Future Sump	998454.519	827090.419	1000	2250	FS-04	13
Future Sump	998599.879	827197.393	1000	2250	FS-08	13
Sump	998358.1	827277.154	630.78	1408.78	S-15	14
Future Sump	998313.549	827349.963	1000	2250	FS-14	14
Future Sump	998470.456	827420.605	1000	2250	FS-16	14
Future Sump	998345.211	827412.608	1000	2250	FS-17	14
Sump	998299.217	827670.5	1040.26	2323.32	S-12	15
Sump	998262.734	827629.514	472.84	1056.02	S-17	15
Future Sump	998292.744	827534.554	1000	2250	FS-13	15
Future Sump	998203.769	827528.371	1000	2250	FS-23	15
Sump	998187.437	827663.362	839.66	1875.27	S-09	16
Sump	998185.926	827708.357	821.18	1834	S-10	16
Future Sump	998033.641	827722.68	1000	2250	FS-29	16
Future Sump	998186.149	827785.872	1000	2250	FS-31	16
Future Sump	998024.289	827779.148	1000	2250	FS-30	17
Future Sump	998016.651	827962.989	1000	2250	FS-33	17
Future Sump	998063.607	828014.609	1000	2250	FS-34	17
Future Sump	997968.121	827902.481	1000	2250	FS-36	17
Future Sump	998082.108	827905.157	1000	2250	FS-37	17
Future Sump	998084.723	827842.211	1000	2250	FS-38	17
Future Sump	997976.312	828090.784	1000	2250	FS-35	18
Future Sump	997918.343	828188.761	1000	2250	FS-51	19
Future Sump	998325.4	827064.638	1000	2250	FS-05	20
Future Sump	998318.868	827166.93	1000	2250	FS-06	20
Sump	998171.475	827265.237	625.76	1397.56	S-16	21
Future Sump	998207.52	827343.193	1000	2250	FS-22	21
Future Sump	998038.51	827517.819	1000	2250	FS-24	22
Future Sump	998046.38	827394.57	1000	2250	FS-27	22
Future Sump	998163.142	827402.025	1000	2250	FS-28	22
Future Sump	998022.842	827629.804	1000	2250	FS-25	23
Future Sump	997988.171	827505.843	1000	2250	FS-26	23
Infiltration Gallery	997942.693	827715.835	0	26322.38	IG	24
Future Sump	998095.347	827065.981	1000	2250	FS-03	25
Sump	998076.619	827219.234	964.76	2154.65	S-03	26
Sump	998054.126	827244.73	815.1	1820.4	S-04	26
Future Sump	998147.442	827155.984	1000	2250	FS-02	26
Future Sump	998018.637	827061.083	1000	2250	FS-18	26
Future Sump	997937.979	827155.134	1000	2250	FS-19	26
Future Sump	997931.486	827256.826	1000	2250	FS-20	27
Future Sump	997982.978	827328.855	1000	2250	FS-21	27
Future Sump	998535.6	828295.7	1000	2250	FS-53	28
Future Sump	998448.3	828290.1	1000	2250	FS-54	28
Future Sump	998436.3	828289.4	1000	2250	FS-55	28

October 19, 2020 *VIA EMAIL*

Kody Swartz
Woith Engineering
3860 O'Leary Street, Suite A
Missoula, Montana 59808

Subject: **Addendum to Hydrogeologic Evaluation**
Proposed McNett Flats Subdivision

Dear Kody

NewFields issued a Technical Memorandum titled *Hydrogeologic Evaluation, McNett Flats, Missoula, Montana* in August 2020, i.e. NewFields (2020). That report presented an evaluation of the potential risk for groundwater to flood basements and crawlspaces in the proposed subdivision (Site, **Figure 1**) and on surrounding properties, as well as the potential effect of using sumps to manage storm water on groundwater levels at the subdivision.

The purpose of the information contained in this letter is to address comments you received from the City regarding the analysis in NewFields (2020) and to incorporate new site information. In an email dated October 8, you indicated that grading concept for the subdivision was revised and that some of the sump locations changed, and also that the City requested an evaluation of sump impacts for a 100-year storm event and an evaluation of potential impacts of managing stormwater with sump on groundwater quality. These items are addressed below. A revised set of figures resulting from this work is attached.

1.0 Revised Sump Locations

Figure 2 shows revised sump locations were provided by Woith Engineering. As in the previous hydrogeologic evaluation (NewFields 2020), MODFLOW's Well Package was used to simulate infiltration of stormwater via sumps. The number of sumps within each model cell was identified and the infiltration rate for each Well Package cell was calculated by summing the individual sump rates identified for each model cell for both the 2-year and 100-year events. **Table 1** summarizes the location of each Well Package cell in the model, the number of sumps in each cell, and the 2-year and 100-year infiltration rates based on rates provided by Woith.

Similar to the approach used in NewFields (2020), the simulations were completed by adding Well Package cells to the same transient simulation replicating period of seasonal high flows in Grant Creek and associated high groundwater levels during 2004. Infiltration via sumps for the 2-year and 100-year storm event was simulated to occur over a 24-hour (1-day) period using the rates indicated in **Table 1,** followed by a 9-day period with no sump infiltration.

Table 1. Summary of Model Well Package Cells Representing Sump Discharge

Well	Model Cell Row	Model Cell Column	Number of Sumps	2-Year Flood Rate (ft^3/d)	100-Year Flood Rate (ft^3/d)
1	48	25	1	1,000	2,250
2	48	26	3	3,000	6,750
3	48	27	5	3,366	7,950
4	48	28	2	763	1,836
5	49	23	2	2,000	4,500
6	49	24	2	2,000	4,500
7	49	25	4	3,055	7,196
8	49	26	5	3,802	8,635
9	49	27	4	2,015	4,714
10	49	28	5	3,412	7,929
11	49	29	1	1,000	2,250
12	50	22	1	1,000	2,250
13	50	23	5	3,948	9,277
14	50	24	3	3,000	6,750
15	50	25	7	4,020	9,264
16	50	26	6	3,673	8,572
17	50	27	6	6,000	13,500
18	50	28	3	1,453	3,558
19	50	29	1	1,000	2,250
20	51	23	3	2,227	5,125
21	51	24	6	2,794	6,768
22	51	25	3	3,000	6,750
23	51	26	4	2,421	5,967
24	52	23	1	1,000	2,250
25	52	24	5	3,990	9,244
26	52	25	2	2,000	4,500

2.0 Groundwater Mounding

The model was used to simulate potential groundwater mounding (increase in water table elevation) for both the 2-year and 100-year events. Simulation of the 2-year storm event completed previously (NewFields 2020) was rerun using the new sump configuration provided by Woith. simulation of the 100-year storm event is new and addresses one of the City's requests.

Simulated groundwater mounding due to sump discharge of stormwater during a 2-year event is shown on **Figure 3**. Results are similar to the previous 2-year simulation (NewFields 2020), and the map shows that the maximum increase in the elevation of the water table is approximately 0.6 feet beneath the middle of the Site and generally less than 0.5 feet beyond the Site boundary.

Potential groundwater mounding due to sump discharge of stormwater during a 100-year event is shown on **Figure 4**. This map shows that the maximum increase in the elevation of the water table is approximately 1.4 feet beneath the middle of the Site. Maximum mounding at the Site boundary occurs to the south and is approximately 1.2 feet.

3.0 Depth to Groundwater

Figure 5 is a potentiometric surface map showing typical seasonal high groundwater elevations (this was Figure 4 in NewFields [2020]). This map was constructed by first digitizing groundwater elevation contours on the June 2004 potentiometric surface map from (HDR/Maxim 2005). Then, 2.85 feet was added to each groundwater elevation contour. Contour data were then converted to a raster data set for the entire model domain with 1-foot cell spacing, and that data set was then used to create elevation contours in even 1-foot increments. In addition, 2.85 feet was added to posted groundwater elevations for each monitoring well in the area.

Figure 6 is a revised map showing depth to groundwater during typical high groundwater conditions (revised from Figure 5 in NewFields (2020). Groundwater elevations in **Figure 5** described above were subtracted from the revised final grade elevations provided by Woith to develop **Figure 6**. Depths to groundwater beneath the Site for the typical seasonal high groundwater conditions on **Figure 6** range from 14.5 to 15.5 feet below ground surface (bgs) in the west portion of the subdivision to greater than 19 feet bgs along the eastern boundary and portions of the south-central area. Similar to results reported in NewFields (2020), results indicate that groundwater levels under typical seasonal high groundwater conditions are estimated to be greater than 10 feet beneath the entire subdivision.

Comparing **Figure 3** to **Figure 6** indicates that following a 2-year storm event, depth to groundwater would range from approximately 14 feet bgs along the western Site boundary, to 16 feet bgs beneath the middle of the Site, to 18 feet bgs beneath the east boundary of the Site.

Comparing **Figure 4** to **Figure 6** indicates that following a 100-year storm event, depth to groundwater would range from approximately 13 feet bgs along the western Site boundary, to about 15 feet bgs beneath the middle of the Site, to 17 feet bgs beneath the east boundary of the Site.

4.0 Potential Groundwater Quality Impacts

The numerical model was used to simulate fate and transport of nitrate in storm water through sumps to the underlying shallow aquifer. MT3D software was used to simulate transport and fate of nitrate from sumps through the aquifer. The flow field was established using the transient MODLFOW simulation of the 2-year storm event.

City of Missoula staff had previously provided NewFields with water quality data for storm water outfalls at three locations around Missoula. The city collected samples from each outfall five times from April 2017 through April 2019. Samples were analyzed for several constituents including total nitrogen. The average total nitrogen in the samples is 2.44 milligrams per liter (mg/L). Assuming total nitrogen is representative of nitrate, source concentrations in Well Package cells representing sumps in the transport model were assigned nitrate concentrations of 2.44 mg/L. The transport simulation was executed and run for the same period as the flow model.

Assumptions inherent in the fate and transport simulation include the following conservative assumptions:

- Average concentrations from the City of Missoula data are representative of nitrate concentrations that would occur during a 2-year storm event. In reality, appreciable dilution might be expected to occur during this type of event.
- No chemical attenuation of nitrate would occur in the sumps or the vadose zone beneath the sumps.

The maximum predicted extent of nitrate in groundwater is shown on **Figure 7**. The model predicts that the maximum predicted nitrate concentration beneath the Site is 0.05 mg/L, which is slightly above the laboratory reporting limit of 0.020 mg/L and well below the groundwater human health standard of 10 mg/L (Circular DEQ-7). This figure indicates that maximum nitrate concentrations in groundwater beyond the Site boundary would be below the laboratory reporting limit.

5.0 Summary and Conclusions

Predicted mounding of the groundwater table from use of sumps at the Site during a 2-year storm event will be minimal, a maximum increase of 0.6 feet in water table elevation, and generally less than 0.5 feet beyond the Site boundary (**Figure 3**). Predicted mounding of the water table from use of sumps at the Site during a 100-year storm event will greater, with a maximum 1.4 feet of increased water table elevation, and generally less than 1.2 feet beyond the Site boundary (**Figure 4**). .

Similar to that reported in NewFields (2020), depth to groundwater beneath the Site during typical seasonally high groundwater conditions is estimated to range from 14.5 to 19.5 feet **Figure 6**).

Use of sumps to manage stormwater will have a minimal impact on groundwater elevations. Following a 2-year storm event, depth to groundwater would range from approximately 14 feet bgs along the western Site boundary to 16 feet bgs beneath the middle of the Site, to 18 feet bgs beneath the east boundary of the Site. Following a 100-year storm event, depth to groundwater would range from approximately 13 feet bgs along the western Site boundary to about 15 feet bgs beneath the middle of the Site, to 17 feet bgs beneath the east boundary of the Site.

Use of sumps to manage stormwater at the site is unlikely to have a measurable impact on nitrate concentration in groundwater. The maximum nitrate concentration predicted in shallow groundwater beneath the Site is predicted to be 0.05 mg/L (**Figure 7**), which is well below the groundwater human health standard of 10 mg/L. Maximum nitrate concentrations in groundwater predicted beyond the Site boundary would be below the laboratory reporting limit.

6.0 References

NewFields, 2020. Hydrogeologic Evaluation, McNett Flats Missoula, Montana. Technical Memorandum prepared for Woith Engineering and Tollefson Properties, LLC. August 21.

HDR/Maxim, 2005. Grant Creek Environmental Restoration/Flood Control Project: Task 500 Groundwater Studies. Prepared for Missoula County by Maxim Technologies in association with HDR Engineering, Inc. 44 pp.

Sincerely,
NewFields MES

Gary E. Andres

A. Campbell Stringer, P.G.

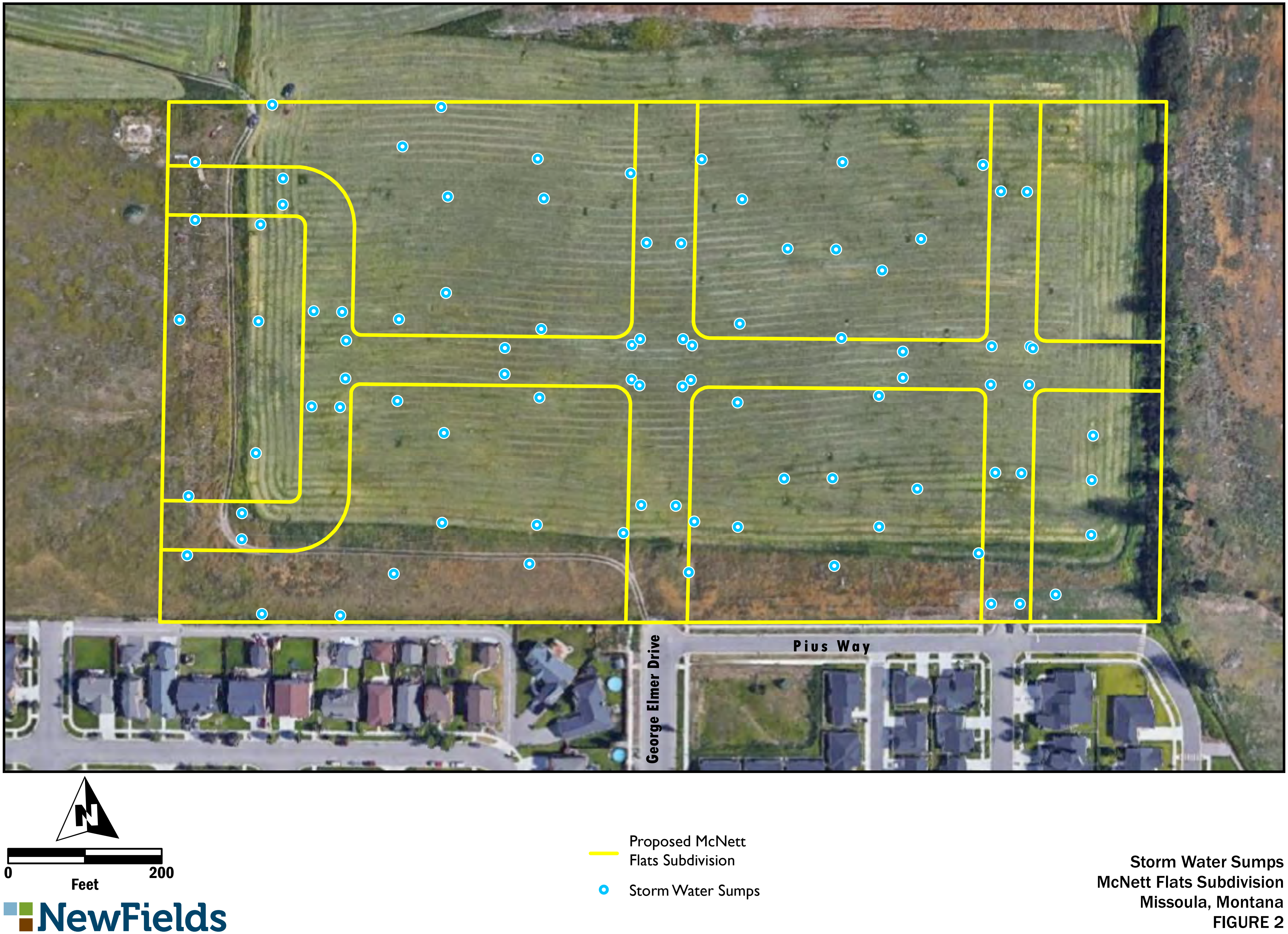
Attachment: Revised Figures

ATTACHMENT
Revised Figures

NewFields

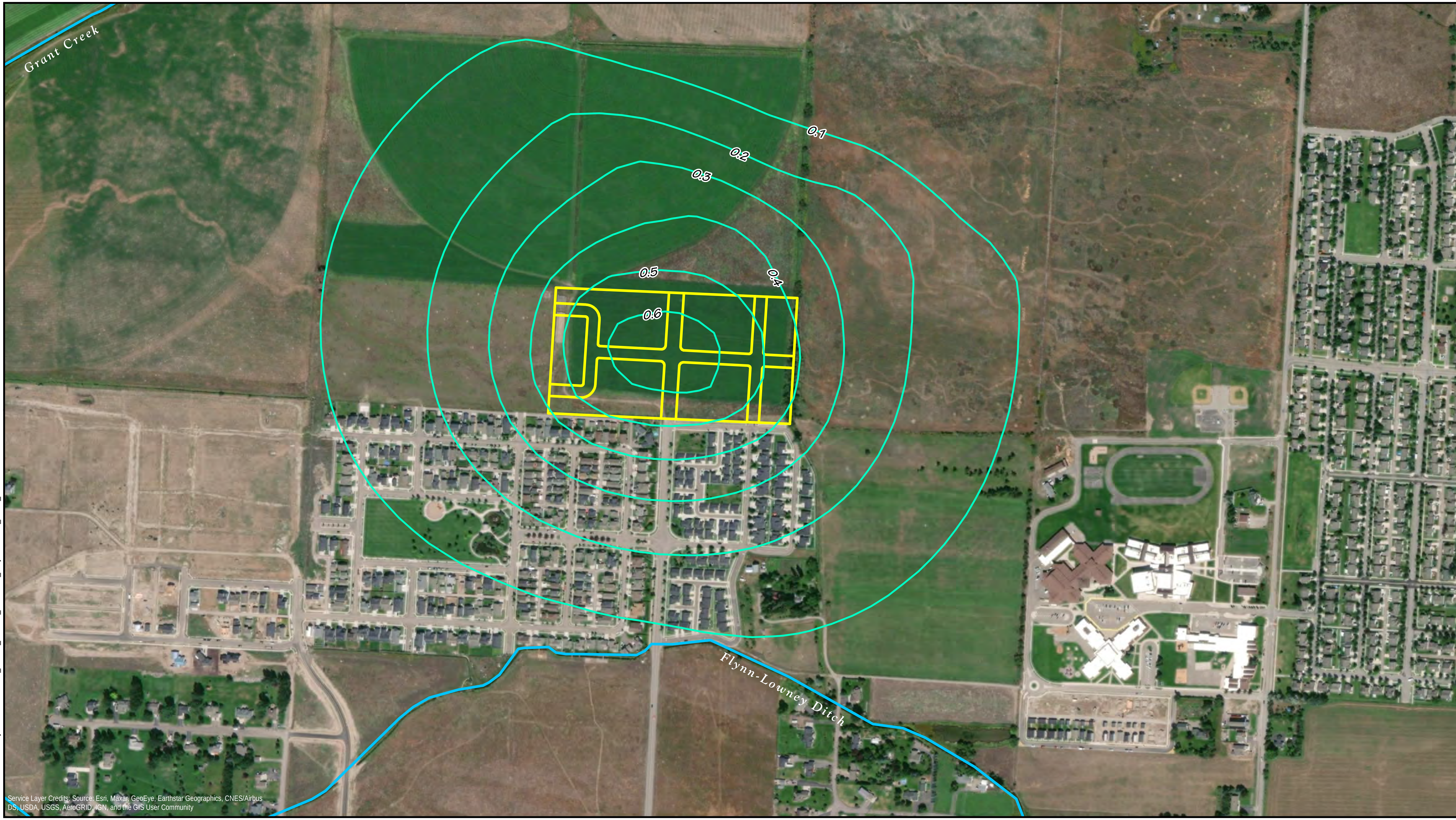
Location Map
McNett Flats Subdivision
Missoula, Montana
FIGURE 1

\\NFHELENA\shares\Projects\350.0523.000_McNett_Flats\05_GIS\05.01_Projects\Stormwater_Drains.mxd



NewFields

Storm Water Sumps
McNett Flats Subdivision
Missoula, Montana
FIGURE 2



\\NFHELENA\shares\Projects\350.0523.000_McNett_Flats\05_GIS\05.01_Projects\Storm_Event_2YR.mxd

N

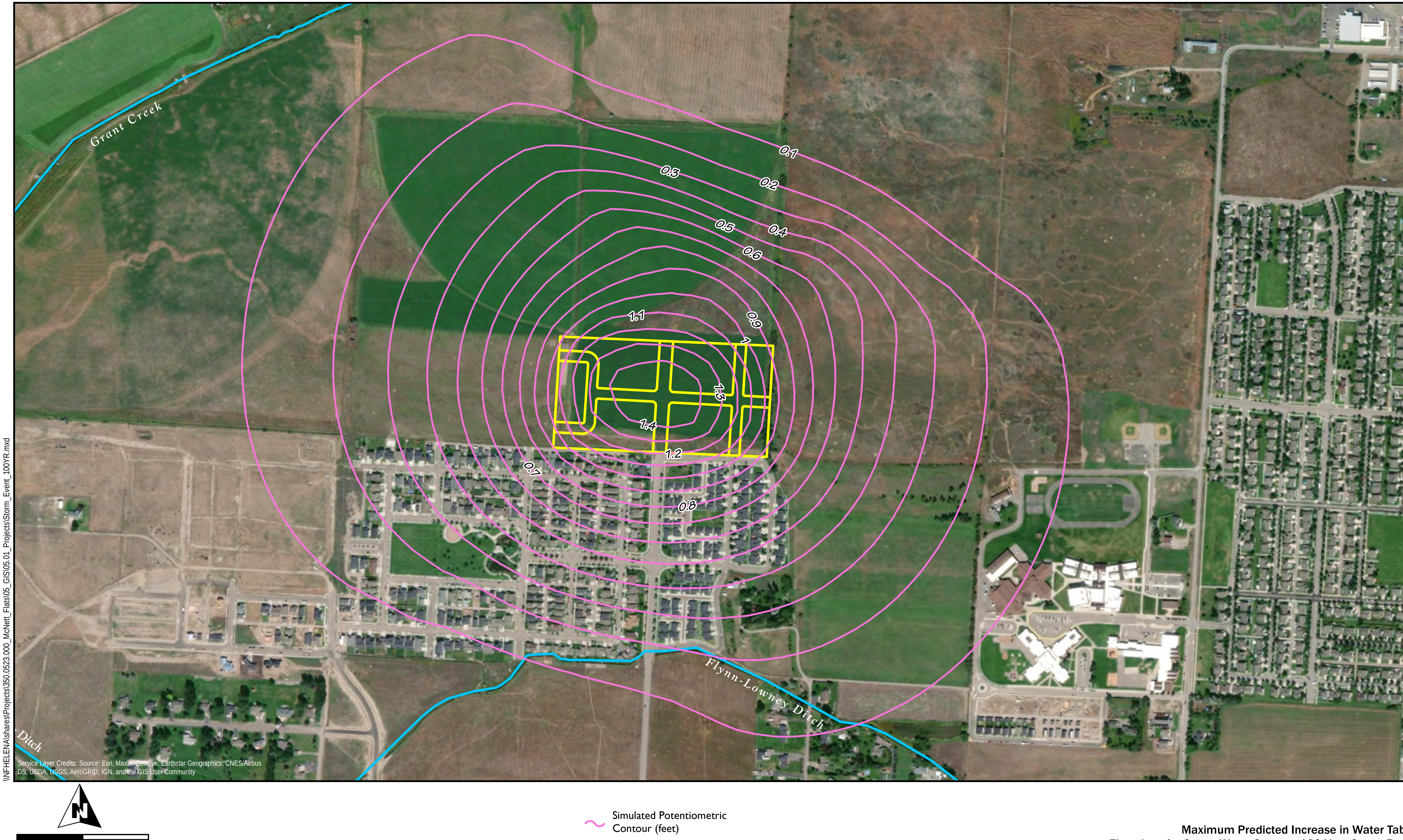
0 Feet 500

NewFields

Simulated Potentiometric Contour (feet)

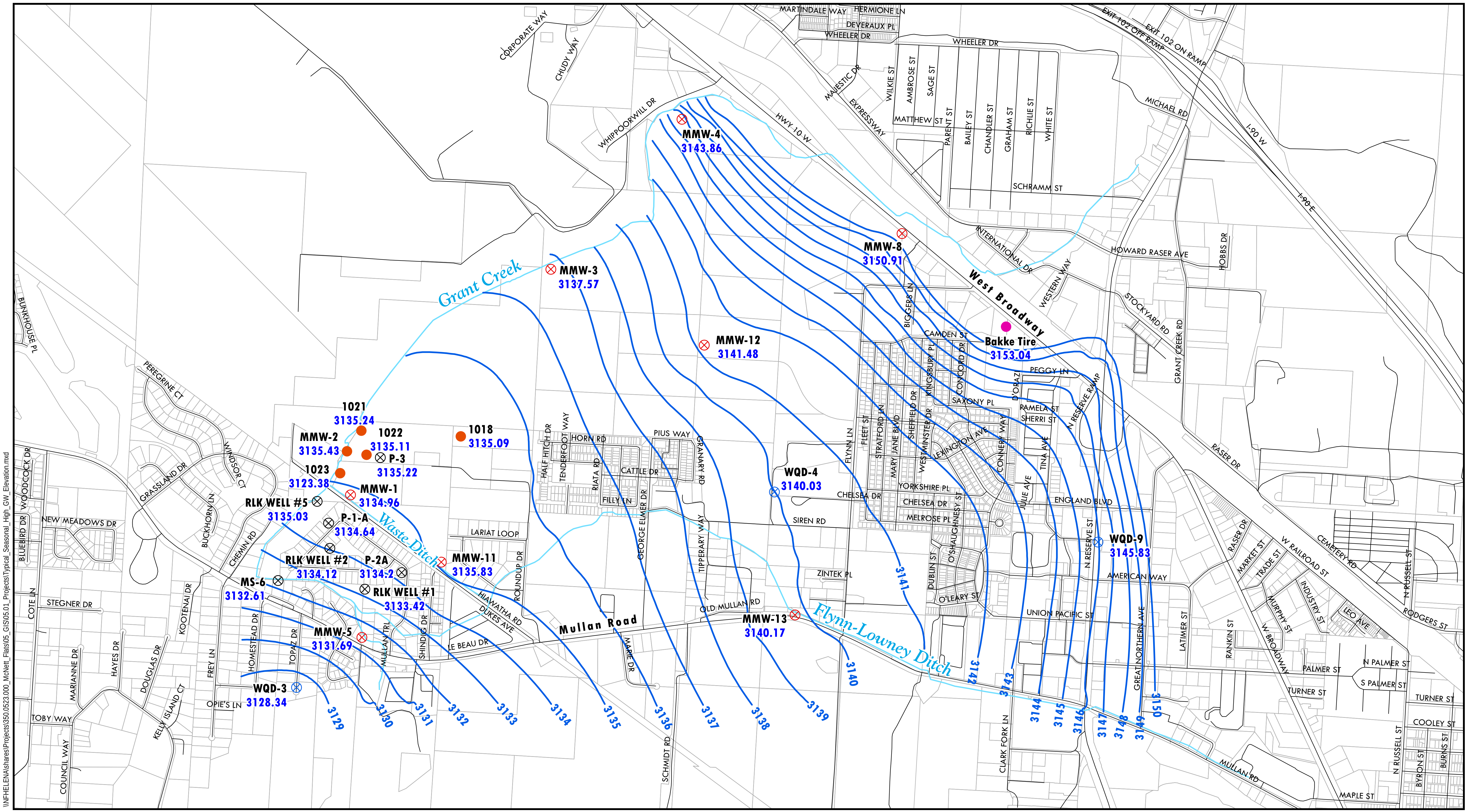
Proposed McNett Flats Subdivision

Maximum Predicted Increase in Water Table Elevations for Storm Water Sumps - 2 Year Storm Event
McNett Flats Subdivision
Missoula, Montana
FIGURE 3



NewFields

Maximum Predicted Increase in Water Table Elevations for Storm Water Sumps - 100 Year Storm Event
McNett Flats Subdivision
Missoula, Montana
FIGURE 4



\\NFHELENA\shares\Projects\350.0523.000_McNett_Flats\05_GIS\05.01_Projects\Typical_Seasonal_High_GW_Elevation.mxd

0 Feet 1,500

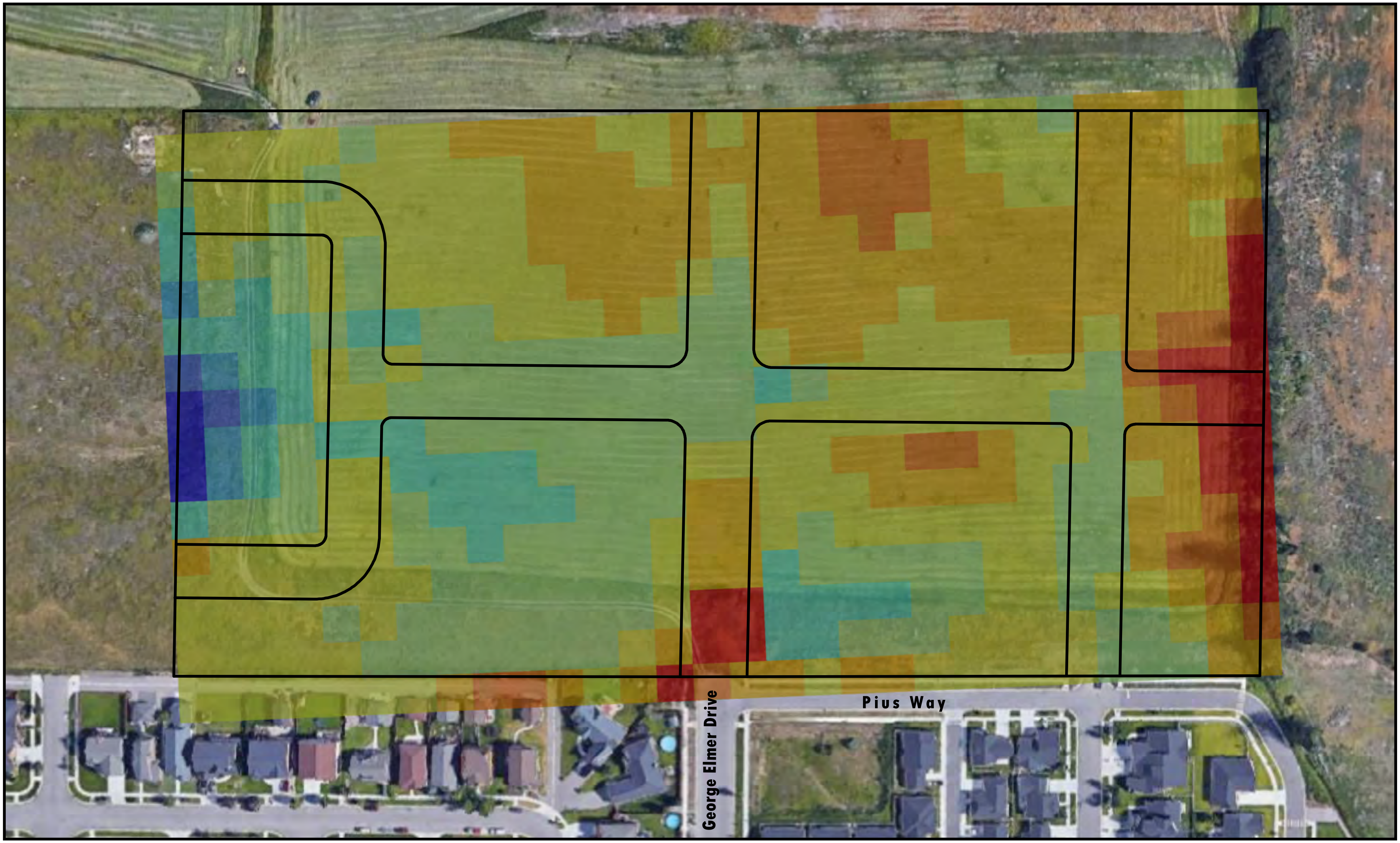
NewFields

- Monitoring Well
- Previous Investigation Well
- Private Supply Well
- Test Pit Piezometer
- Water Quality District Well
- Water Table Elevation Contour (feet amsl)

Note:
Data are from June 2004 +2.85 feet

Typical Seasonal High Groundwater Elevation
McNett Flats Subdivision
Missoula, Montana
FIGURE 5

\\NFHELENA\shares\Projects\350.0523.000_McNett_Flats\05_GIS\05.01_Projects\Predicted_Depth_To_GWater.mxd



0 Feet 200

NewFields

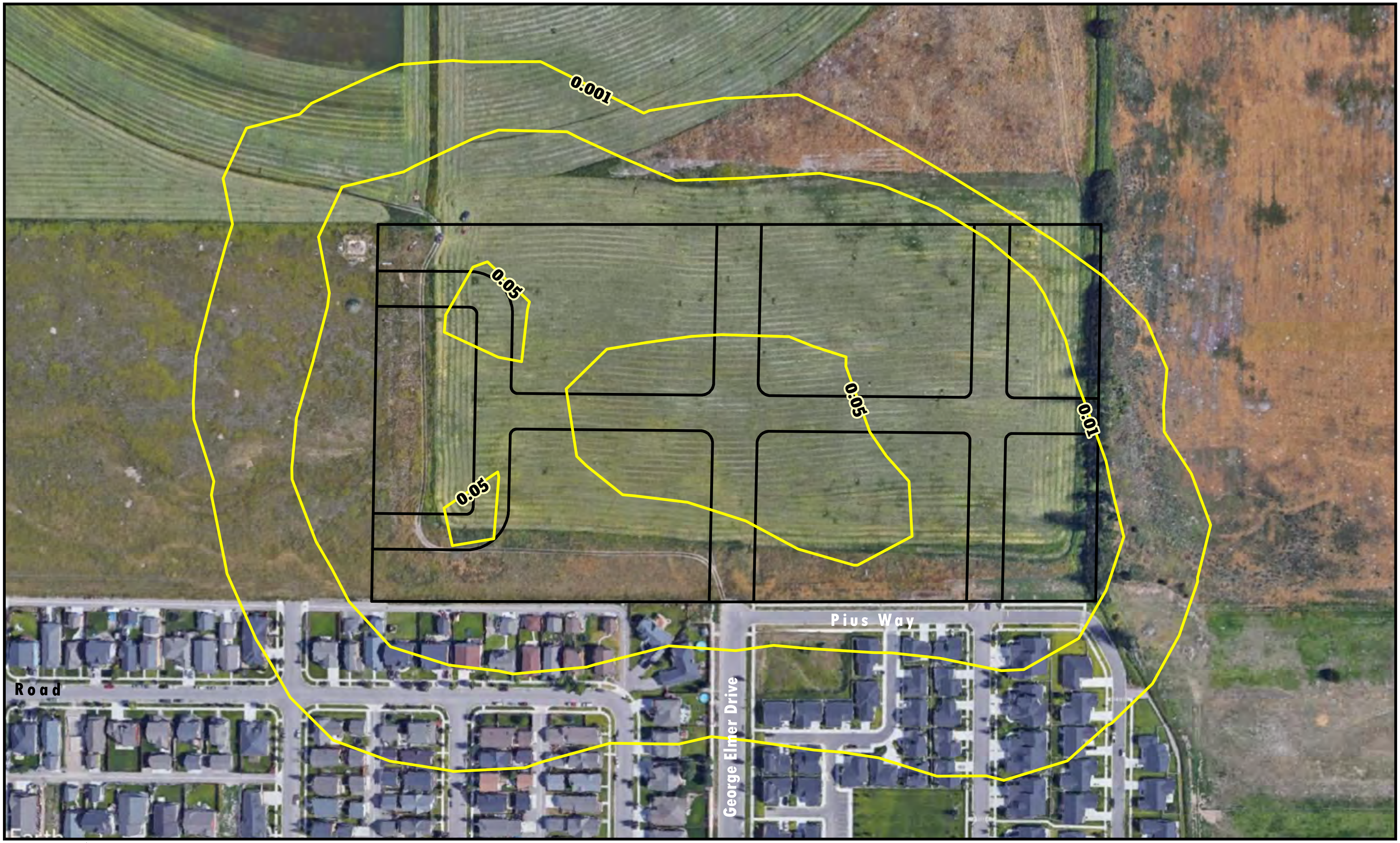
Depth to Groundwater (feet) Below Final Design Ground Surface

Proposed McNett Flats Subdivision

14.5 - 15	16 - 16.5	17.5 - 18
15 - 15.5	16.5 - 17	18 - 18.5
15.5 - 16	17 - 17.5	18.5 - 19

Depth to Groundwater During Typical Seasonal High Groundwater Conditions- June 2004 + 2.85 feet
McNett Flats Subdivision
Missoula, Montana
FIGURE 6

\\NFHELENA\shares\Projects\350.0523.000_McNett_Flats\05_GIS\05.01_Projects\Nitrate_Concentrations.mxd



NewFields

Maximum Extent of Simulated Nitrate Concentrations
2-Year Storm Event
McNett Flats Subdivision
Missoula, Montana
FIGURE 7