Summary of Findings

Field investigations occurred over three weeks between October and December 2019. The following observations and conclusions were made during the field investigation:

- Infiltration rates of the receptor unit(s) at:
  - The Deadman Creek site are too low (0.01 inches per hour [in/hr]) to feasibly implement surface infiltration; therefore, the alternative Dry Creek site was evaluated.
  - Dry Creek and the Bear Creek site have adequate subsurface conditions for surface infiltration.
- Surface water and groundwater quality and aquifer characteristics at Deadman Creek were not evaluated further due to limited feasibility for surface infiltration.
- Dry Creek was evaluated for surface water parameters only due to unsaturated conditions above a confining unit (competent bedrock). No surface water quality criteria were exceeded. The thickness of the overlying unconsolidated sand unit (coarse-grained outburst flood deposit) is 52 feet.
- Bear Creek was evaluated for surface water and groundwater quality. No surface water quality criteria were exceeded; however, groundwater quality criteria were exceeded for total dissolved solids (TDS), chloride, and total iron. Groundwater quality has likely been affected by storage of road salt on the ground without cover at the County gravel pit.
- The depth to the water table aquifer at Bear Creek is 71 feet below ground surface (bgs). The aquifer transmissivity is estimated at 2,300 square feet per day ($feet^2/day$) based on the aquifer testing conducted in this study. The aquifer thickness is approximately 12 feet resulting in a horizontal hydraulic conductivity of 194 feet/day.

The Bear and Dry Creek sites appear suitable for surficial infiltration of diverted surface water based on the raw infiltration rates and depth to water table or confining units. The groundwater quality at the Bear Creek site should see water quality improvement with infiltration of surface water if best management practices (BMPs) are implemented to prevent further infiltration of road salts.

Aspect recommends Spokane County Environmental Services continuously monitor groundwater levels in monitoring well MB1 at the Bear Creek site to better understand seasonal changes to the water table aquifer. In addition, surface water quality monitoring at Bear and Dry Creek during peak runoff is recommended to provide additional characterization of the water source for MAR infiltration. Lastly, additional investigation at the Bear Creek site should occur as part of final design work to determine if diversion of surface water with large capacity wells adjacent to the creek is feasible, as this would simplify permitting by eliminating a surface diversion structure and reduce infrastructure required for settling solids in the source water prior to infiltration.

Project Location

The project is located within Spokane County, Little Spokane River watershed (WRIA 55) as shown on Figure 1. Detail study locations for individual projects are shown on Figures 2, 3, and 4.

Methodology

The objectives of this field investigation are to characterize each selected MAR site in terms of physical attributes (infiltration rates, depth to water table or confining unit, water quality). An adaptive management approach based on the results of infiltration testing was implemented to control costs and move forward with potential MAR implementation sites. The investigation process is described below.

Soils and Geology

Subsurface investigations were conducted at all three project sites. Shallow subsurface conditions were investigated using a small excavator (Caterpillar 304E and Bobcat E50) and deeper excavations (greater than 5 feet below ground surface [bgs]) were obtained using an air rotary drill rig (Speedstar 50K). Shallow subsurface samples were collected from the excavator bucket; whereas, drill cuttings were collected either directly from the rotary swivel (Bear Creek) or from a cyclone (Dry Creek).

Samples were described in the field and bagged for analysis. Per the QAPP (Aspect, 2019b), the soils were analyzed for grain size, cation exchange capacity, percent organic matter, major cations and anions, plus nitrate and phosphorous.

Infiltration

Infiltration rates were measured following the small-scale pilot infiltration (PIT) tests as described in the QAPP (Aspect, 2019b). At each site a test pit was excavated. Due to the coarse-grained nature of the Dry and Bear Creek sites a new, never-used, bottom-less, 55-gallon drum was set into the receptor unit. This allowed for the PIT to occur over a known area and eliminate potential for sidewalls to slough into the excavation. A staff gage and stilling well (equipped with a Van Essen Diver and Baro) instrumented the test pit to allow for manual observations and collection of continuous pressure data.

A 2,000-gallon water truck was used as a water source for the PIT. A 2-inch discharge line was used to convey water from the truck through a 2-inch Seametrics MJ series water meter and into the test pit. Manual reads were made from the water meter during the duration of the PIT.

The continuous pressure and flowrate data were managed in EXCEL to perform the analysis. The barometrically compensated pressure data was reduced to determine water levels in the test pit. These water levels were then associated with an observed flowrate to evaluate the constant head portion of the test and determine when the falling head portion of the test began. Both the constant head and falling head tests were used to determine the infiltration rate. Depending on the quality of the test either the constant or falling head portion of the test was used to calculate a raw infiltration rate.

Pumping Test

A step rate pumping test was performed on the Bear Creek monitoring well (MB1, BKW220) using a contractor supplied submersible test pump and the flowrate was measured using a 5-gallon bucket and a stopwatch. The flowrate during the pumping test was controlled using a ball valve. Pumped water was conveyed downhill away from MB1 and discharged onto the ground.

Groundwater levels during the pumping test were measured using an electronic water level indicator, and continuous pressure measurements were collected using an Instrument Northwest PT2X gaged pressure transducer.

The step rate test consisted of three one-hour long steps followed by a 2-hour last step.

Manually collected flow rate and depth to water measurements were compiled with the continuous pressure measurements from the PT2X in EXCEL. The manual measurements and continuous pressure measurements were evaluated graphically for quality control and assurance.

Recovery measurements were used to calculate aquifer transmissivity using the Theis recovery method for an unconfined aquifer. The Theis method is appropriate for determining transmissivity using the late-time recovery measurements only (Kruseman and deRidder, 2001).

Water Quality

Surface water was collected from Dry and Bear Creek at locations shown on Figure 3 and 4, respectively. Due to the shallow depth, a peristaltic pump was used to collect samples, as shown on Photograph 1 of Attachment 2. Clean low-density polythene (LDPE) tubing and silicone tubing were used at each site. Samples were pumped directly into lab supplied bottles. Filtered samples were filtered through a 0.45-micron (um) filter cartridge. Preservative was added to bottles as necessary prior to placing sample bottles into a cooler. A calibrated YSI Pro Series multi-parameter water meter (YSI) was used to collect field parameters during sample collection.

Groundwater samples were collected from MB1 using a submersible pump (12V stainless steel Hurricane XL) and LDPE tubing. Samples were collected using low-flow sampling techniques. Groundwater was pumped through a flow-cell connected to the calibrated YSI and field parameters were measured every 5 minutes until the parameters stabilized. Pumped water was discharged onto the ground. Samples were collected and stored in the same manner as the surface water samples for transport to the respective laboratories for analysis.

All samples were received at the respective laboratory within holding times and in good condition.

QAPP Deviations

The Quality Assurance Project Plan (QAPP) planned for 6-hour pre-wetting phase during the pilot infiltration tests (PIT). A shorter pre-wetting phase was conducted to control costs for mobilizing multiple water trucks and labor. Therefore, each PIT was limited to a single water truck capacity of 2,000 gallons. This deviation is not expected to affect the quality of the results. Pre-wetting of the soil profile is conducted to demonstrate if infiltration rates are limited by strata underlying the receptor unit. The Deadman Creek site has very low infiltration rates, therefore wetting exceeded the 6-hour timeframe due to ponding. The Bear Creek and Dry Creek sites were over-excavated, which demonstrated the underlying strata are consistent with the receptor unit. In addition, further subsurface investigation via drilling with air rotary indicated that a boundary condition due to poorly transmissive material was unlikely to occur that would limit infiltration into the shallow subsurface.

Deadman Creek

The Deadman Creek site subsurface consists of a thick (greater than 200 feet) glaciolacustrine deposit underlain by a thin sandy water bearing unit that is underlain by granitic bedrock. The upper glaciolacustrine deposit is characterized as fine-grained glacial deposit (Kahle et. al., 2013) in the project area and turns to a coarse-grained glacial deposit downstream of the project site.

Domestic water use in the area targets the thin sandy water bearing unit underlying the fine-grained glacial deposit. Static water levels in this water bearing unit vary from 60 to 140 feet bgs depending on location. The aquifer is in a confined to semi-confined condition with recharge occurring along the glacial deposit and bedrock contact and higher elevations to the east of the Peone Prairie, and groundwater discharge toward the west and the Little Spokane River.

Soils

A 7 x 9-foot test pit was excavated to a total depth of 13 feet bgs. The surficial soils (1 to 10 feet bgs) are a very soft, brown, silt (ML) that transitions to a stiff, platy, clay (CH) with some calcium precipitate between peds. A soils log (FD-S) is presented in Attachment 1 and a photograph of the soil profile is included on Photograph 2 of Attachment 2.

Analytical results from soils analysis of major cations and anions plus nitrate and phosphorous are presented in Table 1.

Infiltration

As shown on Figure 5, an average of 22 gallons per minute (gpm) was introduced into the test pit over a 4-minute period rapidly raising the water level in the test pit to 28 inches. The flow rate was then reduced to 8 gpm for the next 45 minutes raising the water level to 33 inches. The flow rate was further reduced to 4.5 gpm for 15 minutes, then further reduced to 1.75 gpm to obtain a constant head of 3 feet in the test pit. A near constant head was maintained for 30 minutes at 1.75 gpm; however, incremental increase in head (0.5 inches) was observed.

Following the constant head portion of the test the water was shut-off and the falling head portion of the test was measured over a 12-hour period using pressure transducers, as shown on Figure 6.

Reduction of the constant head and falling head data result in a raw infiltration of 3 and 0.25 in/hr, respectively. The raw infiltration rate of 0.25 in/hr from the falling head portion of the test likely better represents the long-term infiltration rate and the high water-entry-pressure necessary to infiltrate water into the tight material.

Dry Creek

The Dry Creek subsurface consists of a 50 to 150 feet thick layer of coarse-grained glacial deposits that overlay a weathered granitic bedrock. Domestic water use in the area targets fracture zones within the granitic bedrock at depths of 200 to 550 feet bgs. Static water levels range from 100 to 180 feet bgs. Recharge is expected to occur on the higher surrounding elevations creating a semi-confined to confined groundwater condition in the fractured water bearing zones. Discharge likely occurs down valley toward the west and ultimately to the Little Spokane River. Interflow at the site is expected to mimic the local topography.

Soils and Geology

A 5 x 5-foot test pit was excavated to a total depth of 4 feet bgs. The soils are a medium dense, gray brown sand (SW) with crossbedding across the entire excavated depth. A profile of the excavation is shown in Photograph 3 of Attachment 2.

A nominal 8-inch drill bit and casing were driven to 57 feet bgs. The subsurface was consistent with the well sorted sand deposit observed in the test pit to a depth of 45 feet where some gravel was encountered. This is interpreted as a weathered granite (gruss) zone from 45 to 52 feet bgs. At 52 feet bgs a hard, granitic, basement rock was encountered.

A soil log (ND-S) and borehole log (ND1) with schematic of monitoring well are shown in Attachment 1. No water was encountered while drilling; however, a monitoring well was installed with a completion above the granitic basement rock for future monitoring of infiltrated water. The monitoring well construction consists of a screen interval between 42 to 52 feet bgs, immediately above the competent bedrock. A bentonite seal was installed from ground surface to 38 feet bgs and a filter pack of 10/20 silica sand was installed from 38 to 57 feet bgs.

Analytical results from soils analysis of major cations and anions plus nitrate and phosphorous are presented in Table 1. A copy of the laboratory data deliverables is provided in Attachment 3.

Infiltration

As shown on Figure 7, an average of 20 gpm was introduced into the 400 square inch infiltration ring. Minor adjustments to the flowrate resulted in 3 small (approximately 1 to 1.5 inch each) increases in head over the 2.7-hour PIT.

Following the infiltration of 2,000 gallons of water into the infiltration ring, the falling head portion of the test was measured over a 3-minute period until the infiltration ring drained, as shown on Figure 8.

Reduction of the constant head and falling head data result in a raw infiltration of 700 and 165 in/hr, respectively. The more conservative raw infiltration rate of 165 in/hr was selected as representative of a long-term infiltration rate.

Water Quality

Surface water samples were collected at the location shown on Figure 3. No surface water quality criteria were exceeded. A summary of the detected analytes and field parameters are presented in Tables 2 and 3, respectively. A copy of the laboratory data deliverables is provided in Attachment 3.

Bear Creek

The Bear Creek site consists of a vertically stratified coarse-grained glacial deposit that overlays a granitic bedrock. Groundwater in the area may occur as a multilayer aquifer system. A water table aquifer (unconfined) was encountered at 71 feet bgs in a sandy unit that is comprised of both coarse-grained glacial deposit and weathered granite (gruss). Domestic water use in the area targets fractured or weathered zones of granitic bedrock at a depth of 100 to 200 feet bgs, or the shallower weathered granitic surface at 50 to 70 feet bgs.

Regional recharge of the upper unconfined aquifer in the Bear Creek area likely occurs from the north-northwest with limited local recharge occurring in the lowland area near the Bear Creek site. Discharge of groundwater from the local area is expected to occur toward the south-southwest mimicking the Bear Creek drainage. The Bear Creek drainage appears to follow a glacial outburst channel carved into the underlying granitic bedrock. The flow of groundwater in the unconfined aquifer is expected to follow the buried surface of the granitic bedrock.

Soil and Geology

A 6 x 6-foot test pit was excavated to a depth of 6 feet bgs. The top 2 feet of the subsurface consisted of a brown silty gravel. At 2-feet bgs a cemented layer is encountered, and the gravels are oxidized. Below 3 feet the subsurface is gravel with silt and cobbles becoming more course with depth. Boulders were present at total depth. A soil log (MB-S) is presented in Attachment 1 and a photograph of the soil profile is shown on Photograph 4 of Attachment 2.

A nominal 8-inch drill bit and casing were driven to 87 feet bgs. The subsurface was consistent with the observations in the test pit with coarse grained glacial deposits coarser (boulders and gravels) than the Dry Creek site (sand). The upper 9 feet consists predominantly of a gravel with silt, cobbles and boulders. Below the very coarse unit of boulders, the subsurface material fines to a 13-foot gravelly unit underlain by a 4-foot clayey unit (23 to 27 feet bgs). Below the clayey unit the subsurface is predominantly sand. At 47 feet bgs the subsurface material changes to a sandy unit (gruss) derived from weathered granitic bedrock. Groundwater was encountered at 76 feet bgs during drilling. At 83 feet bgs competent granitic bedrock was encountered. The drill bit and casing were advanced to 87 feet bgs, which sealed-off the overlying water bearing unit, so drilling ceased, and a monitoring well was installed with a completion above the granitic basement rock for monitoring of infiltrated water.

The static water level raised to 71 feet bgs after completion of drilling. The borehole log (MB1) and monitoring well construction are presented in Attachment 1. The monitoring well construction consists of a screen interval between 72.5 to 82.5 feet bgs, immediately above the competent bedrock. A bentonite seal was installed from ground surface to 67 feet bgs and a filter pack of 10/20 silica sand was installed from 67 to 87 feet bgs. The monitoring well was developed by pumping until the discharged water ran clear.

Analytical results from soils analysis of major cations and anions plus nitrate and phosphorous are presented in Table 1. A copy of the laboratory data deliverables are provided in Attachment 3.

Infiltration

As shown on Figure 9, an initial flow rate of 30 gpm was introduced in the first 3 minutes into the 400 square inch infiltration ring. An average of 23 gpm was introduced for 1 hour and 22 minutes. Then the flow rate was increased to 50 gpm over the final 25 minutes. The flow rate was insufficient to exceed the time to ponding for the gravel, cobble, boulder subsurface during the PIT, indicating excellent infiltration capacity.

Following the infiltration of 2,000 gallons of water into the infiltration ring, no falling head portion of the test was measured due to the rapid infiltration.

Reduction of the constant head data result in a raw infiltration greater than 770 in/hr.

Water Quality

Surface water samples were collected at the location shown on Figure 4. No surface water quality criteria were exceeded. A summary of the field parameters and detects are presented in Tables 2 and 3, respectively. A copy of the laboratory data deliverables are provided in Attachment 3.

Groundwater samples were collected from the monitoring well (MB1). Groundwater quality results are shown in Table 2. Groundwater quality criteria were exceeded for TDS, chloride, and total iron. It is presumed the source of TDS and chloride is from road salt stockpiled on bare ground without cover. The road salt provided an opportunity to determine if the 4-foot clayey unit behaves as a confining unit impeding recharge of the underlying aquifer with surface infiltration. The detection of apparent road salt elements suggests the clayey unit does not impede recharge from surface infiltration, supporting the suitability of the site for MAR infiltration.

An equipment blank for total and dissolved metals was collected by pumping distilled water through the submersible pump used to collect groundwater samples. Total calcium was detected (0.104 mg/L) in the equipment blank sample. The detect in the equipment blank suggest the groundwater result for total calcium (517 mg/L) may be biased high; however, this represents a small fraction of the concentration compared to the observed groundwater concentration.

Aquifer Characteristics

The extended step rate pumping test hydrograph and associated flow rates are presented on Figure 10. The upward trending drawdown measurements along the first step (1 gpm) indicates some well development may have occurred. Subsequent steps (2.5, 5, and 18 gpm) show the typical downward trend with drawdown over time for each step. At later pumping times, as seen in the final step, the drawdown curve typically approaches an asymptotic horizontal slope until a boundary condition is encountered (recharge or barrier). Neither a recharge nor barrier boundary to groundwater flow is evident in the drawdown curve.

Care was taken in conducting the initial step at lower flow rates due to the uncertainty of well performance and aquifer extent. The first three steps (1, 2.5, and 5 gpm) resulted in minimal drawdown. Therefore, the final step was conducted at the maximum flow rate possible with a submersible pump installed. The final step ran for a total of two hours, then recovery was measured. The recovery portion of the test was used to determine the aquifer transmissivity.

A comparison of the manual and continuously measured drawdown revealed an average difference of 0.03 feet, ranging from 0.00 to 0.07 feet, as shown on Figure 10. This variability is within the expected total field and measurement error.

Figure 11 presents the residual drawdown versus ratio of t/t', which is the ratio of the time since pumping started (t) and the time since pumping stopped (t'). Late time recovery data was selected for calculating the transmissivity (Kruseman and deRidder, 2001). Transmissivity was calculated using the Cooper-Jacob Straight-line Method (Driscoll, 1986) which states:

$T = \frac{264Q}{\Delta(s-s')}$ where;

$T = transmissivity$

$Q = pumping\ rate$, and

$\Delta(s - s') = water\ level\ recovery\ per \log cycle.$

For a calculated transmissivity of 2,300 square feet per day (ft^2/day), or 17,400 gallons per day per foot (gpd/ft).

The hydraulic conductivity of the water bearing unit was calculated using the relationship that the transmissivity is the product of the effective hydraulic conductivity and the saturated thickness of the aquifer given by:

$T = Kb$ where;

$K = hydraulic\ conductivity, and$

$b = aquifer\ thickness.$

The total aquifer thickness is 12 feet; therefore, the effective hydraulic conductivity is approximately 7 x 10^{-2} centimeters per second (cm/s), or 194 feet per day (feet/day). This hydraulic conductivity is consistent with literature values for a well sorted sand (Fetter, 2001) and observed conditions.

The aquifer is unconfined, therefore the storativity (specific yield) is equivalent to the effective porosity of the aquifer, or approximately 0.25.

References

Aspect Consulting, LLC, 2019. Memorandum: Managed Aquifer Recharge Site Optimization and Selection WRIA 55 ESSB 6091/RCW 90.94 Watershed Plan Update, December 2, 2019.

Aspect Consulting, LLC, 2019. Managed Aquifer Recharge Field Investigation, Quality Assurance Project Plan, Agreement No. WRSRPPG-2019-SCUWRS-00010. November 7, 2019.

Driscoll, F. G., 1986, Groundwater and Wells, Second Edition, Johnson Screens, St. Paul, MN.

Fetter, C.W, 2001, Applied Hydrogeology, Prentice-Hall Upper Saddle River, NJ.

Kahle, S.C., Olsen, T.D., and Fasser, E.T., 2013, Hydrogeology of the Little Spokane River Basin, Spokane, Stevens, and Pend Oreille Counties, Washington: U.S. Geological Survey Scientific Investigations Report 2013–5124, 52 p.

Kruseman, G.P. and N.A. de Ridder, 2001, Analysis and Evaluation of Pumping Test Data, Second Edition, International Institute for Land Reclamation and Improvement, The Netherlands.

Limitations

Work for this project was performed for the Spokane County Environmental Services (Client), and this memorandum was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This memorandum does not represent a legal opinion. No other warranty, expressed or implied, is made.

All reports prepared by Aspect Consulting for the Client apply only to the services described in the Agreement(s) with the Client. Any use or reuse by any party other than the Client is at the sole risk of that party, and without liability to Aspect Consulting. Aspect Consulting's original files/reports shall govern in the event of any dispute regarding the content of electronic documents furnished to others.

Attachments:
Table 1 – Soil Laboratory Results
Table 2 – Surface Water and Groundwater Laboratory Results for Detects
Table 3 – Surface Water and Groundwater Field Parameters
Figure 1 – Field Investigation Locations
Figure 2 – Feryn Conservation Area - Deadman Creek
Figure 3 – Dry Creek
Figure 4 – Milan Road - Bear Creek
Figure 5 – Deadman Creek Constant Head
Figure 6 – Deadman Creek Falling Head
Figure 7 – Dry Creek Constant Head
Figure 8 – Dry Creek Falling Head
Figure 9 – Bear Creek Constant Head
Figure 10 – Bear Creek Pumping Test Hydrograph
Figure 11 – Bear Creek Theis Recovery Analysis
Attachment 1 – Exploration Logs
Attachment 2 – Photograph Log
Attachment 3 – Laboratory Results

V:\180249 WRIA 55 Watershed Plan Update\Deliverables\MAR Field Report\Final\MAR Field Inv Report 6_18_20.docx

TABLES

FIGURES

ATTACHMENT 1

Exploration Logs

ATTACHMENT 2

Photograph Log

ATTACHMENT 3

Laboratory Results