# EGRP Infiltration Test at Coleman Young International Airport

# Final Report

*Written By*

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*Submitted To*

MDEQ
Groundwater Discharge Program

*and*

Parjana, Inc.

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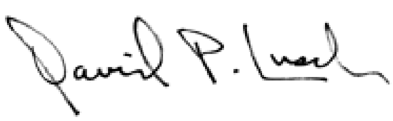
## INTRODUCTION

On May 3, 2013, SME submitted a work plan to Parjana, Inc. proposing a scope of services and procedures designed to test Parjana's EGRP technology at a site in the southwest corner of the Coleman Young International Airport (CYIA) in Detroit, Michigan. The purpose of their proposed activities was to evaluate the performance of the EGRP technology with respect to the concerns of their Michigan Department of Environmental Quality (MDEQ) regarding the potential for EGRPs to accelerate the downward migration of surficial contaminants into a lower usable aquifer. The objective of their proposed testing was to evaluate whether the EGRPs allowed surface water to "short circuit" down the system compared to nearby areas with no EGRPs installed. This preliminary study was not intended to evaluate how EGRPs function, nor was it designed to determine the fate and transport characteristics of infiltration water constituents in the presence of EGRPs.

The SME work plan of May 3, 2013 incorporated feedback received from the MDEQ in a March 11, 2013 letter regarding review of a proposed testing protocol for the EGRPs provided by Mr. Roy Cole of Parjana; a project meeting held on March 20, 2013, and follow-up conversations with Mr. Eric Chatterson and Mr. Jim McEwan of the MDEQ. A revised work plan, based on the original testing concept of SME's May 3, 2013 plan, was developed by Parjana, Inc. in response to comments received from MDEQ at a review meeting held on July 10, 2013.

On July 19, 2013, Parjana, Inc. retained my services as an independent consultant to assist them in developing and executing the infiltration water quality test at Coleman Young International Airport.

I, David P. Lusch, certify that I was the sole author of this report and that all interpretations and conclusions herein were made solely by me with no inputs, alterations or edits from Parjana, Inc.



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# METHODOLOGY

## Site Description

***Location at CYIA***

The infiltration study site is located on the property of Coleman Young International Airport, which is situated near the intersection of Gratiot Avenue and Conner Street in Detroit, Michigan (Figure 1). The site is just north of the turn-pad at the west end of taxiway H, which parallels runway 07 – 25 (Figure 2).


*Figure 1. General location of Coleman Young International Airport and the infiltration study site.*

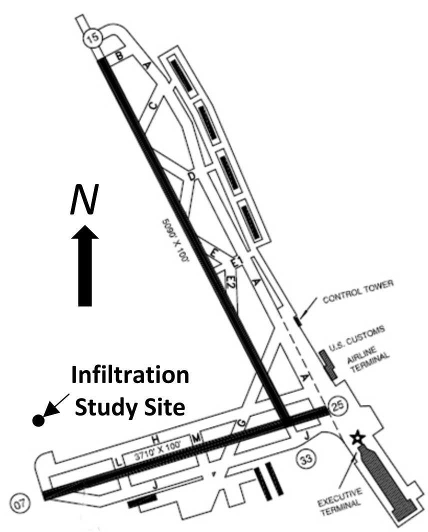


*Figure 2. Location of the infiltration study site at CYIA.*

***Summary of soil borings***

Prior to the infiltration study, SME installed five monitoring wells (MWs) in the immediate vicinity of the study site, designated as P1 - P5. MWs P1 and P2 were installed on October 4, 2012; P3 was installed on October 5, 2012; and P4 and P5 were installed on October 10, 2012 at the locations shown on Figure 3.

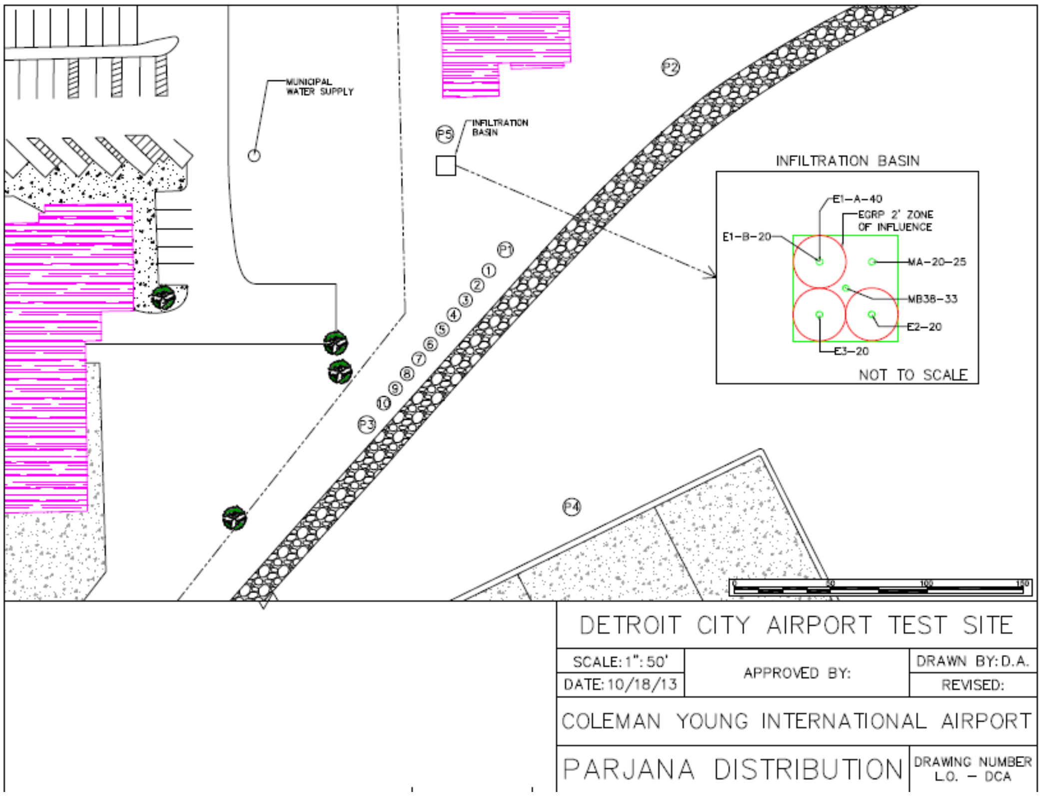


*Figure 3. CYIA Infiltration Study Site Layout.*

The MWs were installed at depths ranging from 30 to 42 feet below ground surface. The subsurface media penetrated by the borings was predominantly silty clay, with occasional to frequent, thin sand seams and layers. During the soil borings, groundwater was encountered at depths ranging from 22 to 38 feet below ground surface at P1, P2, P3 and P5, but was not encountered during the boring of P4. Soil boring logs for these five MWs are provided in Appendix A.

## Infiltration Test Infrastructure

***Monitoring Well hardware and installation***

The specific location of the infiltration study site was chosen to be within the envelop of the previous MWs P1, P2 and P5 and far enough north of the airport road to avoid several deep ruts in the soil that would have hindered the mobility and stability of the pickup truck mounted Geoprobe® and the EGRP drilling rig. On August 1, 2013, SME attempted to install two monitoring wells for the infiltration test site using their truck-mounted, Geoprobe® rig. Soil samples were collected continuously from grade to the termination depth of the borings using a 48-inch long, 2-inch OD Geoprobe® Macro Sampler fitted with a disposable acetate liner (Figure 4).


*Figure 4. Truck-mounted GeoProbe® taking continuous soil cores at the site.*

During the initial installation of the 40-ft. MW, the five ft.-long, sand pre-pack screened section (Figure 5) became lodged in the bottommost 2-inch push-tube section. SME personnel concluded that up-hole groundwater pressure transported regolith into the annulus between the screen and the 2-inch push-tube, after the drive plug had released. SME attempted to pull the schedule 40 PVC, 0.75-inch ID MW, but it broke off at a coupling, leaving about 25 feet of 0.75-inch PVC pipe in the hole (5 ft. of screened section, plus about 20 feet of 0.75-inch ID schedule 40 PVC casing). SME attempted to plug this hole with *EnviroPlug*® medium chip bentonite, but they were only able to get half a bag down the hole. In general, one bag of medium chip bentonite should fill about 20 feet of a 2-inch bore hole. This means that only the uppermost 9 – 10 feet of the 40-ft. hole was grouted (the bentonite chips likely bridged at depth).

SME moved about 15 feet northwest of the “closed” hole and again sampled the earth materials to a depth of 40 feet. They encountered significant groundwater leakage below a depth of about 24 – 28 feet. SME staff and I were in agreement that it was very likely that the same problem of the screen “locking” in the 2-inch push-tube would occur again. With SME staff concurrence, I recommended that the MWs NOT be installed with the Geoprobe®. All parties agreed that the use of a hollow-stem auger drill rig was strongly advised. Parjana’s site manager, Mr. Chris Tylenda, concurred with this recommendation.

On August 7, 2013, Heritage Hydrologics, LLC of Saline, MI, a certified Parjana installer, brought a self-propelled, auger drill rig to the site in order to install both the monitoring wells and the EGRP nests (Figure 6). When using the hollow-stem auger flights, a wooden plug closed the drill-stem orifice allowing the insertion of the MW tubes (Figure 7). For these operations, Heritage was responsible for all drilling and the installation of the EGRP nests, while SME was responsible for the installation, grouting and development of the two monitoring wells.


*Figure 5. A five-ft.-long, sand pre-pack, screened section for the 0.75-inch ID, schedule 40 PVC, MW.*

*Figure 6. Parjana's custom, self-propelled, auger drill rig.*

*Figure 7. Hollow-stem auger with drilling plug installed.*

The location of the infiltration study site was moved about 20 feet northwest of the "closed" initial MW hole. Both MWs installed by SME through Heritage's hollow-stem augers (Figure 8) used sand-pre-pack screens that were five feet in length, with a slot size of 0.010 inches and attached to ¾-inch ID, schedule 40 PVC riser pipe (Figure 9). The screens were set at depths of 20 to 25 feet for the shallow MW and 33 to 38 feet for the deep MW. In both cases, the riser pipes were extended about 2.5 feet above the ground surface and capped. For both MWs, SME installed addition sand around the pre-packed screen and extended the sand pack two feet above the screened interval (Figure 10). SME grouted the remaining annular spaces in both MWs with *EnviroPlug*® medium chip bentonite to the ground surface, wetting the down-hole bentonite chips after each two ft. thickness was installed (Figure 11).

*Figure 8. SME installing a ¾" MW through Heritage's hollow-stem auger.*


*Figure 9. Close-up of sand-pre-packed screen with 10-slot mesh.*

*Figure 10a. Sand packing one of the monitoring wells (sealed ¾" riser tube is within the hollow-stem auger about 4 inches below the top of the flight).*

*Figure 10b. Checking the depth of the top of the sand pack prior to grouting the MW.*

*Figure 11. Grouting one of the MWs using medium bentonite chips (down-hole bentonite being wetted).*

***EGRP hardware and installation***

Parjana staff constructed the three EGRP nests on site. Heritage staff installed them in close proximity to each other (~ 2 ft. apart) and adjacent to the two MWs. Each EGRP nest consisted of a cluster of three EGRPs that were fitted together and zip-tied along with a 3/8 inch OD sampling tube (Figure 12).

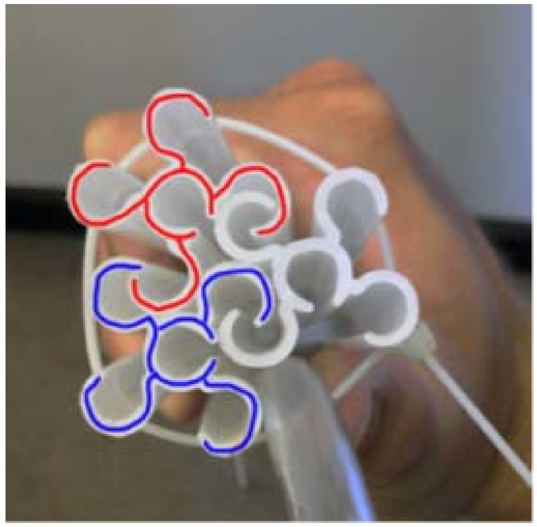

*Figure 12. EGRP nest composed of three individual EGRPs (colored for clarity) and a sampling tube zip-tied together.*

The study design called for one 20-ft. EGRP nest to be installed with its top approximately 6 inches below grade. A second 20-ft. EGRP nest and a 40-ft. EGRP nest were to be installed with their tops two feet below grade, consistent with the current installation standards as restricted by the MDEQ (Appendix B). I observed the construction and installation of these EGRP nests, to ensure their conformance with the study plan (Figures 13 – 15).

In accordance with standard practice, Heritage drilled the three holes for the EGRP nests with their solid-stem augers. The two 20-ft. EGRP installations went smoothly, but the top-depths ended up at 4 inches and 16 inches below grade, respectively. I judged these depths to be adequate and Mr. Tylenda concurred.

On their first try at installing the 40-ft. EGRP nest, Heritage drilled a 42-ft. hole, but upon insertion, the top of the 40-ft. EGRP nest was only at 6 inches below grade. The EGRP nest was removed and the hole was bored to a depth of 45 feet. This time, however, upon removing the solid-stem auger, slumping in the hole occurred at a depth of about 25 feet (presumably due to groundwater seepage into the open bore hole at that depth). Heritage staff decided to abandon this hole and move to another nearby location. I concurred with that decision.

Under my supervision, this abandoned hole was plugged using *EnviroPlug*® medium bentonite chips to fill the interval between depths of 19 – 25 feet (*i.e.*, at and 6-ft. above the groundwater seepage zone). The bentonite was hydrated from above with approximately 3 gallons of water. The interval from 19 ft. to 3 ft. below grade was filled with cuttings and tamped with one auger flight (not rotating) about every three feet. The upper 3 ft. of the hole was filled with medium bentonite chips and hydrated.

The solid-stem auger drill was moved over 3 feet and a new hole was drilled to a depth of 47 feet. Immediately upon removing the auger flights, the 40-ft. EGRP nest was installed. It came to rest with its top 16 inches below grade, which both Heritage staff and I agreed was a sufficient depth. The cuttings from this hole were moist at some depths, but none were saturated and "soupy" as they had been in the first 45-ft. hole (even though the two holes were only 3 feet apart).

*Figure 13. 20-ft. EGRP nest installed 4-inches below grade.*

*Figure 14. 40-ft. EGRP nest being installed in an open bore hole that had been drilled with a solid-stem auger.*

*Figure 15. 40-ft. EGRP nest installed 16 inches below grade*

Groundwater sampling tubes, 3/8-inch OD, were installed down the side of each of the three EGRP nests. The two 20-ft. EGRP nests had a single sampling tube on each, allowing the collection of groundwater samples from a depth of approximately 20 feet. The single 40-ft. EGRP had two sampling tubes installed along its length, allowing the independent collection of groundwater samples from depths of approximately 20 feet and 40 feet. The bottom opening of each sampling tube was plugged and the bottommost 10 inches of each tube were perforated with numerous 3/32-inch holes and wrapped with fabric, which served as a screen (Figures 16 and 17). In all cases, the sampling tubing for each EGRP extended at least four feet above the ground surface to facilitate sampling (Figure 18).

### ***Final In-ground Infiltration Infrastructure***

| ***Name*** | ***Sample Interval*** | ***Description*** |
|---|---|---|
| MA-20-25 | 20 - 25 ft. | Shallow monitoring well (¾-inch ID, schedule 40 PVC) |
| MB-38-33 | 33 - 38 ft. | Deep monitoring well (¾-inch ID, schedule 40 PVC) |
| E1-A-40 | 39.2 - 40 ft. | Deep sampling tube on 40 ft. EGRP nest (top @ 16 in. depth) |
| E1-B-20 | 19.2 - 20 ft. | Shallow sampling tube on 40 ft. EGRP nest (top @ 16 in. depth) |
| E2-20 | 19.2 - 20 ft. | Sampling tube on 20 ft. EGRP nest (top @ 4 in. depth) |
| E3-20 | 19.2 - 20 ft. | Sampling tube on 20 ft. EGRP nest (top @ 24 in. depth) |

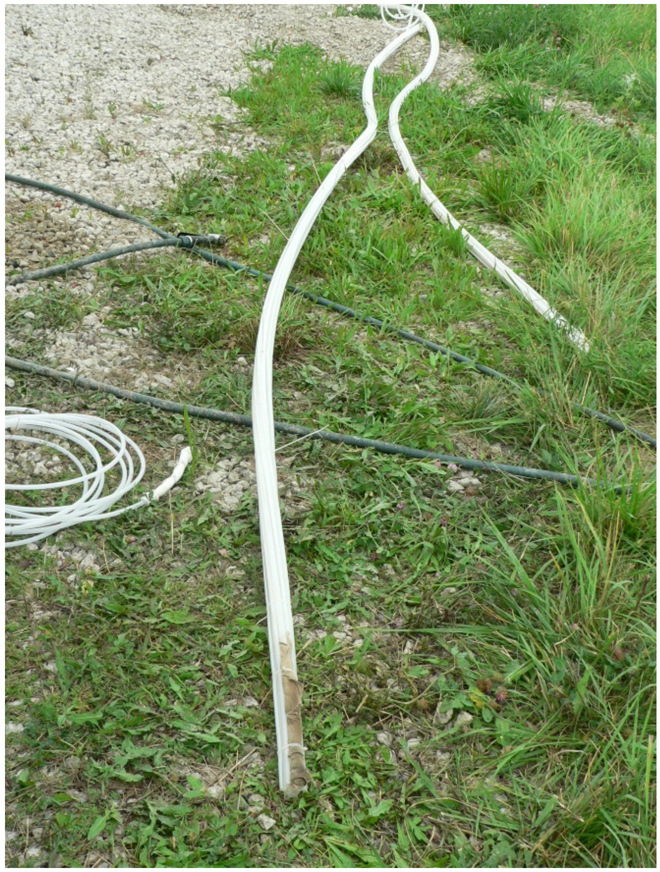

*Figure 16. 20-ft. EGRP nest showing sampling tube "screen."*


*Figure 17. Close-up of 20-ft. EGRP nest showing sampling tube "screen.*


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*Figure 18. EGRP nest sampling tubes extended above grade to facilitate sample collection. The arrow points out the 40-ft. EGRP nest that has two sampling tubes, one at a depth of 20 feet and a second at a depth of 40 feet.*

***Infiltration Pool Description***

For ease of construction, the infiltration pool was re-designed to be square (in the original study plan it was envisioned to be round). Given the spacing between the two MWs and the three EGRP nests, and the desire to have the infiltration pool walls about 24 inches from any MW or EGRP, it was decided that an 8-ft. by 8-ft. pool would be optimum. The pool design addressed two major concerns: (1) minimize any leakage through or under the walls; and (2) have walls sturdy enough to withstand the pressure of holding up to 12 inches of water (*i.e*., 64 cubic feet). Pool construction occurred on August 23, 2013.

Sheets of ¾” pressure-treated plywood (4’ x 8’) were cut to 3 x 8 feet. The 3-ft. height was determined on the basis of the maximum depth-of-cut that the available trenching machine could make: 1.5 feet (Figure 19). The plywood sheets were screwed into 2” x 2” corner braces to produce a roughly square pool wall. This assembly was wrapped in double-thickness, 0.012”, rip-stop poly sheeting, which provided 0.024” thickness of waterproof wrap. The ends of the wrap were overlapped about 4 feet and sealed with commercial, waterproofing spray (Figure 20). With this design, half the wall height was below grade in the trench (providing stability) and the other half was above grade, providing 1.5 feet of freeboard for the infiltration pool (Figure 21). To prevent leakage under the walls, the inside trench was filled with bentonite chips and thoroughly hydrated before the pool was filled the first time (Figure 22).

*Figure 19. Self-propelled trenching machine cutting the trench for the infiltration pool walls.*

*Figure 20. Pool wall assembly wrapped in 0.024-inch rip-stop poly sheeting and sealed with commercial waterproofing spray (black stripe).*

*Figure 21. Infiltration pool walls installed in the trench, exposing 1.5 feet above grade.*

*Figure 22. The inside trenches were filled with bentonite, which was thoroughly hydrated before filling the pool.*

### *Water Supply Description*

The water supply for the infiltration study was obtained from a nearby municipal fire hydrant located approximately 150 feet west of the test site. This hydrant is situated on the grounds of the former Benjamin O. Davis, Jr. Aerospace Technical High School. The hydrant is outside the security fence for the airport, but within the security fence for the former high school (Figure 23). The physical security of the hydrant site was an important consideration, since the hydrant valve was kept in the open position throughout the infiltration test and vandalism was a real concern. Parjana staff obtained a security gate pass from the Detroit School District, which allowed them access to the hydrant while maintaining site security. Once the hydrant hardware was installed, the system was covered so as to not attract the attention of passersby.

*Figure 23. Overview of the hydrant location (white arrow) relative to the infiltration test site.*

Prior to introducing any hydrant water into the infiltration basin, the hydrant was “bled” for a number of hours to flush stagnant water from the system. In order to establish a consistent and controllable flow between the hydrant and the infiltration basin, it was necessary to install coupling and thread reducers, a backflow prevention valve and a pressure relief valve (Figure 24). A standard ¾” garden hose served as the feed line from the hydrant to the infiltration basin.

A flow control system was fabricated to solve the logistical issues associated with maintaining a more or less constant head of water within the infiltration basin at all times. This system was based on a standard toilet float valve assembly (Figure 25). It was mandatory to reduce the pressure of the hydrant water to that of standard household plumbing, in order to use the float valve.

The float control valve works as a reactive system providing hydrant water to the infiltration basin only when the float switch drops from its preset level. The float switch level was set to maintain a water depth of 6 to 7 inches in the infiltration basin. An aluminum ruler was affixed to one of the MWs to permit visual measurement of the water depth in the basin. The zero-end of the ruler was installed 3 inches below ground surface, so an apparent water height of 10 inches on the ruler meant that the water depth was actually 7 inches (Figure 26).

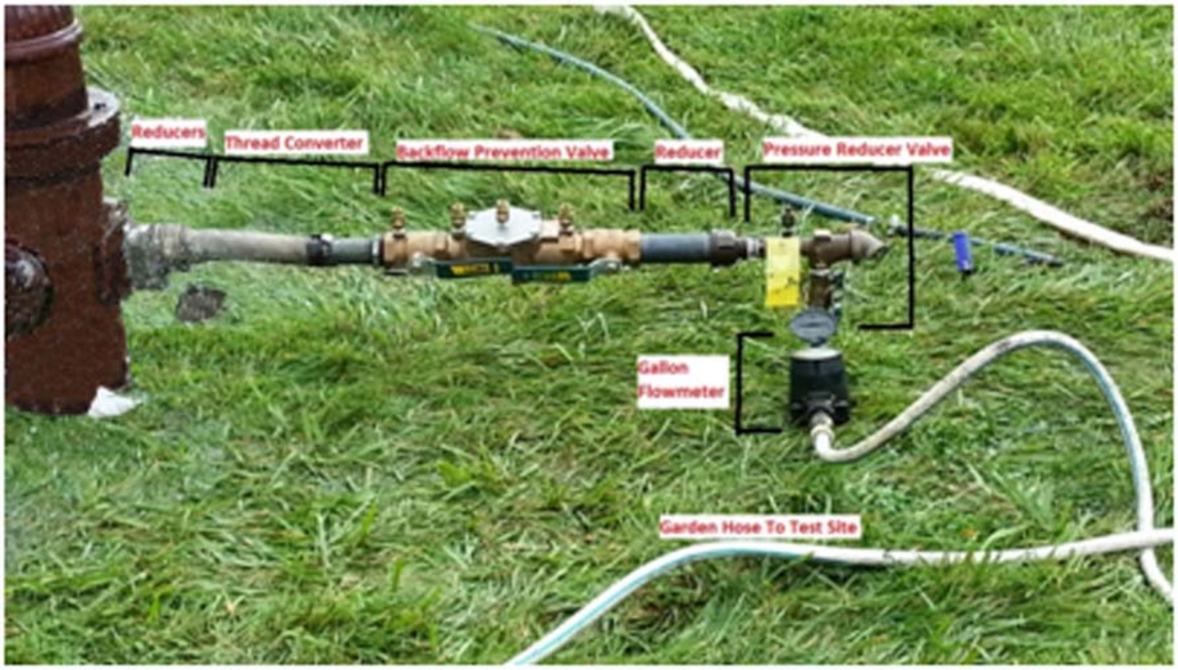



*Figure 24. Hydrant hardware necessary to reduce the pressure, prevent backflow and step-down the thread size to accommodate a standard garden hose connection.*

*Figure 25. Custom float valve installed within the infiltration basin. To avoid scouring the bottom of the basin, the valve discharge is dispersed across the metal plate.*

A totalizing flow meter was also installed near the infiltration basin to record the number of gallons of hydrant water entering the basin when the float valve was open (Figure 27). Effectively, the flow meter recorded the amount of water that entered the basin in order to keep the float valve closed. Since the basin was covered with a waterproof tarp, it was assumed that the cumulative volume of hydrant water (gallons) discharged into the basin following the first fill was all lost through infiltration.

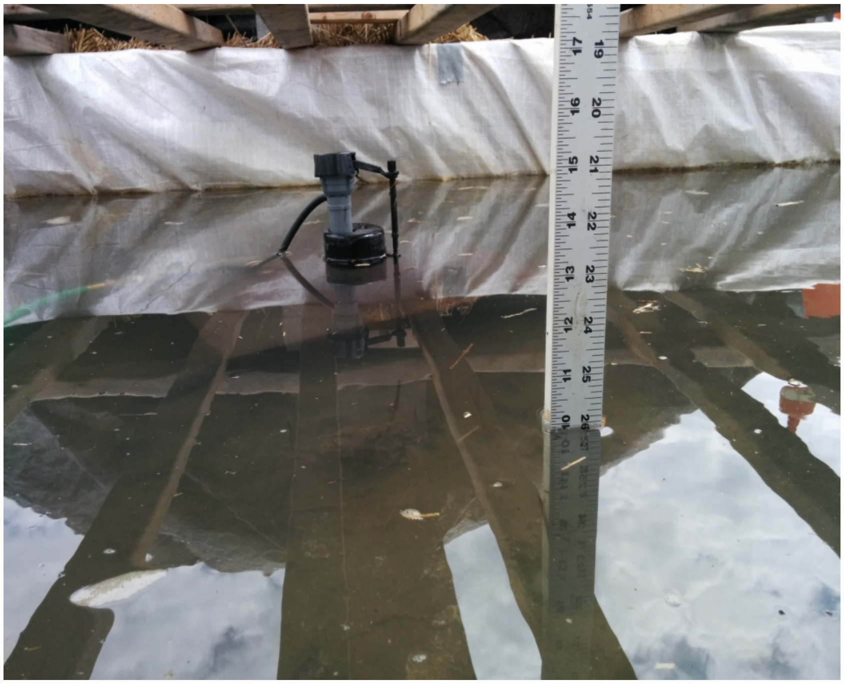


*Figure 26. Float valve (background) and water level gauge.*

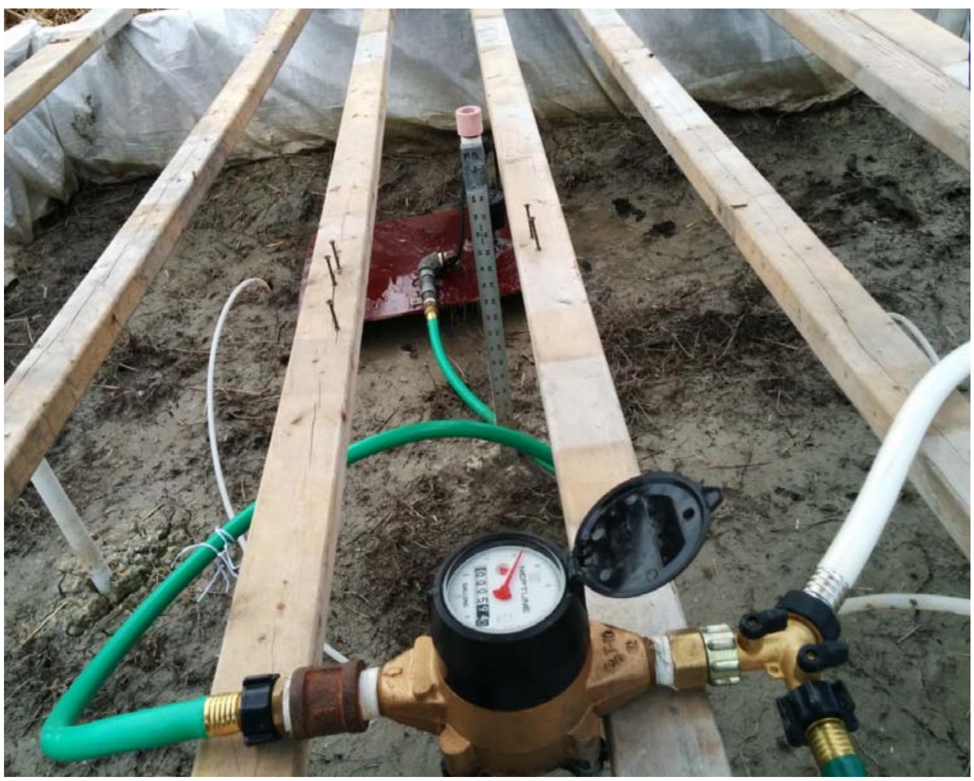


*Figure 27. Totalizing flow meter connected to the infill hose (white). The green hose in the lower-right of the picture provided hydrant water for filling the 250-gallon poly tank used to mix the tracer slug (note the valves which allowed the poly tank to be filled without the water running through the totalizing flow meter).*

The flow meter was installed on 7/2/14 with an initial reading of 6,223 gallons. At the end of the first slug test (10/7/14), the totalized reading was 14,272 gallons. Including the 250 gallon volume of the slug itself, the total amount of infiltration during the first slug test (7/2/14 to 10/7/14) was 8,299 gallons.

At the beginning of the second slug test (10/8/14), the totalized reading was still 14,272 gallons. Another 250 gallons of NaBr water was added as the second slug. Due to the onset of nighttime freezing temperatures, the flow meter was disconnected on 11/12/14. The totalized reading at this time was 16,485 gallons. Including the 250 gallon volume of the second slug, the total amount of infiltration during the second slug test (10/8/14 to 11/12/14) was 2,463 gallons. For the period 7/2/14 through 11/12/14, a total of 10,262 gallons of hydrant water infiltrated out of the test basin (Figure 28).

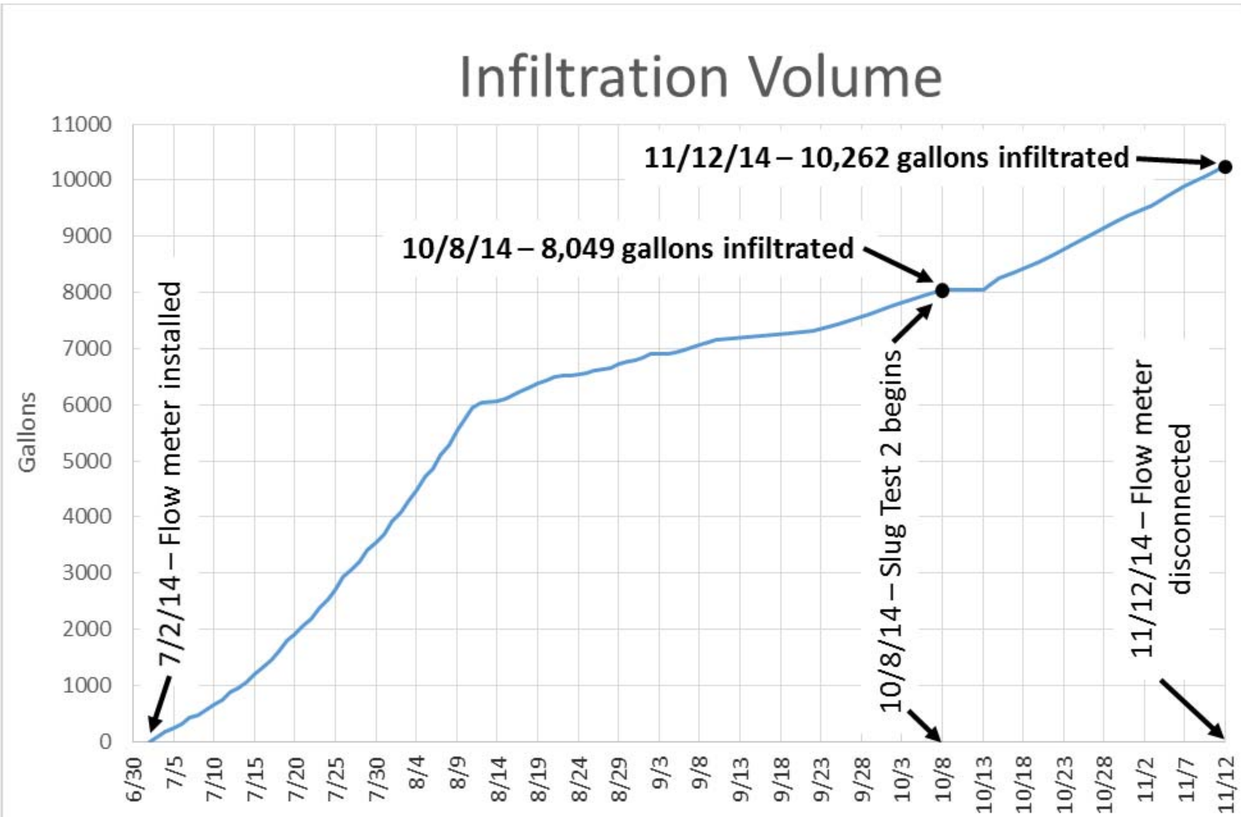



*Figure 28. Total hydrant water infiltration measured by the flow meter.*

***Slug Test Description***

Inorganic ions are the most commonly used tracers in infiltration and groundwater movement studies because they are easily available, relatively inexpensive and mix easily on site. Bromide ($Br^-$) and chloride ($Cl^-$) are considered by many to be the almost ideal conservative tracers for water movement studies (Domenico and Schwartz, 1990; Flury and Wai, 2003). Bromide and chloride transport with infiltrating water is generally not retarded because these anions are repulsed by the negative charges on soil particles (Flury and Wai, 2003). Compared to chloride, bromide is a more suitable tracer because chloride concentrations in native groundwater and soil media can be relatively high. The concentration of bromide in natural waters, on the other hand, is very low (Davis et al., 1980; Davis et al., 1998). More importantly, the toxicity of bromide is low (Flury and Papritz, 1993). For this study, bromide (in the form of NaBr) was the chosen as the tracer. It was measured and mixed on site.

An initial slug test was begun on June 25, 2014. This protocol relied primarily on field measurements by Parjana staff of bromide concentrations in groundwater samples using an ion-specific probe. These more-frequent probe measurements were supplemented with less-frequent lab measurements of samples performed by Fibertec Environmental Services. Unfortunately, due to persistent calibration problems with the ion-specific probe, the accuracy of the bromide concentration data collected during June – September, 2014 was insufficient to allow meaningful interpretations to be made. In consultation with MDEQ, it was decided to perform a second slug test, which began on October 8, 2014, using the following protocol.

The infiltration pool was emptied with a pump to as close to a "no standing water" condition as possible (Figure 29). The on-site 250-gallon poly tank was filled with municipal water (from the fire hydrant hook-up) and 50.07 grams of NaBr was added and well stirred. This amount of NaBr provided a bromide concentration of approximately 40 mg/L (*i.e*., 40 - 80 times the background levels in groundwater at the site). The pool was kept covered with a poly tarp to avoid dilution by rainwater.

The entire 250 gallons of NaBr solution was discharged by gravity flow into the infiltration pool, bringing the water depth to approximately 7 3/8" [measurement gauge reads 10 3/8" because datum is 3" below grade] (Figure 30). No residual NaBr was observed in the empty poly tank after its contents were discharged into the pool. Fibertec Environmental Services analyzed samples of the test pool water taken on the initiation day (10/8/14), the next day (10/9/14) and five days after initiation (10/13/14). The bromide concentrations for these pool-water samples were 41.0 mg/L, 40.0 mg/L and 38.0 mg/L, respectively.

Groundwater samples were collected by Parjana personnel three times a week (Monday, Wednesday and Friday) from the two MWs and three EGRP nests (six samples in all) within the infiltration pool for the duration of the test. The "hold" time for any sample prior to delivery to the lab was always less than 7 days. Two or three samples were delivered to Fibertec Environmental Services in a group (*e.g*., M, W, F samples delivered on F; W, F, M samples delivered to the lab on M).

The NaBr solution in the test pool was allowed to infiltrate to a "no standing water, but not dried out" condition (*i.e*., the 250 gallon "slug" of the NaBr solution had nearly completely infiltrated). After this point, the automated fill-valve system refilled the test pool with municipal water to roughly 5" – 6" in depth. The bromide concentration in the pool was sampled four times after the initial slug had drained. Fibertec analyzed these samples and reported the following: 10/15/14 $Br^-$ = 9.7 mg/L; 10/17/14 $Br^-$ = 5.8 mg/L; 10/20/14 $Br^-$ = 2.7 mg/L; and 10/27/14 $Br^-$ = 0.29 mg/L.

The automatic fill-valve system maintained the pool water level at 6" - 7" of head for the duration of the second slug test. Due to the onset of nighttime freezing temperatures, the flow meter was disconnected on 11/12/14, after which no additional hydrant water was added to the infiltration basin. Sampling continued for the next four weeks, until freezing of the sampling tubes caused a halt to the sampling campaign. The last day a full suite of samples could be taken was December 15, 2014, after which the infiltration basin was drained by pumping and the site was winterized. The total duration of the second slug test (10/8/14 – 12/15/14) was 68 days.

*Figure 29. Infiltration pool pumped nearly dry in preparation for the second slug test.*

*Figure 30. Second slug test filled the pool to 7 3/8" [10 3/8" on staff gauge] with 41.0 mg/L $Br^-$ water.*

# RESULTS

## *Shallow Sampling*

On October 8, 2014, 250 gallons of water with a bromide concentration of 41 mg/L filled the infiltration basin. Samples from the next day (10/9/14), showed that the groundwater bromide concentration in the shallow MW (MA-20-25) was 0.39 mg/L, while the concentrations in the three shallow EGRP nests (E2-20, E3-20 and E1-B-20) ranged from 0.27 to 0.30 mg/L. During the whole period of the second slug test, the bromide concentrations in groundwater from the shallow MW (MA-20-25) held fairly constant, ranging from 0.38 to 0.45 mg/L.

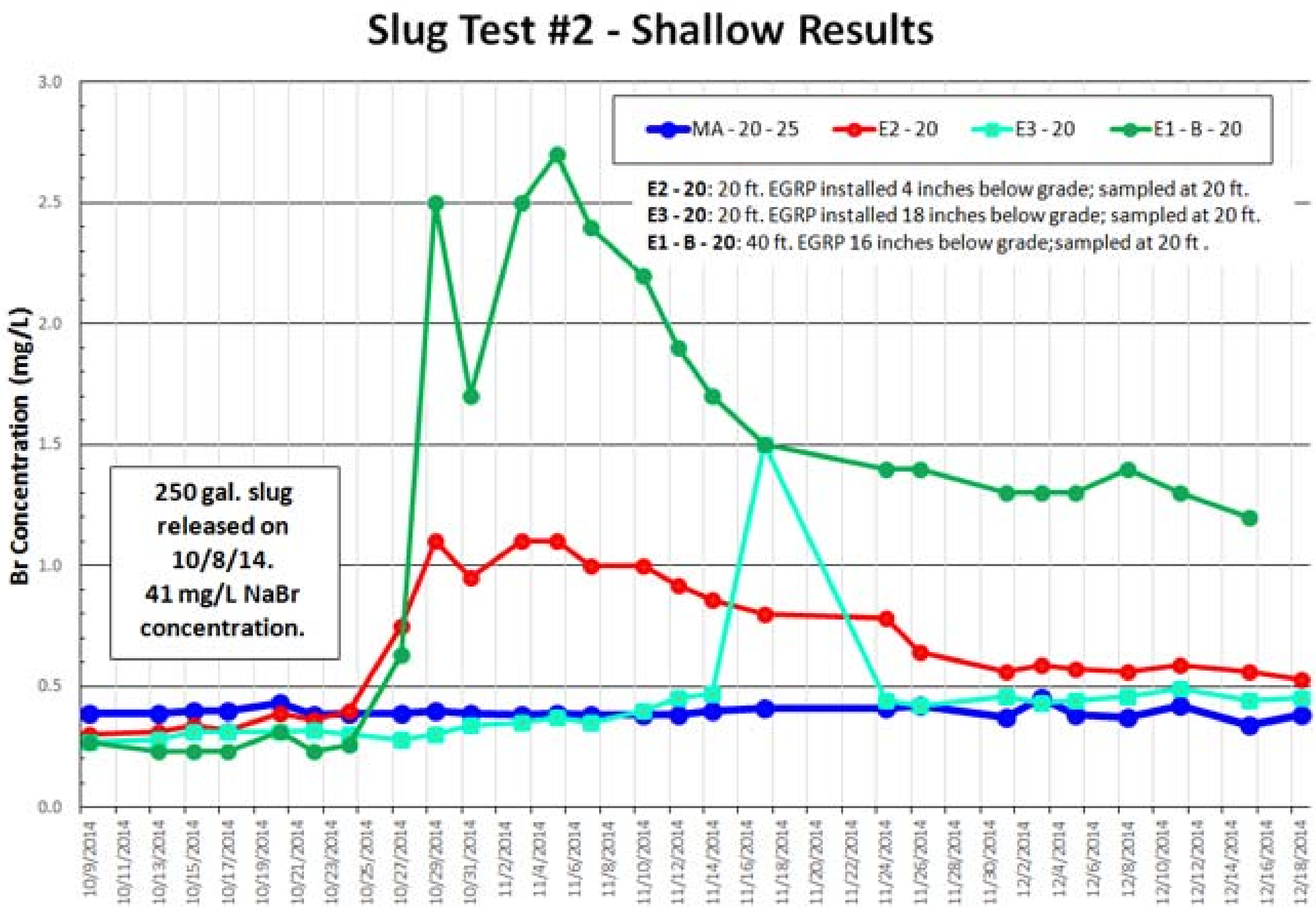
After sixteen days, the bromide concentration in groundwater from the E1-B-20 EGRP began to rise rapidly from 0.26 mg/L on 10/24/14, reaching a concentration of 2.50 mg/L on 10/29/14. Its sample from 10/31/14 showed a marked decline to 1.70 mg/L, after which the bromide levels in E1-B-20 climbed steeply, reaching their maximum (2.70 mg/L) on 11/5/14. After this peak concentration, the bromide values from E1-B-20 steadily declined to 1.20 mg/L on 12/15/14 (see Graph 1).

Sixteen days after the slug introduction, the bromide concentration in groundwater from the E2-20 EGRP also began to rise sharply from 0.40 mg/L on 10/24/14 to its maximum concentration of 1.10 mg/L on 10/29/14. The bromide concentrations in groundwater from E2-20 remained high until 11/5/14, after which they slowly declined, reaching a value of 0.56 mg/L on 12/15/14.

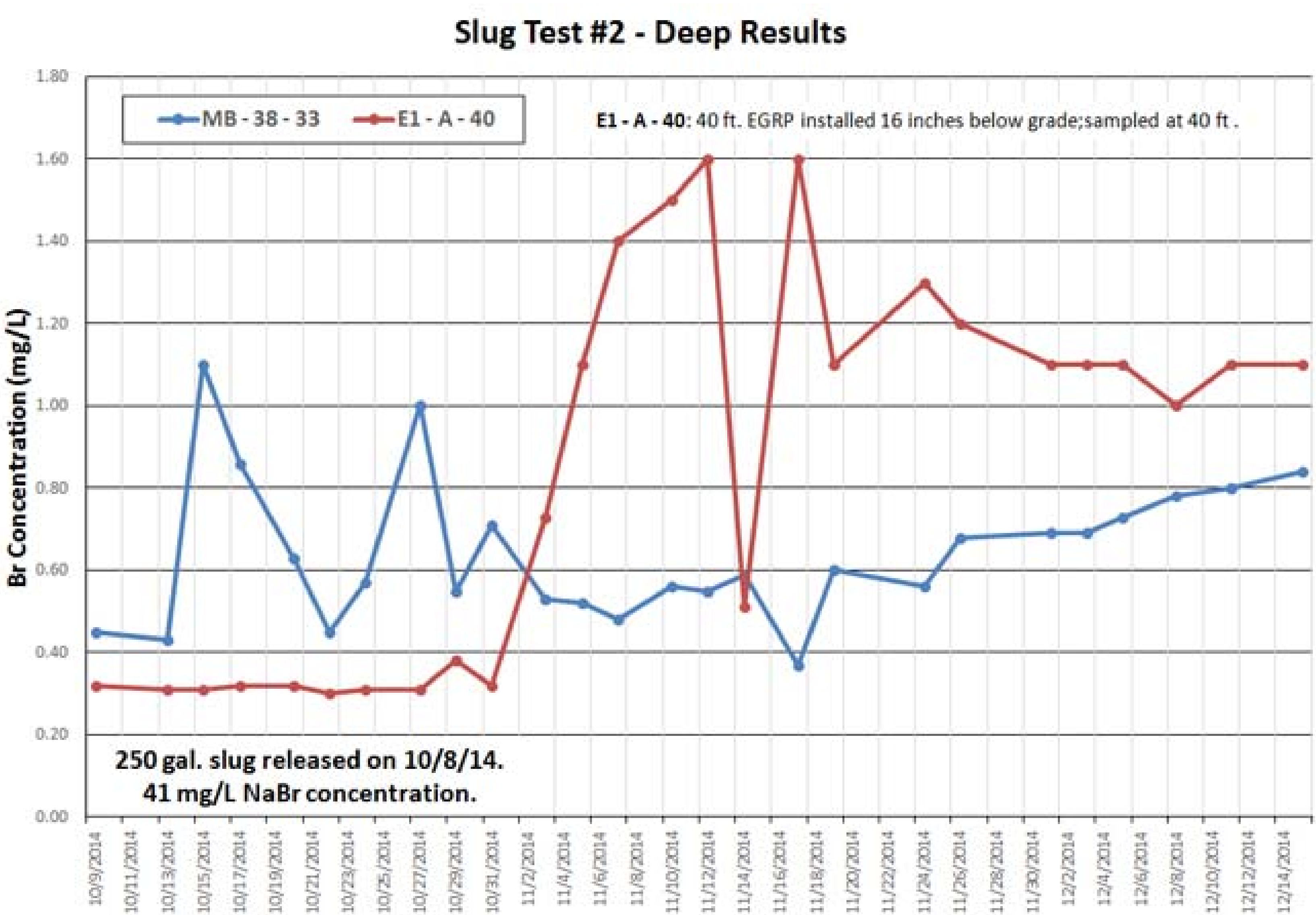
The bromide concentrations in groundwater from the E3-20 EGRP did not markedly change until after 11/14/14, some 36 days after the start of the second slug test. The bromide concentration in groundwater from E3-20 jumped from 0.47 mg/L on 11/14/14 to 1.50 mg/L on 11/17/14. By the next sample date, 11/24/14, the bromide level in E3-20 had dropped to 0.44 mg/L. For the rest of the test, the bromide concentrations in groundwater from E3-20 remained fairly low, in the range of 0.42 to 0.49 mg/L.

## *Deep Sampling*

In the first 25 days of the second slug test, the bromide concentrations in groundwater from the deep MW (MB-38-33) fluctuated dramatically, ranging from 0.43 to 1.10 mg/L. In contrast, during this same period, the bromide concentrations in groundwater from the 40 ft sampling port on the E1 EGRP nest (*i.e.*, E1-A-40) remained fairly constant, ranging from 0.30 to 0.38 mg/L. After 23 days, however, the bromide concentrations in groundwater from the E1-A-40 EGRP nest increased sharply, reaching a maximum concentration of 1.60 mg/L on 11/12/14. The E1-A-40 sample from 11/14/14 was anomously low (0.51 mg/L); the next sample three days later (11/17/14) returned a value of 1.60 mg/L. Following 11/17/14, the bromide concentrations from the E1-A-40 EGRP nest decreased gradually, reaching a value of 1.10 mg/L on 12/15/14 (see Graph 2).




**Graph 1. Bromide concentration in shallow groundwater - results from the second slug test.**




**Graph 2. Bromide concentration in deep groundwater - results from the second slug test.**

# Discussion

## *Shallow Sampling*

This infiltration test was designed and executed to be a “worst case” scenario regarding the functioning of the EGRP technology. Under design conditions, the EGRPs function within the unsaturated zone and respond to partially-penetrating infiltration events due to rainfall, snowmelt and/or site runon. The CYIA Infiltration Test was designed to test EGRPs under ***saturated*** conditions that are very rare under normal conditions. In the four month period prior to the onset of the second slug test (7/2/14 to 10/7/14), the infiltration basin had been continuously flooded with 7 – 8 inches of water. During this period, 8,299 gallons were added to the infiltration basin. During the second slug test, an additional 2,463 gallons of water were added. If the EGRPs functioned like open conduits into which infiltration water could “free fall” to their bottom depth, this long-term, saturated, experimental condition could have documented such a process.

For the first 16 days of the second slug test, the groundwater bromide concentration in the shallow MW (MA-20-25) varied from 0.38 – 0.43 mg/L, while the concentrations in the three shallow EGRP nests (E2-20, E3-20 and E1-B-20) were very similar, ranging from 0.23 to 0.40 mg/L. As explained below, these data clearly show that the EGRP nests do NOT function like open pipes into which near-surface infiltration “free falls” to the bottom. On the contrary, the shallow data (Graph 1) show that although infiltration near an EGRP is enhanced compared to the MW (*i.e.*, native soil conditions), it occurs at a much slower rate than the “direct injection” hypothesis envisioned.

### *Calculated Water Flux*

One-dimensional water flow in saturated soils can be quantitatively described by Darcy's Law:

$$\mathbf{J = -K_{sat}i}$$

where **J** is the water flux (*i.e.*, flow of water), $\mathbf{K_{sat}}$ is the saturated hydraulic conductivity, and **i** is the hydraulic gradient. The minus sign keeps $K_{sat}$ positive and maintains directional integrity. Darcy’s law demonstrates that flux (**J**) is proportional to the hydraulic gradient (**i**), while the saturated hydraulic conductivity ($\mathbf{K_{sat}}$) is the constant that defines the proportionate relationship of flux to hydraulic gradient (National Soil Survey Center, 2004).

Recall that EGRP nest E2-20 was installed with its top only 4 inches below ground. The plastic cap fitted over the upper end of the EGRPs encloses the top 4 inches of the device, so the first openings on E2-20 nest occur at a depth of 8 inches. During the first 16 days of the second slug test, a total of 1,051 gallons of infiltration occurred (250 gal slug + 801 gal of hydrant water). The infiltration basin has an area of about 60 $ft^2$ (8.0 x 7.5 ft). The water flux (**J**) = **Q/At** = 1,051 gal/(60 $ft^2$ * 384 hrs) = 140.50 $ft^3$/(60 $ft^2$ * 384 hrs) = 1,686 inches/23,040 hrs (National Soil Survey Center, 2004). The water flux (**J**) at 16 days into the second slug test was **0.0732 in/hr**.

The vertical hydraulic gradient (**i**) at a depth of 8 inches equals the sum of the depth of submergence (7.375 in) and the gravity head (8 in), divided by the length (depth = 8 in) (National Soil Survey Center, 2004). At a depth of 8 inches, the calculated vertical hydraulic gradient (**i**) = **1.9219**. Solving Darcy's Law for saturated hydraulic conductivity ($K_{sat}$ = J/i), the $K_{sat}$ at a depth of 8 inches = 0.0732/1.9219 = **0.0381 in/hr**. Using this calculated $K_{sat}$ value, the bromide-spiked infiltrate would have reached the first opening in EGRP E2-20 210 hours (*i.e.*, 8.75 days) after the initiation of the second slug test. If EGRPs function as open conduits allowing infiltration water to "free fall" or "flow"to their bottom depth, there should have been a measurable spike in the bromide concentration from the 20 ft. samples of E2-20 on the ninth day (10/17/14) of the test. There was not. Instead, the bromide concentration in groundwater from the E2-20 EGRP rose sharply on the 16th day after the slug introduction, increasing from 0.40 mg/L on 10/24/14 to its maximum concentration of 1.10 mg/L on 10/29/14. The bromide concentration from E2-20 slowly declined thereafter, reaching a value of 0.56 mg/L on 12/15/14.

These data show that EGRP E2-20 enhanced the native infiltration rate by a factor of 8.6 times. The depth to the top of the "screened" interval of E2-20 is 234.4 inches. The vertical hydraulic gradient (**i**) at this depth equals the sum of the depth of submergence (7.375 in) plus the gravity head (234.4 in), divided by the length (depth = 234.4 in) (National Soil Survey Center, 2004). At a depth of 234.4 inches, the calculated vertical hydraulic gradient (**i**) = **1.0315**. Solving Darcy's Law for saturated hydraulic conductivity ($K_{sat}$ = J/i), the $K_{sat}$ at a depth of 234.4 inches = 0.0732/1.1.0315 = **0.0710 in/hr**. Using this calculated $K_{sat}$ value, under natural conditions the bromide-spiked infiltrate would have reached the depth of 234.4 inches in 3,301.4 hours (*i.e.*, 137.6 days). Since the bromide breakthrough occurred in 16 days, this represents an infiltration rate 8.6 times faster than native conditions.

### *Erratic Bromide Concentrations*

During the whole period of the second slug test, the bromide concentrations in groundwater from the shallow MW (MA-20-25) were fairly constant, ranging from 0.38 to 0.45 mg/L, while the bromide concentration in groundwater from the E1-B-20 EGRP reached a maximum concentration of 2.70 mg/L on 11/5/14, after which its bromide values steadily declined to 1.20 mg/L on 12/15/14. The bromide concentrations in groundwater from the E3-20 EGRP did not markedly change until after 11/14/14, some 36 days after the start of the second slug test. The bromide concentration in groundwater from E3-20 jumped from 0.47 mg/L on 11/14/14 to 1.50 mg/L on 11/17/14 and by the next sample date, 11/24/14, had dropped to 0.44 mg/L. For the rest of the test, the bromide concentrations in groundwater from E3-20 remained fairly low, in the range of 0.42 to 0.49 mg/L (very similar to those measured in the shallow MW).

Given the temporal pattern of the bromide concentrations in E3-20, it is likely that the 1.50 mg/L concentration recorded for 11/17/14 is an error. The most likely scenario is that E1-B-20 was mistakenly sampled twice, once labeled as sample #3 and a second time labeled as sample #4 (sample #3 should have been from E3-20). It is highly unlikely that both samples #3 and #4 would have returned the same bromide concentration (1.50 mg/L) if they were from two different sample locations. Ignoring the 11/17/14 sample result for E3-20 as an error, the E3-20 bromide concentration range (0.27 – 0.49 mg/L) is very similar to that from the shallow MW (MA-20-25), which ranged from 0.38 to 0.45 mg/L.

In summary, only two of the three shallow EGRPs exhibited a bromide breakthrough and then only after 16 days following the slug infiltration. The third EGRP (E3-20), assuming its 11/17/14 bromide concentration sample was erroneous, functioned very much like the shallow MW.

## *Deep Sampling*

The anomolus E1-A-40 reading on 11/14/14 (0.51 mg/L) may be another sample mislabeling problem where the deep MW (MB-38-33) was sampled twice, once labeled correctly as sample #5 and a second time labeled incorrectly as sample #6, which was supposed to be from E1-A-40. Sample #5 (presumed to be from the deep MW (MB-38-33) had a bromide concentration of 0.59 mg/L, while sample #6 (presumed to be a second (erroneous) sample from MB-38-33) had a bromide concentration of 0.51 mg/L. This 0.08 mg/L variation in bromide concentration from the same source is well within the accuracy limits of the FiberTec lab analyses (reporting limit = 0.1 mg/L).

The results from the deep samples are ambiguous and difficult to interpret. The multiple spikes in groundwater bromide concentrations from the deep MW (MB-38-33) on 10/15/14 (1.10 mg/L), 10/27/14 (1.00 mg/L) and 10/31/14 (0.71 mg/L) may be an early breakthrough from the second slug test. The breakthrough associated with the E1-A-40 EGRP nest occurred after 10/31/14 and reached a maximum of 1.60 mg/L on 11/12/14. Since the MB-38-33 MW was constructed and grouted to industry standards, while the E1-A-40 EGRP nest was installed in an open borehole (which presumably collapsed around the device in the first two or three months following installation), these results (*i.e.*, breakthrough occurring in the MW before it occurs in the EGRP) are counterintuitive. It should be noted that following 11/26/14, the groundwater bromide concentration in samples from the deep MW (MB-38-33) rose continuously, reaching a value of 0.84 mg/L by the end of the monitoring on 12/15/14. Although the large fluctuations in bromide concentrations from the deep MW (MB-38-33) during the period 10/15/14 to 10/31/14 remain enigmatic, it could be that the increasing concentrations following 11/26/14 were the rising limb of a breakthrough event that the sampling campaign did not capture due to its termination due to freezikng conditions.

### ***Calculated Water Flux***

During the 35 days of the second slug test, a total of 2,713 gallons of infiltration occurred (250 gal. slug + 2,463 gal. of hydrant water). The infiltration basin has an area of about 60 $ft^2$ (8.0 x 7.5 ft). The water flux (**J**) = Q/At = 2,713 gal/(60 $ft^2$ * 840 hrs) = 362.68 $ft^3$/(60 $ft^2$ * 840 hrs) = 4,352.16 inches/50,400 hrs. So, the water flux (**J**) at the end of the second slug test was **0.0864 in/hr**.

The vertical hydraulic gradient (**i**) for the 20 ft depth measurements is the sum of the depth of submergence ($H_{ip}$ = 7.375”) and the gravity head ($H_{ig}$ = 240”), divided by the length (depth = 240”). For the 20 ft depth measurements, the calculated vertical hydraulic gradient (**i**) = **1.0307**. The vertical hydraulic gradient (**i**) for the 40 ft depth measurements is the sum of the depth of submergence ($H_{ip}$ = 7.375”) and the gravity head ($H_{ig}$ = 480”), divided by the length (depth = 480”). For the 40 ft. depth measurements, the calculated vertical hydraulic gradient (**i**) = **1.0154**.

Solving Darcy's Law for saturated hydraulic conductivity ($K_{sat}$ = J/i), the bulk $K_{sat}$ for the 20 ft depth measurements = 0.0864/1.0307 = **0.0838 in/hr**. The bulk $K_{sat}$ for the 40 ft depth measurements = J/i = 0.0864/1.0154 = **0.0851 in/hr**.

According to the soil borings done by SME (see Appendix A), the dominant soil texture at the infiltration site is silty clay. The text book value of $K_{sat}$ for silty clay is **0.1304 in/hr**, suggesting that infiltration would have only reached a depth of 50 inches after 16 days (384 hours). Based on the data for the E1-B-20 EGRP (see Graph 1), breakthrough occurred 16 days (384 hours) into the second slug test, demonstrating that bromide-spiked infiltration reached 240 inches (20 ft) after 384 hours. These data suggest that $K_{sat}$ = 0.625 in/hr (*i.e.*, 7.4 times greater than the calculated $K_{sat}$ = 0.0838 in/hr).

Based on the data for the E1-A-40 EGRP (see Graph 2), breakthrough occurred 23 days (552 hours) into the second slug test, demonstrating that bromide-spiked infiltration reached 480 inches (40 ft) after 552 hours. These data suggest that $K_{sat}$ = 0.870 in/hr (*i.e.*, 10.2 times greater than the calculated $K_{sat}$ = 0.0851 in/hr).

According to the NRCS, Soil Survey Manual (Soil Survey Division Staff, 1993), saturated hydraulic conductivity is a highly variable soil property, which can vary by 10-fold or more for a specific small site. The results for both the shallow (20 ft) and the deep (40 ft) EGRPs at the CYIA test site are generally within this range of natural variability.

## Conclusions

Analysis of the data collected during the second slug test support the following conclusions.

- Most of the EGRPs within the infiltration basin enhanced the local infiltration rate.
  - The infiltration rates associated with two of the shallow EGRPs were 7.4 - 8.6 times faster than the infiltration rate associated with native soil conditions.
  - The infiltration rate associated with the deep EGRP was 10.2 times faster than the infiltration rate associated with native soil conditions.

- Analyses of both the shallow- and deep-data ***reject*** the hypothesis that EGRPs function like a pipe which allows shallow infiltration water to "free fall" to the bottom of the devices.

- Both the shallow- and deep-data demonstrate that infiltration at an EGRP site occurs at a much slower rate than the "direct injection" hypothesis envisioned.
  - Two of the three shallow EGRPs exhibited a bromide breakthrough 16 days following the initiation of the slug infiltration.
  - The third shallow EGRP did not exhibit a bromide breakthrough during the 68 days of the second slug test. Throughout the duration of the second slug test, the bromide concentrations from this EGRP were very similar to those from the shallow MW.
  - The deep EGRP exhibited a bromide breakthrough 23 days following the initiation of the slug infiltration.
  - The large fluctuations in bromide concentrations from the deep monitoring well during the period 10/15/14 to 10/31/14 remain enigmatic and unexplained.

# REFERENCES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Domenico, P. and Schwartz, F. 1990. Physical and Chemical Hydrogeology. NY: Wiley.

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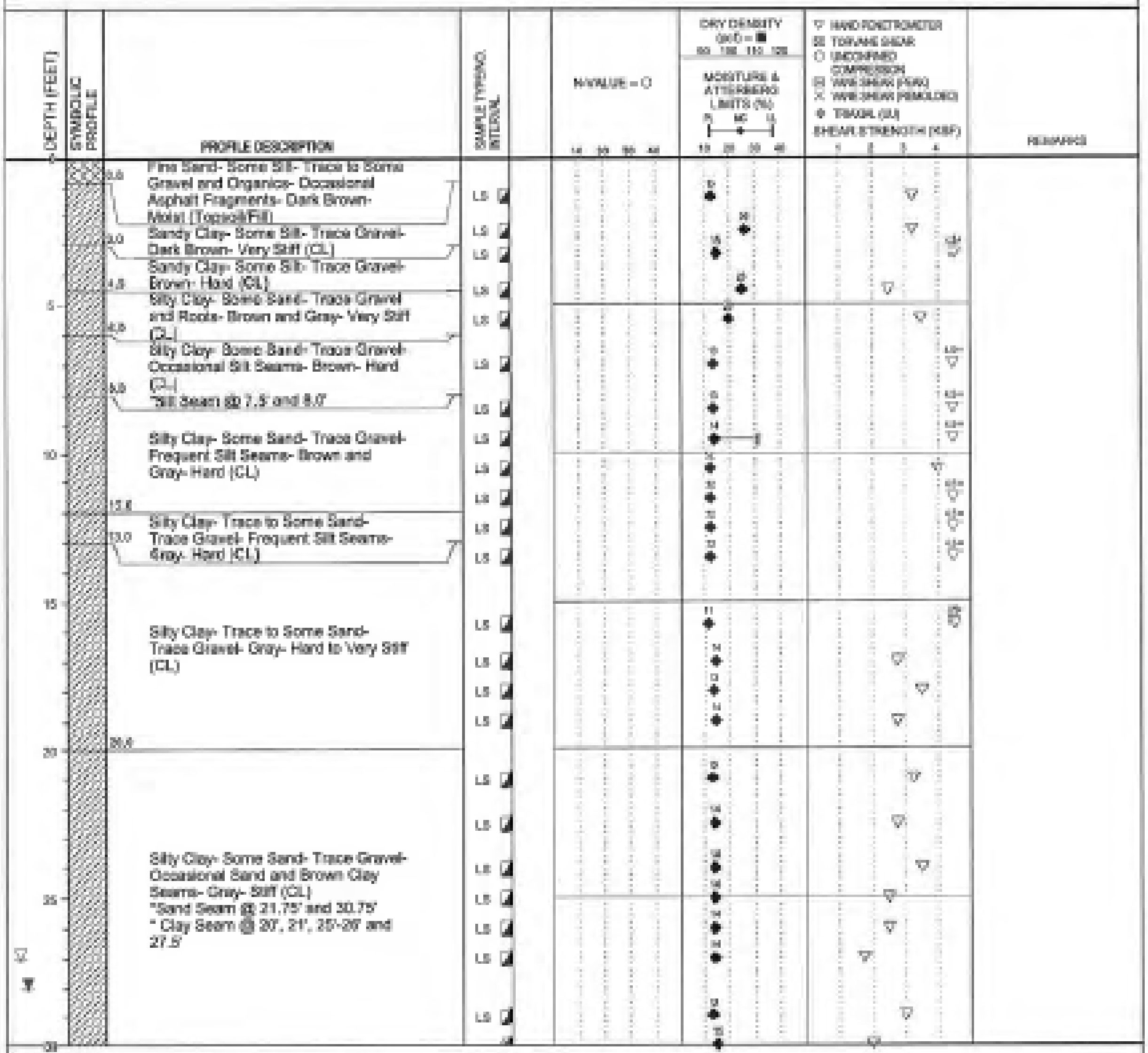
# APPENDIX A



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**BORING P1**
PAGE 1 OF 2

| | | | |
|---|---|---|---|
| PROJECT NAME: | Parjana: Coleman Young Site | PROJECT NUMBER: | P02442.12 |
| CLIENT: | Parjana | PROJECT LOCATION: | Detroit, Michigan |
| DATE STARTED: 10/4/12 | COMPLETED: 10/4/12 | BORING METHOD: | Continuous Liner |
| DRILLER: BM | RIG NO.: Geoprobe | LOGGED BY: SB | CHECKED BY: CRB |

| Depth (ft) | Profile Description |
|---|---|
| 0.0–2.5 | Fine Sand- Some Silt- Trace to Some Gravel and Organics- Occasional Asphalt Fragments- Dark Brown- Moist (Topsoil/Fill) |
| 2.5–3.0 | Sandy Clay- Some Silt- Trace Gravel- Dark Brown- Very Stiff (CL) |
| 3.0–4.5 | Sandy Clay- Some Silt- Trace Gravel- Brown- Hard (CL) |
| 4.5–6.0 | Silty Clay- Some Sand- Trace Gravel and Roots- Brown and Gray- Very Stiff (CL) |
| 6.0–8.0 | Silty Clay- Some Sand- Trace Gravel- Occasional Silt Seams- Brown- Hard (CL)<br>*Silt Seam @ 7.5' and 8.0' |
| 8.0–12.0 | Silty Clay- Some Sand- Trace Gravel- Frequent Silt Seams- Brown and Gray- Hard (CL) |
| 12.0–13.0 | Silty Clay- Trace to Some Sand- Trace Gravel- Frequent Silt Seams- Gray- Hard (CL) |
| 13.0–20.0 | Silty Clay- Trace to Some Sand- Trace Gravel- Gray- Hard to Very Stiff (CL) |
| 20.0–30.0 | Silty Clay- Some Sand- Trace Gravel- Occasional Sand and Brown Clay Seams- Gray- Stiff (CL)<br>*Sand Seam @ 21.75' and 30.75'<br>* Clay Seam @ 20', 21', 25'-26' and 27.5' |

Sample type: LS

**GROUNDWATER & BACKFILL INFORMATION**

| | DEPTH (FT) |
|---|---|
| ▽ DURING BORING: | 27.0 |
| ▼ AT END OF BORING: | 28.0 |

BACKFILL METHOD: Grout/Well

NOTES:
1. The indicated stratification lines are approximate. In situ, the transition between materials may be gradual.
2. A groundwater monitoring well was installed: screen at 15 to 20 feet, grout above 13 feet.
3. GPS Data: N = 42.40466, W = 83.01616
4. Additional Groundwater Data: 2 hours = 28 feet, 4 hours = 28 feet, next morning = 24 feet

November 7, 2012

(Continued Next Page)

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# BORING P1



**PROJECT NAME:** Parjana: Coleman Young Site
**PROJECT NUMBER:** P02442.12
**CLIENT:** Parjana
**PROJECT LOCATION:** Detroit, Michigan

| DEPTH (FEET) | SYMBOLIC PROFILE | PROFILE DESCRIPTION | SAMPLE TYPE/NO. INTERVAL |
|---|---|---|---|
| 31.5 | | | LS |
| | | Silty Clay- Some Sand- Trace Gravel- Frequent Sand Seams and Layers- Gray- Very Stiff to Soft (CL) | LS, LS, LS |
| 36.5 | | | |
| | | Silty Clay- Some Sand- Trace Gravel- Gray- Very Stiff (CL) | LS, LS, LS, LS |
| 40.0 | | END OF BORING AT 40.0 FEET. | |

N-VALUE – ○
10 20 30 40

DRY DENSITY (pcf) – ■
90 100 110 120

MOISTURE & ATTERBERG LIMITS (%)
PL MC LL
10 20 30 40

▽ HAND PENETROMETER
⊠ TORVANE SHEAR
○ UNCONFINED COMPRESSION
⊟ VANE SHEAR (PEAK)
✕ VANE SHEAR (REMOLDED)
✦ TRIAXIAL (UU)
SHEAR STRENGTH (KSF)
1 2 3 4

REMARKS

November 7, 2013

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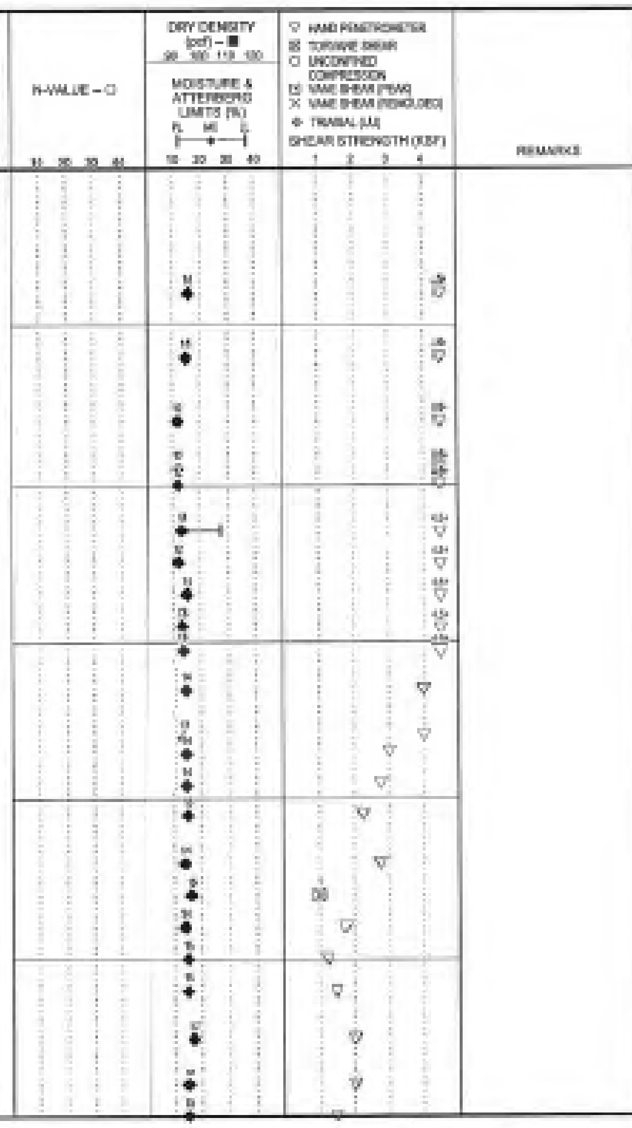
# BORING P2



**PROJECT NAME:** Parjana: Coleman Young Site
**PROJECT NUMBER:** P02442.12
**CLIENT:** Parjana
**PROJECT LOCATION:** Detroit, Michigan
**DATE STARTED:** 10/4/12
**COMPLETED:** 10/4/12
**BORING METHOD:** Continuous Liner
**DRILLER:** BM
**RIG NO.:** Geoprobe
**LOGGED BY:** SB
**CHECKED BY:** CRB

| DEPTH (FEET) | PROFILE DESCRIPTION | SAMPLE TYPE/NO. INTERVAL |
|---|---|---|
| 0.8 | Fine Sand- Some Silt- Trace Gravel and Roots- Dark Brown (SM/Topsoil) | |
| 2.4 | Fine to Medium Sand- Trace to Some Silt- Trace Gravel- Occasional Topsoil Seams- Brown (SP-SM) *Topsoil Seam at 1.25' | |
| 4.0 | Fine to Medium Sand- Some Silt- Trace to Some Gravel- Brown and Dark Brown (SM) | LS |
| 8.0 | Silty Clay- Trace to Some Sand- Trace Gravel- Gray- Hard (CL) | LS, LS |
| 9.3 | Fine to Coarse Sand- Some Silt- Trace to Some Gravel- Brown (SM) | LS |
| 19.0 | Silty Clay- Some Sand- Trace Gravel- Gray- Hard to Very Stiff (CL) | LS, LS, LS, LS, LS, LS, LS, LS, LS, LS, LS, LS |
| | Silty Clay- Some Sand- Trace Gravel- Occasional Sand Seams and Layers- Gray- Very Stiff to Stiff (CL) *Sand Seams and Layers @ 19.25', 20', 23.5', 25.5', 30', 31.5', 33.75', 34.75' and 37.5' | LS, LS, LS, LS, LS, LS, LS, LS, LS |




**GROUNDWATER & BACKFILL INFORMATION**

| | DEPTH (FT) |
|---|---|
| ▽ DURING BORING: | 38.0 |
| ▼ AT END OF BORING: | 29.0 |

**BACKFILL METHOD:** Grout/Well

NOTES:
1. The indicated stratification lines are approximate. In situ, the transition between materials may be gradual.
2. A groundwater monitoring well was installed: screen at 33 to 38 feet, grout above 20 feet.
3. GPS Data: N = 42.40499, W = 83.01579
4. Additional Groundwater Data: 2 hours = 28 feet, next morning = 19 feet

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*(Continued Next Page)*

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# BORING P2



**PROJECT NAME:** Parjana: Coleman Young Site

**CLIENT:** Parjana

**PROJECT NUMBER:** P02442.12

**PROJECT LOCATION:** Detroit, Michigan

| DEPTH (FEET) | SYMBOLIC PROFILE | PROFILE DESCRIPTION | SAMPLE TYPE/NO. INTERVAL | N-VALUE – O | DRY DENSITY (pcf) – ■ / MOISTURE & ATTERBERG LIMITS (%) PL MC LL | ▽ HAND PENETROMETER ⊠ TORVANE SHEAR ○ UNCONFINED COMPRESSION ⊠ VANE SHEAR (PEAK) ✕ VANE SHEAR (REMOLDED) ✦ TRIAXIAL (UU) SHEAR STRENGTH (KSF) | REMARKS |
|---|---|---|---|---|---|---|---|
| 30–38.4 | | Silty Clay- Some Sand- Trace Gravel- Occasional Sand Seams and Layers- Gray- Very Stiff to Stiff (CL) *Sand Seams and Layers @ 19.25', 20', 23.5', 26.5', 30', 31.5', 33.75', 34.75' and 37.5' *(continued)* | LS, LS, LS, LS, LS, LS, LS | | | | |
| 38.4–40.0 | | Sandy Clay- Some Silt- Trace Gravel- Gray- Occasional Sand Seams- Gray- Stiff *Sand Seam @ 39.25' | LS | | | | |
| | | END OF BORING AT 40.0 FEET. | | | | | |

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# BORING P3



**PROJECT NAME:** Parjana: Coleman Young Site
**PROJECT NUMBER:** P02442.12
**CLIENT:** Parjana
**PROJECT LOCATION:** Detroit, Michigan
**DATE STARTED:** 10/5/12
**COMPLETED:** 10/5/12
**BORING METHOD:** Continuous Liner
**DRILLER:** BM
**RIG NO.:** Geoprobe
**LOGGED BY:** SB
**CHECKED BY:** CRB

DEPTH (FEET) | SYMBOLIC PROFILE | PROFILE DESCRIPTION | SAMPLE TYPE/NO. INTERVAL | N-VALUE – ○ | DRY DENSITY (pcf) – ■ 90 100 110 120 / MOISTURE & ATTERBERG LIMITS (%) PL MC LL 10 20 30 40 | ▽ HAND PENETROMETER ⊠ TORVANE SHEAR ○ UNCONFINED COMPRESSION ⊡ VANE SHEAR (PEAK) ✕ VANE SHEAR (REMOLDED) ✦ TRIAXIAL (UU) SHEAR STRENGTH (KSF) 1 2 3 4 | REMARKS

| Depth to bottom (ft) | Profile Description |
|---|---|
| 0.8 | Fine Sand- Some Silt- Trace Gravel and Roots- Dark Brown (SM) |
| 1.5 | Silty Fine to Medium Sand- Trace to Some Clay- Trace Gravel and Roots- Dark Brown (SM) |
| 3.0 | Sandy Clay- Some Silt- Trace Gravel- Occasional Sand Seam- Brown and Gray- Hard (CL) *Sand Seam @ 2.5' |
| 5.0 | Silty Clay- Trace to Some Sand- Trace Gravel- Occasional Sand Seams- Brown- Hard (CL) *Sand Seams @ 3.75' and 4.25' |
| 8.5 | Silty Clay- Some Sand- Trace Gravel- Occasional Silt and Sand Seams- Brown- Hard (CL) *Silt Seams @ 6' and 6.5' *Sand Seams @ 8' |
| 23.0 | Silty Clay- Some Sand- Trace Gravel- Occasional Sand Seams and Layers- Gray- Hard (CL) *Sand Seams and Layers @ 13', 18' and 23' |
| 25.0 | Sandy Clay- Some Silt- Trace Gravel- Occasional Sand Seam- Gray- Hard (CL) *Sand Seam @ 24.5' |
| 28.0 | Silty Clay- Some Sand- Trace Gravel- Gray- Stiff (CL) |
| 30.0 | Sandy Clay- Some Silt- Trace Gravel- Gray- Very Stiff (CL) |

**GROUNDWATER & BACKFILL INFORMATION**

| | DEPTH (FT) |
|---|---|
| ▽ DURING BORING: | 22.0 |
| ▼ AT END OF BORING: | 10.0 |

**BACKFILL METHOD:** Grout/Well

NOTES:
1. The indicated stratification lines are approximate. In situ, the transition between materials may be gradual.
2. A groundwater monitoring well was installed: screen at 20 to 25 feet, grout above 18 feet.
3. GPS Data: N = 42.40433, W = 83.01657
4. Additional Groundwater Data: next morning = 7 feet

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(Continued Next Page)

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# BORING P3

PAGE 2 OF 2

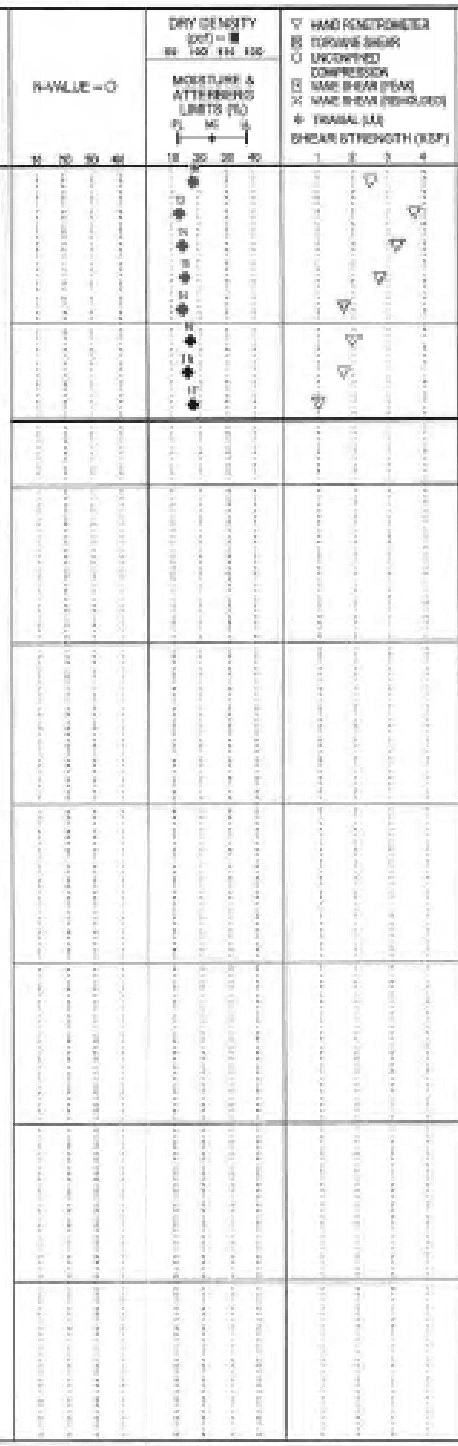
**PROJECT NAME:** Parjana: Coleman Young Site

**CLIENT:** Parjana

**PROJECT NUMBER:** P02442.12

**PROJECT LOCATION:** Detroit, Michigan

| DEPTH (FEET) | SYMBOLIC PROFILE | PROFILE DESCRIPTION | SAMPLE TYPE/NO. INTERVAL |
|---|---|---|---|
| 30 – 38.0 | | Silty Clay- Trace to Some Sand- Trace Gravel- Gray- Very Stiff to Stiff (CL) | LS, LS, LS, LS, LS, LS, LS, LS |
| 38.0 | | END OF BORING AT 38.0 FEET. | |




REMARKS

November 7, 2012

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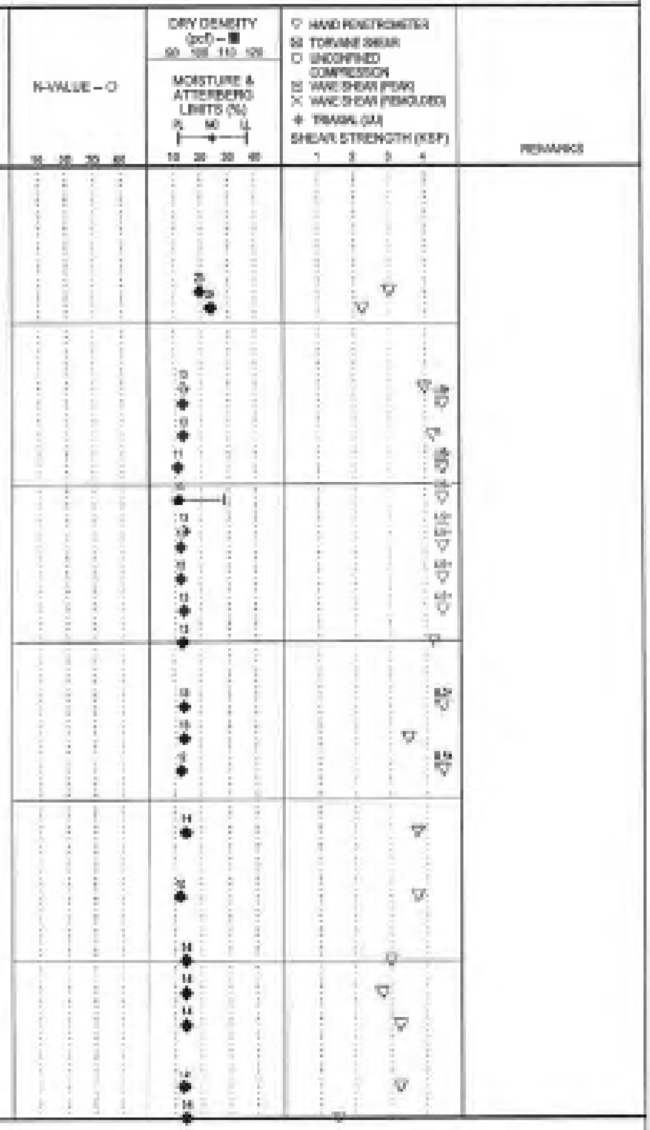
# BORING P4



**PROJECT NAME:** Parjana: Coleman Young Site
**PROJECT NUMBER:** P02442.12
**CLIENT:** Parjana
**PROJECT LOCATION:** Detroit, Michigan
**DATE STARTED:** 10/10/12
**COMPLETED:** 10/10/12
**BORING METHOD:** Continuous Liner
**DRILLER:** BM
**RIG NO.:** Geoprobe
**LOGGED BY:** SB
**CHECKED BY:** CRB

| DEPTH (FEET) | PROFILE DESCRIPTION | SAMPLE TYPE/NO. INTERVAL |
|---|---|---|
| 0.0–0.8 | Fine to Medium Sand- Some Silt- Trace Gravel and Roots- Dark Brown (SM) | |
| 0.8–1.4 | Possible Crushed Steel Furnace Slag | |
| 1.4–3.6 | Fine to Medium Sand- Trace to Some Silt- Trace Gravel- Brown (SP-SM) | |
| 3.6–4.0 | Silty Clay- Trace to Some Sand- Trace Gravel- Dark Gray- Very Stiff (CL) | LS, LS |
| 4.0–7.0 | Silty Clay- Trace to Some Sand- Trace Gravel- Brown- Very Stiff to Hard (CL) | |
| 7.0–11.4 | Silty Clay- Some Sand- Trace Gravel- Frequent Silt Seams- Brown- Hard (CL) | LS, LS, LS, LS, LS |
| 11.4–13.0 | Silty Clay- Some Sand- Trace Gravel- Frequent Silt Seams- Gray- Hard (CL) | LS, LS |
| 13.0–19.0 | Silty Clay- Some Sand- Trace Gravel- Gray (CL) | LS, LS, LS, LS, LS, LS |
| 19.0–30 | Silty Clay- Some Sand- Trace Gravel- Occasional Sand Seams- Gray- Hard to Stiff (CL) *Sand Seams @ 20.5', 25.75', 35.5', 40' and 41.5' | LS, LS, LS, LS, LS, LS |




**GROUNDWATER & BACKFILL INFORMATION**

GROUNDWATER WAS NOT ENCOUNTERED

**BACKFILL METHOD:** Grout/Well

NOTES:
1. The indicated stratification lines are approximate. In situ, the transition between materials may be gradual.
2. A groundwater monitoring well was installed: screen at 34 to 39 feet, grout above 24 feet.
3. GPS Data: N = 42.40419, W = 83.01627

November 7, 2012

(Continued Next Page)

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# BORING P4



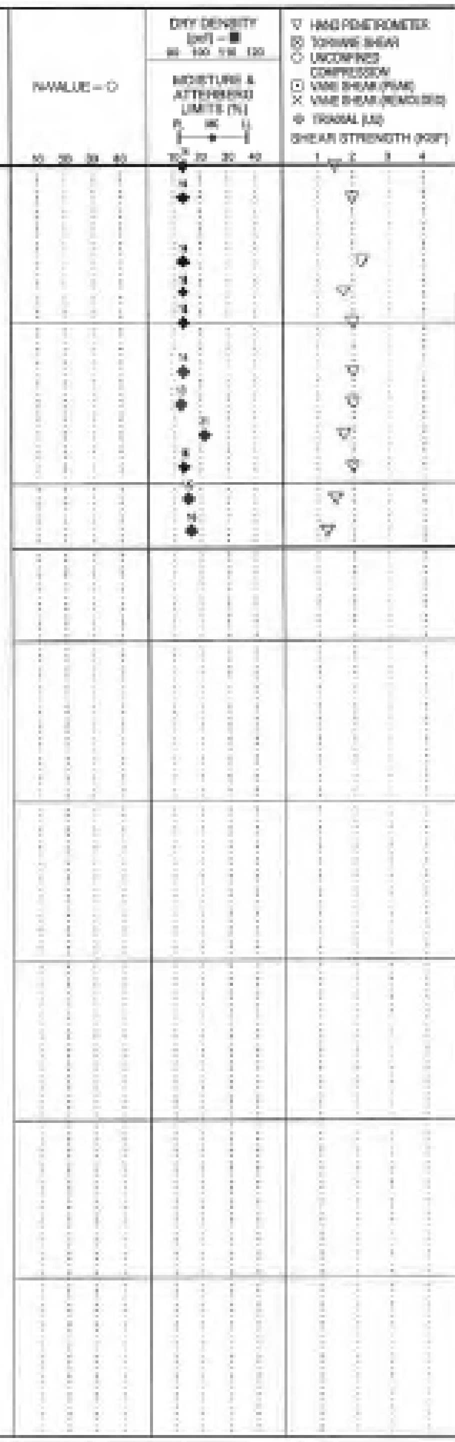
**PROJECT NAME:** Parjana: Coleman Young Site

**CLIENT:** Parjana

**PROJECT NUMBER:** P02442.12

**PROJECT LOCATION:** Detroit, Michigan

| DEPTH (FEET) | SYMBOLIC PROFILE | PROFILE DESCRIPTION | SAMPLE TYPE/NO. INTERVAL | REMARKS |
|---|---|---|---|---|
| 20–42.0 | | Silty Clay- Some Sand- Trace Gravel- Occasional Sand Seams- Gray- Hard to Stiff (CL) *Sand Seams @ 20.5', 25.75', 35.5', 40' and 41.5' (continued) | LS, LS, LS, LS, LS, LS, LS, LS, LS, LS, LS | |
| 42.0 | | END OF BORING AT 42.0 FEET. | | |




November 7, 2012

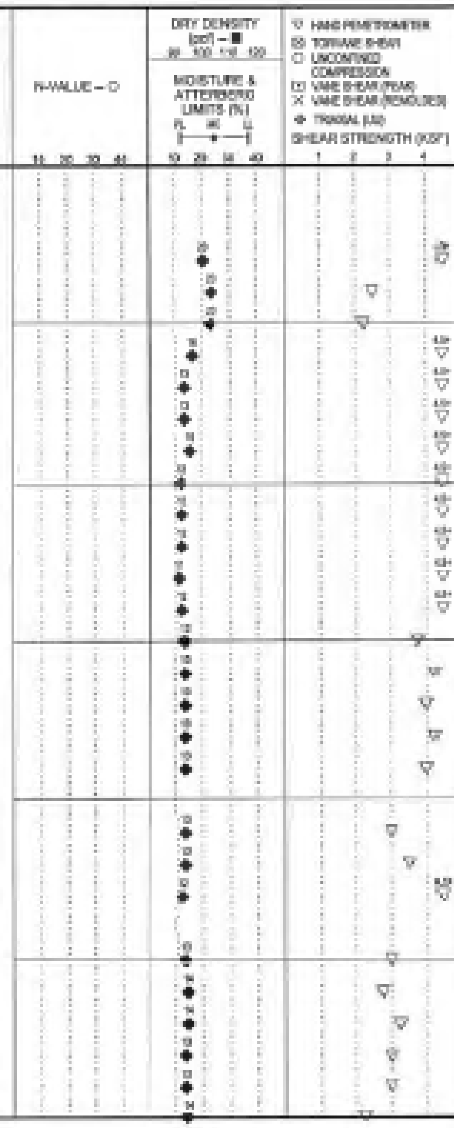
soil and materials engineers, inc.
michigan, ohio and indiana

# BORING P5



**PROJECT NAME:** Parjana: Coleman Young Site
**PROJECT NUMBER:** P02442.12
**CLIENT:** Parjana
**PROJECT LOCATION:** Detroit, Michigan
**DATE STARTED:** 10/10/12
**COMPLETED:** 10/10/12
**BORING METHOD:** Continuous Liner
**DRILLER:** BM
**RIG NO.:** Geoprobe
**LOGGED BY:** SB
**CHECKED BY:** CRB

| DEPTH (FEET) | PROFILE DESCRIPTION | SAMPLE TYPE/NO. INTERVAL |
|---|---|---|
| 0–1.5 | Fine Sand- Some Silt- Trace to Some Gravel- Trace Roots- Dark Brown- Moist (SM/Fill) | |
| 1.5–2.5 | Fine to Medium Sand- Some Silt- Trace Gravel, Clay and Roots- Dark Brown and Black- Moist (SM/Topsoil) | LS |
| 2.5–5.0 | Silty Clay- Trace to Some Sand- Trace Gravel and Roots- Brown and Dark Brown- Hard (CL) | LS, LS, LS |
| 5.0 | Silty Clay- Trace to Some Sand- Trace Travel- Brown and Gray- Very Stiff (CL) | LS, LS |
| –10.5 | Silty Clay- Some Sand- Trace Gravel- Brown- Hard (CL) | LS, LS, LS, LS |
| 10.5–12.0 | Silty Clay- Some Sand- Trace Gravel- frequent Silt Seams- Gray and Brown- Hard (CL) | LS, LS |
| 12.0–20.0 | Silty Clay- Some Sand- Trace Gravel- Gray- Hard (CL) | LS, LS, LS, LS, LS, LS, LS, LS, LS |
| 20.0–30.0 | Silty Clay- Some Sand- Trace Gravel- Occasional Sand Seams- Gray- Very Stiff (CL) *Sand Seam @ 21', 23', 26', 27.25', 29.5' and 30' | LS, LS, LS, LS, LS, LS, LS, LS |




REMARKS

END OF BORING AT 30.0 FEET.

**GROUNDWATER & BACKFILL INFORMATION**

| | DEPTH (FT) |
|---|---|
| ▽ DURING BORING: | 28.0 |
| AT END OF BORING: | Not present |

**BACKFILL METHOD:** Grout/Well

NOTES:
1. The indicated stratification lines are approximate. In situ, the transition between materials may be gradual.
2. A groundwater monitoring well was installed: screen at 24 to 29 feet, grout above 19 feet.
3. GPS Data: N = 42.40476, W = 83.01632

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(Continued Next Page)

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**michigan, ohio and indiana**

# BORING P5

PAGE 2 OF 2

**PROJECT NAME:** Parjana: Coleman Young Site

**CLIENT:** Parjana

**PROJECT NUMBER:** P02442.12

**PROJECT LOCATION:** Detroit, Michigan

| DEPTH (FEET) | SYMBOLIC PROFILE | PROFILE DESCRIPTION | SAMPLE TYPE/NO. INTERVAL | N-VALUE – ○ (10 20 30 40) | DRY DENSITY (pcf) – ■ (90 100 110 120) / MOISTURE & ATTERBERG LIMITS (%) PL WC LL (10 20 30 40) | ▽ HAND PENETROMETER ⊠ TORVANE SHEAR ○ UNCONFINED COMPRESSION ⊡ VANE SHEAR (PEAK) ✕ VANE SHEAR (REMOLDED) ✦ TRIAXIAL (UU) SHEAR STRENGTH (KSF) (1 2 3 4) | REMARKS |
|---|---|---|---|---|---|---|---|
| 30 | | | | | | | |
| 35 | | | | | | | |
| 40 | | | | | | | |
| 45 | | | | | | | |
| 50 | | | | | | | |
| 55 | | | | | | | |
| 60 | | | | | | | |
| 65 | | | | | | | |
| 70 | | | | | | | |

November 7, 2012

# Appendix B

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING

RICK SNYDER
GOVERNOR

DAN WYANT
DIRECTOR

October 5, 2012

Mr. Andrew Niemczyk
Parjana, Inc.
2000 Tower Center Suite 1900
Southfield, Michigan 48075

Dear Mr. Niemczyk:

SUBJECT: Parjana Energy-Passive Groundwater Recharge Pumps (EGRPs)

Thank you for meeting with staff of the Department of Environmental Quality (DEQ) on September 25, 2012 to discuss the DEQ's August 24, 2012 letter. In particular, we discussed regulation of Parjana's ERGPs under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA), and the Part 22, Groundwater Quality, administrative rules promulgated under Part 31 of the NREPA. We appreciate Parjana's continued cooperation in addressing the issues identified by the DEQ and look forward to further constructive dialog regarding these issues.

This letter will address the DEQ's response to Parjana's request for authorization under Part 31 of the NREPA to install EGRPs in residential applications. Based on the discussions during the September 25, 2012 meeting, the DEQ understands that the typical residential use of EGRPs involves installation of 20 foot lengths beginning 2 feet below ground surface, for a total depth of 22 feet below ground surface. In particular we discussed residential applications in areas where municipal water and sewer services are being utilized.

For background information, Rule 2210 of the Groundwater Quality rules identified certain substances that may be discharged without a permit provided that the discharge meets the requirements of Rule 2204. In general, Rule 2204 specifies requirements applicable to all groundwater discharges (including those listed in Rule 2210) to assure that the discharge is not injurious to the waters of the state, or does not cause nuisance conditions. Parjana should become familiar with the requirements of the Part 22 rules before proceeding with installation of ERGPs. A copy of the rules is enclosed for your use.

The DEQ has reviewed the available exemptions available under Rule 2210 of the Groundwater Quality rules as they relate to Parjana's request. While not agreeing at this time that EGRPs perform as presented by Parjana, for a period lasting until six months from the date of this letter, the DEQ will not object to Parjana applying the exemption for domestic or domestic equivalent activities described by Rule 2210(i) to residential installations, as further described below. At that time, the DEQ will reconsider its determination based on the results of the proposed studies to evaluate the effectiveness of ERGPs, provided that such studies include investigations of their impact on groundwater quality.

The DEQ reserves its right to take any action deemed necessary under Part 31 of the NREPA to address violations or Rule 2204 caused by the installation of EGRPs. The DEQ's determination may be rescinded at any time if information is obtained indicating that the installation of EGRPs may be injurious to the waters of the state or otherwise violate the provisions of Part 31 of the NREPA.

The DEQ's determination is applicable only to residential applications in areas with municipal water and sewer, where Parjana limits the installation to a total depth of no greater than 22 feet below ground surface. In order to apply the exemption with no objection from the DEQ, Parjana must also abide by the following:

1. Installation shall not occur within 1) 200 feet from a type I or type IIa water supply well; 2) 75 feet from a type IIb or type III water supply well; or 3) 50 feet from any domestic well.

2. Installation shall not occur within 500 feet of a wetland regulated under Part 303, Wetlands Protection, of the NREPA, or an inland lake or stream regulated under Part 301, Inland Lakes and Streams, of the NREPA.

3. Parjana shall verify that there are no underground fuel oil storage tanks on the property.

4. Parjana shall verify that the location is not within 500 feet of a site listed on the DEQ's Part 201 Site List, or a location on the DEQ's leaking underground storage tank list.

5. Parjana shall maintain a list of all locations where EGRPs are installed. The list shall be retained by Parjana and provided to the DEQ upon request.

If you have any questions, please feel free to call me.

Sincerely,

Rick Rusz, Chief
Groundwater Permits Unit
Water Resources Division
517-335-4709
Fax: 517-241-8133

Enclosure

cc: Mr. Brian Woodworth, Wade Trim
Ms. Carrie Monosmith, DEQ
Mr. Peter Ostlund, DEQ

# APPENDIX C

All of the laboratory analyses conducted by Fibertec reporting the bromide concentrations in the numerous samples submitted to them from the second slug test are included in this Appendix. However, due to its page length, Appendix C is published in a separate document.