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Memorandum

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Subject	**Town of Orleans, MA** **Water Quality and Wastewater Planning** **Task Number 10.1.B – NT Demonstration Projects** **Task 10.1.B.2 - Technical Memorandum for Eldredge Park Permeable Reactive Barrier Demonstration Project –Groundwater Monitoring Quarterly Report - Final**
Project Number	60476644
From	Thomas Parece, P.E., AECOM Project Manager
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Approvals	Date	Signature / Initials
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1. Background

This purpose of this technical memorandum is to provide and summarize quarterly groundwater monitoring results as part of the Eldredge Park Permeable Reactive Barrier (PRB) demonstration program. In addition to presenting baseline and quarterly groundwater monitoring data, this memorandum also summarizes monitoring well installation and emulsified vegetable oil (EVO) substrate injections for the Eldredge Park demonstration test site. AECOM Technical Services, Inc. (AECOM) PRB Technical Team (AECOM and MT Environmental Restoration) prepared this technical memorandum for the Town of Orleans. AECOM is providing water quality and wastewater planning and engineering services to the Town to reduce excessive nitrogen loading to the Town's ponds, estuaries and embayments.

2. Introduction

A. The Project represents the first to implement a "Hybrid" approach under the Cape Cod 208 Water Quality Plan, which has been approved by both the United States Environmental Protection Agency (USEPA) and the Massachusetts Department of Environmental Protection (MassDEP). The Project consists of conceptual and preliminary design to update the Comprehensive Wastewater Management Plan (CWMP) completed by the Town in 2011 to reflect the Consensus Plan (Water Quality Management Plan) developed by the Town in 2015. The Project goal is to reduce the nitrate load to impacted estuaries in the most cost effective manner by maximizing the use of several non-traditional technologies (Coastal Habitat Restoration, Aquaculture, Floating Constructed Wetlands, and Permeable Reactive Barriers).

The Hybrid Plan was vetted through the Orleans Water Quality Advisory Panel (OWQAP), a panel consisting of stakeholder representatives (Orleans Selectmen and representatives of engaged citizen constituencies), and liaisons from key town boards and commissions, organizations, neighboring towns, and regional, state, and federal partners. Potential alternative planning scenarios to meet water quality standards were developed for the OWQAP.

B. PRBs are a non-traditional treatment technology with the potential to reduce the levels of nitrate in the groundwater by treating groundwater biologically before it reaches sensitive surface water bodies such as estuaries.

C. The results of the groundwater monitoring plans will be incorporated into an overall Adaptive Management Plan which will be implemented to evaluate the impacts of the technologies selected by the OWQAP on reducing nitrogen. AECOM will continue to work closely with the Town, its Water Quality Advisory Panel, and the regulatory agencies including the Cape Cod Commission (CCC) and MassDEP, in implementing the Adaptive Management Plan as it is critical to obtaining one of the first watershed permits granted by MassDEP.

D. The Demonstration Test aims to provide data to assess the cost effectiveness and applicability of PRBs as a treatment alternative for the Town. It is expected that the test will demonstrate the level of nitrate removal that can be achieved with PRBs and provide data to prepare a full scale design. The Demonstration Tests will be evaluated by the following performance objectives:

1) Achieve satisfactory distribution of the EVO substrate into the subsurface soils;

2) Establish and maintain necessary dissolved organic carbon concentrations and anaerobic (reducing) conditions in the groundwater while maintaining groundwater flow throughout the targeted treatment area;

3) Demonstrate reduced nitrate concentrations and the mass of nitrate transported in groundwater (nitrate flux) through groundwater monitoring;

4) Evaluate performance through compliance monitoring and assessment of treated water quality, including potential secondary water quality affects, through a groundwater monitoring program;

5) Evaluate the life expectancy of the EVO and time frame for technology performance;

6) Evaluate potential impacts to sensitive receptors (surface water, private wells, etc.); and

7) Obtain data for engineering evaluations and to optimize full scale design and implementation to meet nitrate reduction targets.

3. Summary of Demonstration Test – Monitoring Well Installation

A. Summary of Past Monitoring Well Installation Activities

1) AECOM evaluated numerous potential sites in the Town of Orleans, including locations identified by the Town, for consideration for placement of PRB Demonstration Tests in 2016, as described in the PRB Work Plan (AECOM dated May 19, 2016). The Eldredge Park Demonstration Test site is located in the parking lot area between the Nauset Middle School playing fields and the Town-owned Eldredge Park baseball field. The demonstration site is owned by Nauset Public Schools. The Nauset Regional School Committee granted permission to install monitoring wells and conduct the PRB Demonstration Test at this location. Town Cove is located approximately 2,400 feet to the northeast of the Eldredge Park PRB Demonstration Test site. Groundwater in this area generally flows in a northeasterly direction, toward Town Cove (Figure 1).

2) Existing groundwater monitoring wells were identified at the Nauset Regional Middle School (NRMS) in the recreational field and parking lot area. These wells were installed in 1992 as part of an ongoing program to monitor groundwater in the vicinity of the NRMS wastewater treatment facility's leaching fields. An irrigation well for Eldredge Park was also identified near the corner of Eldredge Park and South Orleans Road with an available boring log and groundwater quality data.

3) In September 2016, four groundwater monitoring wells were installed in the selected demonstration test area. Water levels were measured and the groundwater flow direction was estimated. The orientation of the proposed PRB was modified before installing the remaining 19 groundwater monitoring wells in October 2016. All 23 groundwater monitoring wells were installed in order to allow for water quality measurement upgradient, downgradient, and cross-gradient of the demonstration PRB. One of the existing groundwater monitoring wells (MW-12) was also used as an upgradient well. Two wells (MW-12A and MW-12B) were installed at this location to monitor groundwater at deep and intermediate depths, respectively. The monitoring well network includes monitoring wells located along two transects (A to A' and B to B') oriented upgradient to downgradient in the direction of groundwater flow, perpendicular to the PRB layout. The location of all demonstration test monitoring wells can be seen on Figure 1. Cross-sections showing the multi-level monitoring well screen intervals along transects are presented in Figure 2 and Figure 3.

4) In March 2017, four additional groundwater monitoring wells were installed in order to expand the range of monitoring. A deep well (MW-B2075A) was installed at MW-B2100C (formerly referred to as MW-2100), which previously only had a shallow well. This will allow for a better understanding of the impact of the PRB injections at depth. MW-BC2B is an intermediate well that was installed approximately 50 feet east of MW-B2050A/B/C. This is a cross-gradient well that will provide a better understanding of the groundwater flow direction in this area.

   MW-BX1B and MW-BX1C are intermediate and shallow wells, respectively, that were installed approximately 20 feet northwest of where EVO was injected during the November 2016 demonstration injection activities. The purpose of installing these two wells is to better understand the groundwater flow pattern across the site. Previous surfer plot data (summarized in the Technical Memorandum for Eldredge Park Permeable Reactive Barriers Demonstration Overview of Baseline Sampling, Injection Activities, and Post-Injection Groundwater Monitoring (AECOM, March 2017)) indicates that the shallow wells may be impacted by flow from the direction of Boland Pond and/or mounding in the finer material described at MW-1, which is located to the northwest of the site. The infiltration of stormwater through stormwater leaching basins located under the Middle School parking lot also may be impacting groundwater flow and will continue to be monitored via these wells during the remainder of the demonstration test monitoring program.

B. Summary of Additional Monitoring Well Installation Activities

1) There have been no additional monitoring wells installed since the previous February 2017 quarterly monitoring report was submitted in June 2017.

C. Summary of Topographic Survey Activities

1) Monitoring wells were surveyed by Coastal Engineering for location and top of PVC casing elevation to the nearest 1/100 foot. Top of PVC casing elevations are included in Table 1, and the well coordinates are included in Appendix A.

2) The screen intervals were typically 40 to 50 feet bgs in shallow "C" wells, 55 to 65 feet bgs in intermediate "B" wells, and 70 to 80 feet bgs in deep "A" wells. The depths to groundwater from the top of well casings were used to determine groundwater elevations and estimate the local direction of groundwater flow. The depth to groundwater ranged from approximately 30 to 35 feet bgs. Groundwater elevation data is included in Table 2. Field parameters and analytical results from monitoring well samples are shown in Table 3.

D. Summary of Groundwater Contours

1) Groundwater contours indicate flow to the northeast through the PRB with local variations in direction in shallow and deeper groundwater in the vicinity of the PRB.

2) Variations in local flow direction may be associated with heterogeneities in the aquifer material (i.e. finer silts and clays vs. coarser sands), and other factors including Boland Pond, stormwater recharge through stormwater leaching basins, and wastewater recharge from the Nauset Regional Middle School system located under the soccer field. Groundwater elevation and flow direction data will be monitored over the remainder of the Demonstration Test.

4. Summary of Demonstration Test – Carbon Substrate Injection

A. PRB Treatment Process Description

1) PRBs are a passive treatment technology, designed in this application to intercept and treat nitrate in groundwater through biological denitrification before groundwater reaches downgradient surface waters. The PRB treatment zone is located in the groundwater saturated zone below the water table, where amendments are added to form the PRB. PRBs are typically oriented perpendicular to the direction of groundwater flow and rely on the natural groundwater gradient to carry the contaminant through the PRB (ITRC, 2011). The system is permeable because the amendments added are designed not to interfere with groundwater flow.

2) The PRB in-situ (in place in the ground) treatment method typically introduces a carbon food substrate into the aquifer, allowing naturally occurring microbes in the aquifer to consume the carbon substrate while respiring oxygen and creating anoxic conditions (without oxygen) favorable for denitrifying bacteria. Under anoxic or anaerobic conditions, maximum energy is gained by microbes using nitrate as an electron acceptor (denitrification reaction). / Nitrate is the preferred electron acceptor to soil microbes after dissolved oxygen in the groundwater is consumed. This process of bacterial metabolism results in the conversion of nitrate to inert nitrogen gas and requires both anoxic conditions and sufficient food substrate for bacterial growth.

   Denitrification: $NO_3^- \rightarrow NO_2^- \rightarrow NO + N_2O \rightarrow N_{2\,(g)}$

B. Demonstration Test Layout

The current PRB Demonstration test is oriented northwest to southeast (perpendicular) to the northeasterly regional groundwater flow direction and is approximately 110 feet long. Future full-scale PRBs or sections or PRBs are anticipated to be longer (500 to 3,000 feet, depending on the location). Demonstration Test locations are shorter in length, selected to assess construction/implementation, and allow adequate monitoring of groundwater conditions in the vicinity of the PRBs to monitor the demonstration. A vertical treatment interval from the top of the groundwater table to approximately 35 feet into the saturated soils was selected for this Demonstration Test PRB.

C. Reactive Amendment Application Method

PRBs have been designed and implemented through several construction methods. During this demonstration test, direct-push methods were used place the EVO substrate in the subsurface. Direct–push injection is a method of soil boring modified with a down-hole injection screen and tubing used for placement of organic carbon electron donor EVO substrate. The direct-push injections are temporary injection points that are sealed following injection.

D. PRB Demonstration Test Substrate and System Details

An EVO solution with a larger droplet size was selected so that the EVO droplets will adhere to sand grains in the formation to minimize the advection, or distribution, of EVO after injection. EVO adheres to the sandy aquifer material in the treatment zone and provides a slow release of soluble organic carbon compounds that are distributed by advection, dispersion, and diffusion in groundwater. A larger droplet size will also maximize the persistence of the carbon substrate within the PRB. For this demonstration test, Terra System's 60 percent Large Droplet Slow Release EVO for Nitrate Reduction (SRS-NR) was used. The SRS NR is a modified formulation developed so that the emulsion is "stickier" in order to reduce migration after injection and increase persistence. Injecting EVO diluted with water enhances the distribution of EVO in the subsurface. The 60 percent EVO was

mixed with water making a 15.5 percent solution for injection. Product information, including the Material Safety Data Sheets (MSDS) for EVO substrate was presented in Appendix B of the *Technical Memorandum for Eldredge Park Permeable Reactive Barriers Demonstration Overview of Baseline Sampling, Injection Activities and Post-Injection Groundwater Monitoring – Final (AECOM, March 2017)*.

For in-situ remediation technologies, delivery of an appropriate amount of injected amendments is a primary factor to achieving successful treatment. Sufficient carbon substrate/electron donor material must be applied to establish nitrate reducing conditions in the PRB. Calculations supporting amendment dosages were presented in Appendix C of the *Technical Memorandum for Eldredge Park Permeable Reactive Barriers Demonstration Overview of Baseline Sampling, Injection Activities and Post-Injection Groundwater Monitoring – Final (AECOM, March 2017)*. The Substrate Estimating Tool for Enhanced Anaerobic Bioremediation of Chlorinated Solvents developed for the Environmental Security Technology Certification Program (ESTCP) was used to support EVO quantities for the PRB Demonstration Tests. This tool estimates quantities of various carbon substrates to provide sufficient amendment for the sum of electron donor demand from electron acceptors (dissolved oxygen, nitrate, and sulfate) as well as dissolved volatile organic compounds if present. For the Demonstration Test, the EVO dosage was determined primarily to meet the electron donor demand based on site conditions including expected nitrate concentrations. Actual quantities of EVO used to establish the Demonstration Test treatment zone are summarized in Table 4-1 and can be seen on the injection field reports shown in Appendix D of the *Technical Memorandum for Eldredge Park Permeable Reactive Barriers Demonstration Overview of Baseline Sampling, Injection Activities and Post-Injection Groundwater Monitoring – Final (AECOM, March 2017)*.

The metabolism of added carbon substrate by soil microbes can result in a decrease in groundwater pH, and a neutralization agent (i.e., sodium bicarbonate) is sometimes injected with the carbon substrate to counteract changes in pH. Groundwater pH is typically between pH 5.5 and pH 6 across Cape Cod. Denitrifying bacteria are most active in circumneutral groundwater (pH 6 to 8). Based on groundwater data indicating a lower pH (5.5-6.5) at the site, sodium bicarbonate was used as a pH buffer with the EVO. Approximately 10.3 pounds of sodium bicarbonate was added per 300-gallons of EVO solution.

Table 4-1 - Summary of Design Parameters for Permeable Reactive Barrier Demonstration Test

Parameter	Demonstration Test Site
Area Description	Parking lot between the playing fields off Eldredge Park
Depth to Ground Water	30 to 40 feet below grade
Demonstration Test PRB Length	110 feet
Injection Interval	38 to 68 feet below grade
Injection Point Spacing	10 feet
Injection Points	17
Injection Pore Volume	12 percent (assumed effective porosity of 25 percent)
Total Injection Volume (gal)	10,800
Injection Volume Per Point (gal)	600 (Three points received 720, 820, 860 gal in order to use the remainder of the EVO.)
EVO Dilution	15.5 percent (~3.9:1 dilution from 60 percent EVO delivered)
Total EVO (gal)	2,620 (60 percent soy bean oil)

E. Substrate Delivery Record

Isotec, Inc. performed the injections on November 15 through 18, 2016 with oversight by the AECOM PRB Team. Injection of carbon substrate was performed directly through direct-push (i.e., GeoProbe®) rods, configured in 4-foot or 8-foot intervals with thin, laser cut injection holes. During the Demonstration Test, there were few geological limitations observed. The majority of the EVO was injected successfully with wellhead/injection pressure reading of 0 psi indicating no measureable resistance to injection. Several wells had higher wellhead pressures, close to 20 psi, particularly at their deepest intervals (56 to 68 feet). The higher pressure may indicate injection into lower permeability material such as finer sand and silt. All wellhead pressure observations can be seen on the daily injection reports in Appendix D of the *Technical Memorandum for Eldredge Park Permeable Reactive Barriers Demonstration Overview of Baseline Sampling, Injection Activities and Post-Injection Groundwater Monitoring – Final (AECOM, March 2017)*. The 17 injection points were spaced approximately 10 feet apart. The western side of the PRB consisted of seven points, spaced 10 feet apart. In order to assess the effect of injection point density and injection volume, the eastern side of the PRB consisted of 10 points configured in two parallel, offset lines of five points each. The five points were spaced approximately 10 feet from each other. The second line was five feet downgradient and off-set by five feet. Injection locations are depicted on Figure 1.

F. Field Injection Activities

The system for preparation, mixing, and injection of substrate solutions consisted of mixing tanks, mixers, pumps, piping, meters, valves, and fittings. All components were selected from materials that are compatible for use with the selected amendments. Injection batches were prepared in 300-gallon plastic tanks by adding appropriate quantities of water to achieve the selected dilution concentration. Mobile above-ground pumps and hoses were used to convey EVO directly to the injection points. Flow totalizers, pressure gauges, and shut-off valves were used to monitor injection pressure, flow rates, and total volume added to each injection interval at each injection point.

At each injection point, a direct-push drill rig advanced injection tooling to a targeted depth of 68 feet below grade. Seventy-five gallons of the diluted EVO solution were injected per four-foot interval. Both 4-foot and 8-foot injection points were used for injection. -The injection rods were lifted up four (or eight) feet to the subsequent injection target depth and the process was repeated. This method of direct-push injection is referred to as bottom-up injection. To minimize mounding and improve delivery, injection was generally not performed at adjacent points at the same time. A field log was maintained to record the solution composition, volume of solution delivered to each injection interval at injection point, length of time required for injection, and the injection pressure. Electricity to power remediation equipment was provided by a gasoline-powered generator. Potable water for batching and injection was collected from a nearby hydrant.

5. Permitting

The EPA Underground Injection Control (UIC) Program is responsible for regulating the construction, operation, permitting, and closure of injection wells that place fluids underground for storage and disposal. The UIC Program requirements were developed by EPA and designed to be adopted by states. The Massachusetts Department of Environmental Protection (MassDEP) UIC Program is defined in 310 CMR 27.00: Underground Injection Control Regulations and details the regulation of injection of fluids within Massachusetts.

To implement the Demonstration Test a UIC permit application (MassDEP form BRPWS 06) was filed with MassDEP under the category “Aquifer Remediation.” Similar injections of carbon substrates to enhance biodegradation of chemicals in groundwater have been commonly implemented in Massachusetts. Many of these sites are exempt from the UIC registration process if the injections are conducted for waste site cleanup in accordance with the Massachusetts Contingency Plan (MCP, 310 CMR 40.0000) or similar federal statutes. In implementing the Demonstration Test all injections associated with the PRB complied with the requirements of the Massachusetts UIC regulations and the MCP requirements, including all required monitoring. MassDEP issued UIC Registration ID# MAS41A224209-5B6 for the Demonstration Test.

6. PRB Demonstration Test Performance Monitoring Plan

A. General

Performance monitoring of the PRB Demonstration Test is being implemented to assess nitrate reduction, concentrations of biogeochemical indicators, and the distribution of the injected reagents. It is anticipated that the monitoring program will be frequently evaluated and modified to respond to observations, adjusting the monitoring as necessary. This section details the performance monitoring program.

Groundwater samples will be collected from selected monitoring wells in the Demonstration Test area. The monitoring well network includes multi-level monitoring wells upgradient and downgradient of the PRB. These wells are aligned in two transects in addition to cross gradient and more regional monitoring wells. The monitoring network plan view is presented on Figure 1 and PRB monitoring well cross sections are shown on Figure 2 and Figure 3. The monitoring wells upgradient and downgradient of the PRB will be used to evaluate changes to nitrate concentrations and groundwater quality based on PRB performance. Monitoring wells downgradient of the PRB are located at selected distances from the PRB along the transects to assess distance of emulsion travel, extent of reducing conditions for denitrification, potential for metals mobilization, and for collection of groundwater elevation data for flow direction and groundwater flow velocity monitoring.

B. Sampling Method, Frequency, and Analyses

Groundwater samples are collected using a submersible pump. Groundwater quality parameters measured in the field include pH, oxidation reduction potential (ORP), dissolved oxygen (DO), specific conductivity, temperature, and turbidity. Field parameters are monitored with the use of a multi-parameter probe in a flow-through cell. Samples are collected after field water quality parameters stabilize.

Groundwater samples were collected prior to EVO injection to provide a comparative baseline to evaluate performance of the Demonstration Test. Baseline groundwater samples were analyzed to determine pre-treatment concentrations of nitrate and other indicator parameters whose change will be indicative of the impact of the PRB. In addition, a synoptic water level event was conducted after additional monitoring wells were installed, but prior to the start of injections, to further assess the groundwater flow direction and gradient.

During injection activities, select groundwater wells were monitored for field parameters (pH, temperature, dissolved oxygen, oxidation-reduction potential, and conductivity). Additionally, the EVO vendor Terra Systems monitored the 10 foot and 20 foot downgradient monitoring wells using an in-well probe for these same parameters in order to observe any potential changes during injection. During the third full day of injections, select wells were sampled and analyzed for dissolved organic carbon (DOC) and alkalinity to estimate whether there had been any EVO migration. Generally DOC and alkalinity test results did not indicate EVO migration. Visual monitoring at test wells located 10 foot and 20 foot downgradient of injection points indicated sporadic observation of higher turbidity and what may have been dilute EVO during injection.

The first post-injection sampling event was a stand-alone sampling event approximately 7 weeks after the injections with samples collected on January 5, 2017 and January 10, 2017. It is anticipated that additional routine groundwater sampling will be performed quarterly for a period of three years. Primary objectives of the post-injection sampling will be to:

1) Assess potential reduction in nitrate concentrations in groundwater compared to baseline samples and/or wells upgradient of the PRB;
2) Identify distance traveled by EVO emulsion and DOC;
3) Identify extent of generated reducing conditions;
4) Evaluate potential for reduction in aquifer permeability as a result of EVO application;

5) Evaluate persistence of EVO emulsion and anaerobic conditions favorable for denitrifying bacteria after PRB injection; and

6) Assess changes in groundwater monitoring parameters as a result of the PRB.

As a result of the generation of reducing conditions in groundwater, temporary mobilization of some metals native to the aquifer material may result. Laboratory analysis of select metals will be conducted as part of performance monitoring in select wells. Table 6-1 presents an overview of the Demonstration Test performance monitoring analyses and relevance to the PRB Demonstration Test. It is anticipated the monitoring program will be dynamic and continuously evaluated to adjust the selected monitoring parameters and frequency of monitoring based on data collected and observations.

Table 6-1 - Summary of Analyses for Groundwater Performance Evaluation

Parameter	Relevance to PRB Demonstration Test
Nitrate	Primary groundwater compound targeted for treatment.
Nitrite	Intermediate nitrogen species from the aerobic nitrification of ammonia to nitrate.
Ammonia	Reduced inorganic nitrogen species that occurs in proximity of septic system leach fields and landfills.
TKN	Total Kjeldahl Nitrogen (TKN) is the total concentration of organic nitrogen and ammonia.
Total Nitrogen	Analyses provide a summation of all organic and inorganic nitrogen species in groundwater as a result of leach fields and landfill.
CENSUS-DNA (Denitrifying Bacteria)	Analysis quantifies relative abundance of denitrifying bacteria.
Metals (Fe, Mn, As)	Mobility of metals can be impacted by groundwater geochemistry changes, notably pH and ORP.
DOC	Dissolved Organic Carbon (DOC) is the limiting factor in enhancing denitrification-and is increased by injection of EVO. DOC tracks the area of influence of the PRB.
Sulfate	Sulfate will decrease with generation of sufficiently anaerobic conditions favorable for sulfate-reducing bacteria.
pH	Denitrification optimal pH (6.0 and 8.5). Groundwater pH can decrease as a result of fermentation of injected carbon substrates.
ORP	Oxidation-reduction potential (ORP) will decrease with generation of reducing conditions following injection of carbon substrate.
Chloride	Chloride concentrations indicate potentially infiltrating stormwater.
Alkalinity	Denitrification reactions generate alkalinity (3.57 mg of $CaCO_3$ for each mg of nitrate reduced).
Boron	Boron is present in laundry detergents and is an indicator of groundwater flow emanating from leach fields.

7. PRB Demonstration Test Performance Monitoring Results To Date

A. Baseline Groundwater Monitoring

Preliminary baseline groundwater monitoring samples were collected on October 4, 2016 at a total of six wells, including three previously existing wells that are part of the Nauset Middle School quarterly sampling plan. After additional PRB demonstration monitoring wells were installed, baseline groundwater monitoring sampling was conducted. This sampling occurred on November 3, 2016 and November 4, 2016, where a total of 21 groundwater samples were collected. Field parameters and analytical results are shown in Table 3. Overall, baseline sampling indicated nitrate concentrations ranging from 0.357 mg/L (MW-BU2A) to 37 mg/L (MW-1050A).

B. Monitoring during Injection Activities

During the demonstration injections, field parameters were monitored at select upgradient and downgradient wells. Overall, no distinct patterns between the field parameters (temperature, pH, dissolved oxygen, conductivity, and turbidity) were observed before, during, and immediately following the injections. Raw field data, as monitored by TerraSystems and AECOM, is included in Appendix D of the *Technical Memorandum for Eldredge Park Permeable Reactive Barriers Demonstration Overview of Baseline Sampling, Injection Activities and Post-Injection Groundwater Monitoring – Final (AECOM, March 2017)*.

Laboratory dilutions were completed by Terra Systems producing stock solutions of EVO at various dilutions to determine a reasonable correlation between turbidity and the estimated SRS-NR concentrations. Based on these dilutions and the turbidity measured, data suggests the potential for movement of the SRS-NR emulsion up to 20 feet from the injection at certain depths. However, the conductivity was variable and did not correlate to turbidity. Field visual observations did not indicate significant quantities of emulsion at the downgradient wells. There was potentially a dilute “milky” coloration to the groundwater at the 10 foot and 20 foot wells, however, these observations were soon followed by indications of “clearer” water. These observations support the target area distribution of EVO along the PRB. EVO was not observed following completion of injection indicating the injected material was stable and not migrating.

Groundwater samples were collected from seven wells on November 17, 2016 and analyzed for alkalinity and DOC. Alkalinity was measured as a potential indication of the pH buffer that was added with the injections and DOC was measured as a potential indication of the EVO. The alkalinity at the downgradient wells (MW-1010C, MW-1020C, MW-2010C, and MW-2020B) ranged from 11 to 20 mg/L, which is slightly higher than the upgradient and cross-gradient wells (MW-12C, MW-BC2C, and MW-BU2C), which ranged from 4 to 13 mg/L. DOC ranged from 0.576 to 0.852 mg/L and was similar for both upgradient/cross-gradient and downgradient wells.

C. Initial Post-Injection Sampling (7 weeks)

A total of 14 groundwater samples were collected from select wells on January 5, 2017 and January 10, 2017. The wells sampled included upgradient wells MW-12A/B/C and MW-BU2A/B/C, cross-gradient well MW-BC2C, and downgradient wells MW-B1010C, MW-B1020B/C, MW-B1050A, MW-B2020B/C, and MW-B2050A. MW-B2010C was unable to be sampled due to snow cover. Analytical data is presented in Table 3. Laboratory reports are included in Appendix E of the *Technical Memorandum for Eldredge Park Permeable Reactive Barriers Demonstration Overview of Baseline Sampling, Injection Activities and Post-Injection Groundwater Monitoring – Final* (AECOM, March 2017).

D. Quarterly Sampling

1) February 2017

The first post-injection quarterly sampling event occurred on February 23, 2017 and February 24, 2017, where groundwater samples were collected from 21 monitoring wells and analyzed for nitrate, nitrite, ammonia, Total Kjeldahl Nitrogen (TKN), Total Nitrogen, chloride, sulfate, dissolved iron, dissolved manganese, boron, sodium, total alkalinity, and DOC. Field-measured parameters, such as water level, pH, temperature, DO, ORP, conductivity, and turbidity, were also measured. MW-12C was unable to be sampled due to damage during snow removal at the site. Additionally, water levels were collected for six monitoring wells outside of the core monitoring well network.

The four additional monitoring wells that were installed in March 2017 were sampled in late March 2017 as part of the first round of quarterly sampling. Results of the laboratory analysis are included in this technical memorandum. Laboratory reports for the quarterly sampling event are included in Appendix B.

The expected lag time from PRB injection to measurable nitrate reduction in groundwater immediately downgradient of the barrier is two to four months. During this time the EVO begins to increase DOC concentrations, stimulating biological activity, which leads to an increase in the biomass of desired nitrate reducing bacteria.

The February samples were collected approximately three months post injection. Groundwater sample locations closest to the PRB (MW-B1010C and MW-B2010C) are located approximately ten feet downgradient of the injection zone (Figure 1). The February Quarter-1 (Q-1) sample at MW-B1010C indicated an increase in DOC from less than 1 mg/L during baseline sampling (November 2016) to 14 mg/L at Q-1. The MW-B1010C nitrate concentration decreased 27 percent from 13.6 at baseline to 9.94 mg/L at Q-1. Nitrate concentration data for baseline and quarterly sampling is included in Table 3 and on the cross-sections shown in Figure 4 and Figure 5.

Monitoring well MW-B2010C laboratory results also showed an increase in DOC concentrations. DOC increased from 2.2 mg/L at baseline to 19 mg/L at Q-1. Over the same period of time, the nitrate concentration decreased 68 percent from 15.7 to 5.06 mg/L.

Significant increases in DOC were not observed at other monitoring well locations and changes in nitrate concentration also did not appear to be significant with the exception of nitrate at monitoring well B1050A, where the nitrate concentration decreased 68 percent from 37 mg/L at baseline to 11.8 mg/L at Q-1.

No significant changes for dissolved iron and manganese were noted between the baseline and Q-1 sampling. Methane was not detected in groundwater at any of the locations sampled. These results indicate no significant impacts with respect to secondary water quality. No migration of EVO material was indicated by sampling observations or test results.

2) June 2017

The second post-injection quarterly sampling event occurred on June 28, 2017 and June 29, 2017, approximately seven months post injection. This event was rescheduled from May due to securing funding at the May Town Meeting. Additionally, there were several wet-weather events in May and it is recommended that sampling occur after several consecutive dry days to eliminate potential influences of the stormwater drains at the site.

During the June 2017 quarterly sampling event, groundwater samples were collected from 24 monitoring wells and analyzed for nitrate, nitrite, ammonia, Total Nitrogen, chloride, sulfate, dissolved iron, dissolved manganese, total alkalinity, and DOC. Field-measured parameters, such as water level, pH, temperature, DO, ORP, conductivity, and turbidity, were also measured. MW-12C has not been repaired from the damage during snow removal and was unable to be sampled. Additionally, water levels were collected from 9 monitoring wells outside of the core monitoring well network.

a) Assessment of Groundwater Flow Through the PRB

The PRB treatment line is composed of a series of injection points oriented northwest to southeast (perpendicular) to the northeasterly regional groundwater flow direction and is approximately 110 feet long. Depth to groundwater measurements at monitoring wells in the immediate vicinity of the PRB were completed prior to sampling during each monitoring event. The depth to water information was used to calculate water elevation and assess the direction of groundwater flow by developing contour maps of water level. Water elevation in shallow, intermediate depth, and deep wells were evaluated separately to assess flow direction at different depths.

Note that groundwater elevation can vary over time due to seasonal changes in groundwater recharge and can also change over the short term due to significant precipitation events. These changes can result in local variations in groundwater flow. Groundwater flow direction can also be in different directions at different depths below the water table, resulting in a complex 3-dimensional groundwater flow system. No significant rainfall was recorded between June 21, 2017 and June 29, 2017 at the nearby Chatham Municipal Airport prior to sampling.

As noted above, MW-BX1B and MW-BX1C are intermediate and shallow wells that were installed approximately 20 feet northwest of where EVO was injected during the November 2016 demonstration injection activities. The purpose of installing MW-BX1B and MW-BX1C was to gather more information to get a better understand the groundwater flow pattern across the site and help with the interpretation of observed nitrate concentrations. High nitrate concentrations had been noted along the monitoring transects east of the selected location for these new monitoring wells (e.g. at MW-B1020C, MW-B1050B, MW-B1050A, and MW-B2020B) shown on Figure 1. No similar high nitrate concentrations were observed in monitoring wells upgradient of the PRB (e.g. MW-12A, MW-12B, and MW-12C).

Groundwater elevations calculated from the June 2017 data were interpolated to develop groundwater contour lines. The shallow groundwater data indicated a curved groundwater contour at elevation 12.3 as shown in blue on Figure 6. The resulting groundwater flow direction lines (black lines with arrows on Figure 6) show the groundwater flow pattern with partial flow through the PRB from southwest to northeast but also a significant flow from the northwest to southeast. Groundwater elevations and interpolated groundwater contours from the June 2017 data for intermediate depth (Figure 7) and deeper monitoring wells (Figure 8) indicated some variation but generally a similar pattern. Based on these flow directions, flow through the PRB does not appear to reach the full set of monitoring wells along the established monitoring well transects treated water may only be observed in the nearest monitoring wells. Monitoring wells along transects further to the north also appear to be affected by a local source of high nitrate concentration.

b) Assessment of Groundwater Chemistry Data

Groundwater sample locations closest to the PRB (MW-B1010C and MW-B2010C) are located approximately ten feet downgradient of the injection zone (Figure 1). The June Quarter-2 (Q-2) sample at MW-B1010C indicated an increase in DOC from 14 mg/L during Q-1 sampling (February 2017) to 17 mg/L at Q-2. Similarly, MW-B2010C indicated an increase in DOC from 19 mg/L during Q-1 to 83 mg/L during Q-2. The nitrate concentrations at MW-B1010C appear similar to baseline. The nitrate concentrations at MW-B2010C continued to show a concentration (5.7 mg/L) significantly below baseline (15.7 mg/L) and the oxidation-reduction potential (ORP) at MW-B2010C was negative, which indicates reducing conditions favorable to denitrification.

The DOC concentrations also increased slightly at the wells located approximately 20 feet from the injection points. MW-B1020B increased from 1.1 mg/L in Q-1 to 3.2 mg/L in Q-2, MW-B2020B increased from 1.0 mg/L in Q-1 to 3.5 mg/L in Q-2, MW-B2020C increased from 2 mg/L in Q-1 to 23 mg/L in Q-2.

Nitrate increased at MW-BX1B from 11.4 mg/L at Q-1 to 34.4 mg/L at Q-2, at MW-BX1C from 0.3 mg/L at Q-1 to 38.7 mg/L at Q-2. These high nitrate concentrations appear to be from a local source and are not within the target PRB treatment area.

Nitrate increased at MW-B1050A from 11.8 mg/L at Q-1 to 26.8 mg/L at Q-2, and at MW-B2020B from 14.8 mg/L at Q-1 to 22.4 mg/L at Q-2. While MW-B1050A and MW-B2020B both saw increases in nitrate concentrations, the shallow wells at those locations saw decreases in nitrate concentrations. Nitrate decreased at MW-B1050B from 28.7 mg/L at Q-1 to 18.2 mg/L at Q-2, at MW-B1050C from 4.0 mg/L at Q-1 to 3.3 mg/L at Q-2, and at MW-B2020C from 7.0 mg/L at Q-1 to 0.5 mg/L at Q-2.

Significant increases in DOC were not observed at other monitoring well locations and changes in nitrate concentration also did not appear to be significant. Nitrate concentration data for baseline and quarterly sampling is included in Table 3 and on the cross-sections shown in Figure 4 and Figure 5. Nitrate data are also included with groundwater contours and flow direction for shallow, intermediate depth, and deep groundwater monitoring wells on Figures 6, 7, and 8 respectively.

It was also noted that dissolved iron increased from 1.8 mg/L at Q-1 to 24.2 mg/L at Q-2 and dissolved manganese increased from 0.2 mg/L at Q-1 to 1.6 mg/L at Q-2 in MW-B2010C. Dissolved iron increased from <0.1 mg/L at Q-1 to 8.0 mg/L at Q-2 and dissolved manganese increased from 0.1 mg/L at Q-1 to 1.0 mg/L at Q-2 in MW-B2020C. These two locations are also where the significant increases in DOC were observed. The increases in iron and manganese are also indications of the reducing conditions favorable to denitrification. No significant changes for dissolved iron and manganese were noted between the Q-1 and Q-2 sampling at other locations. Methane was not detected in groundwater at MW-B1010C, but was present at 11.3 µg/L at MW-B2010C. This location demonstrated the highest increase in DOC and dissolved iron. No migration of EVO material was indicated by sampling observations or test results.

8. Independent Review of Draft June 2017 Quarterly Technical Memorandum

The School for Marine Science and Technology (SMAST) conducted an independent review of a preliminary version of this draft technical memorandum (dated August 8, 2017) in order to provide feedback and validate key observations and conclusions from the June quarterly data. This review was recommended by the Town based on the initial information regarding findings of the groundwater flow contours and nitrate concentrations detected in the proximity of the Nauset Regional Middle School on-site systems. SMAST also concluded that complex flow directions have been observed at Eldredge Park and that the high nitrate concentrations suggest N loading from other upgradient sources. A copy of this technical memorandum is found in Appendix C.

9. Summary, Schedule, and Coordination

In summary, the monitoring data indicated the presence of DOC from injected EVO at monitoring wells downgradient but only close to the north/northeast side of the PRB. Some of these monitoring wells showed reducing conditions favorable to denitrifying bacteria and reductions in nitrate concentrations over baseline conditions. However, the locally variable groundwater flow direction in the vicinity of the PRB prevents flow passing through the PRB from reaching monitoring wells further to the northeast along the transects. Groundwater flow reaching these transect monitoring wells also appears to be affected by a local source of high nitrate concentration. The Nauset Regional Middle School 1977 leaching pit wastewater disposal system which is currently in use is located below the north end of the soccer field in the area now known to be upgradient of these monitoring wells (Figure 9). On-going meetings with the Town and the Owner of the site are anticipated in order to evaluate and plan necessary corrective actions to complete the PRB demonstration test, such as expanding the PRB and installing additional monitoring wells.

Completed PRB Demonstration Test milestones include:

- PRB groundwater monitoring network installation;
- Baseline groundwater quality data collection and analysis;
- PRB construction with injection of EVO as planned;
- Initial post-injection water quality data collection and analysis; and
- First and second post-injection quarterly monitoring data collection and analysis.

The current plan includes collecting quarterly samples for a period of three years. Periodic reporting will be conducted to share results and observations with the Town, regulatory agencies, and the public. The next quarterly monitoring event is expected to occur in September 2017.

10. References

AECOM – Technical Memorandum Final for Preliminary Engineering Work Plan for Permeable Reactive Barriers. Submitted to Town of Orleans, MA. May 19, 2016.

AECOM - Technical Memorandum for Eldredge Park Permeable Reactive Barriers Demonstration Overview of Baseline Sampling, Injection Activities and Post-Injection Groundwater Monitoring – Final. March 1, 2017.

Cape Cod Commission - Cape Code Regional Wastewater Management Plan Technology Assessment – Conventional Infrastructure, March 2013.

Cape Cod Commission - Cape Cod Area Wide Water Quality Management Plan Update, June 2015.

Interstate Technology & Regulatory Council (ITRC) - Permeable Reactive Barrier: Technology Update (PRB-5), November 2011.

Terra Systems - Personal communications with Michael Lee, PhD, 2016.

11. List of Appendices

Appendix A – Monitoring Well Coordinates

Appendix B – Analytical Laboratory Reports

Appendix C – Technical Memorandum by SMAST (September 27, 2017)

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Tables

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Table 1 Orleans Monitoring Well Construction Details

Well ID	Surface Elevation (ft)	TOC Elevation (ft)	Total Well Depth (ft bgs)	Screen Beginning Depth (ft bgs)	Screen End Depth (ft bgs)	Top Screen Elevation (ft)	Bottom Screen Elevation (ft)	Mid-Screen Elevation (ft)	Screen Length (ft)	Inst. Date	Location
MW-12A	45.6	45.57	80.0	70.0	80.0	-24.40	-34.40	-29.40	10.0	October 2016	Eldredge Park
MW-12B	45.6	45.58	65.0	55.0	65.0	-9.40	-19.40	-14.40	10.0	October 2016	Eldredge Park
MW-BU1A	43.7	43.48	80.0	70.0	80.0	-26.30	-36.30	-31.30	10.0	September 2016	Eldredge Park
MW-BU1C	44.0	43.65	50.0	40.0	50.0	4.00	-6.00	-1.00	10.0	September 2016	Eldredge Park
MW-BU2A	45.1	44.56	80.0	70.0	80.0	-24.90	-34.90	-29.90	10.0	October 2016	Eldredge Park
MW-BU2B	45.1	44.70	65.0	55.0	65.0	-9.90	-19.90	-14.90	10.0	October 2016	Eldredge Park
MW-BU2C	45.1	44.68	50.0	40.0	50.0	5.10	-4.90	0.10	10.0	October 2016	Eldredge Park
MW-BC1C	42.5	42.50	50.0	40.0	50.0	2.50	-7.50	-2.50	10.0	September 2016	Eldredge Park
MW-BC2C[1]	N/A	N/A	55.0	45.0	55.0	N/A	N/A	N/A	10.0	October 2016	Eldredge Park
MW-B1010C	44.9	44.46	55.0	45.0	55.0	-0.10	-10.10	-5.10	10.0	October 2016	Eldredge Park
MW-B1020B	44.6	44.18	65.0	55.0	65.0	-10.40	-20.40	-15.40	10.0	October 2016	Eldredge Park
MW-B1020C	44.5	44.10	50.0	40.0	50.0	4.50	-5.50	-0.50	10.0	October 2016	Eldredge Park
MW-B1050A	43.9	43.42	80.0	70.0	80.0	-26.10	-36.10	-31.10	10.0	October 2016	Eldredge Park
MW-B1050B	43.9	43.54	65.0	55.0	65.0	-11.10	-21.10	-16.10	10.0	October 2016	Eldredge Park
MW-B1050C	44.9	43.55	50.0	40.0	50.0	4.90	-5.10	-0.10	10.0	October 2016	Eldredge Park
MW-B1075B	43.5	43.29	65.0	55.0	65.0	-11.50	-21.50	-16.50	10.0	October 2016	Eldredge Park
MW-B2010C	45.0	44.70	55.0	45.0	55.0	0.00	-10.00	-5.00	10.0	October 2016	Eldredge Park
MW-B2020B	44.9	44.50	65.0	55.0	65.0	-10.10	-20.10	-15.10	10.0	October 2016	Eldredge Park
MW-B2020C	44.8	44.45	50.0	40.0	50.0	4.80	-5.20	-0.20	10.0	October 2016	Eldredge Park
MW-B2050A	44.6	44.06	80.0	70.0	80.0	-25.40	-35.40	-30.40	10.0	October 2016	Eldredge Park
MW-B2050B	44.6	44.28	65.0	55.0	65.0	-10.40	-20.40	-15.40	10.0	October 2016	Eldredge Park
MW-B2050C	44.6	44.17	50.0	40.0	50.0	4.60	-5.40	-0.40	10.0	October 2016	Eldredge Park
MW-B2075A	44.6	44.23	75.0	65.0	75.0	-20.40	-30.40	-25.40	10.0	March 2017	Eldredge Park
MW-B2100	44.6	44.23	45.0	35.0	45.0	9.60	-0.40	4.60	10.0	September 2016	Eldredge Park
MW-BC3	44.2	43.86	65.0	55.0	65.0	-10.80	-20.80	-15.80	10.0	March 2017	Eldredge Park
MW-BX1B	45.6	45.38	65.0	55.0	65.0	-9.40	-19.40	-14.40	10.0	March 2017	Eldredge Park
MW-BX1C	45.7	45.37	50.0	40.0	50.0	5.70	-4.30	0.70	10.0	March 2017	Eldredge Park

Notes:

N/A = Not Available

1. MW-BC2C has not yet been surveyed.

Table 2 Orleans Groundwater Elevations

Well ID	Location	Date	TOC Elevation (ft)	Depth to Water (ft)	GW Elevation (ft)
MW-1	Eldredge Park	11/3/2016	41.31	30.10	11.21
MW-1	Eldredge Park	11/14/2016	41.31	30.20	11.11
MW-1	Eldredge Park	1/18/2017	41.31	30.43	10.88
MW-1	Eldredge Park	1/27/2017	41.31	30.25	11.06
MW-1	Eldredge Park	2/24/2017	41.31	29.50	11.81
MW-1	Eldredge Park	4/25/2017	41.31	28.17	13.14
MW-1	Eldredge Park	6/29/2017	41.31	28.37	12.94
MW-11	Eldredge Park	11/3/2016	45.14	34.20	10.94
MW-11	Eldredge Park	11/14/2016	45.14	34.20	10.94
MW-11	Eldredge Park	1/18/2017	45.14	34.42	10.72
MW-11	Eldredge Park	1/27/2017	45.14	33.31	11.83
MW-11	Eldredge Park	2/24/2017	45.14	33.87	11.27
MW-11	Eldredge Park	4/25/2017	45.14	32.84	12.30
MW-11	Eldredge Park	6/29/2017	45.14	32.82	12.32
MW-11S	Eldredge Park	11/3/2016	45.25	34.15	11.10
MW-11S	Eldredge Park	11/14/2016	45.25	34.25	11.00
MW-11S	Eldredge Park	1/18/2017	45.25	34.51	10.74
MW-11S	Eldredge Park	1/27/2017	45.25	34.36	10.89
MW-11S	Eldredge Park	2/24/2017	45.25	33.93	11.32
MW-11S	Eldredge Park	4/25/2017	45.25	32.92	12.33
MW-11S	Eldredge Park	6/29/2017	45.25	32.90	12.35
MW-12A	Eldredge Park	11/3/2016	45.57	34.40	11.17
MW-12A	Eldredge Park	11/14/2016	45.57	35.01	10.56
MW-12A	Eldredge Park	1/18/2017	45.57	34.71	10.86
MW-12A	Eldredge Park	1/27/2017	45.57	34.57	11.00
MW-12A	Eldredge Park	2/23/2017	45.57	34.16	11.41
MW-12A	Eldredge Park	4/25/2017	45.57	33.85	11.72
MW-12A	Eldredge Park	6/29/2017	45.57	33.17	12.40
MW-12B	Eldredge Park	11/3/2016	45.58	34.50	11.08
MW-12B	Eldredge Park	11/14/2016	45.58	34.90	10.68
MW-12B	Eldredge Park	1/18/2017	45.58	34.79	10.79
MW-12B	Eldredge Park	1/27/2017	45.58	34.64	10.94
MW-12B	Eldredge Park	2/23/2017	45.58	34.24	11.34
MW-12B	Eldredge Park	4/25/2017	45.58	33.70	11.88
MW-12B	Eldredge Park	6/29/2017	45.58	33.21	12.37
MW-12C (Existing)	Eldredge Park	11/3/2016	46.61	36.27	10.34
MW-12C (Existing)	Eldredge Park	11/14/2016	46.61	35.99	10.62
MW-12C (Existing)	Eldredge Park	1/18/2017	46.61	36.21	10.40
MW-12C (Existing)	Eldredge Park	1/27/2017	46.61	36.06	10.55
MW-12C (Existing)[1]	Eldredge Park	2/23/2017	46.61	36.30	10.31
MW-12C (Existing)[1]	Eldredge Park	4/25/2017	46.61	34.95	11.66
MW-12C (Existing)[1]	Eldredge Park	6/29/2017	46.61	34.79	11.82
MW-2	Eldredge Park	11/3/2016	44.82	33.65	11.17
MW-2	Eldredge Park	11/14/2016	44.82	33.83	10.99
MW-2	Eldredge Park	1/18/2017	44.82	34.03	10.79
MW-2	Eldredge Park	1/27/2017	44.82	33.91	10.91
MW-2	Eldredge Park	2/24/2017	44.82	33.43	11.39
MW-2	Eldredge Park	4/25/2017	44.82	32.68	12.14
MW-2	Eldredge Park	6/29/2017	44.82	32.54	12.28

Table 2 Orleans Groundwater Elevations

Well ID	Location	Date	TOC Elevation (ft)	Depth to Water (ft)	GW Elevation (ft)
MW-4	Eldredge Park	11/3/2016	46.57	35.53	11.04
MW-4	Eldredge Park	11/14/2016	46.57	35.71	10.86
MW-4	Eldredge Park	1/18/2017	46.57	35.98	10.59
MW-4	Eldredge Park	1/27/2017	46.57	35.83	10.74
MW-4	Eldredge Park	2/24/2017	46.57	35.48	11.09
MW-4	Eldredge Park	4/25/2017	46.57	35.63	10.94
MW-4	Eldredge Park	6/29/2017	46.57	34.41	12.16
MW-8	Eldredge Park	October 2016	46.16	35.30	10.86
MW-8	Eldredge Park	11/14/2016	46.16	35.22	10.94
MW-8	Eldredge Park	1/18/2017	46.16	35.62	10.54
MW-8	Eldredge Park	1/27/2017	46.16	35.50	10.66
MW-8	Eldredge Park	2/24/2017	46.16	35.12	11.04
MW-8	Eldredge Park	4/25/2017	46.16	24.51	21.65
MW-8	Eldredge Park	6/29/2017	46.16	34.03	12.13
MW-B1010C	Eldredge Park	11/3/2016	44.46	33.60	10.86
MW-B1010C	Eldredge Park	11/14/2016	44.46	33.98	10.48
MW-B1010C	Eldredge Park	1/18/2017	44.46	33.97	10.49
MW-B1010C	Eldredge Park	1/27/2017	44.46	33.81	10.65
MW-B1010C	Eldredge Park	2/23/2017	44.46	33.25	11.21
MW-B1010C	Eldredge Park	4/25/2017	44.46	32.53	11.93
MW-B1010C	Eldredge Park	6/29/2017	44.46	32.15	12.31
MW-B1020B	Eldredge Park	11/3/2016	44.18	33.42	10.76
MW-B1020B	Eldredge Park	11/14/2016	44.18	33.68	10.50
MW-B1020B	Eldredge Park	1/18/2017	44.18	33.81	10.37
MW-B1020B	Eldredge Park	1/27/2017	44.18	33.66	10.52
MW-B1020B	Eldredge Park	2/23/2017	44.18	33.18	11.00
MW-B1020B	Eldredge Park	4/25/2017	44.18	32.60	11.58
MW-B1020B	Eldredge Park	6/29/2017	44.18	32.14	12.04
MW-B1020C	Eldredge Park	11/3/2016	44.10	33.16	10.94
MW-B1020C	Eldredge Park	11/14/2016	44.10	33.32	10.78
MW-B1020C	Eldredge Park	1/18/2017	44.10	33.53	10.57
MW-B1020C	Eldredge Park	1/27/2017	44.10	33.32	10.78
MW-B1020C	Eldredge Park	2/23/2017	44.10	32.80	11.30
MW-B1020C	Eldredge Park	4/25/2017	44.10	32.10	12.00
MW-B1020C	Eldredge Park	6/29/2017	44.10	31.71	12.39
MW-B1050A	Eldredge Park	11/3/2016	43.42	32.84	10.58
MW-B1050A	Eldredge Park	11/14/2016	43.42	32.92	10.50
MW-B1050A	Eldredge Park	1/18/2017	43.42	32.91	10.51
MW-B1050A	Eldredge Park	1/27/2017	43.42	32.88	10.54
MW-B1050A	Eldredge Park	2/23/2017	43.42	32.54	10.88
MW-B1050A	Eldredge Park	4/25/2017	43.42	31.28	12.14
MW-B1050A	Eldredge Park	6/29/2017	43.42	31.42	12.00
MW-B1050B	Eldredge Park	11/3/2016	43.54	32.65	10.89
MW-B1050B	Eldredge Park	11/14/2016	43.54	32.72	10.82
MW-B1050B	Eldredge Park	1/18/2017	43.54	32.98	10.56
MW-B1050B	Eldredge Park	1/27/2017	43.54	32.81	10.73
MW-B1050B	Eldredge Park	2/23/2017	43.54	32.28	11.26
MW-B1050B	Eldredge Park	4/25/2017	43.54	31.45	12.09
MW-B1050B	Eldredge Park	6/29/2017	43.54	31.21	12.33

Table 2 Orleans Groundwater Elevations

Well ID	Location	Date	TOC Elevation (ft)	Depth to Water (ft)	GW Elevation (ft)
MW-B1050C	Eldredge Park	11/3/2016	43.55	32.80	10.75
MW-B1050C	Eldredge Park	11/14/2016	43.55	32.80	10.75
MW-B1050C	Eldredge Park	1/18/2017	43.55	33.02	10.53
MW-B1050C	Eldredge Park	1/27/2017	43.55	32.96	10.59
MW-B1050C	Eldredge Park	2/23/2017	43.55	32.40	11.15
MW-B1050C	Eldredge Park	4/25/2017	43.55	31.52	12.03
MW-B1050C	Eldredge Park	6/29/2017	43.55	31.21	12.34
MW-B1075B	Eldredge Park	11/3/2016	43.29	32.55	10.74
MW-B1075B	Eldredge Park	11/14/2016	43.29	32.57	10.72
MW-B1075B	Eldredge Park	1/18/2017	43.29	32.78	10.51
MW-B1075B	Eldredge Park	1/27/2017	43.29	32.62	10.67
MW-B1075B	Eldredge Park	2/23/2017	43.29	32.10	11.19
MW-B1075B	Eldredge Park	4/25/2017	43.29	31.22	12.07
MW-B1075B	Eldredge Park	6/29/2017	43.29	30.98	12.31
MW-B2010C	Eldredge Park	11/3/2016	44.70	33.95	10.75
MW-B2010C	Eldredge Park	11/14/2016	44.70	34.10	10.60
MW-B2010C	Eldredge Park	1/18/2017	44.70	34.41	10.29
MW-B2010C	Eldredge Park	1/27/2017	44.70	34.21	10.49
MW-B2010C	Eldredge Park	2/24/2017	44.70	33.77	10.93
MW-B2010C	Eldredge Park	4/25/2017	44.70	33.00	11.70
MW-B2010C	Eldredge Park	6/29/2017	44.70	32.67	12.03
MW-B2020B	Eldredge Park	11/3/2016	44.50	33.90	10.60
MW-B2020B	Eldredge Park	11/14/2016	44.50	33.90	10.60
MW-B2020B	Eldredge Park	1/18/2017	44.50	34.15	10.35
MW-B2020B	Eldredge Park	1/27/2017	44.50	34.03	10.47
MW-B2020B	Eldredge Park	2/24/2017	44.50	33.50	11.00
MW-B2020B	Eldredge Park	4/25/2017	44.50	32.88	11.62
MW-B2020B	Eldredge Park	6/29/2017	44.50	32.45	12.05
MW-B2020C	Eldredge Park	11/3/2016	44.45	33.80	10.65
MW-B2020C	Eldredge Park	11/14/2016	44.45	33.98	10.47
MW-B2020C	Eldredge Park	1/18/2017	44.45	34.22	10.23
MW-B2020C	Eldredge Park	1/27/2017	44.45	34.07	10.38
MW-B2020C	Eldredge Park	2/24/2017	44.45	33.55	10.90
MW-B2020C	Eldredge Park	4/25/2017	44.45	32.90	11.55
MW-B2020C	Eldredge Park	6/29/2017	44.45	32.43	12.02
MW-B2050A	Eldredge Park	11/3/2016	44.06	33.41	10.65
MW-B2050A	Eldredge Park	11/14/2016	44.06	33.60	10.46
MW-B2050A	Eldredge Park	1/18/2017	44.06	33.88	10.18
MW-B2050A	Eldredge Park	1/27/2017	44.06	33.64	10.42
MW-B2050A	Eldredge Park	2/24/2017	44.06	33.04	11.02
MW-B2050A	Eldredge Park	4/25/2017	44.06	32.68	11.38
MW-B2050A	Eldredge Park	6/29/2017	44.06	32.12	11.94
MW-B2050B	Eldredge Park	11/3/2016	44.28	33.60	10.68
MW-B2050B	Eldredge Park	11/14/2016	44.28	33.73	10.55
MW-B2050B	Eldredge Park	1/18/2017	44.28	34.00	10.28
MW-B2050B	Eldredge Park	1/27/2017	44.28	33.84	10.44
MW-B2050B	Eldredge Park	2/24/2017	44.28	33.32	10.96
MW-B2050B	Eldredge Park	4/25/2017	44.28	32.63	11.65
MW-B2050B	Eldredge Park	6/29/2017	44.28	32.20	12.08

Table 2 Orleans Groundwater Elevations

Well ID	Location	Date	TOC Elevation (ft)	Depth to Water (ft)	GW Elevation (ft)
MW-B2050C	Eldredge Park	11/3/2016	44.17	33.35	10.82
MW-B2050C	Eldredge Park	11/14/2016	44.17	33.51	10.66
MW-B2050C	Eldredge Park	1/18/2017	44.17	33.90	10.27
MW-B2050C	Eldredge Park	1/27/2017	44.17	33.87	10.30
MW-B2050C	Eldredge Park	2/24/2017	44.17	33.07	11.10
MW-B2050C	Eldredge Park	4/25/2017	44.17	32.31	11.86
MW-B2050C	Eldredge Park	6/29/2017	44.17	31.93	12.24
MW-B2075A	Eldredge Park	4/25/2017	44.23	32.40	11.83
MW-B2075A	Eldredge Park	6/29/2017	44.23	31.97	12.26
MW-B2100	Eldredge Park	11/3/2016	44.23	33.50	10.73
MW-B2100	Eldredge Park	11/14/2016	44.23	33.65	10.58
MW-B2100	Eldredge Park	1/18/2017	44.23	33.87	10.36
MW-B2100	Eldredge Park	1/27/2017	44.23	33.66	10.57
MW-B2100	Eldredge Park	2/24/2017	44.23	33.10	11.13
MW-B2100	Eldredge Park	4/25/2017	44.23	32.38	11.85
MW-B2100	Eldredge Park	6/29/2017	44.23	32.01	12.22
MW-BC1C	Eldredge Park	11/3/2016	42.50	31.36	11.14
MW-BC1C	Eldredge Park	11/14/2016	42.50	31.87	10.63
MW-BC1C	Eldredge Park	1/18/2017	42.50	31.81	10.69
MW-BC1C	Eldredge Park	1/27/2017	42.50	31.65	10.85
MW-BC1C	Eldredge Park	2/24/2017	42.50	31.14	11.36
MW-BC1C	Eldredge Park	4/25/2017	42.50	30.43	12.07
MW-BC1C	Eldredge Park	6/29/2017	42.50	30.07	12.43
MW-BC2C[2]	Eldredge Park	6/29/2017	N/A	31.61	N/A
MW-BC2C[2]	Eldredge Park	11/3/2016	N/A	32.84	N/A
MW-BC2C[2]	Eldredge Park	11/14/2016	N/A	N/A	N/A
MW-BC2C[2]	Eldredge Park	1/18/2017	N/A	33.22	N/A
MW-BC2C[2]	Eldredge Park	1/27/2017	N/A	33.08	N/A
MW-BC2C[2]	Eldredge Park	2/24/2017	N/A	32.63	N/A
MW-BC2C[2]	Eldredge Park	4/25/2017	N/A	31.93	N/A
MW-BC3B	Eldredge Park	4/25/2017	43.86	32.45	11.41
MW-BC3B	Eldredge Park	6/29/2017	43.86	31.90	11.96
MW-BU1A	Eldredge Park	11/3/2016	43.48	32.55	10.93
MW-BU1A	Eldredge Park	11/14/2016	43.48	32.44	11.04
MW-BU1A	Eldredge Park	1/18/2017	43.48	32.86	10.62
MW-BU1A	Eldredge Park	1/27/2017	43.48	32.74	10.74
MW-BU1A	Eldredge Park	2/24/2017	43.48	32.30	11.18
MW-BU1A	Eldredge Park	4/25/2017	43.48	31.75	11.73
MW-BU1A	Eldredge Park	6/29/2017	43.48	31.36	12.12
MW-BU1C	Eldredge Park	11/3/2016	43.65	32.50	11.15
MW-BU1C	Eldredge Park	11/14/2016	43.65	N/A	N/A
MW-BU1C	Eldredge Park	1/18/2017	43.65	32.84	10.81
MW-BU1C	Eldredge Park	1/27/2017	43.65	32.72	10.93
MW-BU1C	Eldredge Park	2/24/2017	43.65	32.25	11.40
MW-BU1C	Eldredge Park	4/25/2017	43.65	31.71	11.94
MW-BU1C	Eldredge Park	6/29/2017	43.65	31.31	12.34

Table 2 Orleans Groundwater Elevations

Well ID	Location	Date	TOC Elevation (ft)	Depth to Water (ft)	GW Elevation (ft)
MW-BU2A	Eldredge Park	11/3/2016	44.56	33.90	10.66
MW-BU2A	Eldredge Park	11/14/2016	44.56	34.03	10.53
MW-BU2A	Eldredge Park	1/18/2017	44.56	34.22	10.34
MW-BU2A	Eldredge Park	1/27/2017	44.56	34.05	10.51
MW-BU2A	Eldredge Park	2/23/2017	44.56	34.62	9.94
MW-BU2A	Eldredge Park	4/25/2017	44.56	33.25	11.31
MW-BU2A	Eldredge Park	6/29/2017	44.56	32.72	11.84
MW-BU2B	Eldredge Park	11/3/2016	44.70	33.93	10.77
MW-BU2B	Eldredge Park	11/14/2016	44.70	34.07	10.63
MW-BU2B	Eldredge Park	1/18/2017	44.70	34.31	10.39
MW-BU2B	Eldredge Park	1/27/2017	44.70	34.15	10.55
MW-BU2B	Eldredge Park	2/23/2017	44.70	33.75	10.95
MW-BU2B	Eldredge Park	4/25/2017	44.70	33.10	11.60
MW-BU2B	Eldredge Park	6/29/2017	44.70	32.72	11.98
MW-BU2C	Eldredge Park	11/3/2016	44.68	33.99	10.69
MW-BU2C	Eldredge Park	11/14/2016	44.68	34.08	10.60
MW-BU2C	Eldredge Park	1/18/2017	44.68	34.30	10.38
MW-BU2C	Eldredge Park	1/27/2017	44.68	34.15	10.53
MW-BU2C	Eldredge Park	2/23/2017	44.68	34.05	10.63
MW-BU2C	Eldredge Park	4/25/2017	44.68	33.08	11.60
MW-BU2C	Eldredge Park	6/29/2017	44.68	32.64	12.04
MW-BX1B	Eldredge Park	4/25/2017	45.38	33.85	11.53
MW-BX1B	Eldredge Park	6/29/2017	45.38	33.46	11.92
MW-BX1C	Eldredge Park	4/25/2017	45.37	33.29	12.08
MW-BX1C	Eldredge Park	6/29/2017	45.37	32.98	12.39

Notes:

N/A = Not Available

1. MW-12C (Existing) was damaged during winter 2017. Water elevations taken since then may be affected.

2. MW-BC2C has not yet been surveyed.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	**MW-4**[3]	**MW-8**[3]	**MW-12A**				**MW-12B**			
Top of Screen Elevation (ft)	4.50	19.70	-24.4				-9.4			
Bottom of Screen Elevation (ft)	-5.50	9.70	-34.4				-19.4			
Sampling Date	10/4/2016	10/4/2016	11/03/2016[1]	1/5/2017	2/23/2017	6/28/2017	11/03/2016[1]	1/5/2017	2/23/2017	6/28/2017
Type of Sample	Sample	Sample	Sample	Sample	Q1 Sample	Q3 Sample	Sample	Sample	Q1 Sample	Q3 Sample
Field Measurements										
pH (SU)	5.52	5.23	6.94	5.46	5.53	5.58	6.90	5.43	5.40	5.39
Temperature (^{o}C)	15.54	15.87	14.38	11.78	13.81	13.91	14.50	11.82	14.18	14.37
Dissolved Oxygen (DO, mg/L)	7.89	9.58	1.13	3.69	7.03	14.81	1.05	1.16	6.39	12.40
Redox Potential (ORP; mV)	57.90	135.00	70.90	197.60	183.10	173.60	20.30	212.80	263.10	225.20
Specific Conductivity (µS/cm)[c]	171.00	190.00	667.00	572.00	550.00	537.00	231.00	243.00	235.00	253.00
Turbidity (NTU)	-	-	17.70	5.50	5.31	5.13	8.73	1.89	0.91	2.62
Laboratory Analyses										
Nitrogen										
Nitrate as N (mg/L)	**2.45**	**9.24**	**0.783**	**0.669**	**0.849**	**0.786**	**6.17**	**5.08**	**5.33**	**6.19**
Nitrite as N (mg/L)	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ammonia (mg/L)	**0.1**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.19**	<0.1	**0.12**
Total Kjeldahl Nitrogen (TKN) (mg/L)	**0.71**	**1.7**	-	<0.2	**0.4**	-	-	**0.79**	**1.18**	-
Total Nitrogen (mg/L)	**3.15**	**10.9**	**1**	**0.669**	**1.25**	**0.79**	**6.44**	**5.87**	**6.52**	**6.83**
Anions										
Chloride (mg/L)	**27.2**	**18.3**	**190**	**230**	**141**	**154**	**34.1**	**24.2**	**41.6**	**48.9**
Sulfate (mg/L)	**12.8**	**10.1**	**10**	**16.1**	**13.4**	**12.6**	**9.8**	**13.6**	**9.7**	**9.2**
Elements										
Dissolved Iron (mg/L)	-	-	**0.7**	-	<0.1	<0.1	**0.36**	-	<0.05	<0.1
Dissolved Manganese (mg/L)	-	-	**0.325**	-	**0.033**	<0.02	**0.228**	-	**0.046**	<0.02
Boron (mg/L)	-	-	<0.05	-	<0.05	-	<0.05	-	<0.05	-
Sodium (mg/L)	-	-	-	-	**98.3**	-	-	-	**18.7**	-
Other										
DOC (mg/L)	<0.5	<0.5	**0.55**	-	<0.5	**2.16**	**1.82**	-	<0.5	**1.02**
Methane (µg/L)	-	-	-	-	-	**-**	-	-	-	**-**
Alkalinity as CaCO3 (mg/L)	-	-	-	**5**	**7**	-	-	**2**	**10**	-

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D -Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: http://www.hbuehrer.ch/Rechner/O2satur.html

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	**MW-12C**[2,3]					**MA-BU1A**	**MW-BU1C**	**MW-BU2A**			
Top of Screen Elevation (ft)	8.60					-26.3	4	-24.9			
Bottom of Screen Elevation (ft)	-1.40					-36.3	-6	-34.9			
Sampling Date	10/4/2016	11/03/2016[1]	11/17/2016	1/5/2017	2/23/2017	10/4/2016	10/4/2016	11/03/2016[1]	1/5/2017	2/23/2017	6/29/2017
Type of Sample	Sample	Sample	Sample	Sample	Q1 Sample[4]	Sample	Sample	Sample	Sample	Q1 Sample	Q3 Sample
Field Measurements											
pH (SU)	4.98	6.45	5.23	5.09	NS	5.44	5.27	6.73	6.00	5.72	5.68
Temperature (^{o}C)	17.50	14.08	14.42	12.60	NS	13.75	13.95	14.15	11.75	13.71	14.00
Dissolved Oxygen (DO, mg/L)	6.93	0.83	0.68	1.61	NS	7.60	8.75	1.18	1.30	6.82	15.26
Redox Potential (ORP; mV)	167.80	246.00	279.70	205.60	NS	70.90	130.90	37.50	127.00	149.50	225.20
Specific Conductivity (µS/cm)[c]	178.00	216.00	156.00	199.00	NS	1464.00	351.00	406.00	421.00	427.00	439.00
Turbidity (NTU)	-	0.60	2.58	0.84	NS	-	-	44.50	257.00	378.00	2.55
Laboratory Analyses											
Nitrogen											
Nitrate as N (mg/L)	**6.74**	**6.51**	-	**6.03**	NS	**0.443**	**1.97**	**0.357**	**0.426**	**0.452**	**0.408**
Nitrite as N (mg/L)	-	-	-	<0.01	NS	-	-	<0.01	<0.01	<0.01	<0.01
Ammonia (mg/L)	<0.1	**0.11**	-	**0.12**	NS	**0.24**	<0.1	<0.1	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	**1.34**	-	-	**1.24**	NS	**0.38**	**0.4**	-	<0.2	**0.3**	-
Total Nitrogen (mg/L)	**8.08**	**6.51**	-	**7.27**	NS	**0.827**	**2.37**	**0.357**	**0.426**	**0.76**	**0.408**
Anions											
Chloride (mg/L)	**24.1**	-	-	**22.4**	NS	**458**	**96.1**	**103**	**118**	**117**	**120**
Sulfate (mg/L)	**8.7**	**9.3**	-	**8.6**	NS	**6.9**	**9.1**	**7.2**	**5.2**	**5.3**	<5
Elements											
Dissolved Iron (mg/L)	-	<0.05	-	-	NS	**0.799**	**0.099**	**1.09**	-	**0.477**	<0.1
Dissolved Manganese (mg/L)	-	**0.02**	-	-	NS	**0.185**	**0.047**	**0.18**	-	**0.03**	<0.02
Boron (mg/L)	-	<0.05	-	-	NS	<0.05	<0.05	<0.05	-	<0.05	-
Sodium (mg/L)	-	-	-	-	-	-	-	-	-	**63**	-
Other											
DOC (mg/L)	<0.5	**0.87**	**0.674**	-	NS	<0.5	<0.5	<0.5	-	**0.53**	<0.5
Methane (µg/L)	-	-	-	-	NS	<2	<2	-	-	-	-
Alkalinity as CaCO3 (mg/L)	-	-	**4**	**6**	NS	-	-	-	**11**	**10**	-

Notes:

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D -Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: http://www.hbuehrer.ch/Rechner/O2satur.html

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	**MW-BU2B**				**MW-BU2C**					**MW-BC1C**
Top of Screen Elevation (ft)	-9.9				5.10					2.5
Bottom of Screen Elevation (ft)	-19.9				-4.90					-7.5
Sampling Date	11/03/2016[1]	1/5/2017	2/23/2017	6/29/2017	11/03/2016[1]	11/17/2016	1/10/2017	2/23/2017	6/29/2017	10/4/2016
Type of Sample	Sample	Sample	Q1 Sample	Q3 Sample	Sample	Sample	Sample	Q1 Sample	Q3 Sample	Sample
Field Measurements										
pH (SU)	7.11	5.94	5.73	5.68	7.14	5.46	5.49	5.62	5.27	5.48
Temperature (^{o}C)	14.70	12.07	14.18	14.70	15.20	14.89	12.78	14.78	15.22	13.37
Dissolved Oxygen (DO, mg/L)	1.30	1.07	6.25	13.80	1.31	2.17	2.40	5.96	11.94	7.75
Redox Potential (ORP; mV)	20.20	136.30	177.60	221.40	203.00	51.20	194.10	227.50	249.50	70.10
Specific Conductivity (µS/cm)[c]	379.00	362.00	343.00	336.00	535.00	516.00	569.00	367.00	579.00	1029.00
Turbidity (NTU)	102.00	146.00	32.60	4.16	11.40	14.20	5.55	7.33	2.08	-
Laboratory Analyses										
Nitrogen										
Nitrate as N (mg/L)	**1.06**	**0.826**	**1.01**	**0.768**	**5.39**	-	**7.42**	**1.78**	**5.39**	**0.481**
Nitrite as N (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	-
Ammonia (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	-	**0.1**	<0.1	<0.1	-
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	<0.2	**0.43**	-	-	-	<0.2	**0.55**	-	-
Total Nitrogen (mg/L)	**1.06**	**0.826**	**1.44**	**0.768**	**5.39**	-	-	**2.32**	**5.39**	**0.481**
Anions										
Chloride (mg/L)	**97.3**	**92.2**	**90.7**	**88.3**	**134**	-	**143**	**96.8**	**146**	**438**
Sulfate (mg/L)	<5	<5	<5	<5	<5	-	<5	<5	<5	**11.5**
Elements										
Dissolved Iron (mg/L)	**0.667**	-	**0.138**	<0.1	**0.817**	-	-	<0.1	<0.1	-
Dissolved Manganese (mg/L)	**0.088**	-	<0.02	<0.02	**0.26**	-	-	**0.077**	**0.081**	-
Boron (mg/L)	<0.05	-	<0.05	-	<0.05	-	-	<0.05	-	-
Sodium (mg/L)	-	-	**37.2**	-	-	-	-	**44.9**	-	-
Other										
DOC (mg/L)	**0.612**	-	<0.5	**0.579**	**0.684**	**0.728**	<0.5	<0.5	**0.599**	<0.5
Methane (µg/L)	<2	-	-	-	<2	-	-	-	-	-
Alkalinity as CaCO3 (mg/L)	-	**18**	**16**	-	-	**13**	**11**	**17**	-	-

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D -Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: http://www.hbuehrer.ch/Rechner/O2satur.html

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	**MW-BC2C**					**MW-BC3**		**MW-BX1B**		**MW-BX1C**	
Top of Screen Elevation (ft)	N/A					-10.80		-9.40		5.70	
Bottom of Screen Elevation (ft)	N/A					-20.80		-19.40		-4.30	
Sampling Date	11/04/2016	11/17/2016	1/10/2017	2/24/2017	6/29/2017	3/27/2017	6/29/2017	3/27/2017	6/28/2017	3/27/2017	6/28/2017
Type of Sample	Sample	Sample	Sample	Q1 Sample	Q3 Sample	Sample	Q3 Sample	Sample	Q3 Sample	Sample	Q3 Sample
Field Measurements											
pH (SU)	7.05	5.40	5.55	5.17	5.28	5.38	5.31	4.67	5.05	4.44	4.70
Temperature (^{o}C)	15.25	14.54	12.65	15.10	15.07	14.19	14.13	13.76	14.28	13.87	14.32
Dissolved Oxygen (DO, mg/L)	1.65	1.67	1.87	5.73	12.16	2.50	6.98	1.73	1.87	0.63	2.30
Redox Potential (ORP; mV)	74.80	100.70	169.00	259.10	239.90	113.80	251.90	153.70	283.60	199.90	315.80
Specific Conductivity (µS/cm)[c]	368.00	340.00	363.00	332.00	361.00	518.00	611.00	367.00	446.00	521.00	473.00
Turbidity (NTU)	6.00	19.20	16.60	20.40	3.76	5.69	16.40	29.80	326.00	0.98	55.80
Laboratory Analyses											
Nitrogen											
Nitrate as N (mg/L)	**4.16**	-	**5.91**	**3.32**	**3.42**	**2.2**	**4.59**	**11.4**	**34.4**	**0.25**	**38.7**
Nitrite as N (mg/L)	-	-	<0.01	<0.01	<0.01	**0.032**	<0.01	**0.018**	<0.01	**0.012**	<0.01
Ammonia (mg/L)	<0.1	-	<0.1	<0.1	<0.1	**0.91**	<0.1	**0.4**	**0.7**	**1.09**	**0.5**
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	-	<0.2	**0.92**	-	-	-	-	-	-	-
Total Nitrogen (mg/L)	**4.43**	-		**4.24**	**3.42**	**2.59**	**4.59**	**12.9**	**37**	**1.52**	**42**
Anions											
Chloride (mg/L)	**83.8**	-	**85.4**	**83.3**	**86.5**	**143**	**161**	**43.1**	**41**	**49.6**	**40.8**
Sulfate (mg/L)	**6.4**	-	<5	**6.3**	<5	**8.3**	**6.8**	**7.6**	<5	<5	<5
Elements											
Dissolved Iron (mg/L)	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dissolved Manganese (mg/L)	-	-	-	**0.092**	**0.062**	**0.298**	**0.077**	**0.335**	**0.478**	**0.566**	**0.517**
Boron (mg/L)	-	-	-	<0.05	-	-	-	-	-	-	-
Sodium (mg/L)	-	-	-	41.8	-	-	-	-	-	-	-
Other											
DOC (mg/L)	**0.764**	**0.576**	<0.5	**1.54**	**1.68**	**1.86**	**1.02**	**2.97**	**1.55**	**2.7**	**2.02**
Methane (µg/L)	-	-	-	-	-	-	-	-	**-**	-	**-**
Alkalinity as CaCO3 (mg/L)	-	**8**	**9**	**9**	-	-	-	-	-	-	-

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D -Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: http://www.hbuehrer.ch/Rechner/O2satur.html

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	**MW-B1010C**					**MW-B1020B**			
Top of Screen Elevation (ft)	-0.10					-10.4			
Bottom of Screen Elevation (ft)	-10.10					-20.4			
Sampling Date	11/03/2016[1]	11/17/2016	1/5/2017	2/23/2017	6/28/2017	11/04/2016[1]	1/5/2017	2/23/2017	6/28/2017
Type of Sample	Sample	Sample	Sample	Q1 Sample	Q3 Sample	Sample	Sample	Q1 Sample	Q3 Sample
Field Measurements									
pH (SU)	6.90	5.18	5.61	5.32	5.36	6.78	5.20	5.01	5.00
Temperature (^{o}C)	14.60	14.28	12.22	14.69	15.04	13.70	11.94	14.13	14.71
Dissolved Oxygen (DO, mg/L)	0.87	0.71	0.49	1.07	1.39	1.03	0.60	2.77	1.44
Redox Potential (ORP; mV)	110.70	231.60	190.80	252.20	204.80	45.00	190.70	251.30	276.30
Specific Conductivity (µS/cm)[c]	262.00	230.00	289.00	258.00	269.00	465.00	355.00	353.00	352.00
Turbidity (NTU)	16.00	5.97	10.60	5.62	2.73	67.90	321.00	11.00	14.60
Laboratory Analyses									
Nitrogen									
Nitrate as N (mg/L)	**13.6**	-	**6.74**	**9.94**	**13.8**	**28.4**	**17.9**	**20.1**	**24.9**
Nitrite as N (mg/L)	-	-	**0.509**	**0.474**	**0.171**	-	<0.01	<0.01	**0.158**
Ammonia (mg/L)	<0.1	-	<0.1	**0.18**	<0.1	**0.53**	**0.11**	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	-	**1.36**	**1.95**	-	-	**1.79**	**2.92**	-
Total Nitrogen (mg/L)	**13.9**	-	**8.61**	**12.4**	**15.7**	**28.5**	**19.6**	**23**	**27.1**
Anions									
Chloride (mg/L)	**27.5**	-	**24.3**	**25.2**	**24.2**	**49.8**	**33.6**	**34**	**32.3**
Sulfate (mg/L)	-	-	**23.7**	**16.5**	**11**	-	<5	<5	<5
Elements									
Dissolved Iron (mg/L)	-	-	-	<0.1	**0.143**	**2.52**	-	**0.153**	<0.1
Dissolved Manganese (mg/L)	-	-	-	**0.234**	**0.324**	**0.948**	-	**0.293**	**0.333**
Boron (mg/L)	-	-	-	<0.05	-	<0.05	-	**0.053**	-
Sodium (mg/L)	-	-	-	**22.8**	-	**27.5**	-	**24.6**	-
Other									
DOC (mg/L)	-	**0.696**	-	**13.9**	**16.9**	-	-	**1.11**	**3.24**
Methane (µg/L)	-	-	-	-	<2	-	-	-	**-**
Alkalinity as CaCO3 (mg/L)	-	**11**	**31**	**15**	-	-	**9**	**6**	-

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D -Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: http://www.hbuehrer.ch/Rechner/O2satur.html

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	**MW-B1020C**					**MW-B1050A**				**MW-B1050B**		
Top of Screen Elevation (ft)	4.50					-26.1				-11.1		
Bottom of Screen Elevation (ft)	-5.50					-36.1				-21.1		
Sampling Date	11/04/2016[1]	11/17/2016	1/5/2017	2/23/2017	6/28/2017	11/04/2016[1]	1/5/2017	2/23/2017	6/28/2017	11/04/2016[1]	2/23/2017	6/28/2017
Type of Sample	Sample	Sample	Sample	Q1 Sample	Q3 Sample	Sample	Sample	Q1 Sample	Q3 Sample	Sample	Q1 Sample	Q3 Sample
Field Measurements												
pH (SU)	6.88	5.27	5.38	5.17	5.16	7.15	5.60	5.50	5.00	7.06	5.13	5.10
Temperature (^{o}C)	14.24	14.66	12.73	15.06	15.26	13.77	11.87	14.05	14.27	14.08	14.27	14.70
Dissolved Oxygen (DO, mg/L)	1.44	0.56	0.31	2.69	3.72	1.34	0.26	4.24	1.75	1.17	2.12	4.53
Redox Potential (ORP; mV)	50.30	106.70	194.80	292.20	277.20	43.00	142.20	226.20	264.40	80.30	304.40	260.10
Specific Conductivity (µS/cm)[c]	242.00	227.00	269.00	253.00	247.00	612.00	505.00	1648.00	508.00	446.00	463.00	387.00
Turbidity (NTU)	321.00	15.60	6.31	18.00	8.87	962.00	297.00	76.60	4.10	3.97	7.20	0.72
Laboratory Analyses												
Nitrogen												
Nitrate as N (mg/L)	**10.6**	-	**11.1**	**12.6**	**13.9**	**37**	**26.6**	**11.8**	**26.8**	**25.7**	**28.7**	**18.2**
Nitrite as N (mg/L)	-	-	<0.01	<0.01	<0.01	-	**0.105**	<0.01	**0.038**	-	<0.01	<0.01
Ammonia (mg/L)	<0.1	-	**0.19**	<0.1	<0.1	**1.93**	**1.72**	**0.54**	**0.57**	**0.19**	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	-	**1.99**	**2.25**	-	-	**3.75**	**1.83**	-	-	**1.85**	-
Total Nitrogen (mg/L)	**10.6**	-	**13.1**	**14.9**	**15**	**37.2**	**30.5**	**13.7**	**26.8**	**26**	**30.5**	**18.2**
Anions												
Chloride (mg/L)	**25.5**	-	**25.6**	**25.6**	**24.8**	**54.8**	**48.9**	**399**	**48.9**	**48.2**	**50.7**	**41.7**
Sulfate (mg/L)	-	-	**5.6**	**6.1**	**5.8**	-	**6.1**	<5	<5	-	<5	<5
Elements												
Dissolved Iron (mg/L)	**2.23**	-	-	<0.1	<0.1	**4.29**	-	<0.1	<0.1	**0.734**	<0.1	<0.1
Dissolved Manganese (mg/L)	**0.249**	-	-	**0.076**	**0.057**	**0.655**	-	**0.18**	**0.654**	**0.332**	**0.142**	**0.101**
Boron (mg/L)	**0.085**	-	-	**0.083**	-	<0.05	-	<0.05	-	<0.05	<0.05	-
Sodium (mg/L)	**13.4**	-	-	**18.4**	-	**33.7**	-	**345**	-	**26.8**	**16.9**	-
Other												
DOC (mg/L)	-	**0.85**	-	**1.02**	**1.34**	-	-	**0.808**	**1.85**	-	**0.722**	**1.31**
Methane (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-
Alkalinity as CaCO3 (mg/L)	-	**13**	**11**	**8**	-	-	**24**	**11**	-	-	**7**	-

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D -Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: http://www.hbuehrer.ch/Rechner/O2satur.html

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	**MW-B1050C**			**MW-B1075B**			**MW-B2010C**			
Top of Screen Elevation (ft)	4.9			-11.5			0			
Bottom of Screen Elevation (ft)	-5.1			-21.5			-10			
Sampling Date	11/04/2016[1]	2/23/2017	6/28/2017	11/04/2016[1]	2/23/2017	6/28/2017	11/03/2016[1]	11/17/2016	2/24/2017	6/28/2017
Type of Sample	Sample	Q1 Sample	Q3 Sample	Sample	Q1 Sample	Q3 Sample	Sample	Sample	Q1 Sample	Q3 Sample
Field Measurements										
pH (SU)	7.20	5.43	5.34	7.19	5.59	5.66	7.04	5.32	5.70	6.11
Temperature (^{o}C)	14.55	14.95	15.06	15.20	14.20	14.74	15.12	14.58	14.81	15.39
Dissolved Oxygen (DO, mg/L)	1.34	1.83	5.39	0.71	1.50	1.95	0.67	0.61	3.38	1.78
Redox Potential (ORP; mV)	48.60	205.90	230.20	82.20	157.90	223.10	12.40	213.80	103.30	-41.60
Specific Conductivity (µS/cm)[c]	571.00	511.00	542.00	631.00	1755.00	736.00	333.00	304.00	302.00	431.00
Turbidity (NTU)	8.21	2.27	0.98	13.00	126.00	1.87	149.00	44.40	19.90	6.89
Laboratory Analyses										
Nitrogen										
Nitrate as N (mg/L)	**3.83**	**3.96**	**3.26**	**1.93**	**1**	**0.553**	**15.7**	-	**5.06**	**5.74**
Nitrite as N (mg/L)	-	<0.01	<0.01	-	**0.048**	**0.05**	-	-	**0.499**	**0.128**
Ammonia (mg/L)	<0.1	<0.1	<0.1	**3.73**	**5.26**	**11**	**0.14**	-	<0.1	**0.24**
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	1.28	-	-	**7.2**	-	-	-	**14.7**	-
Total Nitrogen (mg/L)	**4.05**	**5.24**	**3.26**	**6.36**	**8.25**	**13.6**	**16.1**	-	**20.3**	**7.69**
Anions										
Chloride (mg/L)	**141**	**123**	**134**	**96.3**	**440**	**170**	**38.6**	-	**27.5**	**30**
Sulfate (mg/L)	-	**20.1**	**15.2**	-	**25.6**	**28.9**	**11**	-	**24.3**	**39.8**
Elements										
Dissolved Iron (mg/L)	**0.493**	<0.1	<0.1	-	**0.342**	<0.1	-	-	**1.84**	**24.2**
Dissolved Manganese (mg/L)	**0.146**	**0.042**	**0.057**	-	**0.119**	**0.111**	-	-	**0.189**	**1.62**
Boron (mg/L)	<0.05	<0.05	-	-	<0.05	-	-	-	<0.05	-
Sodium (mg/L)	**81.6**	**94.5**	-	-	**379**	-	-	-	**28.5**	-
Other										
DOC (mg/L)	-	**0.592**	**1.62**	-	**1.96**	**4.86**	**2.18**	**0.852**	**19.4**	**83.3**
Methane (µg/L)	-	-	-	-	-	-	-	-	-	**11.3**
Alkalinity as CaCO3 (mg/L)	-	**17**	-	-	**46**	-	-	**16**	**48**	-

Notes:

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D -Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: http://www.hbuehrer.ch/Rechner/O2satur.html

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	**MW-B2020B**					**MW-B2020C**			
Top of Screen Elevation (ft)	-10.1					4.8			
Bottom of Screen Elevation (ft)	-20.1					-5.2			
Sampling Date	11/03/2016[1]	11/17/2016	1/10/2017	2/24/2017	6/28/2017	11/03/2016[1]	1/10/2017	2/24/2017	6/28/2017
Type of Sample	Sample	Sample	Sample	Q1 Sample	Q3 Sample	Sample	Sample	Q1 Sample	Q3 Sample
Field Measurements									
pH (SU)	7.00	5.22	5.05	5.10	5.04	7.00	5.12	5.09	5.60
Temperature (^{o}C)	14.91	14.39	12.23	14.53	14.86	15.20	12.90	15.42	15.57
Dissolved Oxygen (DO, mg/L)	1.15	0.63	0.85	2.03	3.88	1.31	1.30	3.96	1.70
Redox Potential (ORP; mV)	90.80	182.60	170.50	308.10	285.90	29.80	201.50	316.20	73.80
Specific Conductivity (µS/cm)[c]	321.00	307.00	344.00	338.00	354.00	249.00	251.00	225.00	264.00
Turbidity (NTU)	14.30	17.40	6.95	6.11	8.12	28.00	5.81	5.17	6.23
Laboratory Analyses									
Nitrogen									
Nitrate as N (mg/L)	**16.9**	-	**25.6**	**14.8**	**22.4**	**8.71**	**12.6**	**6.95**	**0.457**
Nitrite as N (mg/L)	**0.022**	-	<0.01	<0.01	<0.01	**0.016**	<0.01	<0.01	**0.072**
Ammonia (mg/L)	**0.1**	-	<0.1	<0.1	<0.1	**0.24**	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	-	<0.2	**3.86**	-	-	<0.2	**2.33**	-
Total Nitrogen (mg/L)	**17.2**	-	-	**18.7**	**24.2**	**9.02**	-	**9.28**	**0.85**
Anions									
Chloride (mg/L)	**32.5**	-	**34.9**	**32.7**	**39.3**	**26.8**	**31**	**28.4**	**32.2**
Sulfate (mg/L)	**7.7**	-	**6**	**7.1**	**6.4**	**11.6**	**9.7**	**11.9**	**36.8**
Elements									
Dissolved Iron (mg/L)	**1.2**	-	-	<0.1	<0.1	**1.42**	-	<0.1	**7.97**
Dissolved Manganese (mg/L)	**0.126**	-	-	**0.028**	**0.029**	**1.14**	-	**0.067**	**0.964**
Boron (mg/L)	<0.05	-	-	**0.054**	-	<0.05	-	<0.05	-
Sodium (mg/L)	-	-	-	**21.6**	-	-	-	**15.2**	-
Other									
DOC (mg/L)	**1.45**	**0.694**	<0.5	**1.02**	**3.47**	**1.17**	<0.5	**2.04**	**23.3**
Methane (µg/L)	<2	-	-	-	**-**	<2	-	-	**-**
Alkalinity as CaCO3 (mg/L)	-	**20**	**12**	**8**	-	-	**10**	**7**	-

Notes:

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D -Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: http://www.hbuehrer.ch/Rechner/O2satur.html

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	**MW-B2050A**				**MW-B2050B**			**MW-B2050C**			**MW-B2075A**	
Top of Screen Elevation (ft)	-25.4				-10.4			4.6			-20.40	
Bottom of Screen Elevation (ft)	-35.4				-20.4			-5.4			-30.40	
Sampling Date	11/03/2016[1]	1/10/2017	2/24/2017	6/28/2017	11/03/2016[1]	2/24/2017	6/28/2017	11/03/2016[1]	2/24/2017	6/28/2017	3/27/2017	6/28/2017
Type of Sample	Sample	Sample	Q1 Sample	Q3 Sample	Sample	Q1 Sample	Q3 Sample	Sample	Q1 Sample	Q3 Sample	Sample	Q3 Sample
Field Measurements												
pH (SU)	7.11	5.39	5.29	5.27	7.06	5.22	5.29	7.22	5.49	5.38	5.21	5.50
Temperature (^{o}C)	14.44	11.96	14.06	14.47	14.95	14.64	15.27	16.72	16.56	16.90	14.42	14.98
Dissolved Oxygen (DO, mg/L)	0.60	0.09	0.83	1.66	1.29	3.75	5.97	1.09	5.76	8.95	4.08	7.83
Redox Potential (ORP; mV)	0.80	182.80	251.80	217.00	80.50	304.60	242.20	82.50	179.50	236.30	130.70	234.90
Specific Conductivity (µS/cm)[c]	540.00	520.00	550.00	505.00	512.00	645.00	502.00	658.00	932.00	896.00	744.00	748.00
Turbidity (NTU)	50.70	8.10	14.10	26.70	123.00	4.67	5.78	212.00	36.10	9.68	159.00	3.85
Laboratory Analyses												
Nitrogen												
Nitrate as N (mg/L)	**35**	**39.3**	**27**	**32.8**	**4.75**	**3.64**	**5.27**	**3.01**	**1.68**	**3.05**	**0.348**	**0.539**
Nitrite as N (mg/L)	-	**0.025**	<0.010	<0.01	-	<0.010	<0.01	-	<0.010	<0.01	<0.01	<0.01
Ammonia (mg/L)	**1.05**	**0.87**	**0.89**	**1**	<0.1	<0.1	<0.1	**0.11**	<0.1	**0.12**	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	**3.32**	**3.5**	-	-	**1.22**	-	-	**0.66**	-	-	-
Total Nitrogen (mg/L)	**35.3**	-	**30.5**	**35.4**	**5.15**	**4.86**	**5.91**	**3.3**	**2.34**	**3.75**	**0.35**	**0.779**
Anions												
Chloride (mg/L)	**49.9**	**64.5**	**63.3**	**66.8**	**123**	**173**	**124**	-	**251**	**253**	**246**	**214**
Sulfate (mg/L)	**5.6**	**5.6**	**6.2**	**7.5**	**11.5**	**11.5**	**11**	**11.9**	**11.1**	**10.1**	**5.7**	<5
Elements												
Dissolved Iron (mg/L)	**3.2**	-	<0.1	<0.1	**0.551**	<0.1	<0.1	-	**0.308**	<0.1	**0.119**	<0.1
Dissolved Manganese (mg/L)	**0.407**	-	**0.293**	**0.26**	**0.258**	**0.297**	**0.258**	-	**0.254**	**0.13**	**0.529**	**0.062**
Boron (mg/L)	<0.05	-	<0.05	-	<0.05	<0.05	-	-	<0.05	-	-	-
Sodium (mg/L)	-	-	**40**	-	-	**81.7**	-	-	**120**	-	-	-
Other												
DOC (mg/L)	**1.61**	-	**1.08**	**1.37**	**1.15**	**1.08**	**0.754**	**1.13**	**0.87**	**0.639**	**1.08**	**0.668**
Methane (µg/L)	-	-	-	**-**	-	-	**-**	-	-	**-**	-	-
Alkalinity as CaCO3 (mg/L)	-	**17**	**13**	-	-	**11**	-	-	**9**	-	-	-

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D -Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: http://www.hbuehrer.ch/Rechner/O2satur.html

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Table 3 Orleans Monitoring Well Groundwater Data Summary

Sample ID	**MW-B2100**			
Top of Screen Elevation (ft)	9.6			
Bottom of Screen Elevation (ft)	-0.4			
Sampling Date	10/4/2016	11/03/2016[1]	2/24/2017	6/28/2017
Type of Sample	Sample	Sample	Q1 Sample	Q3 Sample
Field Measurements				
pH (SU)	5.26	6.98	5.46	5.27
Temperature (^{o}C)	14.42	14.95	16.84	14.44
Dissolved Oxygen (DO, mg/L)	5.90	1.50	7.37	10.84
Redox Potential (ORP; mV)	110.50	124.70	189.80	217.40
Specific Conductivity (µS/cm)[c]	272.00	297.00	346.00	364.00
Turbidity (NTU)	-	8.44	OVER	5.71
Laboratory Analyses				
Nitrogen				
Nitrate as N (mg/L)	**1.29**	**1.29**	**0.959**	**0.724**
Nitrite as N (mg/L)	-	-	<0.010	<0.01
Ammonia (mg/L)	<0.1	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	**0.72**	-	**0.54**	-
Total Nitrogen (mg/L)	**2.01**	**1.29**	**1.5**	**0.724**
Anions				
Chloride (mg/L)	**65.4**	**67.8**	**83.2**	**96.4**
Sulfate (mg/L)	**14.1**	**16.2**	**12.1**	**10**
Elements				
Dissolved Iron (mg/L)	**0.115**	-	**0.147**	<0.1
Dissolved Manganese (mg/L)	**0.126**	-	**0.196**	**0.114**
Boron (mg/L)	<0.05	-	<0.05	-
Sodium (mg/L)	-	-	**53.7**	-
Other				
DOC (mg/L)	<0.5	**0.866**	**0.862**	**0.959**
Methane (µg/L)	<2	-	-	-
Alkalinity as CaCO3 (mg/L)	-	-	**14**	-

Notes:

NS - Not Sampled

Bold - detected above the Minimum Detection Limit

D -Duplicate

1. DO was measured in the field as DO(%) and was converted using the online tool at: http://www.hbuehrer.ch/Rechner/O2satur.html

2. MW-12C references "MW-12" that was installed as part of the Nauset Regional Middle School monitoring well network.

3. Existing wells (MW-4, MW-8, MW-12C) screen elevations were determined based on field measurement of depth to bottom of well. Actual screen depths may vary if bottom was affected by silt build-up in well.

4. MW-12C (existing) was damaged during snow removal at the site. A sample was unable to be taken during the Quarter 1 and 2 Sampling Events.

Figures

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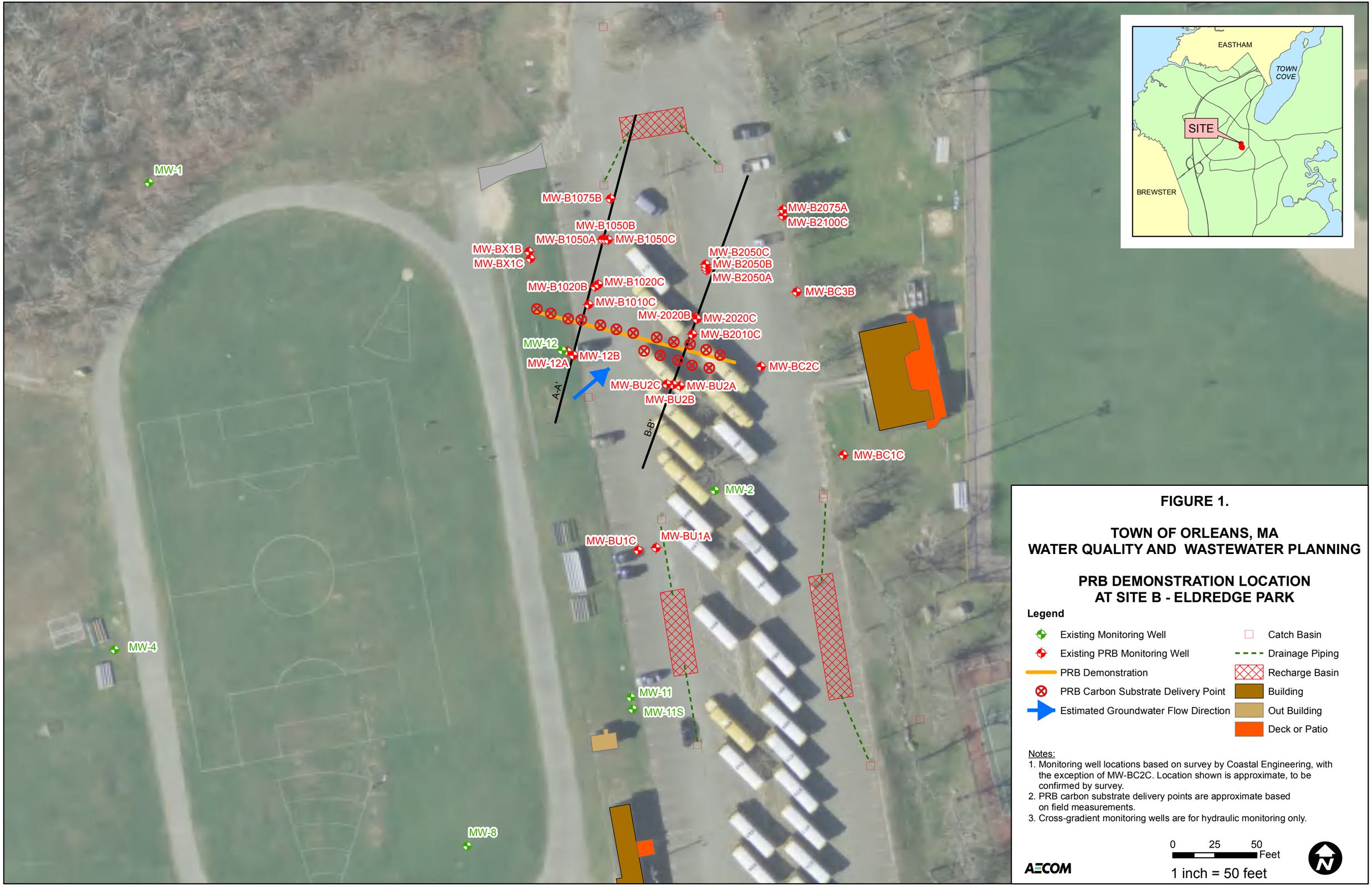

FIGURE 1.

TOWN OF ORLEANS, MA
WATER QUALITY AND WASTEWATER PLANNING

PRB DEMONSTRATION LOCATION AT SITE B - ELDREDGE PARK

Legend

- Existing Monitoring Well
- Existing PRB Monitoring Well
- PRB Demonstration
- PRB Carbon Substrate Delivery Point
- Estimated Groundwater Flow Direction
- Catch Basin
- Drainage Piping
- Recharge Basin
- Building
- Out Building
- Deck or Patio

Notes:
1. Monitoring well locations based on survey by Coastal Engineering, with the exception of MW-BC2C. Location shown is approximate, to be confirmed by survey.
2. PRB carbon substrate delivery points are approximate based on field measurements.
3. Cross-gradient monitoring wells are for hydraulic monitoring only.

0 25 50 Feet

1 inch = 50 feet

AECOM

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A
SOUTHWEST

A'
NORTHEAST

MW-12B
MW-12
MW-12A
MW-B1010C
MW-B1020B
MW-B1020C
MW-B1050A
MW-B1050B
MW-B1050C
MW-B1075B

Approximate
Ground Surface

Unsaturated
Zone

Approximate
Water Table

Approximate
Groundwater
Flow Direction

MW-12
EL. 5.12

EL. -4.90

MW-12B
EL. -9.90

EL. -19.90

MW-12A
EL. -24.40

EL. -34.90

PRB
INJECTION
ZONE

MW-B1010C
EL. 0

EL. -10.90

MW-B1020C
EL. 4.80

EL. -5.20

MW-B1020B
EL. -10.10

EL. -20.10

MW-B1050C
EL. 4.60

EL. -5.40

MW-B1050B
EL. -10.40

EL. -20.40

MW-B1050A
EL. -35.40

EL. -35.40

MW-B1075B
EL. -10.40

EL. -20.40

Saturated
Zone

Elevation (ft)
40
30
20
10
0
-10
-20
-30
-40

Feet Below Ground Surface
0
-5
-15
-25
-35
-45
-55
-65
-75
-85

Horizontal Scale (ft)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
138

AECOM
Figure: 2

CROSS SECTION A-A'
WATER QUALITY AND WASTEWTER PLANNING
TOWN OF ORLEANS, MA
Project No.: 60476644 Date: 2017-01-23

B
SOUTHWEST

B'
NORTHEAST

MW-BU2C
MW-BU2B
MW-BU2A
MW-B2010C
MW-B2020C
MW-B2020B
MW-B2050A
MW-B2050B
MW-B2050C
MW-B2100

Approximate
Ground Surface

Unsaturated
Zone

Approximate
Water Table

Approximate
Groundwater
Flow Direction

MW-BU2C
EL. 5.12

EL. -4.90

MW-BU2B
EL. -9.90

EL. -19.90

MW-BU2A
EL. -24.40

EL. -34.90

PRB
INJECTION
ZONE

MW-B2010C
EL. 0

EL. -10.90

MW-B2020C
EL. 4.80

EL. -5.20

MW-B2020B
EL. -10.10

EL. -20.10

MW-B2050C
EL. 4.60

EL. -5.40

MW-B2050B
EL. -10.40

EL. -20.40

MW-B2050A
EL. -35.40

EL. -35.40

MW-B2100
EL. 10.00

EL. 0

Saturated
Zone

Elevation (ft)
40
30
20
10
0
-10
-20
-30
-40

Feet Below Ground Surface
0
-5
-15
-25
-35
-45
-55
-65
-75
-85

0 10 20 30 40 50 60 70 80 90 100 110 120 130
Horizontal Scale (ft)

Project Management Initials: Designer:____ Checked:____ Approved:____ ANSI B 11" x 17"

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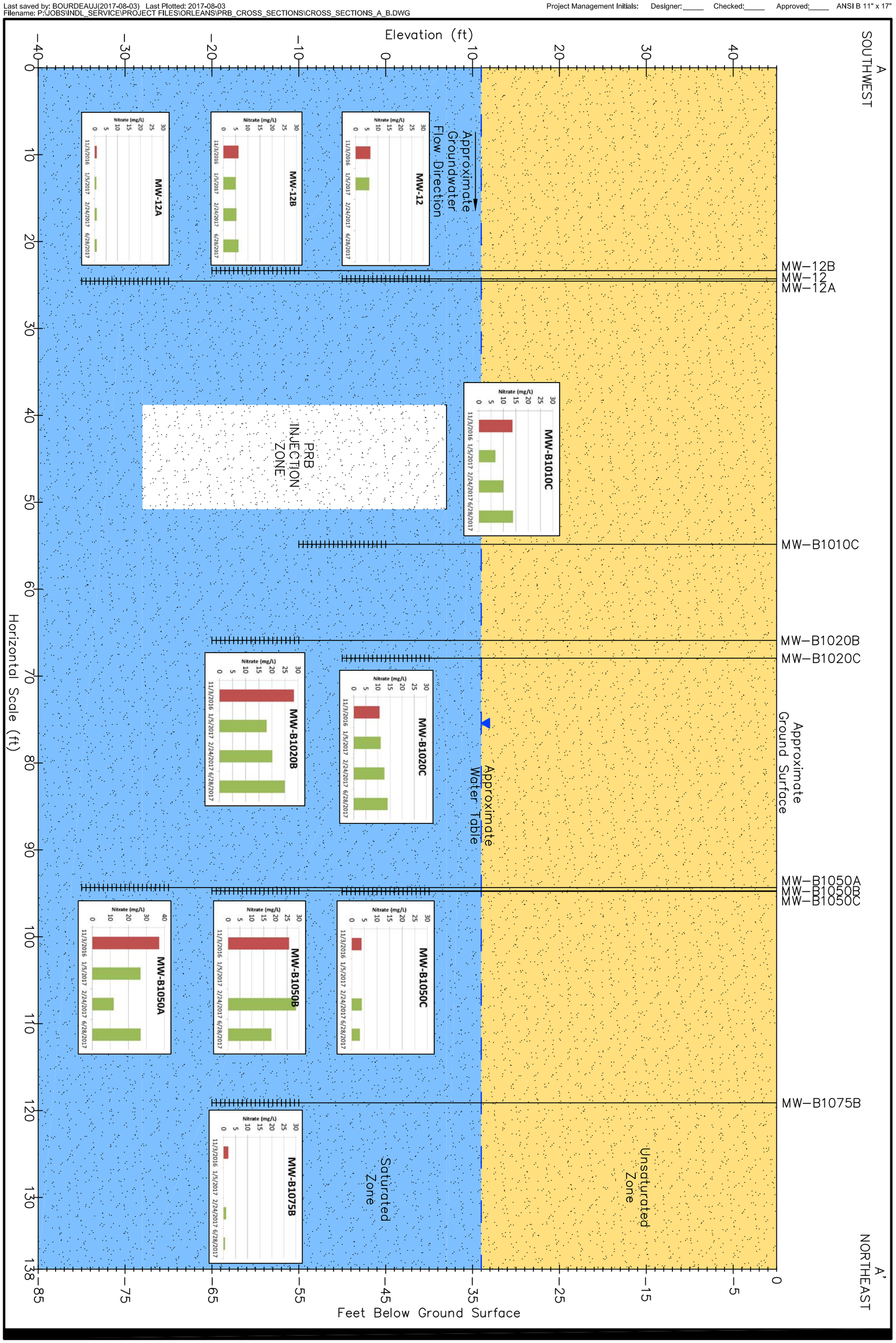
AECOM
Figure: 3

CROSS SECTION B-B'
WATER QUALITY AND WASTEWTER PLANNING
TOWN OF ORLEANS, MA
Project No.: 60476644 Date: 2017-01-23



CROSS SECTION A-A'
WITH NITRATE CONCENTRATION DATA
TOWN OF ORLEANS, MA
Project No.: 60476644 Date: 2017-08-03

AECOM

Figure: 4

B
SOUTHWEST

B'
NORTHEAST

MW-BU2C
MW-BU2B
MW-BU2A
MW-B2010C
MW-B2020C
MW-B2020B
Approximate
Ground Surface
MW-B2050A
MW-B2050B
MW-B2050C
MW-B2100
MW-B2075A

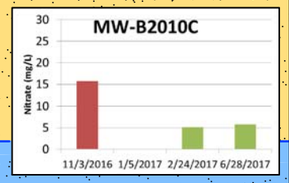
Unsaturated
Zone

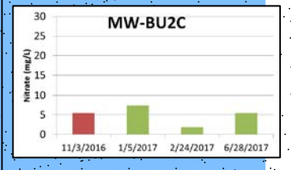
Approximate
Water Table

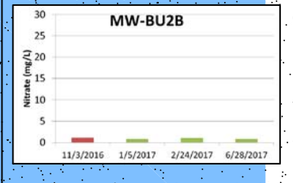
Approximate
Groundwater
Flow Direction

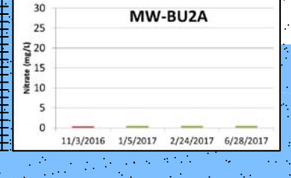
PRB
INJECTION
ZONE

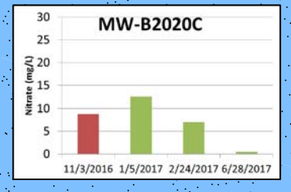
Saturated
Zone

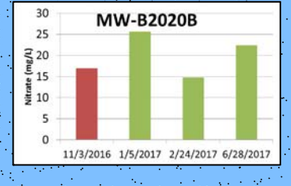


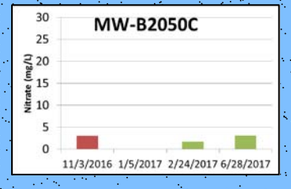


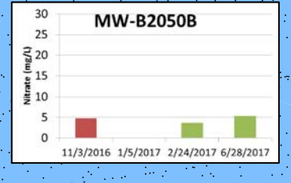


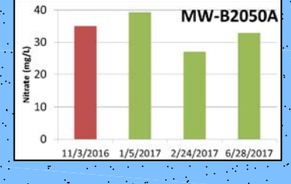


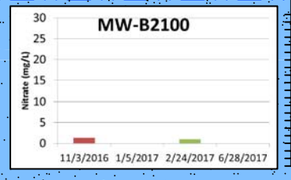


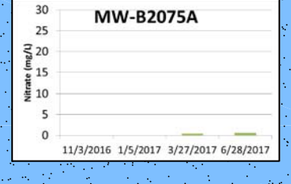












Elevation (ft)
40 30 20 10 0 −10 −20 −30 −40

Feet Below Ground Surface
0 −5 −15 −25 −35 −45 −55 −65 −75 −85

0 10 20 30 40 50 60 70 80 90 100 110 120 130
Horizontal Scale (ft)

CROSS SECTION B-B'
WITH NITRATE CONCENTRATION DATA
TOWN OF ORLEANS, MA
Project No.: 60476644 Date: 2017-08-03

Figure: 5

AECOM

Project Management Initials: Designer:____ Checked:____ Approved:____ ANSI B 11" x 17"

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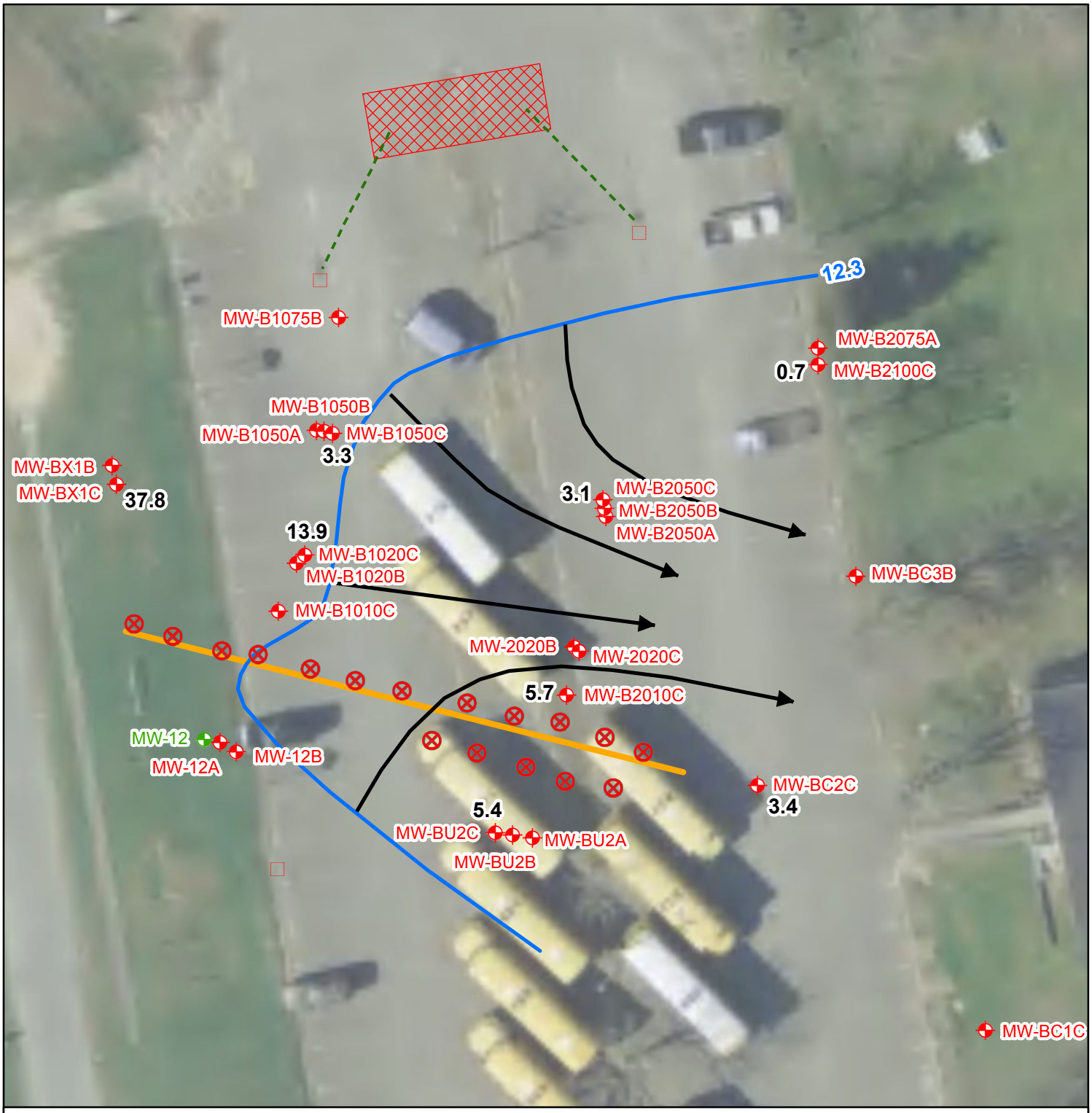

Legend

- Existing Monitoring Well
- Existing PRB Monitoring Well
- PRB Carbon Substrate Delivery Point
- PRB Demonstration
- June 2017 Shallow Groundwater Contour
- June 2017 Shallow Groundwater Flowline
- Catch Basin
- Drainage Piping
- Recharge Basin

FIGURE 6.

TOWN OF ORLEANS, MA
WATER QUALITY AND WASTEWATER PLANNING

JUNE 2017 SHALLOW GROUNDWATER CONTOURS, FLOWLINES, AND NITRATE CONCENTRATIONS

0 20 40 Feet

1 inch = 30 feet

AECOM

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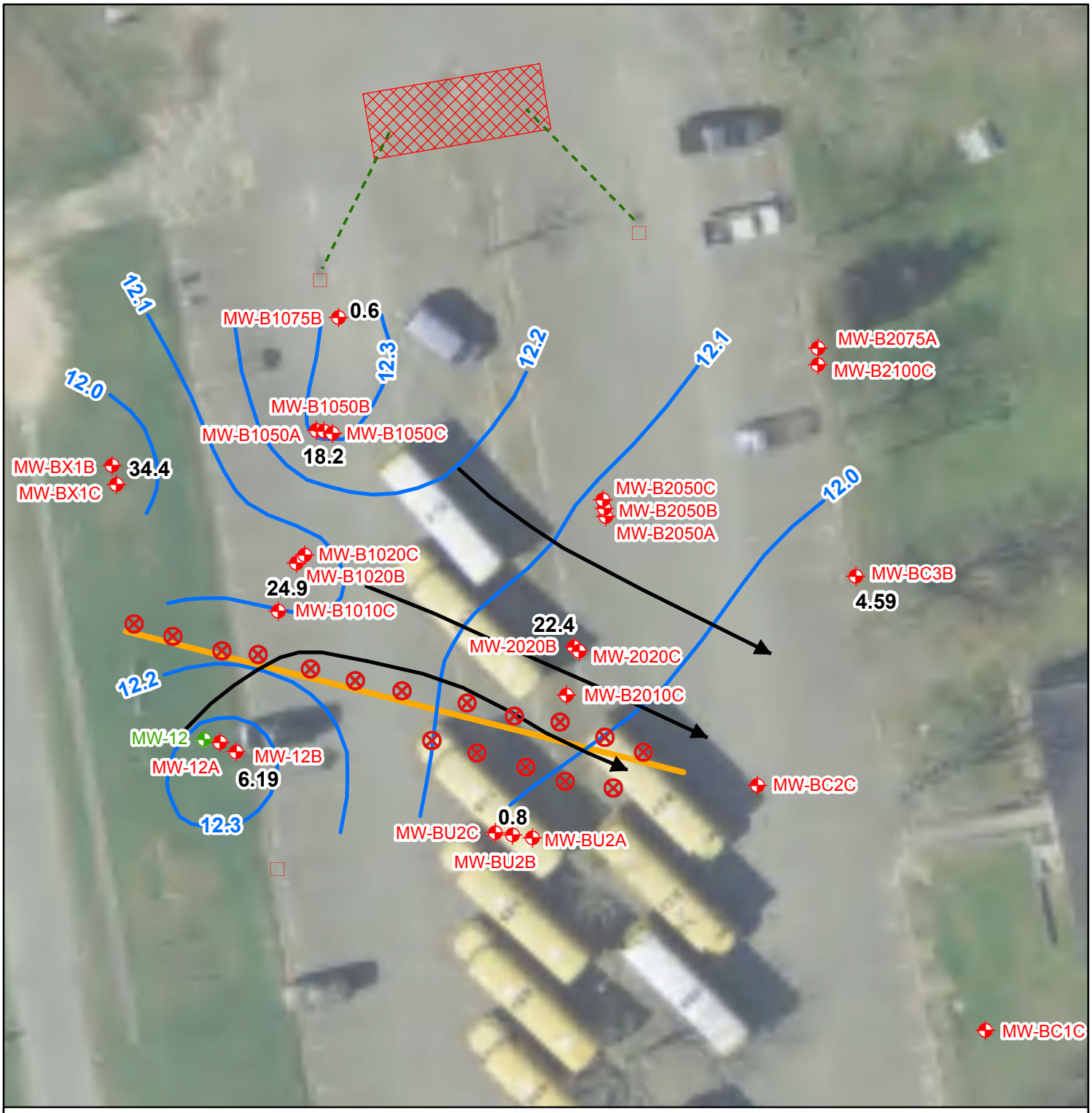

Legend

- Existing Monitoring Well
- Existing PRB Monitoring Well
- PRB Carbon Substrate Delivery Point
- PRB Demonstration
- June 2017 Intermediate Groundwater Contour
- June 2017 Intermediate Groundwater Flowline
- Catch Basin
- Drainage Piping
- Recharge Basin

FIGURE 7.

TOWN OF ORLEANS, MA
WATER QUALITY AND WASTEWATER PLANNING

JUNE 2017 INTERMEDIATE GROUNDWATER CONTOURS, FLOWLINES, AND NITRATE CONCENTRATIONS

0 20 40 Feet

1 inch = 30 feet

AECOM

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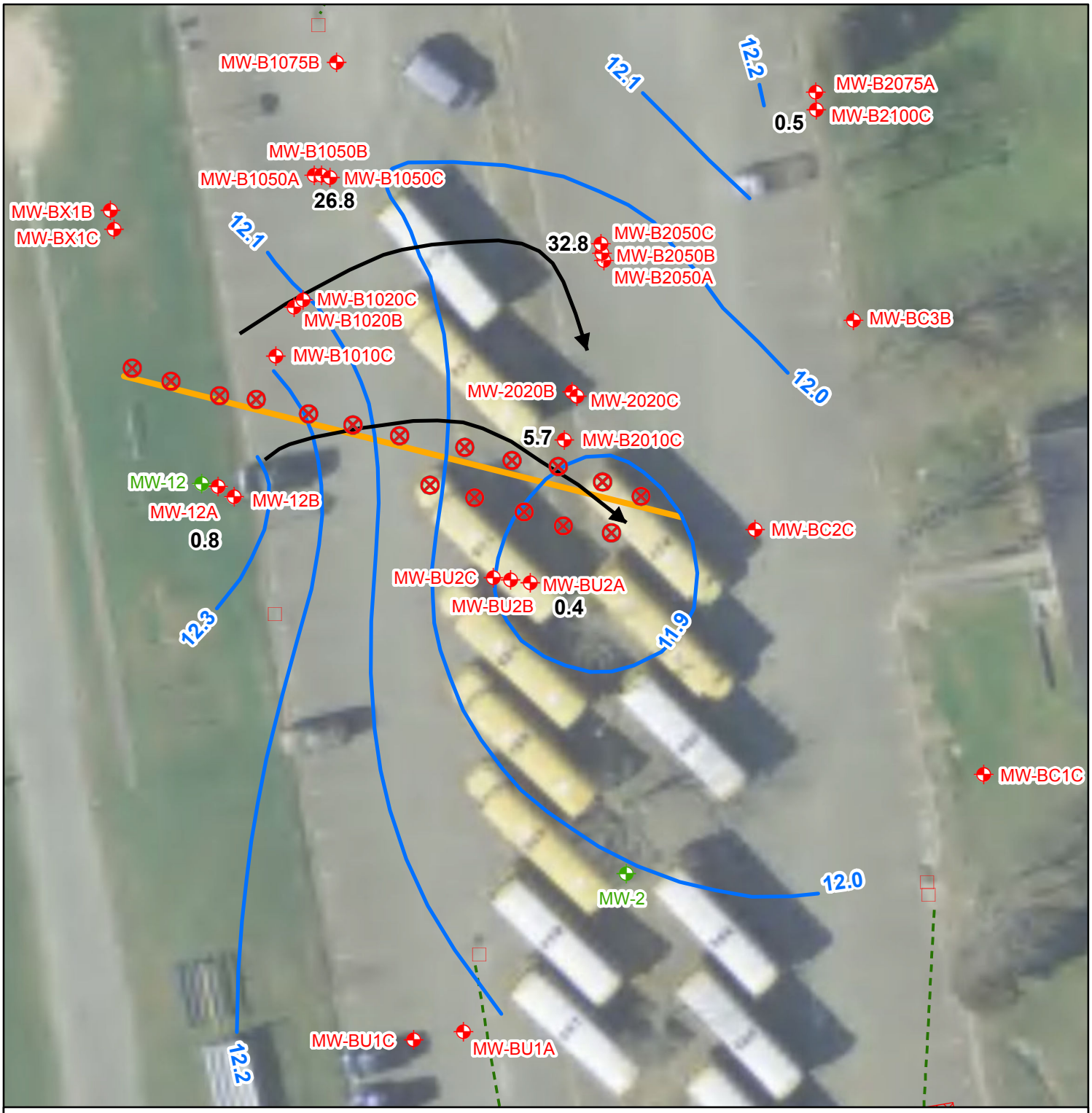

Legend

- Existing Monitoring Well
- Existing PRB Monitoring Well
- PRB Carbon Substrate Delivery Point
- PRB Demonstration
- June 2017 Deep Groundwater Contour
- June 2017 Deep Groundwater Flowline
- Catch Basin
- Drainage Piping
- Recharge Basin

FIGURE 8.

TOWN OF ORLEANS, MA
WATER QUALITY AND WASTEWATER PLANNING

JUNE 2017 DEEP GROUNDWATER CONTOURS, FLOWLINES, AND NITRATE CONCENTRATIONS

0 20 40 Feet

1 inch = 30 feet

AECOM

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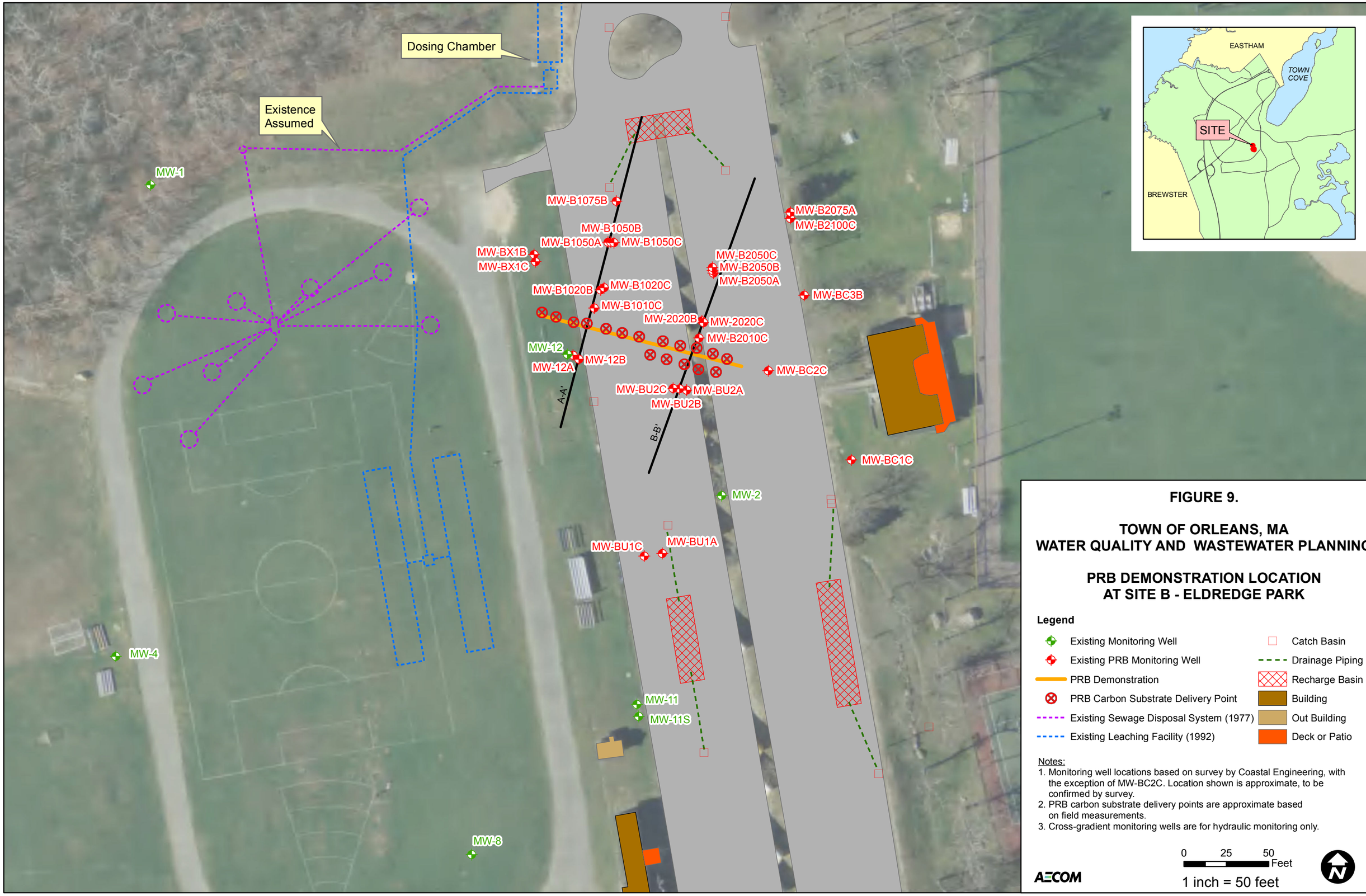

FIGURE 9.

TOWN OF ORLEANS, MA
WATER QUALITY AND WASTEWATER PLANNING

PRB DEMONSTRATION LOCATION
AT SITE B - ELDREDGE PARK

Legend

- Existing Monitoring Well
- Existing PRB Monitoring Well
- PRB Demonstration
- PRB Carbon Substrate Delivery Point
- Existing Sewage Disposal System (1977)
- Existing Leaching Facility (1992)
- Catch Basin
- Drainage Piping
- Recharge Basin
- Building
- Out Building
- Deck or Patio

Notes:
1. Monitoring well locations based on survey by Coastal Engineering, with the exception of MW-BC2C. Location shown is approximate, to be confirmed by survey.
2. PRB carbon substrate delivery points are approximate based on field measurements.
3. Cross-gradient monitoring wells are for hydraulic monitoring only.

0 25 50 Feet

1 inch = 50 feet

AECOM

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Appendix A

Monitoring Well Coordinates

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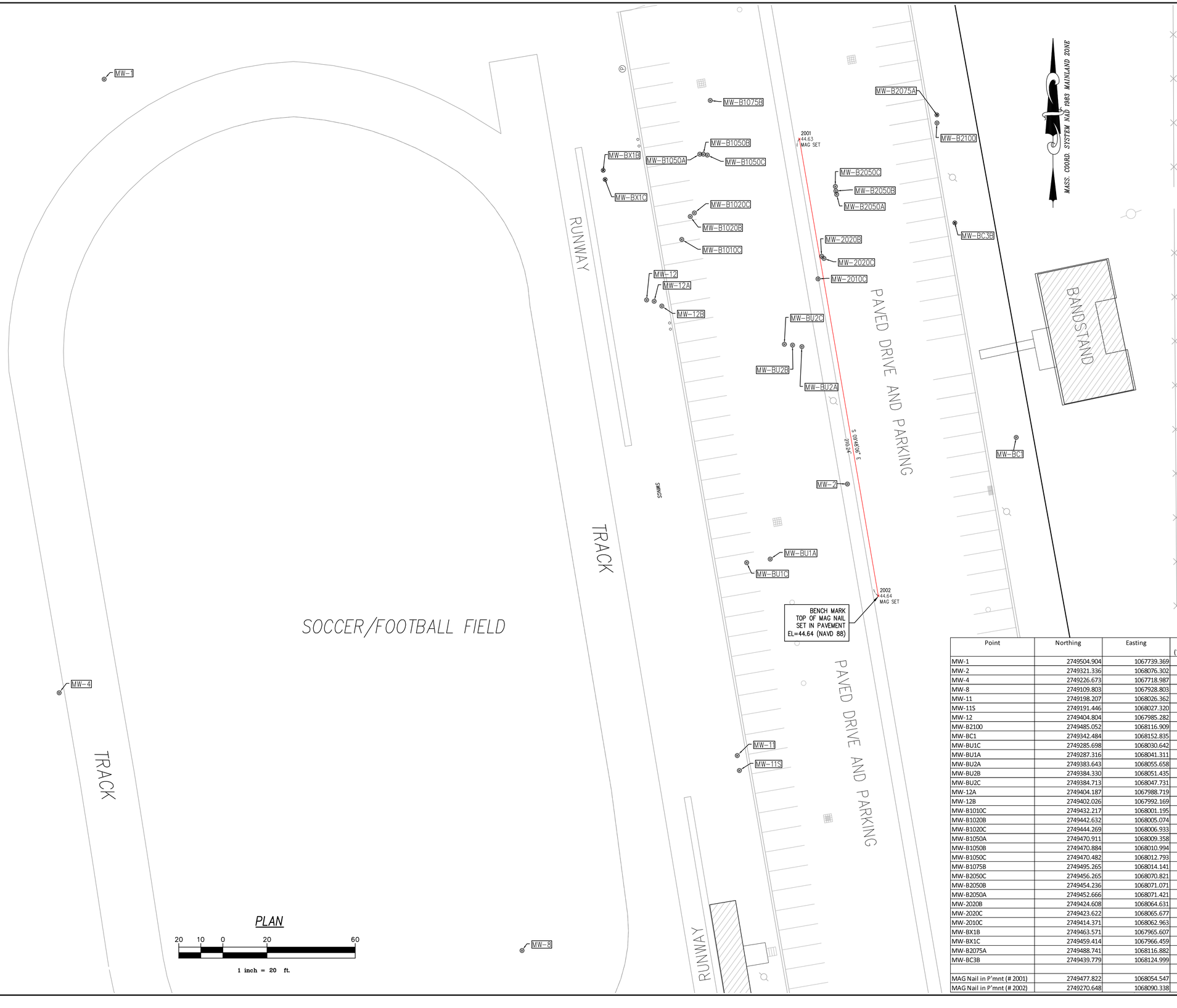

DATUM NOTE:

ELEVATIONS SHOWN HEREON ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 1988)

LEGEND

EXISTING

- CATCH BASIN
- DRAIN MANHOLE
- MONITORING WELL
- POST
- UTILITY POLE

Point	Northing	Easting	Elevation (Top of Casing)	Elevation (Ground)
MW-1	2749504.904	1067739.369	41.31	40.8
MW-2	2749321.336	1068076.302	44.82	44.6
MW-4	2749226.673	1067718.987	46.57	46.1
MW-8	2749109.803	1067928.803	46.16	46.9
MW-11	2749198.207	1068026.362	45.14	45.4
MW-11S	2749191.446	1068027.320	45.25	45.4
MW-12	2749404.804	1067985.282	46.61	45.6
MW-B2100	2749485.052	1068116.909	44.23	44.6
MW-BC1	2749342.484	1068152.835	42.14	42.5
MW-BU1C	2749285.698	1068030.642	43.65	44.0
MW-BU1A	2749287.316	1068041.311	43.48	43.7
MW-BU2A	2749383.643	1068055.658	44.56	45.1
MW-BU2B	2749384.330	1068051.435	44.70	45.1
MW-BU2C	2749384.713	1068047.731	44.68	45.1
MW-12A	2749404.187	1067988.719	45.11	45.6
MW-12B	2749402.026	1067992.169	45.18	45.6
MW-B1010C	2749432.217	1068001.195	44.46	44.9
MW-B1020B	2749442.632	1068005.074	44.18	44.6
MW-B1020C	2749444.269	1068006.933	44.10	44.5
MW-B1050A	2749470.911	1068009.358	43.42	43.9
MW-B1050B	2749470.884	1068010.994	43.54	43.9
MW-B1050C	2749470.482	1068012.793	43.55	44.9
MW-B1075B	2749495.265	1068014.141	43.29	43.5
MW-B2050C	2749456.265	1068070.821	44.17	44.6
MW-B2050B	2749454.236	1068071.071	44.28	44.6
MW-B2050A	2749452.666	1068071.421	44.06	44.6
MW-2020B	2749424.608	1068064.631	44.50	44.9
MW-2020C	2749423.622	1068065.677	44.45	44.8
MW-2010C	2749414.371	1068062.963	44.70	45.0
MW-BX1B	2749463.571	1067965.607	45.38	45.6
MW-BX1C	2749459.414	1067966.459	45.37	45.7
MW-B2075A	2749488.741	1068116.882	44.23	44.6
MW-BC3B	2749439.779	1068124.999	43.86	44.2
MAG Nail in P'mnt (# 2001)	2749477.822	1068054.547		44.63
MAG Nail in P'mnt (# 2002)	2749270.648	1068090.338		44.64

COASTAL engineering co.
260 Cranberry Hwy, Orleans, MA 02653
508.255.6511 P 508.255.6700 F

NO.	DATE	REVISION	BY

SEAL

PROJECT
AECOM
NAUSET REGIONAL MIDDLE SCHOOL - OFF ELDGREDGE PARK WAY ORLEANS, MA

SHEET TITLE
WELL PLAN OF LAND
SHOWING MONITOR WELL LOCATIONS

SCALE AS NOTED
DRAWING FILE C18470-C3D-NRMS.dwg
DATE REV 4/20/2017 ~~1/26/2017~~
DRAWN BY BPM
CHECKED BY

SKC-5

⊥ OF ⊥ SHEETS

PROJECT NO. C18470.00

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Appendix B

Analytical Laboratory Reports

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CERTIFICATE OF ANALYSIS

Mark Owen
AECOM Environment - ENSR
9 Jonathon Bourne Dr.
Pocasset, MA 02559

RE: Orleans MA (60476644)
ESS Laboratory Work Order Number: 1706748

This signed Certificate of Analysis is our approved release of your analytical results. These results are only representative of sample aliquots received at the laboratory. ESS Laboratory expects its clients to follow all regulatory sampling guidelines. Beginning with this page, the entire report has been paginated. This report should not be copied except in full without the approval of the laboratory. Samples will be disposed of thirty days after the final report has been delivered. If you have any questions or concerns, please feel free to call our Customer Service Department.

Laurel Stoddard
Laboratory Director

REVIEWED
By ESS Laboratory at 12:51 pm, Jul 07, 2017

Analytical Summary
The project as described above has been analyzed in accordance with the ESS Quality Assurance Plan. This plan utilizes the following methodologies: US EPA SW-846, US EPA Methods for Chemical Analysis of Water and Wastes per 40 CFR Part 136, APHA Standard Methods for the Examination of Water and Wastewater, American Society for Testing and Materials (ASTM), and other recognized methodologies. The analyses with these noted observations are in conformance to the Quality Assurance Plan. In chromatographic analysis, manual integration is frequently used instead of automated integration because it produces more accurate results.

The test results present in this report are in compliance with TNI and relative state standards, and/or client Quality Assurance Project Plans (QAPP). The laboratory has reviewed the following: Sample Preservations, Hold Times, Initial Calibrations, Continuing Calibrations, Method Blanks, Blank Spikes, Blank Spike Duplicates, Duplicates, Matrix Spikes, Matrix Spike Duplicates, Surrogates and Internal Standards. Any results which were found to be outside of the recommended ranges stated in our SOPs will be noted in the Project Narrative.

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706748

SAMPLE RECEIPT

The following samples were received on June 28, 2017 for the analyses specified on the enclosed Chain of Custody Record.

The samples and analyses listed below were analyzed in accordance with the Guidelines Establishing Test Procedures for the Analysis of Pollutants, 40 CFR Part 136, as amended.

Lab Number	Sample Name	Matrix	Analysis
1706748-01	MW-B2050A	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706748-02	MW-B2050B	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706748-03	MW-B2050C	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706748-04	MW-B2020B	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706748-05	MW-B2020C	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706748-06	MW-B2010C	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250, RSK175
1706748-07	MW-12A	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706748-08	MW-12B	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706748-09	MW-B1010C	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250, RSK175
1706748-10	MW-B1020B	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706748-11	MW-B1020C	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706748-12	MW-BX1B	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706748-13	MW-BX1C	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706748

PROJECT NARRATIVE

No unusual observations noted.

End of Project Narrative.

DATA USABILITY LINKS

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Definitions of Quality Control Parameters

Semivolatile Organics Internal Standard Information

Semivolatile Organics Surrogate Information

Volatile Organics Internal Standard Information

Volatile Organics Surrogate Information

EPH and VPH Alkane Lists

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706748

CURRENT SW-846 METHODOLOGY VERSIONS

Analytical Methods

1010A - Flashpoint
6010C - ICP
6020A - ICP MS
7010 - Graphite Furnace
7196A - Hexavalent Chromium
7470A - Aqueous Mercury
7471B - Solid Mercury
8011 - EDB/DBCP/TCP
8015C - GRO/DRO
8081B - Pesticides
8082A - PCB
8100M - TPH
8151A - Herbicides
8260B - VOA
8270D - SVOA
8270D SIM - SVOA Low Level
9014 - Cyanide
9038 - Sulfate
9040C - Aqueous pH
9045D - Solid pH (Corrosivity)
9050A - Specific Conductance
9056A - Anions (IC)
9060A - TOC
9095B - Paint Filter
MADEP 04-1.1 - EPH / VPH

Prep Methods

3005A - Aqueous ICP Digestion
3020A - Aqueous Graphite Furnace / ICP MS Digestion
3050B - Solid ICP / Graphite Furnace / ICP MS Digestion
3060A - Solid Hexavalent Chromium Digestion
3510C - Separatory Funnel Extraction
3520C - Liquid / Liquid Extraction
3540C - Manual Soxhlet Extraction
3541 - Automated Soxhlet Extraction
3546 - Microwave Extraction
3580A - Waste Dilution
5030B - Aqueous Purge and Trap
5030C - Aqueous Purge and Trap
5035 - Solid Purge and Trap

SW846 Reactivity Methods 7.3.3.2 (Reactive Cyanide) and 7.3.4.1 (Reactive Sulfide) have been withdrawn by EPA. These methods are reported per client request and are not NELAP accredited.

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2050A
Date Sampled: 06/28/17 10:15
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-01
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	06/29/17 21:52	10	10	CF72806
Manganese	**0.260** (0.020)		200.7		1	KJK	06/29/17 21:52	10	10	CF72806

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2050A
Date Sampled: 06/28/17 10:15
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-01
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	**1.00** (0.10)		350.1		1	JLK	06/30/17 20:47	mg/L	CF72952
Chloride	**66.8** (3.0)		9250		1	EEM	07/03/17 13:57	mg/L	CG70316
Dissolved Organic Carbon (Average)	**1.37** (0.500)		5310B		1	CRR	07/05/17 9:54	mg/L	[CALC]
Nitrate as N	**32.8** (1.01)		353.2		50	JLK	06/29/17 21:51	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/29/17 20:23	mg/L	CF72941
Sulfate	**7.5** (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**35.4** (1.20)		4500N		50	JLK	07/03/17 16:42	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2050B
Date Sampled: 06/28/17 10:40
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-02
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	06/29/17 22:09	10	10	CF72806
Manganese	**0.258** (0.020)		200.7		1	KJK	06/29/17 22:09	10	10	CF72806

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2050B
Date Sampled: 06/28/17 10:40
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-02
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	06/30/17 20:48	mg/L	CF72952
Chloride	**124** (15.0)		9250		5	EEM	07/03/17 14:28	mg/L	CG70316
Dissolved Organic Carbon (Average)	**0.754** (0.500)		5310B		1	CRR	07/03/17 18:06	mg/L	[CALC]
Nitrate as N	**5.27** (0.210)		353.2		10	JLK	06/29/17 21:39	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/29/17 20:26	mg/L	CF72941
Sulfate	**11.0** (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**5.91** (0.40)		4500N		10	JLK	07/03/17 16:45	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2050C
Date Sampled: 06/28/17 11:05
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-03
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	06/29/17 22:13	10	10	CF72806
Manganese	**0.130** (0.020)		200.7		1	KJK	06/29/17 22:13	10	10	CF72806

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2050C
Date Sampled: 06/28/17 11:05
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-03
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	**0.12** (0.10)		350.1		1	JLK	06/30/17 20:49	mg/L	CF72952
Chloride	**253** (30.0)		9250		10	EEM	07/03/17 14:29	mg/L	CG70316
Dissolved Organic Carbon (Average)	**0.639** (0.500)		5310B		1	CRR	07/03/17 18:18	mg/L	[CALC]
Nitrate as N	**3.05** (0.110)		353.2		5	JLK	06/29/17 21:40	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/29/17 20:27	mg/L	CF72941
Sulfate	**10.1** (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**3.75** (0.30)		4500N		5	JLK	07/03/17 16:46	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2020B
Date Sampled: 06/28/17 11:30
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-04
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	06/29/17 22:17	10	10	CF72806
Manganese	**0.029** (0.020)		200.7		1	KJK	06/29/17 22:17	10	10	CF72806

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2020B
Date Sampled: 06/28/17 11:30
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-04
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	06/30/17 20:49	mg/L	CF72952
Chloride	**39.3** (3.0)		9250		1	EEM	07/03/17 14:07	mg/L	CG70316
Dissolved Organic Carbon (Average)	**3.47** (0.500)		5310B		1	CRR	07/03/17 18:30	mg/L	[CALC]
Nitrate as N	**22.4** (1.01)		353.2		50	JLK	06/29/17 21:54	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/29/17 20:28	mg/L	CF72941
Sulfate	**6.4** (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**24.2** (1.20)		4500N		50	JLK	07/03/17 16:46	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2020C
Date Sampled: 06/28/17 11:50
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-05
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	**7.97** (0.100)		200.7		1	KJK	06/29/17 22:22	10	10	CF72806
Manganese	**0.964** (0.020)		200.7		1	KJK	06/29/17 22:22	10	10	CF72806

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2020C
Date Sampled: 06/28/17 11:50
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-05
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	06/30/17 20:50	mg/L	CF72952
Chloride	**32.2** (3.0)		9250		1	EEM	07/03/17 14:08	mg/L	CG70316
Dissolved Organic Carbon (Average)	**23.3** (2.50)		5310B		5	CRR	07/05/17 10:07	mg/L	[CALC]
Nitrate as N	**0.457** (0.030)		353.2		1	JLK	06/29/17 21:12	mg/L	[CALC]
Nitrite as N	**0.072** (0.010)		353.2		1	JLK	06/29/17 20:29	mg/L	CF72941
Sulfate	**36.8** (10.0)		9038		2	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**0.85** (0.22)		4500N		1	JLK	07/03/17 16:47	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2010C
Date Sampled: 06/28/17 12:15
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-06
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	**24.2** (0.100)		200.7		1	KJK	06/29/17 22:26	10	10	CF72806
Manganese	**1.62** (0.020)		200.7		1	KJK	06/29/17 22:26	10	10	CF72806

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2010C
Date Sampled: 06/28/17 12:15
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-06
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	**0.24** (0.10)		350.1		1	JLK	06/30/17 20:51	mg/L	CF72952
Chloride	**30.0** (3.0)		9250		1	EEM	07/03/17 14:09	mg/L	CG70316
Dissolved Organic Carbon (Average)	**83.3** (5.00)		5310B		10	CRR	07/05/17 10:20	mg/L	[CALC]
Nitrate as N	**5.74** (0.210)		353.2		10	JLK	06/29/17 21:42	mg/L	[CALC]
Nitrite as N	**0.128** (0.010)		353.2		1	JLK	06/29/17 20:30	mg/L	CF72941
Sulfate	**39.8** (10.0)		9038		2	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**7.69** (0.40)		4500N		10	JLK	07/03/17 16:48	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2010C
Date Sampled: 06/28/17 12:15
Percent Solids: N/A
Initial Volume: 1
Final Volume: 1
Extraction Method: No Prep

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-06
Sample Matrix: Ground Water
Units: ug/L
Analyst: ZLC
Prepared: 7/6/17 12:00

All methods used are in accordance with 40 CFR 136.

Methane / Ethane / Ethene by Headspace GCFID (RSK175)

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Sequence	Batch
Methane	**11.3** (2.0)		RSK175		1	ZLC	07/06/17 17:07	C7G0066	CG70616

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-12A
Date Sampled: 06/28/17 13:45
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-07
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	06/29/17 22:42	10	10	CF72806
Manganese	ND (0.020)		200.7		1	KJK	06/29/17 22:42	10	10	CF72806

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-12A
Date Sampled: 06/28/17 13:45
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-07
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	06/30/17 20:52	mg/L	CF72952
Chloride	**154** (15.0)		9250		5	EEM	07/03/17 14:31	mg/L	CG70316
Dissolved Organic Carbon (Average)	**2.16** (0.500)		5310B		1	CRR	07/03/17 19:35	mg/L	[CALC]
Nitrate as N	**0.786** (0.030)		353.2		1	JLK	06/29/17 21:16	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/29/17 20:32	mg/L	CF72941
Sulfate	**12.6** (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**0.79** (0.22)		4500N		1	JLK	07/03/17 16:48	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-12B
Date Sampled: 06/28/17 14:15
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-08
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	06/29/17 22:46	10	10	CF72806
Manganese	ND (0.020)		200.7		1	KJK	06/29/17 22:46	10	10	CF72806

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-12B
Date Sampled: 06/28/17 14:15
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-08
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	**0.12** (0.10)		350.1		1	JLK	06/30/17 20:53	mg/L	CF72952
Chloride	**48.9** (3.0)		9250		1	EEM	07/03/17 14:11	mg/L	CG70316
Dissolved Organic Carbon (Average)	**1.02** (0.500)		5310B		1	CRR	07/03/17 19:47	mg/L	[CALC]
Nitrate as N	**6.19** (0.210)		353.2		10	JLK	06/29/17 21:43	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/29/17 20:33	mg/L	CF72941
Sulfate	**9.2** (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**6.83** (0.40)		4500N		10	JLK	07/03/17 16:49	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1010C
Date Sampled: 06/28/17 14:45
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-09
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	**0.143** (0.100)		200.7		1	KJK	06/29/17 22:51	10	10	CF72806
Manganese	**0.324** (0.020)		200.7		1	KJK	06/29/17 22:51	10	10	CF72806

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1010C
Date Sampled: 06/28/17 14:45
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-09
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	06/30/17 20:53	mg/L	CF72952
Chloride	**24.2** (3.0)		9250		1	EEM	07/03/17 14:12	mg/L	CG70316
Dissolved Organic Carbon (Average)	**16.9** (0.500)		5310B		1	CRR	07/03/17 20:01	mg/L	[CALC]
Nitrate as N	**13.8** (0.410)		353.2		20	JLK	06/29/17 21:55	mg/L	[CALC]
Nitrite as N	**0.171** (0.010)		353.2		1	JLK	06/29/17 20:34	mg/L	CF72941
Sulfate	**11.0** (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**15.7** (0.60)		4500N		20	JLK	07/03/17 16:50	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1010C
Date Sampled: 06/28/17 14:45
Percent Solids: N/A
Initial Volume: 1
Final Volume: 1
Extraction Method: No Prep

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-09
Sample Matrix: Ground Water
Units: ug/L
Analyst: ZLC
Prepared: 7/6/17 12:00

All methods used are in accordance with 40 CFR 136.

Methane / Ethane / Ethene by Headspace GCFID (RSK175)

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Sequence	Batch
Methane	ND (2.0)		RSK175		1	ZLC	07/06/17 17:13	C7G0066	CG70616

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1020B
Date Sampled: 06/28/17 15:20
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-10
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	06/29/17 22:55	10	10	CF72806
Manganese	**0.333** (0.020)		200.7		1	KJK	06/29/17 22:55	10	10	CF72806

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1020B
Date Sampled: 06/28/17 15:20
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-10
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	06/30/17 20:54	mg/L	CF72952
Chloride	**32.3** (3.0)		9250		1	EEM	07/03/17 14:13	mg/L	CG70316
Dissolved Organic Carbon (Average)	**3.24** (0.500)		5310B		1	CRR	07/03/17 20:13	mg/L	[CALC]
Nitrate as N	**24.9** (1.01)		353.2		50	JLK	06/29/17 21:56	mg/L	[CALC]
Nitrite as N	**0.158** (0.010)		353.2		1	JLK	06/29/17 20:35	mg/L	CF72941
Sulfate	ND (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**27.1** (1.20)		4500N		50	JLK	07/03/17 16:51	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1020C
Date Sampled: 06/28/17 15:55
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-11
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	06/29/17 22:59	10	10	CF72806
Manganese	**0.057** (0.020)		200.7		1	KJK	06/29/17 22:59	10	10	CF72806

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1020C
Date Sampled: 06/28/17 15:55
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-11
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	06/30/17 20:57	mg/L	CF72952
Chloride	**24.8** (3.0)		9250		1	EEM	07/03/17 14:21	mg/L	CG70316
Dissolved Organic Carbon (Average)	**1.34** (0.500)		5310B		1	CRR	07/03/17 20:25	mg/L	[CALC]
Nitrate as N	**13.9** (0.410)		353.2		20	JLK	06/29/17 21:57	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/29/17 20:36	mg/L	CF72941
Sulfate	**5.8** (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**15.0** (0.60)		4500N		20	JLK	07/03/17 16:51	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-BX1B
Date Sampled: 06/28/17 16:15
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-12
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	06/29/17 23:03	10	10	CF72806
Manganese	**0.478** (0.020)		200.7		1	KJK	06/29/17 23:03	10	10	CF72806

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-BX1B
Date Sampled: 06/28/17 16:15
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-12
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	**0.70** (0.10)		350.1		1	JLK	06/30/17 20:59	mg/L	CF72952
Chloride	**41.0** (3.0)		9250		1	EEM	07/03/17 14:22	mg/L	CG70316
Dissolved Organic Carbon (Average)	**1.55** (0.500)		5310B		1	CRR	07/03/17 21:03	mg/L	[CALC]
Nitrate as N	**34.4** (1.01)		353.2		50	JLK	06/29/17 22:00	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/29/17 20:37	mg/L	CF72941
Sulfate	ND (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**37.0** (1.20)		4500N		50	JLK	07/03/17 16:54	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-BX1C
Date Sampled: 06/28/17 16:40
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-13
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	06/29/17 23:07	10	10	CF72806
Manganese	**0.517** (0.020)		200.7		1	KJK	06/29/17 23:07	10	10	CF72806

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-BX1C
Date Sampled: 06/28/17 16:40
Percent Solids: N/A

ESS Laboratory Work Order: 1706748
ESS Laboratory Sample ID: 1706748-13
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	**0.50** (0.10)		350.1		1	JLK	06/30/17 21:00	mg/L	CF72952
Chloride	**40.8** (3.0)		9250		1	EEM	07/03/17 14:23	mg/L	CG70316
Dissolved Organic Carbon (Average)	**2.02** (0.500)		5310B		1	CRR	07/03/17 21:15	mg/L	[CALC]
Nitrate as N	**38.7** (2.01)		353.2		100	JLK	06/29/17 22:01	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/29/17 20:38	mg/L	CF72941
Sulfate	ND (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**42.0** (2.20)		4500N		100	JLK	07/03/17 16:55	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706748

Quality Control Data

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Qualifier
Dissolved Metals										
Batch CF72806 - 200.7/6010BNoDigest										
Blank										
Iron	ND	0.100	mg/L							
Manganese	ND	0.020	mg/L							
Blank										
Iron	ND	0.100	mg/L							
Manganese	ND	0.020	mg/L							
LCS										
Iron	2.47		mg/L	2.500		99	80-120			
Manganese	0.512		mg/L	0.5000		102	80-120			
Classical Chemistry										
Batch CF72941 - [CALC]										
Blank										
Nitrate as N	ND	0.010	mg/L							
Nitrite as N	ND	0.010	mg/L							
Nitrite as N	ND	0.010	mg/L							
LCS										
Nitrate as N	ND		mg/L							
Nitrite as N	0.251		mg/L	0.2497		100	90-110			
Nitrite as N	0.251		mg/L	0.2497		100	90-110			
Batch CF72942 - [CALC]										
Blank										
Nitrate as N	ND	0.020	mg/L							
Nitrate/Nitrite as N	ND	0.020	mg/L							
Nitrate/Nitrite as N	ND	0.020	mg/L							
Total Nitrogen	ND	0.02	mg/L							
LCS										
Nitrate as N	0.497		mg/L							
Nitrate/Nitrite as N	0.497		mg/L	0.5000		99	90-110			
Nitrate/Nitrite as N	0.497		mg/L	0.5000		99	90-110			
Total Nitrogen	0.497		mg/L							
Batch CF72952 - NH4 Prep										
Blank										
Ammonia as N	ND	0.10	mg/L							
LCS										
Ammonia as N	0.12	0.10	mg/L	0.09994		117	80-120			
LCS										
Ammonia as N	0.99	0.10	mg/L	0.9994		99	80-120			
Batch CF73003 - TKN Prep										
Blank										
Total Kjeldahl Nitrogen as N	ND	0.20	mg/L							
Total Nitrogen	ND	0.20	mg/L							

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706748

Quality Control Data

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Qualifier
Classical Chemistry										
Batch CF73003 - TKN Prep										
LCS										
Total Kjeldahl Nitrogen as N	10.6	2.00	mg/L	9.430		113	80-120			
Total Nitrogen	10.6	2.00	mg/L							
Batch CG70316 - General Preparation										
Blank										
Chloride	ND	3.0	mg/L							
LCS										
Chloride	29.7		mg/L	30.00		99	90-110			
Batch CG70327 - General Preparation										
Blank										
Dissolved Organic Carbon (1)	ND	0.500	mg/L							
Dissolved Organic Carbon (2)	ND	0.500	mg/L							
Dissolved Organic Carbon (Average)	ND	0.500	mg/L							
LCS										
Dissolved Organic Carbon (1)	5.23	0.500	mg/L	5.000		105	80-120			
Dissolved Organic Carbon (2)	5.54	0.500	mg/L	5.000		111	80-120			
Dissolved Organic Carbon (Average)	5.39	0.500	mg/L							
LCS Dup										
Dissolved Organic Carbon (1)	5.38	0.500	mg/L	5.000		108	80-120	3	200	
Dissolved Organic Carbon (2)	5.62	0.500	mg/L	5.000		112	80-120	1	200	
Dissolved Organic Carbon (Average)	5.50	0.500	mg/L							
Batch CG70343 - General Preparation										
Blank										
Sulfate	ND	5.0	mg/L							
LCS										
Sulfate	9.6		mg/L	9.988		96	85-115			
Methane / Ethane / Ethene by Headspace GCFID (RSK175)										
Batch CG70616 - No Prep										
Blank										
Methane	ND	2.0	ug/L							
LCS										
Methane	23.9		ug/L	36.00		66	60-140			
LCS Dup										
Methane	22.0		ug/L	36.00		61	60-140	9	30	

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706748

Notes and Definitions

U	Analyte included in the analysis, but not detected
D	Diluted.
ND	Analyte NOT DETECTED at or above the MRL (LOQ), LOD for DoD Reports, MDL for J-Flagged Analytes
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference
MDL	Method Detection Limit
MRL	Method Reporting Limit
LOD	Limit of Detection
LOQ	Limit of Quantitation
DL	Detection Limit
I/V	Initial Volume
F/V	Final Volume
§	Subcontracted analysis; see attached report
1	Range result excludes concentrations of surrogates and/or internal standards eluting in that range.
2	Range result excludes concentrations of target analytes eluting in that range.
3	Range result excludes the concentration of the C9-C10 aromatic range.
Avg	Results reported as a mathematical average.
NR	No Recovery
[CALC]	Calculated Analyte
SUB	Subcontracted analysis; see attached report
RL	Reporting Limit
EDL	Estimated Detection Limit

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706748

ESS LABORATORY CERTIFICATIONS AND ACCREDITATIONS

ENVIRONMENTAL

Rhode Island Potable and Non Potable Water: LAI00179
http://www.health.ri.gov/find/labs/analytical/ESS.pdf

Connecticut Potable and Non Potable Water, Solid and Hazardous Waste: PH-0750
http://www.ct.gov/dph/lib/dph/environmental_health/environmental_laboratories/pdf/OutofStateCommercialLaboratories.pdf

Maine Potable and Non Potable Water, and Solid and Hazardous Waste: RI00002
http://www.maine.gov/dhhs/mecdc/environmental-health/dwp/partners/labCert.shtml

Massachusetts Potable and Non Potable Water: M-RI002
http://public.dep.state.ma.us/Labcert/Labcert.aspx

New Hampshire (NELAP accredited) Potable and Non Potable Water, Solid and Hazardous Waste: 2424
http://des.nh.gov/organization/divisions/water/dwgb/nhelap/index.htm

New York (NELAP accredited) Non Potable Water, Solid and Hazardous Waste: 11313
http://www.wadsworth.org/labcert/elap/comm.html

New Jersey (NELAP accredited) Non Potable Water, Solid and Hazardous Waste: RI006
http://datamine2.state.nj.us/DEP_OPRA/OpraMain/pi_main?mode=pi_by_site&sort_order=PI_NAMEA&Select+a+Site:=58715

United States Department of Agriculture Soil Permit: P330-12-00139

Pennsylvania: 68-01752
http://www.dep.pa.gov/Business/OtherPrograms/Labs/Pages/Laboratory-Accreditation-Program.aspx

ESS Laboratory

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185 Frances Avenue, Cranston RI 02910
Tel. (401) 461-7181 Fax (401) 461-4486
www.esslaboratory.com

CHAIN OF CUSTODY

ESS Lab # 1706748

Turn Time: 5-Day Rush
Regulatory State
Is this project for any of the following?: ○CT RCP ○MA MCP ○RGP
Reporting Limits
Electonic Deliverables: ☐Limit Checker ☐Standard Excel ☐Other (Please Specify →)

Company Name	Project #	Project Name
AECOM	60476644	Orleans PRB
Contact Person	**Address**	
Julianne Marion	250 Apollo Drive	
City	**State**	**Zip Code** / **PO #**
Chelmsford	MA	
Telephone Number	**FAX Number**	**Email Address**
978-905-2419		Julianne.marion@aecom.com

ESS Lab ID	Collection Date	Collection Time	Sample Type	Sample Matrix	Sample ID	Analysis: TN, Ammonia	NO_3, NO_2, SO_4, Cl	Diss Lab-Filtered, Mn	DOC	Methane											
1	06/28/17	10:15	G	GW	MW-B2050A	X	X	X	X												
2	06/28/17	10:40	G	GW	MW-B2050B	X	X	X	X												
3	06/28/17	11:06	G	GW	MW-B2050C	X	X	X	X												
4	06/28/17	11:30	G	GW	MW-B2020B	X	X	X	X												
5	06/28/17	11:50	G	GW	MW-B2020C	X	X	X	X												
6	06/28/17	12:15	G	GW	MW-B2010C	X	X	X	X	X											
7	06/28/17	13:45	G	GW	MW-12A	X	X	X	X												
8	06/28/17	14:15	G	GW	MW-12B	X	X	X	X												
9	06/28/17	14:45	G	GW	MW-B1010C	X	X	X	X	X											
10	06/28/17	15:20	G	GW	MW-B1020B	X	X	X	X												
Container Type: AC-Air Cassette AG-Amber Glass B-BOD Bottle C-Cubitainer G - Glass O-Other P-Poly S-Sterile V-Vial						P	P	P	AG	V											
Container Volume: 1-100 mL 2-2.5 gal 3-250 mL 4-300 mL 5-500 mL 6-1L 7-VOA 8-2 oz 9-4 oz 10-8 oz 11-Other*						6	5	3	3	7											
Preservation Code: 1-Non Preserved 2-HCl 3-H2SO4 4-HNO3 5-NaOH 6-Methanol 7-Na2S2O3 8-ZnAce, NaOH 9-NH4Cl 10-DI H2O 11-Other*						3	1	1	1	2											
Number of Containers per Sample:						1	1	1	1	2											

Laboratory Use Only
Cooler Present: ✓
Seals Intact: ✓
Cooler Temperature: 1.2, 2.1, 1.8 °C Sample temp 19:47 6-28-17

Sampled by: Briley Morrill
Comments: Please specify "Other" preservative and containers types in this space

Relinquished by: (Signature, Date & Time)	Received By: (Signature, Date & Time)	Relinquished By: (Signature, Date & Time)	Received By: (Signature, Date & Time)
Briley Morrill 6-28-17 1835	6-28-17 18:35	6-28-17 19:47	6/28/17 1955
Relinquished by: (Signature, Date & Time)	Received By: (Signature, Date & Time)	Relinquished By: (Signature, Date & Time)	Received By: (Signature, Date & Time)

ESS Laboratory

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CHAIN OF CUSTODY

ESS Lab # 706748

Turn Time: 5-Day Rush

Regulatory State

Is this project for any of the following?: ○CT RCP ○MA MCP ○RGP

Reporting Limits

Electonic Deliverables: ☐Limit Checker ☐Standard Excel ☐Other (Please Specify →)

Company Name	Project #	Project Name
AECom	60476644	Orleans PRB

Contact Person	Address	
Julianne Mamon	250 Apollo DR	

City	State	Zip Code	PO #
Chelmsford	MA		

Telephone Number	FAX Number	Email Address
978-905-2419		Julianne.Mamon@aecom.com

ESS Lab ID	Collection Date	Collection Time	Sample Type	Sample Matrix	Sample ID	Analysis: TN, Ammonia	NO3, SO4, Cl	diss Lab Fe, Mn	DOC
11	06/28/17	15:55	G	GW	MW-B102OC	X	X	X	X
12	06/28/17	16:15	G	GW	MW-BX1B	X	X	X	X
13	06/28/17	16:40	G	GW	MW-BX1C	X	X	X	X

Container Type:	AC-Air Cassette	AG-Amber Glass	B-BOD Bottle	C-Cubitainer	G - Glass	O-Other	P-Poly	S-Sterile	V-Vial	P	P	P	AG
Container Volume:	1-100 mL	2-2.5 gal	3-250 mL	4-300 mL	5-500 mL	6-1L	7-VOA	8-2 oz	9-4 oz	10-8 oz	11-Other*	6	5	3	3
Preservation Code:	1-Non Preserved	2-HCl	3-H2SO4	4-HNO3	5-NaOH	6-Methanol	7-Na2S2O3	8-Zn... NaOH	9-NH4Cl	10-DI H2O	11-Other*	3	1	1	1
										Number of Containers per Sample:		1	1	1	1

Laboratory Use Only

Cooler Present: _____

Seals Intact: ✓

Cooler Temperature: 1.2 28.1 °C sample @ 19:47 temp 6-28-17

Sampled by :

Comments: Please specify "Other" preservative and containers types in this space

Relinquished by: (Signature, Date & Time)	Received By: (Signature, Date & Time)	Relinquished By: (Signature, Date & Time)	Received By: (Signature, Date & Time)
Brittey Merrill 6-28-17 1835	6-28-17 18:36	6-28-17 19:47	6/28/17 1955
Relinquished by: (Signature, Date & Time)	Received By: (Signature, Date & Time)	Relinquished By: (Signature, Date & Time)	Received By: (Signature, Date & Time)

CERTIFICATE OF ANALYSIS

Mark Owen
AECOM Environment - ENSR
9 Jonathon Bourne Dr.
Pocasset, MA 02559

RE: Orleans MA (60476644)
ESS Laboratory Work Order Number: 1706772

This signed Certificate of Analysis is our approved release of your analytical results. These results are only representative of sample aliquots received at the laboratory. ESS Laboratory expects its clients to follow all regulatory sampling guidelines. Beginning with this page, the entire report has been paginated. This report should not be copied except in full without the approval of the laboratory. Samples will be disposed of thirty days after the final report has been delivered. If you have any questions or concerns, please feel free to call our Customer Service Department.

Laurel Stoddard
Laboratory Director

REVIEWED
By ESS Laboratory at 2:53 pm, Jul 10, 2017

Analytical Summary
The project as described above has been analyzed in accordance with the ESS Quality Assurance Plan. This plan utilizes the following methodologies: US EPA SW-846, US EPA Methods for Chemical Analysis of Water and Wastes per 40 CFR Part 136, APHA Standard Methods for the Examination of Water and Wastewater, American Society for Testing and Materials (ASTM), and other recognized methodologies. The analyses with these noted observations are in conformance to the Quality Assurance Plan. In chromatographic analysis, manual integration is frequently used instead of automated integration because it produces more accurate results.

The test results present in this report are in compliance with TNI and relative state standards, and/or client Quality Assurance Project Plans (QAPP). The laboratory has reviewed the following: Sample Preservations, Hold Times, Initial Calibrations, Continuing Calibrations, Method Blanks, Blank Spikes, Blank Spike Duplicates, Duplicates, Matrix Spikes, Matrix Spike Duplicates, Surrogates and Internal Standards. Any results which were found to be outside of the recommended ranges stated in our SOPs will be noted in the Project Narrative.

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706772

SAMPLE RECEIPT

The following samples were received on June 29, 2017 for the analyses specified on the enclosed Chain of Custody Record.

The samples and analyses listed below were analyzed in accordance with the Guidelines Establishing Test Procedures for the Analysis of Pollutants, 40 CFR Part 136, as amended.

Lab Number	Sample Name	Matrix	Analysis
1706772-01	MW-B2100C	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706772-02	MW-B2075A	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706772-03	EP Irrigation Well	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 8270D SIM, 9038, 9250
1706772-04	MW-BC3B	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706772-05	MW-BU2A	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706772-06	MW-BU2B	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706772-07	MW-BU2C	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706772-08	MW-B1050C	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706772-09	MW-B1050B	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706772-10	MW-B1050A	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706772-11	MW-B1075B	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250
1706772-12	NW-B2C2	Ground Water	200.7, 350.1, 353.2, 4500N, 5310B, 9038, 9250

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706772

PROJECT NARRATIVE

No unusual observations noted.

End of Project Narrative.

DATA USABILITY LINKS

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Definitions of Quality Control Parameters

Semivolatile Organics Internal Standard Information

Semivolatile Organics Surrogate Information

Volatile Organics Internal Standard Information

Volatile Organics Surrogate Information

EPH and VPH Alkane Lists

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706772

CURRENT SW-846 METHODOLOGY VERSIONS

Analytical Methods

1010A - Flashpoint
6010C - ICP
6020A - ICP MS
7010 - Graphite Furnace
7196A - Hexavalent Chromium
7470A - Aqueous Mercury
7471B - Solid Mercury
8011 - EDB/DBCP/TCP
8015C - GRO/DRO
8081B - Pesticides
8082A - PCB
8100M - TPH
8151A - Herbicides
8260B - VOA
8270D - SVOA
8270D SIM - SVOA Low Level
9014 - Cyanide
9038 - Sulfate
9040C - Aqueous pH
9045D - Solid pH (Corrosivity)
9050A - Specific Conductance
9056A - Anions (IC)
9060A - TOC
9095B - Paint Filter
MADEP 04-1.1 - EPH / VPH

Prep Methods

3005A - Aqueous ICP Digestion
3020A - Aqueous Graphite Furnace / ICP MS Digestion
3050B - Solid ICP / Graphite Furnace / ICP MS Digestion
3060A - Solid Hexavalent Chromium Digestion
3510C - Separatory Funnel Extraction
3520C - Liquid / Liquid Extraction
3540C - Manual Soxhlet Extraction
3541 - Automated Soxhlet Extraction
3546 - Microwave Extraction
3580A - Waste Dilution
5030B - Aqueous Purge and Trap
5030C - Aqueous Purge and Trap
5035 - Solid Purge and Trap

SW846 Reactivity Methods 7.3.3.2 (Reactive Cyanide) and 7.3.4.1 (Reactive Sulfide) have been withdrawn by EPA. These methods are reported per client request and are not NELAP accredited.

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2100C
Date Sampled: 06/29/17 09:20
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-01
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	07/01/17 19:57	10	10	CF73019
Manganese	**0.114** (0.020)		200.7		1	KJK	07/01/17 19:57	10	10	CF73019

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2100C
Date Sampled: 06/29/17 09:20
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-01
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	07/06/17 16:30	mg/L	CG70531
Chloride	**96.4** (3.0)		9250		1	EEM	07/03/17 14:24	mg/L	CG70316
Dissolved Organic Carbon (Average)	**0.959** (0.500)		5310B		1	CRR	07/03/17 21:39	mg/L	[CALC]
Nitrate as N	**0.724** (0.030)		353.2		1	JLK	06/30/17 17:44	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/30/17 16:37	mg/L	CF73034
Sulfate	**10.0** (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**0.724** (0.220)		4500N		1	EEM	07/06/17 11:50	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2075A
Date Sampled: 06/29/17 10:35
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-02
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	07/01/17 20:14	10	10	CF73019
Manganese	**0.062** (0.020)		200.7		1	KJK	07/01/17 20:14	10	10	CF73019

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B2075A
Date Sampled: 06/29/17 10:35
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-02
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	07/06/17 16:30	mg/L	CG70531
Chloride	**214** (30.0)		9250		10	EEM	07/03/17 14:36	mg/L	CG70316
Dissolved Organic Carbon (Average)	**0.668** (0.500)		5310B		1	CRR	07/03/17 21:52	mg/L	[CALC]
Nitrate as N	**0.539** (0.030)		353.2		1	JLK	06/30/17 17:47	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/30/17 16:40	mg/L	CF73034
Sulfate	ND (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**0.779** (0.220)		4500N		1	EEM	07/06/17 11:52	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: EP Irrigation Well
Date Sampled: 06/29/17 09:45
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-03
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	07/01/17 20:18	10	10	CF73019
Manganese	ND (0.020)		200.7		1	KJK	07/01/17 20:18	10	10	CF73019

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: EP Irrigation Well
Date Sampled: 06/29/17 09:45
Percent Solids: N/A
Initial Volume: 500
Final Volume: 0.5
Extraction Method: 3535A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-03
Sample Matrix: Ground Water
Units: ug/L
Analyst: IBM
Prepared: 7/3/17 15:30

All methods used are in accordance with 40 CFR 136.

8270D(SIM) Semi-Volatile Organic Compounds w/ Isotope Dilution

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyzed	Sequence	Batch
1,4-Dioxane	ND (0.250)		8270D SIM		1	07/05/17 17:35	C7G0036	CG70351

	%Recovery	Qualifier	Limits
Surrogate: 1,4-Dioxane-d8	33 %		15-115

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: EP Irrigation Well
Date Sampled: 06/29/17 09:45
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-03
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	07/06/17 16:31	mg/L	CG70531
Chloride	**67.9** (3.0)		9250		1	EEM	07/03/17 14:26	mg/L	CG70316
Dissolved Organic Carbon (Average)	**0.599** (0.500)		5310B		1	CRR	07/05/17 10:23	mg/L	[CALC]
Nitrate as N	**3.15** (0.110)		353.2		5	JLK	06/30/17 18:09	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/30/17 16:41	mg/L	CF73034
Sulfate	**10.2** (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**3.15** (0.300)		4500N		5	EEM	07/06/17 11:53	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-BC3B
Date Sampled: 06/29/17 11:05
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-04
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	07/01/17 20:22	10	10	CF73019
Manganese	**0.077** (0.020)		200.7		1	KJK	07/01/17 20:22	10	10	CF73019

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-BC3B
Date Sampled: 06/29/17 11:05
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-04
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	07/06/17 16:32	mg/L	CG70531
Chloride	**161** (15.0)		9250		5	EEM	07/03/17 15:08	mg/L	CG70317
Dissolved Organic Carbon (Average)	**1.02** (0.500)		5310B		1	CRR	07/03/17 22:42	mg/L	[CALC]
Nitrate as N	**4.59** (0.410)		353.2		20	JLK	06/30/17 18:10	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/30/17 16:42	mg/L	CF73034
Sulfate	**6.8** (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**4.59** (0.600)		4500N		20	EEM	07/06/17 11:54	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-BU2A
Date Sampled: 06/29/17 11:45
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-05
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	07/01/17 20:27	10	10	CF73019
Manganese	ND (0.020)		200.7		1	KJK	07/01/17 20:27	10	10	CF73019

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-BU2A
Date Sampled: 06/29/17 11:45
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-05
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	07/06/17 16:34	mg/L	CG70531
Chloride	**120** (15.0)		9250		5	EEM	07/03/17 15:11	mg/L	CG70317
Dissolved Organic Carbon (Average)	ND (0.500)		5310B		1	CRR	07/03/17 22:54	mg/L	[CALC]
Nitrate as N	**0.408** (0.030)		353.2		1	JLK	06/30/17 17:50	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/30/17 16:43	mg/L	CF73034
Sulfate	ND (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**0.408** (0.220)		4500N		1	EEM	07/06/17 11:55	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-BU2B
Date Sampled: 06/29/17 12:10
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-06
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	07/01/17 20:31	10	10	CF73019
Manganese	ND (0.020)		200.7		1	KJK	07/01/17 20:31	10	10	CF73019

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-BU2B
Date Sampled: 06/29/17 12:10
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-06
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	07/06/17 16:37	mg/L	CG70531
Chloride	**88.3** (3.0)		9250		1	EEM	07/03/17 14:53	mg/L	CG70317
Dissolved Organic Carbon (Average)	**0.579** (0.500)		5310B		1	CRR	07/05/17 10:25	mg/L	[CALC]
Nitrate as N	**0.768** (0.030)		353.2		1	JLK	06/30/17 17:51	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/30/17 16:46	mg/L	CF73034
Sulfate	ND (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70343
Total Nitrogen	**0.768** (0.220)		4500N		1	EEM	07/06/17 11:55	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-BU2C
Date Sampled: 06/29/17 12:35
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-07
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	07/01/17 20:59	10	10	CF73019
Manganese	**0.081** (0.020)		200.7		1	KJK	07/01/17 20:59	10	10	CF73019

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-BU2C
Date Sampled: 06/29/17 12:35
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-07
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	07/06/17 16:37	mg/L	CG70531
Chloride	**146** (15.0)		9250		5	EEM	07/03/17 15:16	mg/L	CG70317
Dissolved Organic Carbon (Average)	**0.599** (0.500)		5310B		1	CRR	07/03/17 23:19	mg/L	[CALC]
Nitrate as N	**5.39** (0.410)		353.2		20	JLK	06/30/17 18:11	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/30/17 16:47	mg/L	CF73034
Sulfate	ND (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70344
Total Nitrogen	**5.39** (0.600)		4500N		20	EEM	07/06/17 12:02	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1050C
Date Sampled: 06/29/17 13:10
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-08
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	07/01/17 21:04	10	10	CF73019
Manganese	**0.057** (0.020)		200.7		1	KJK	07/01/17 21:04	10	10	CF73019

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1050C
Date Sampled: 06/29/17 13:10
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-08
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	07/06/17 16:38	mg/L	CG70531
Chloride	**134** (15.0)		9250		5	EEM	07/03/17 15:17	mg/L	CG70317
Dissolved Organic Carbon (Average)	**1.62** (0.500)		5310B		1	CRR	07/07/17 11:05	mg/L	[CALC]
Nitrate as N	**3.26** (0.110)		353.2		5	JLK	06/30/17 18:12	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/30/17 16:48	mg/L	CF73034
Sulfate	**15.2** (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70344
Total Nitrogen	**3.26** (0.300)		4500N		5	EEM	07/06/17 12:03	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1050B
Date Sampled: 06/29/17 13:35
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-09
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	07/01/17 21:08	10	10	CF73019
Manganese	**0.101** (0.020)		200.7		1	KJK	07/01/17 21:08	10	10	CF73019

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1050B
Date Sampled: 06/29/17 13:35
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-09
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	07/06/17 16:41	mg/L	CG70531
Chloride	**41.7** (3.0)		9250		1	EEM	07/03/17 14:56	mg/L	CG70317
Dissolved Organic Carbon (Average)	**1.31** (0.500)		5310B		1	CRR	07/06/17 15:16	mg/L	[CALC]
Nitrate as N	**18.2** (2.01)		353.2		100	JLK	06/30/17 18:13	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/30/17 16:49	mg/L	CF73034
Sulfate	ND (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70344
Total Nitrogen	**18.2** (2.20)		4500N		100	EEM	07/06/17 12:03	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1050A
Date Sampled: 06/29/17 13:55
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-10
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	07/01/17 21:12	10	10	CF73019
Manganese	**0.654** (0.020)		200.7		1	KJK	07/01/17 21:12	10	10	CF73019

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1050A
Date Sampled: 06/29/17 13:55
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-10
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	**0.57** (0.10)		350.1		1	JLK	07/06/17 16:41	mg/L	CG70531
Chloride	**48.9** (3.0)		9250		1	EEM	07/03/17 15:01	mg/L	CG70317
Dissolved Organic Carbon (Average)	**1.85** (0.500)		5310B		1	CRR	07/06/17 15:28	mg/L	[CALC]
Nitrate as N	**26.8** (2.01)		353.2		100	JLK	06/30/17 18:14	mg/L	[CALC]
Nitrite as N	**0.038** (0.010)		353.2		1	JLK	06/30/17 16:50	mg/L	CF73034
Sulfate	ND (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70344
Total Nitrogen	**26.8** (2.20)		4500N		100	EEM	07/06/17 12:04	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1075B
Date Sampled: 06/29/17 14:25
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-11
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	07/01/17 21:16	10	10	CF73019
Manganese	**0.111** (0.020)		200.7		1	KJK	07/01/17 21:16	10	10	CF73019

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: MW-B1075B
Date Sampled: 06/29/17 14:25
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-11
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	**11.0** (0.50)		350.1		5	JLK	07/06/17 16:49	mg/L	CG70531
Chloride	**170** (15.0)		9250		5	EEM	07/03/17 15:18	mg/L	CG70317
Dissolved Organic Carbon (Average)	**4.86** (0.500)		5310B		1	CRR	07/06/17 15:40	mg/L	[CALC]
Nitrate as N	**0.553** (0.030)		353.2		1	JLK	06/30/17 17:58	mg/L	[CALC]
Nitrite as N	**0.050** (0.010)		353.2		1	JLK	06/30/17 16:51	mg/L	CF73034
Sulfate	**28.9** (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70344
Total Nitrogen	**13.6** (2.02)		4500N		10	EEM	07/06/17 12:16	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: NW-B2C2
Date Sampled: 06/29/17 15:00
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-12
Sample Matrix: Ground Water
Units: mg/L

Extraction Method: 200.7/6010BNoDigest
All methods used are in accordance with 40 CFR 136.

Dissolved Metals

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	I/V	F/V	Batch
Iron	ND (0.100)		200.7		1	KJK	07/01/17 21:20	10	10	CF73019
Manganese	**0.062** (0.020)		200.7		1	KJK	07/01/17 21:20	10	10	CF73019

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA
Client Sample ID: NW-B2C2
Date Sampled: 06/29/17 15:00
Percent Solids: N/A

ESS Laboratory Work Order: 1706772
ESS Laboratory Sample ID: 1706772-12
Sample Matrix: Ground Water

All methods used are in accordance with 40 CFR 136.

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Ammonia as N	ND (0.10)		350.1		1	JLK	07/06/17 16:43	mg/L	CG70531
Chloride	**86.5** (3.0)		9250		1	EEM	07/03/17 15:04	mg/L	CG70317
Dissolved Organic Carbon (Average)	**1.68** (0.500)		5310B		1	CRR	07/07/17 10:15	mg/L	[CALC]
Nitrate as N	**3.42** (0.110)		353.2		5	JLK	06/30/17 18:15	mg/L	[CALC]
Nitrite as N	ND (0.010)		353.2		1	JLK	06/30/17 16:52	mg/L	CF73034
Sulfate	ND (5.0)		9038		1	JLK	07/03/17 16:30	mg/L	CG70344
Total Nitrogen	**3.42** (0.300)		4500N		5	EEM	07/06/17 12:06	mg/L	[CALC]

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706772

Quality Control Data

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Qualifier
Dissolved Metals										
Batch CF73019 - 200.7/6010BNoDigest										
Blank										
Iron	ND	0.100	mg/L							
Manganese	ND	0.020	mg/L							
Blank										
Iron	ND	0.100	mg/L							
Manganese	ND	0.020	mg/L							
LCS										
Iron	2.45		mg/L	2.500		98	80-120			
Manganese	0.491		mg/L	0.5000		98	80-120			
8270D(SIM) Semi-Volatile Organic Compounds w/ Isotope Dilution										
Batch CG70351 - 3535A										
Blank										
1,4-Dioxane	ND	0.250	ug/L							
Surrogate: 1,4-Dioxane-d8	*2.26*		ug/L	*5.000*		*45*	*15-115*			
LCS										
1,4-Dioxane	10.3	0.250	ug/L	10.00		103	40-140			
Surrogate: 1,4-Dioxane-d8	*2.55*		ug/L	*5.000*		*51*	*15-115*			
LCS Dup										
1,4-Dioxane	9.93	0.250	ug/L	10.00		99	40-140	4	20	
Surrogate: 1,4-Dioxane-d8	*2.70*		ug/L	*5.000*		*54*	*15-115*			
Classical Chemistry										
Batch CF73034 - [CALC]										
Blank										
Nitrate as N	ND	0.010	mg/L							
Nitrite as N	ND	0.010	mg/L							
Nitrite as N	ND	0.010	mg/L							
LCS										
Nitrate as N	ND		mg/L							
Nitrite as N	0.249		mg/L	0.2497		100	90-110			
Nitrite as N	0.249		mg/L	0.2497		100	90-110			
Batch CF73035 - [CALC]										
Blank										
Nitrate as N	ND	0.020	mg/L							
Nitrate/Nitrite as N	ND	0.020	mg/L							
Nitrate/Nitrite as N	ND	0.020	mg/L							
Total Nitrogen	ND	0.020	mg/L							
LCS										
Nitrate as N	0.501		mg/L							
Nitrate/Nitrite as N	0.501		mg/L	0.5000		100	90-110			
Nitrate/Nitrite as N	0.501		mg/L	0.5000		100	90-110			

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706772

Quality Control Data

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Qualifier
Classical Chemistry										
Batch CF73035 - [CALC]										
Total Nitrogen	0.501		mg/L							
Batch CG70316 - General Preparation										
Blank										
Chloride	ND	3.0	mg/L							
LCS										
Chloride	29.7		mg/L	30.00		99	90-110			
Batch CG70317 - General Preparation										
Blank										
Chloride	ND	3.0	mg/L							
LCS										
Chloride	28.9		mg/L	30.00		96	90-110			
Batch CG70327 - General Preparation										
Blank										
Dissolved Organic Carbon (1)	ND	0.500	mg/L							
Dissolved Organic Carbon (2)	ND	0.500	mg/L							
Dissolved Organic Carbon (Average)	ND	0.500	mg/L							
LCS										
Dissolved Organic Carbon (1)	5.23	0.500	mg/L	5.000		105	80-120			
Dissolved Organic Carbon (2)	5.54	0.500	mg/L	5.000		111	80-120			
Dissolved Organic Carbon (Average)	5.39	0.500	mg/L							
LCS Dup										
Dissolved Organic Carbon (1)	5.38	0.500	mg/L	5.000		108	80-120	3	200	
Dissolved Organic Carbon (2)	5.62	0.500	mg/L	5.000		112	80-120	1	200	
Dissolved Organic Carbon (Average)	5.50	0.500	mg/L							
Batch CG70343 - General Preparation										
Blank										
Sulfate	ND	5.0	mg/L							
LCS										
Sulfate	9.6		mg/L	9.988		96	85-115			
Batch CG70344 - General Preparation										
Blank										
Sulfate	ND	5.0	mg/L							
LCS										
Sulfate	9.6		mg/L	9.988		96	85-115			
Batch CG70514 - TKN Prep										
Blank										
Total Kjeldahl Nitrogen as N	ND	0.20	mg/L							
Total Nitrogen	ND	0.200	mg/L							
LCS										
Total Kjeldahl Nitrogen as N	9.02	2.00	mg/L	9.430		96	80-120			

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706772

Quality Control Data

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Qualifier
Classical Chemistry										
Batch CG70514 - [CALC]										
Total Nitrogen	9.02	2.00	mg/L							
Batch CG70531 - NH4 Prep										
Blank										
Ammonia as N	ND	0.10	mg/L							
LCS										
Ammonia as N	0.08	0.10	mg/L	0.09994		81	80-120			
LCS										
Ammonia as N	0.94	0.10	mg/L	0.9994		94	80-120			
Batch CG70604 - General Preparation										
Blank										
Dissolved Organic Carbon (1)	ND	0.500	mg/L							
Dissolved Organic Carbon (2)	ND	0.500	mg/L							
Dissolved Organic Carbon (Average)	ND	0.500	mg/L							
LCS										
Dissolved Organic Carbon (1)	4.93	0.500	mg/L	5.000		99	80-120			
Dissolved Organic Carbon (2)	5.37	0.500	mg/L	5.000		107	80-120			
Dissolved Organic Carbon (Average)	5.15	0.500	mg/L							
LCS Dup										
Dissolved Organic Carbon (1)	4.95	0.500	mg/L	5.000		99	80-120	0.5	200	
Dissolved Organic Carbon (2)	5.37	0.500	mg/L	5.000		107	80-120	0.04	200	
Dissolved Organic Carbon (Average)	5.16	0.500	mg/L							

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706772

Notes and Definitions

U	Analyte included in the analysis, but not detected
D	Diluted.
ND	Analyte NOT DETECTED at or above the MRL (LOQ), LOD for DoD Reports, MDL for J-Flagged Analytes
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference
MDL	Method Detection Limit
MRL	Method Reporting Limit
LOD	Limit of Detection
LOQ	Limit of Quantitation
DL	Detection Limit
I/V	Initial Volume
F/V	Final Volume
§	Subcontracted analysis; see attached report
1	Range result excludes concentrations of surrogates and/or internal standards eluting in that range.
2	Range result excludes concentrations of target analytes eluting in that range.
3	Range result excludes the concentration of the C9-C10 aromatic range.
Avg	Results reported as a mathematical average.
NR	No Recovery
[CALC]	Calculated Analyte
SUB	Subcontracted analysis; see attached report
RL	Reporting Limit
EDL	Estimated Detection Limit

CERTIFICATE OF ANALYSIS

Client Name: AECOM Environment - ENSR
Client Project ID: Orleans MA

ESS Laboratory Work Order: 1706772

ESS LABORATORY CERTIFICATIONS AND ACCREDITATIONS

ENVIRONMENTAL

Rhode Island Potable and Non Potable Water: LAI00179
http://www.health.ri.gov/find/labs/analytical/ESS.pdf

Connecticut Potable and Non Potable Water, Solid and Hazardous Waste: PH-0750
http://www.ct.gov/dph/lib/dph/environmental_health/environmental_laboratories/pdf/OutofStateCommercialLaboratories.pdf

Maine Potable and Non Potable Water, and Solid and Hazardous Waste: RI00002
http://www.maine.gov/dhhs/mecdc/environmental-health/dwp/partners/labCert.shtml

Massachusetts Potable and Non Potable Water: M-RI002
http://public.dep.state.ma.us/Labcert/Labcert.aspx

New Hampshire (NELAP accredited) Potable and Non Potable Water, Solid and Hazardous Waste: 2424
http://des.nh.gov/organization/divisions/water/dwgb/nhelap/index.htm

New York (NELAP accredited) Non Potable Water, Solid and Hazardous Waste: 11313
http://www.wadsworth.org/labcert/elap/comm.html

New Jersey (NELAP accredited) Non Potable Water, Solid and Hazardous Waste: RI006
http://datamine2.state.nj.us/DEP_OPRA/OpraMain/pi_main?mode=pi_by_site&sort_order=PI_NAMEA&Select+a+Site:=58715

United States Department of Agriculture Soil Permit: P330-12-00139

Pennsylvania: 68-01752
http://www.dep.pa.gov/Business/OtherPrograms/Labs/Pages/Laboratory-Accreditation-Program.aspx

ESS Laboratory Sample and Cooler Receipt Checklist

Client: AECOM Environment - ENSR - KPB/MM

Shipped/Delivered Via: ESS Courier

ESS Project ID: 1706772
Date Received: 6/29/2017
Project Due Date: 7/7/2017
Days for Project: 5 Day

1. Air bill manifest present? No
   Air No.: NA
2. Were custody seals present? No
3. Is radiation count <100 CPM? Yes
4. Is a Cooler Present? Yes
   Temp: 3.6 Iced with: Ice
5. Was COC signed and dated by client? Yes
6. Does COC match bottles? Yes
7. Is COC complete and correct? Yes
8. Were samples received intact? Yes
9. **Were labs informed about short holds & rushes?** (Yes) / No / NA
10. Were any analyses received outside of hold time? Yes (No)

11. Any Subcontracting needed? Yes / (No)
    ESS Sample IDs:
    Analysis:
    TAT:
12. Were VOAs received? (Yes) / No
    a. Air bubbles in aqueous VOAs? Yes / No
    b. Does methanol cover soil completely? Yes / No / NA
13. Are the samples properly preserved? (Yes) / No
    a. If metals preserved upon receipt: Date: Time: By:
    b. Low Level VOA vials frozen: Date: Time: By:

Sample Receiving Notes:

14. Was there a need to contact Project Manager? Yes / (No)
    a. Was there a need to contact the client? Yes / No
    Who was contacted? Date: Time: By:

Sample Number	Container ID	Proper Container	Air Bubbles Present	Sufficient Volume	Container Type	Preservative	Record pH (Cyanide and 608 Pesticides)
01	145330	Yes	NA	Yes	1L Poly - H2SO4	H2SO4	
01	145341	Yes	NA	Yes	500 mL Poly - Unpres	NP	
01	145352	Yes	NA	Yes	250 mL Amber - Unpres	NP	
01	145363	Yes	NA	Yes	250 mL Poly - Unpres	NP	
01	145386	Yes	NA	Yes	VOA Vial - HCl	HCl	
01	145387	Yes	NA	Yes	VOA Vial - HCl	HCl	
02	145329	Yes	NA	Yes	1L Poly - H2SO4	H2SO4	
02	145340	Yes	NA	Yes	500 mL Poly - Unpres	NP	
02	145351	Yes	NA	Yes	250 mL Amber - Unpres	NP	
02	145362	Yes	NA	Yes	250 mL Poly - Unpres	NP	
02	145384	Yes	NA	Yes	VOA Vial - HCl	HCl	
02	145385	Yes	NA	Yes	VOA Vial - HCl	HCl	
03	145328	Yes	NA	Yes	1L Poly - H2SO4	H2SO4	
03	145339	Yes	NA	Yes	500 mL Poly - Unpres	NP	
03	145350	Yes	NA	Yes	250 mL Amber - Unpres	NP	
03	145361	Yes	NA	Yes	250 mL Poly - Unpres	NP	
03	145364	Yes	NA	Yes	1L Amber - Unpres	NP	
03	145365	Yes	NA	Yes	1L Amber - Unpres	NP	
03	145382	Yes	NA	Yes	VOA Vial - HCl	HCl	
03	145383	Yes	NA	Yes	VOA Vial - HCl	HCl	
04	145327	Yes	NA	Yes	1L Poly - H2SO4	H2SO4	
04	145338	Yes	NA	Yes	500 mL Poly - Unpres	NP	
04	145349	Yes	NA	Yes	250 mL Amber - Unpres	NP	
04	145360	Yes	NA	Yes	250 mL Poly - Unpres	NP	

ESS Laboratory Sample and Cooler Receipt Checklist

Client: AECOM Environment - ENSR - KPB/MM

ESS Project ID: 1706772

Date Received: 6/29/2017

04	145380	Yes	NA	Yes	VOA Vial - HCl	HCl
04	145381	Yes	NA	Yes	VOA Vial - HCl	HCl
05	145326	Yes	NA	Yes	1L Poly - H2SO4	H2SO4
05	145337	Yes	NA	Yes	500 mL Poly - Unpres	NP
05	145348	Yes	NA	Yes	250 mL Amber - Unpres	NP
05	145359	Yes	NA	Yes	250 mL Poly - Unpres	NP
05	145378	Yes	NA	Yes	VOA Vial - HCl	HCl
05	145379	Yes	NA	Yes	VOA Vial - HCl	HCl
06	145325	Yes	NA	Yes	1L Poly - H2SO4	H2SO4
06	145336	Yes	NA	Yes	500 mL Poly - Unpres	NP
06	145347	Yes	NA	Yes	250 mL Amber - Unpres	NP
06	145358	Yes	NA	Yes	250 mL Poly - Unpres	NP
06	145376	Yes	NA	Yes	VOA Vial - HCl	HCl
06	145377	Yes	NA	Yes	VOA Vial - HCl	HCl
07	145324	Yes	NA	Yes	1L Poly - H2SO4	H2SO4
07	145335	Yes	NA	Yes	500 mL Poly - Unpres	NP
07	145346	Yes	NA	Yes	250 mL Amber - Unpres	NP
07	145357	Yes	NA	Yes	250 mL Poly - Unpres	NP
07	145374	Yes	NA	Yes	VOA Vial - HCl	HCl
07	145375	Yes	NA	Yes	VOA Vial - HCl	HCl
08	145323	Yes	NA	Yes	1L Poly - H2SO4	H2SO4
08	145334	Yes	NA	Yes	500 mL Poly - Unpres	NP
08	145345	Yes	NA	Yes	250 mL Amber - Unpres	NP
08	145356	Yes	NA	Yes	250 mL Poly - Unpres	NP
08	145372	Yes	NA	Yes	VOA Vial - HCl	HCl
08	145373	Yes	NA	Yes	VOA Vial - HCl	HCl
09	145322	Yes	NA	Yes	1L Poly - H2SO4	H2SO4
09	145333	Yes	NA	Yes	500 mL Poly - Unpres	NP
09	145344	Yes	NA	Yes	250 mL Amber - Unpres	NP
09	145355	Yes	NA	Yes	250 mL Poly - Unpres	NP
09	145370	Yes	NA	Yes	VOA Vial - HCl	HCl
09	145371	Yes	NA	Yes	VOA Vial - HCl	HCl
10	145321	Yes	NA	Yes	1L Poly - H2SO4	H2SO4
10	145332	Yes	NA	Yes	500 mL Poly - Unpres	NP
10	145343	Yes	NA	Yes	250 mL Amber - Unpres	NP
10	145354	Yes	NA	Yes	250 mL Poly - Unpres	NP
10	145368	Yes	NA	Yes	VOA Vial - HCl	HCl
10	145369	Yes	NA	Yes	VOA Vial - HCl	HCl
11	145320	Yes	NA	Yes	1L Poly - H2SO4	H2SO4
11	145331	Yes	NA	Yes	500 mL Poly - Unpres	NP
11	145342	Yes	NA	Yes	250 mL Amber - Unpres	NP
11	145353	Yes	NA	Yes	250 mL Poly - Unpres	NP
11	145366	Yes	NA	Yes	VOA Vial - HCl	HCl
11	145367	Yes	NA	Yes	VOA Vial - HCl	HCl
12	145388	Yes	NA	Yes	1L Poly - H2SO4	H2SO4
12	145389	Yes	NA	Yes	500 mL Poly - Unpres	NP
12	145390	Yes	NA	Yes	250 mL Amber - Unpres	NP
12	145391	Yes	NA	Yes	250 mL Poly - Unpres	NP
12	145392	Yes	NA	Yes	VOA Vial - HCl	HCl
12	145393	Yes	NA	Yes	VOA Vial - HCl	HCl

2nd Review
Are barcode labels on correct containers? (Yes) / No

Completed By: _____ Date & Time: 6/29/17 2014

Reviewed By: _____ Date & Time: 6/29/17 2031

Delivered By: _____ 6/29/17 2031

ESS Laboratory
Division of Thielsch Engineering, Inc.
185 Frances Avenue, Cranston RI 02910
Tel. (401) 461-7181 Fax (401) 461-4486
www.esslaboratory.com

CHAIN OF CUSTODY

ESS Lab # 106772

Turn Time: 5-Day Rush
Regulatory State
Is this project for any of the following?: ○CT RCP ○MA MCP ○RGP
Reporting Limits
Electonic Deliverables: ☐Limit Checker ☐Standard Excel ☐Other (Please Specify →)

Company Name	Project #	Project Name
AECOM	60476044	Orleans PRB
Contact Person	**Address**	
Julianne Marmon	250 Apollo Drive	
City	**State**	**Zip Code** / **PO #**
Chelmsford	MA	
Telephone Number	**FAX Number**	**Email Address**
978·905·2419		Julianne.Marmon@aecom.com

ESS Lab ID	Collection Date	Collection Time	Sample Type	Sample Matrix	Sample ID	Analysis: TN, Ammonia	NO_3, NO_2, SO_4, Cl	Dissolved Fe, Mn	DOC	1,4 Dioxane
1	06/29/17	09:20	G	GW	MW-B2100C	X	X	X	X	
2	06/29/17	~~09:45~~ 1035	G	GW	MW-B2075A	X	X	X	X	
3	06/29/17	0945	G	GW	EP Irrigation Well	X	X	X	X	X
4	06/29/17	11:05	G	GW	MW-BC3B	X	X	X	X	
5	06/29/17	11:45	G	GW	MW-BU2A	X	X	X	X	
6	06/29/17	12:10	G	GW	MW-BU2B	X	X	X	X	
7	06/29/17	12:35	G	GW	MW-BU2C	X	X	X	X	
8	06/29/17	13:10	G	GW	MW-B1050C	X	X	X	X	
9	06/29/17	13:35	G	GW	MW-B1050B	X	X	X	X	
10	06/29/17	13:55	G	GW	MW-B1050A	X	X	X	X	
Container Type:	AC-Air Cassette AG-Amber Glass B-BOD Bottle C-Cubitainer G - Glass O-Other P-Poly S-Sterile V-Vial					P	P	P	AG	AG
Container Volume:	1-100 mL 2-2.5 gal 3-250 mL 4-300 mL 5-500 mL 6-1L 7-VOA 8-2 oz 9-4 oz 10-8 oz 11-Other*					6	5	3	3	6
Preservation Code:	1-Non Preserved 2-HCl 3-H2SO4 4-HNO3 5-NaOH 6-Methanol 7-Na2S2O3 8-ZnAce, NaOH 9-NH4Cl 10-DI H2O 11-Other*					3	1	1	1	1
					Number of Containers per Sample:	1	1	1	1	2

Laboratory Use Only
Cooler Present: ✓
Seals Intact: N
Cooler Temperature: Ice temp 19:18C 6-29-17

2.8 c
3.6 c
3.2 c

Sampled by: Briley Morrill
Comments: Please specify "Other" preservative and containers types in this space

Relinquished by: (Signature, Date & Time)	Received By: (Signature, Date & Time)	Relinquished By: (Signature, Date & Time)	Received By: (Signature, Date & Time)
Briley Morrill 06/29/17 1820	6/29/17 18:20	6-29-17 19:15	1942
Relinquished by: (Signature, Date & Time)	Received By: (Signature, Date & Time)	Relinquished By: (Signature, Date & Time)	Received By: (Signature, Date & Time)

ESS Laboratory
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CHAIN OF CUSTODY

ESS Lab # 1706772

Turn Time 5-Day Rush
Regulatory State
Is this project for any of the following?: ○CT RCP ○MA MCP ○RGP
Reporting Limits
Electonic Deliverables ☐Limit Checker ☐Standard Excel ☐Other (Please Specify →)

Company Name: AECOM	Project #: 60476044	Project Name: Orleans PRB	
Contact Person: Julianne Marion	Address: 250 Apollo Drive		
City: Chelmsford	State: MA	Zip Code:	PO #
Telephone Number: 978.905.2419	FAX Number:	Email Address: Julianne.Marion@aecom.com	

ESS Lab ID	Collection Date	Collection Time	Sample Type	Sample Matrix	Sample ID	Analysis: TN, Ammonia	NO_3, NO_2, SO_4, Cl	Dissolved Fe, Mn	DOC
11	06/29/17	14:25	G	GW	MW-B107SB	X	X	X	X
12	06/29/17	15:00	G	GW	MW-B2C2	X	X	X	X

BKM 06/29/17

Container Type: AC-Air Cassette AG-Amber Glass B-BOD Bottle C-Cubitainer G - Glass O-Other P-Poly S-Sterile V-Vial	P	P	P	AG
Container Volume: 1-100 mL 2-2.5 gal 3-250 mL 4-300 mL 5-500 mL 6-1L 7-VOA 8-2 oz 9-4 oz 10-8 oz 11-Other*	6	5	3	3
Preservation Code: 1-Non Preserved 2-HCl 3-H2SO4 4-HNO3 5-NaOH 6-Methanol 7-Na2S2O3 8-ZnAce, NaOH 9-NH4Cl 10-DI H2O 11-Other*	3	1	1	1
Number of Containers per Sample:	1	1	1	1

2.8
3.6
3.7

Laboratory Use Only
Cooler Present: _____
Seals Intact: N
Cooler Temperature: Ice temp 19/18 6-29-17

Sampled by: Bailey Morrill
Comments: Please specify "Other" preservative and containers types in this space

Relinquished by: (Signature, Date & Time)	Received By: (Signature, Date & Time)	Relinquished By: (Signature, Date & Time)	Received By: (Signature, Date & Time)
Bailey Morrill 06/29/17 1820	6/29/17 18:20	6-29-17 19:15	6/29/17 1942
Relinquished by: (Signature, Date & Time)	Received By: (Signature, Date & Time)	Relinquished By: (Signature, Date & Time)	Received By: (Signature, Date & Time)

Appendix C

Technical Memorandum by SMAST (September 27, 2017)

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SMAST University of Massachusetts Dartmouth
The School for Marine Science and Technology

Technical Memorandum

To: Mike Domenica, Water Resources Associates
George Meservey, Town of Orleans

From: Brian Howes, Coastal Systems Program
Ed Eichner, Coastal Systems Program

Date: August 19, 2017
September 27, 2017 (updated)

RE: Review of AECOM 8/8/17 Eldredge Park Permeable Reactive Barrier Demonstration Project draft Quarterly Report/Technical Memorandum and previous data provided by AECOM

At the request of the Town, we completed a review of the draft August 8, 2017 AECOM Quarterly Report/Technical Memorandum on the Eldredge Park Permeable Reactive Barrier (PRB) on August 19, 2017. That review has been expanded in this present TM based on another request from the Town and additional information provided by AECOM, including two conference calls and additional information gathered by MT Environmental. In this expanded review, SMAST was asked to include all available data on groundwater levels and chemical constituents, especially nitrogen concentrations, including reports prepared by AECOM, as well as a 2015 Quarterly Report by Coastal Engineering (CE) on monitoring of the Nauset Regional Middle School wastewater treatment discharge. The initial review and this subsequent follow-up, was the first formal review we had conducted relative to this PRB project, monitoring well network or performance monitoring.

The purpose of the Eldredge Park PRB Demonstration Project is to determine the overall feasibility of siting, designing, operating and testing a pilot-scale PRB. This PRB was located to test its operation to cost-effectively reduce nitrogen flux to Town Cove. Town Cove has been identified by MassDEP as having impaired conditions by excessive nitrogen.

The Eldredge Park PRB was installed and went into operation in November 2016 with the injection of emulsified vegetable oil (EVO); EVO provides organic carbon to create conditions conducive to nitrogen removal through *in situ* microbial denitrification. The PRB is located in the parking lot area between the Nauset Regional Middle School playing fields and the Eldredge Park baseball field. To install the PRB, a total of 10,800 gallons of EVO solution was injected through 17 injection points. Approximately 10.3 pounds of sodium bicarbonate was also injected per 300-gallons of EVO solution to increase the pH buffering of affected groundwater. The PRB is approximately 110 ft long and is located from approximately +5 ft to -30 ft elevation above sea level or 5 ft to 40 ft below the water table. The western side of the PRB consisted of 7

injection points, spaced 10 feet apart, while the eastern side of the PRB consisted of 10 points configured in two parallel, offset lines of five points each. The eastern and western sides were designed differently in order to assess the effect of injection point density and injection volume on nitrogen removal. The second line on the western side was five feet downgradient of the first line and injection points were off-set by five feet.

The Middle School wastewater treatment system includes two effluent leachfields: one installed in 1977 and another installed in 1992 (Figure 1). During initial discussions and review of PRB performance, it was believed that the 1992 leachfield was a replacement for 1977 leachfield. After our initial review of PRB performance, it was revealed that both leachfields are still in use. Subsequent review of Orleans Board of Health records show that the Title 5 wastewater design flow for the Middle School in 1992 was 20,425 gallons per day (gpd). Leachfield design capacity is slightly larger with two leachfields: a) a 1977 leachfield composed of 10 leachpits with a design flow of 10,560 gpd and b) a 1992 leachfield composed of 2 leaching galleries with a design flow of 10,960 gpd (personal communication, MT Environmental). Actual water use, which is generally reduced by 10% to estimate wastewater flows, averaged only 2,131 gpd in 2012 and 2015 (average of 571 students[1]). This average student population was down 26% from the reported average 1994-1997 population. Using the 2012 to 2015 average ratio of students to water use, the estimated average 1994 to 1997 water use would be 2,876 gpd. Based on these flows, it appears that the Title 5 system has almost 10 times the needed effluent capacity and that either the 1977 or 1992 leaching system should have sufficient capacity for disposal of the Middle School effluent.[2] This is consistent with information from CE which indicated that during a recent 2 year period only one leachfield was used due to a switch failure (fields are generally equally dosed). It has not been established what the beginning and end dates of the switch problem. See below for a discussion of actual flows to the leaching systems during this period.

At the time of the 1992 leachfield installation at the Middle School, a network of 7 monitoring wells were installed. These long-term monitoring wells generally surround the leachfield and are located 200 to 350 ft from the current PRB installation (*i.e.*, "far field wells"). Similarly, the 1992 leachfield is located approximately 100 to 200 ft from the PRB. According to an available 2015 CE report, 6 of these far-field wells have been sampled quarterly for nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen (TKN), and total nitrogen since 1992 with groundwater elevations determined quarterly for all 7 wells since June 2012.

In addition to these 7 older far-field wells, there are approximately 25 "near-field" wells installed by AECOM that are located within 10 to 100 ft of the PRB. These near-field wells include well clusters with groups of wells at the same location but screened at different depths within the aquifer. Groundwater monitoring during and after the PRB installation included: a) baseline, pre-PRB sampling in October and early November 2016, b) sampling on November 17, 2016 during the PRB installation, and c) post-PRB installation sampling in January, February, April and June 2017. Monitoring included field measurements of groundwater elevation, pH, temperature, dissolved oxygen (DO), oxidation reduction potential (ORP), conductivity, and

[1] Massachusetts Department of Elementary and Secondary Education (http://profiles.doe.mass.edu/profiles/student.aspx?orgcode=06600305&orgtypecode=6&&fycode=2017)

[2] This excess capacity is not uncommon for school wastewater systems due to provisions in Title 5 design criteria.

turbidity and collection of water samples with assays for: nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen (TKN), total nitrogen, chloride, sulfate, dissolved iron, dissolved manganese, boron, sodium, total alkalinity, and dissolved organic carbon (DOC). Each monitoring date did not include all wells; because of staggered well installation dates and sampling choices, but most sampling events included a majority of the wells.

This Technical Memorandum reviews the water elevation and water quality data collected from the well network near the PRB (both near-field and far-field wells). This review is based on available information provided by AECOM, including AECOM quarterly reports on the PRB installation, water table contours from measured groundwater elevations, and a 2015 CE report on the Middle School leachfield monitoring.

I. Groundwater Elevations

I.A. Far-field Wells

Groundwater elevations have been collected at both the far-field and near-field wells with the longest term records spanning June 2012 to present for the far-field wells. Review of these groundwater elevation records between 2012 and 2017 generally show a relatively flat water table south of the PRB with variations likely due to changes in the volume of discharge through the Middle School leachfields. In addition, it appears that there may have been a change in the water table configuration over the past two years.

Among the far-field wells, MW-1 clearly had the highest groundwater elevations in both AECOM and CE readings (12.73 ft and 11.74 ft NAVD88, respectively[3]) (Figure 2). MW-1 is located northwest of the PRB and is the closest well to Boland Pond. The next highest average elevation in the AECOM readings was at MW-11 (11.47 ft), while MW-2 was the next highest average among the CE readings (11.97 ft). The smaller difference between the two highest averages in the AECOM readings was due to a decrease of nearly a foot (-0.99 ft) in the MW-1 average. The decreases in the AECOM averages are likely due in part to the impact of the 2016 drought[4], but the differences in impact among the wells likely reflects other factors such as whether Middle School discharge was changed from one leachfield to another. In any case, overall comparison of the AECOM and CE elevation readings suggest a relatively consistent water table configuration with the highest groundwater elevation near MW-1, a slightly lower groundwater mound toward the southeast (*e.g.*, near wells MW-2, MW-11) with the Middle School leachfields at a lower elevation between them. Five of 6 of the AECOM contour maps also show this water table configuration; the January 18, 2017 map has higher elevations near MW-2 and MW-11, but does not have a mound near MW-1. Given that AECOM and CE readings seem to suggest a similar area-wide water table, this suggests that even if malfunctions at the Nauset Middle School leachfield dosing had localized effects, it did not significantly alter the area-wide water table.

Comparison among the average elevations at all the far-field wells showed that though the general water table configuration has been relatively constant, detailed evaluation among the wells showed changeable conditions and a significant change near the PRB in the more recent AECOM readings (2016-2017). CE average elevations showed that MW-12 had the third

[3] All groundwater elevations are in NAVD88

[4] Precipitation during 2016 was 11% less than the average from 2012 to 2016. (source: https://www.ncdc.noaa.gov)

highest reading (11.78 ft) after MW-1 and MW-2 with MW-4 and MW-8 next (11.68 ft and 11.66 ft, respectively), with MW-11 having the lowest elevation (11.56 ft). MW-4 and MW-8 are south of the 1992 Middle School leachfield, while MW-12 is approximately 25 ft south of the PRB. These readings suggest average flow toward MW-11 and the southeast, away from the PRB site with a relatively flat water table. If MW-1 and MW-2 are excluded, the average elevations at the other wells are all within ~0.2 ft of each other, which is consistent with a relatively flat water table. AECOM average elevations were slightly different and showed that MW-2 had the third highest reading (11.38 ft) after MW-1 and MW-11 with MW-4 and MW-8 next (11.06 ft and 11.16 ft, respectively), with MW-12 having the lowest elevation (10.81 ft). Statistical comparison of the CE and AECOM averages show that though the AECOM averages are lower, they are not significantly different from the CE averages, consistent with a relatively stable long-term water table configuration, except for the readings at MW-12. Comparison of MW-12 averages showed a significant decrease ($\rho<0.05$) in the AECOM average compared to the CE average. The net result of the AECOM averages would be groundwater flow from the higher elevations at MW-1 and MW-11/MW-2 with a division of flow between MW-4/MW-8 and MW-12. A hinge line dividing flows to the north (MW-12) and south (MW-4/MW-8) was a regular feature of the available AECOM water table maps.

Changes in groundwater flow direction are often seen in areas with relatively flat water tables, but the significant change at MW-12 caused us to evaluate whether there were other issues that may have led to this finding. We reviewed regional groundwater elevations at the closest long term monitoring well (OSW-22) and found that the timing of fluctuations in the far-field PRB area more or less followed regional and seasonal fluctuations (Figure 3). Also, review of maximum and minimum readings at OSW-22 and all of the far-field wells generally were within the same relative range when adjusted for their location in the aquifer. OSW-22 is closer to the ocean, so it has a smaller range of fluctuations than the PRB study area wells.

Since the Nauset Middle School leachfields are located in the middle of the far-field wells, we also reviewed student populations in order to assess the potential wastewater fluctuations. Between 1994 and 2017[5], student populations at the Middle School ranged between 498 and 820. Based on Title 5 design flows for schools (310 CMR 15.203), corresponding estimated Title 5 wastewater flow range for students only (excluding staff) during the same period would be 9,960 gpd to 16,400 gpd. During the period where groundwater elevations have been collected (*i.e.*, 2012 to 2017) student population has been relatively stable: range of 535 to 585 students and a corresponding Title 5 wastewater flow estimate of 10,700 gpd to 11,700 gpd. This relatively stable flow would mean that changes measured in the water table configuration are more likely to be due to how and where the wastewater was discharged rather than changes in the volume of discharge. As noted above, actual wastewater generation at schools is typically significantly less than Title 5 design flow.[6] CE reviewed water use at the Middle School between 2012 and 2016 in the available quarterly report and found an average flow of 2,131 gpd; MEP water use for the Middle School in the Town Cove nitrogen loading model, which was based on Town readings from 2002 to 2003, was 2,400 gpd. Collectively, these available water use readings suggest a

[5] 1994 is the earliest year available on-line from Massachusetts Department of Elementary and Secondary Education (http://profiles.doe.mass.edu/profiles/student.aspx?orgcode=06600305&orgtypecode=6&&fycode=2017).

[6] Title 5 flows are generally designed to be 2X actual estimated flow in order to accommodate peak flows and occupancy, but school flows are often 4X measured flows.

relatively small wastewater discharge and accompanying impact on groundwater levels, even if discharged to only one leachfield and especially if it dispersed equally between the two leaching fields.

One other consideration we found when evaluating the changes at MW-12 was that there are differences in the casing elevations among the CE and AECOM datasets; examination of the well survey data indicated that the CE and AECOM elevation measurements of the top of the well casings were different for the same wells. Differences in casing elevations could create differences in groundwater elevations even if the depth to water measurements were the same. The differences were discussed with AECOM staff, and it was decided to use the most recent AECOM survey casing elevations and adjust all readings to these elevations. Historic CE groundwater elevation readings were corrected to these casing elevations and those corrected readings are used throughout this memo. The overall sense from all of these secondary data reviews is that, unless additional information comes to light, the recent significant change in groundwater elevations at MW-12 represents part of the regular fluctuations and changes in flow direction at this location.

The net result of the far-field groundwater elevations is that the predominant direction of groundwater flow in the PRB area fluctuates and effluent from the Nauset Middle School leachfields regularly flows both toward and away from the PRB. This split of flow varies depending on localized changes in the water table configuration, which may be partially due to how wastewater effluent discharge changes at the Middle School. These variations also mean that the portion of the nitrogen load from the leachfields that flows toward the PRB also varies.

I.B. Near-field Wells

As mentioned above, AECOM installed approximately 25 near-field wells that are located within 10 to 100 ft of the PRB installation with selected clusters of wells screened at multiple depths within the aquifer. Water table elevations have been measured at these wells 7 times between November 2016 and June 2017 and AECOM has contoured the measurements for each of these dates. In order to facilitate comparison among individual wells and to evaluate groups wells potentially influenced by the PRB in the same way, we assigned the wells to one of four quadrants around the PRB: a) east and west sections depending on whether wells are near the section of the PRB with a high density of injection points (east) or the lower density (west) or b) north or south of the PRB (Figure 4).

Average elevations at the 19 near-field wells where elevations were collected during all 7 water table measurements generally show only slight differences in average elevations, consistent with the relatively flat water table seen in the far-field groundwater elevation data, but the average elevations also show patterns and projected flow directions that would make consistent evaluation of the PRB efficacy difficult. On the eastern portion of the PRB, the nearfield shallow wells in the NE quadrant had a slightly (0.05 to 0.1 ft) higher average than those on the south side of the PRB (Figure 5). On average, this would mean groundwater flow is from the north to the south through the PRB on the eastern side of the PRB. Similarly, on the western portion of the PRB, groundwater elevations in the shallow wells in the NW quadrant were also on average higher than elevations in the single well on the south side (MW-12C). It is also notable, and somewhat atypical, that deeper wells in the MW-12 cluster had higher elevations

suggesting possible flow to the north at depth. Review of elevations in the other well clusters suggests that these deep readings at MW-12 are inconsistent (Figure 6). Most of the other clusters show little or no head differences between shallow, intermediate, and deep screens and those with slight differences tend to show highest heads in the shallow wells. Similar heads/elevations in well clusters would tend to suggest largely parallel flow with little movement up or down in the aquifer. In areas with steeper tilts/gradients to the water table, higher heads are usually seen in the shallower screens as groundwater near the top of the aquifer is pushed deeper into the aquifer by precipitation (or significant wastewater discharge).

Review of the individual elevation surveys of the near-field wells showed more complexity than seen in the average readings. Groundwater levels in the 11/3/16, 2/23/17, and 6/29/17 contour maps/surveys show readings at MW-12 as a low point in the water table, creating a focal point of all flowpaths, and suggesting flow from the north to the south through the PRB. The 5/1/17 contour maps shows higher elevations to the north of the PRB and a groundwater "valley" with flow through the PRB toward the southwest (MW-4). The two January 2017 contour maps (1/18 and 1/27) show low points just to the north of the eastern portion of the PRB, suggesting flow to the north through this PRB section, but flowpaths parallel to the western portion of the PRB, thereby avoiding flow through the PRB. The 4/25/17 map shows higher contours on the northern side of the PRB, also suggesting flow to the south through the PRB. Collectively, these maps show inconsistent groundwater flow paths through and around the PRB, sometimes with flow to the north through the PRB, sometimes with flow to the south through the PRB, and sometimes parallel and avoiding flow through the PRB depending on a given starting location. These inconsistencies create uncertainty about projecting potential nitrogen removal by the PRB given that it is often unclear what nitrogen might be passing through it, which direction it is going, and how its flowpath may have changed month to month. This review also reinforces the need to have parallel determination of groundwater levels and flow direction for each test of potential nitrogen removal.

These reviews also reiterate the important influence that water level readings at MW-12 create on the near-field contours and flow directions. Based on the strength of this influence, AECOM may want to double check the measuring point elevation and readings for MW-12. AECOM may also want to evaluate what contours might look like if MW-12 readings are removed from the contouring. This review would also be aided by any stratigraphic information at the MW-12 site.

In addition, AECOM and Town should consider the addition of selected wells in key locations. The PRB is located near the northern boundary of the available well network with limited wells to the west, north, and northwest; addition of wells in these areas would provide clarification of flows near the PRB, as well as the potential impacts effluent discharges at the 1977 wastewater leachfield. In addition, given the large impact of readings at MW-12 on flow patterns and the lack of other wells between the PRB and the 1992 Middle School leachfield, consideration should be given to supplementing the well information in the SW quadrant. Clarifying the flow paths around the two leachfields would help to clarify flow paths through the PRB.

Based on the presently available data, it would be difficult to clearly define average flow and flowpaths for water through the PRB or even the two sections of the PRB. The water table maps

show groundwater flowpaths avoiding and, depending on the date, flowing either direction through the PRB. Additional wells and accompanying monitoring are recommended to help clarify these uncertainties.

II. Water Quality

II.A. Far-field Wells

As mentioned above, CE has been collecting water quality samples from 6 of the "far-field" wells on a quarterly basis since the installation of the 1992 Nauset Middle School leachfield. Collected samples have been assayed for nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen (TKN), and total nitrogen. The currently available CE dataset extends through December 2015 and has 83 to 96 nitrate-N and total-N readings and 9 to 18 ammonia-N and TKN readings depending on the well. Most of the ammonia-N and TKN readings were below detection limits and this explains the difference between the available reading counts for each of the assays. Nitrate-N was 92% to 98% of the TN concentrations, so this analysis focuses on the nitrate-N concentrations.

Nitrate-N concentrations at these wells have shown a variety of changes. MW-4, which is located west of the leachfield, has been relatively consistent since 1992 with an overall average NO3-N concentration of 3.2 mg/L (Figure 7). Similarly, MW-11, MW-11S, and MW-12 have also been relatively consistent, albeit with higher overall average concentrations of 5.1 mg/L, 4.6 mg/L, and 6.8 mg/L, respectively. The relative consistency of these concentrations suggests relatively stable nitrogen sources and groundwater flowpaths. In contrast, concentrations at MW-2 have gradually decreased with an initial average of 2.8 mg/L between 1992 and 1995 declining to an average of 0.6 mg/L between 2012 and 2015. This decrease would be consistent with CE and most of AECOM groundwater elevations showing MW-2 as a high point in the water table; groundwater at MW-2 would tend to flow toward the 1992 Middle School leachfield and the low concentrations suggest it draws from largely unimpacted upgradient groundwater. While MW-2 concentrations decreased, concentrations at MW-8, which is located south of the 1992 leachfields, gradually increased throughout the CE monitoring record from an initial average of 1.9 mg/L between 1992 and 1995 to an average of 5.9 mg/L between 2008 and 2011 and then an average of 11.4 mg/L between 2012 and 2015. The doubling of NO3-N concentrations at MW-8 over the past ~5 years suggests that the proportion of the overall Middle School leachfield flow toward MW-8 has increased over time.

The NO3-N concentrations at the far-field wells between 1992 and 2015 generally reinforce the findings from the review of water table measurements: higher elevations and lower concentrations to the southeast of the PRB with generally pervasive nitrate-N contamination throughout the area surrounding the 1992 Middle School leachfield. Unfortunately, no water quality readings were collected at MW-1, so it is not known if there has been any trend in concentrations to the northwest or their impact on near-field concentrations or the role of the older leachfield on the water quality readings. The relatively stable and high concentrations at MW-12 suggest relatively stable loads near the current location of the PRB, as well as locations to the west (MW-4) and southeast (MW-11). The increasing concentrations to the south (MW-8) suggest that the proportion of the flow from the leachfields toward the south and away from the PRB location has increased with time.

II.B. Near-field Wells

As mentioned above, water quality samples have been collected a total of 6 times from varying subsets of wells near the PRB before, during and after the PRB installation. Monitoring included field measurements of pH, temperature, dissolved oxygen (DO), oxidation reduction potential (ORP), conductivity, and turbidity and collection of water samples with assays for: nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen (TKN), total nitrogen, chloride, sulfate, dissolved iron, dissolved manganese, boron, sodium, total alkalinity, and dissolved organic carbon (DOC). We reviewed individual well data, but most of the wells have either large variability in results or apparent contradictions among results (*e.g.*, high DOC with increasing DO). In order to try to increase the understanding of the impacts of the PRB, we grouped the water quality results into the same quadrants used to evaluate the near-field water elevation readings (see Figure 3).

Given the relative flatness of the water table and the nearly universal contamination seen in the far-field wells, many of the near-field wells have similar readings for pH, temperature, and dissolved oxygen. Temperature and pH would tend to be expected to be relatively similar, but most of the near-field wells also have low dissolved oxygen concentrations: averaging only 3.6 mg/L with an average 35% saturation over all the nearfield wells. This low DO suggests pervasive oxygen demand throughout most of the study area, consistent with relatively similar wastewater impacts. Grouping of DO results into quadrants showed the highest average DO concentrations in the SE quadrant (average DO concentrations between 5 and 6 mg/L), which would make sense since the water table shows this area receives flow off the largest unimpacted portion of the area's water table (Figure 8). In the SW quadrant, averages (which are only from MW-12 cluster data) also had lower DO in shallow well screens, but had higher DO averages at depth. These averages would suggest shallow flow from the 1992 Middle School leachfield toward the western portion of the PRB with little depression of the leachfield plume into the aquifer. It is unclear how much contribution the older leachfield makes to the measurements seen at MW-12 given the lack of other wells in SW quadrant, but the lower DO concentrations in the shallow NW quadrant wells compared to the NE quadrant suggest that there is more oxygen demand closer to the 1977 leachfield. The lower DO in the shallow MW-12 well (SW quadrant) would also tend to be somewhat consistent with the shallow groundwater flow paths from the 1992 leachfield toward MW-12. The higher DO in the intermediate and deep wells in the same cluster are inconsistent, however, with accompanying contour maps that also suggested flow from the 1992 leachfield toward MW-12. These results tend to confirm the importance of MW-12 readings to overall interpretation of the site's groundwater flow field and supports the need for at least one additional well in this quadrant.

Review of the water quality data shows that the highest average nitrate-N concentrations were north of the PRB (see Figure 8), which would seem to indicate complexities in flowpaths associated with use of both Middle School leachfields and significant portions of leachfield flow largely avoiding the current PRB placement. Average northern nitrate-N concentrations seem to confirm the groundwater flow paths parallel to the PRB from west to east, consistent with many of the AECOM individual water table maps. This pattern was also seen at all depths within the aquifer, suggesting that the older leachfield receives more of the wastewater flow than the newer leachfield during the AECOM measurement period. Review of nitrate-N concentrations also tend to confirm the low level impacts seen in the DO readings in the SE quadrant, but also show

low concentrations in the SW quadrant. Comparison of average nitrate-N concentrations at the various screen depths showed increasing nitrate-N concentrations with increasing depth among the two northern quadrants, but decreasing averages with depth in the two southern quadrants. The changing use of both leachfields for effluent discharge complicates groundwater flow paths and interpretation of the water quality results. Further clarification is recommended from CE regarding dosing fluctuations for the leachfields; the average near-field water quality data suggests that the older leachfield received more of the flow than the newer one during the measurement period. It may also be worthwhile to explore the potential impact of Boland Pond on groundwater movements in this area, perhaps through the use of the groundwater model prepared to explore the path of the landfill plume.

Review of the water quality data from individual wells suggests additional complexities in the groundwater flow directions. There are three wells with significant DOC increases indicative of EVO spreading from the PRB: MW-B1010C, MW-B2010C, and MW-B2020C. All of these wells are within 25 feet of the PRB and all are north of the PRB. Since the PRB is likely the only significant source of DOC near these wells, this finding suggests at least periodic flow from south to north, opposite of what is seen in the review of the average quadrant heads and nitrate-N concentrations. MW-B1010C, which is approximately 10 ft north of the PRB had DOC concentrations that increased between November and June as would be expected if flow moved from south to north through the PRB, but nitrate-N concentrations also increased by >2 fold and oxygen increased slightly between January and June. This is the opposite of what would be expected (*i.e.*, increased DOC should accompany lower DO and nitrate levels). MW-B2020C (approximately 20 ft north of the PRB) also showed DOC increases, but had inconsistent responses in nitrate levels. Of the three wells with significant DOC, two had reductions in nitrate-N concentrations, which, though a small sample, suggest that the carbon addition of the PRB might be working to lower nitrate levels near the PRB, but this is somewhat contradicted by some of the other flow paths and the average groundwater flow showing flow from north to south. Additional monitoring runs would help to clarify whether these are emerging trends or results only measured in these two runs.

Equally important to note is the variation in DO and nitrate levels over time at a number of near-field wells, not associated with the PRB. These variations appear to be due to variations in groundwater flowpaths as indicated by the complex flow lines derived from the AECOM contour maps. For example, BU2B showed hypoxic conditions in January, but DO levels well above saturation (136%) in June. It appears that the wells may not be consistently capturing the same source water over time and that the observed changes result from shifting flow directions, hence varying source waters and varying associated water quality measured at the wells. In addition, closer review of many of the DO saturation levels in June suggests that there may have been a problem with the calibration of the DO meter: 7 of 24 DO readings in June were above saturation; none of the previous 73 readings were above 100% saturation.

III. Summary

PRBs are typically sited either adjacent to a contamination source or adjacent to a groundwater discharge area. These siting strategies increase the odds that contaminant-laden groundwater flow paths will be intersected by the PRB and that downgradient samples can be directly compared to upgradient samples to determine PRB effectiveness. Due to the complex flow directions at the Eldredge Park PRB site and the as-yet-explained relationships between DOC/DO/Nitrate in the nearby wells, there appears to be sufficient uncertainty to be overcome before an accurate determination of the efficacy of nitrate removal by this PRB can be quantified. Other findings from our review of available data include the following:

- The PRB study area has a relatively flat water table with two slight mounds: one to the northwest of the PRB near Boland Pond and a second to the southeast of the PRB.
- Areas with a flat water table are sensitive to slight changes in patterns of discharge/recharge, such as variable discharge to the Middle School leachfields; these small changes in groundwater elevation can change groundwater flow paths/directions.
- Groundwater elevation and water quality monitoring data near the PRB generally suggests groundwater flow moving parallel to the PRB from the northwest (near Boland Pond), possibly with occasional flow through the PRB toward both to the north and to the south apparently depending on slight changes in the study area water table.
- High nitrate-N concentrations in deep portions of the aquifer near the PRB seem to suggest that N loading from other upgradient sources are flowing through the area.
- Recent monitoring suggests that a larger portion of the leachfields flows/discharges have been moving toward the south away from the PRB.
- Excess design capacity in the Middle School septic system means it is likely that all of the current wastewater effluent flow from the Middle School could be accommodated by either of the leachfields attached to the system, as has occurred for extended periods.

IV. Recommendations

- Additional information from the operators of the Middle School wastewater treatment system may help to clarify the division of effluent flow to the leachfields, which may, in turn, help to better understand the water quality and groundwater elevation measurements in the monitoring well network and clarify groundwater flow directions.
- Selected targeted data collection in additional wells and additional rounds of sampling may also help to clarify flow directions and nitrogen responses, especially since EVO-associated factors have now been detected in some wells.
- Further extension of the PRB based on available groundwater flow directions may be warranted to greatly increase N capture.
- MW-12 is yielding some confounding information. AECOM should double check readings at monitoring well MW-12, including its elevation and groundwater elevations at all three wells in the cluster.
- AECOM should review its groundwater contours to ascertain the effects of including/excluding MW-12 from the analysis.
- AECOM needs to resolve the shift from oxygen depletion to over-saturation in groundwater dissolved oxygen readings collected in June 2017.

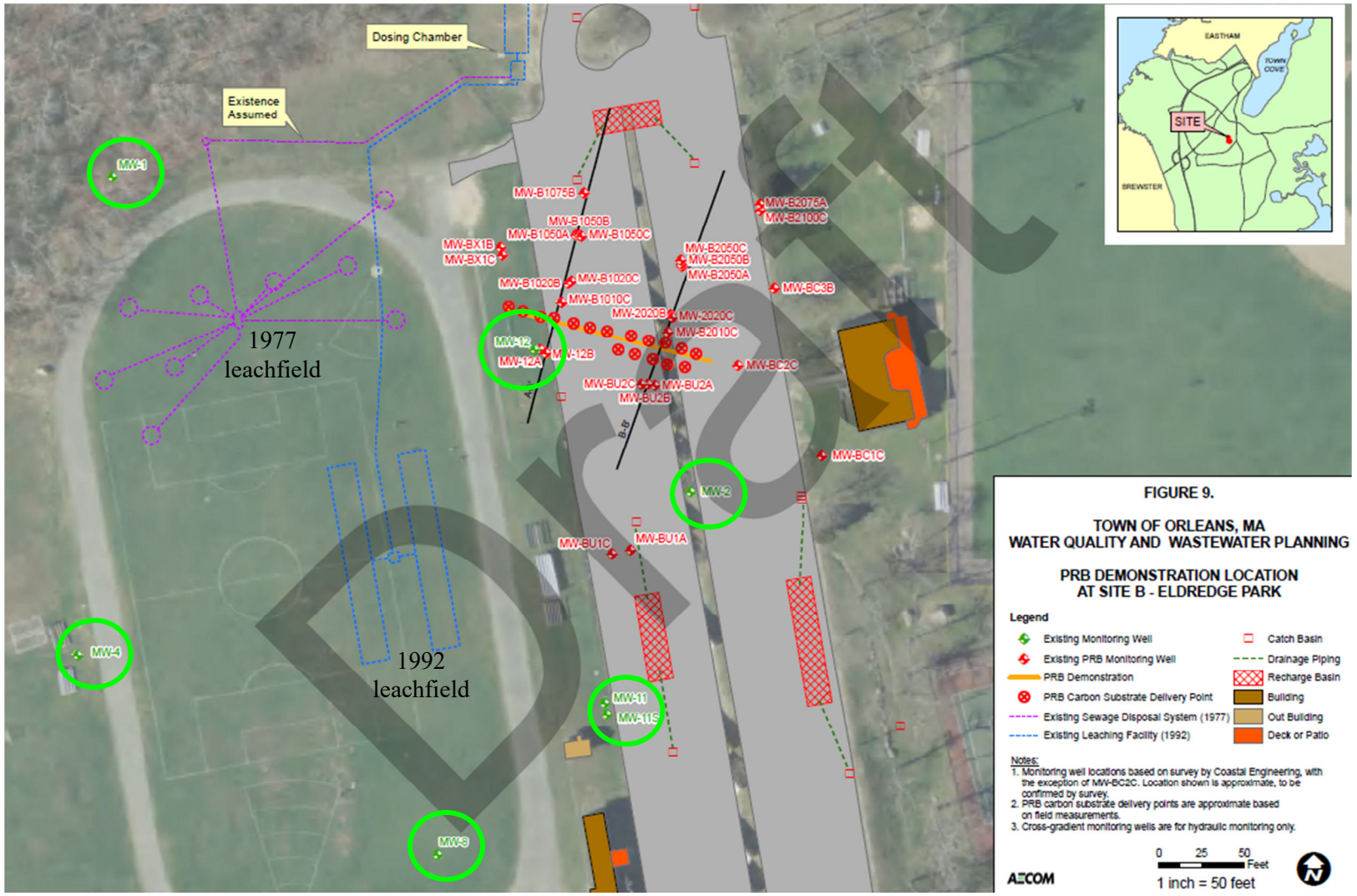

Figure 1. Eldredge Park Monitoring Well Network. Far-field wells were installed by Coastal Engineering to monitor the Middle School wastewater impacts are generally 200 to 350 feet from the PRB, except for MW-12, and include MW-1, MW-4, MW-8, MW-11, and MW-2 (green circles). Near-field wells were generally installed by AECOM and are generally 10 to 100 feet from the PRB. 1977 and 1992 Middle School wastewater leachfields are also indicated. Modified from Figure 9 in draft AECOM Tech Memo (8/8/17).

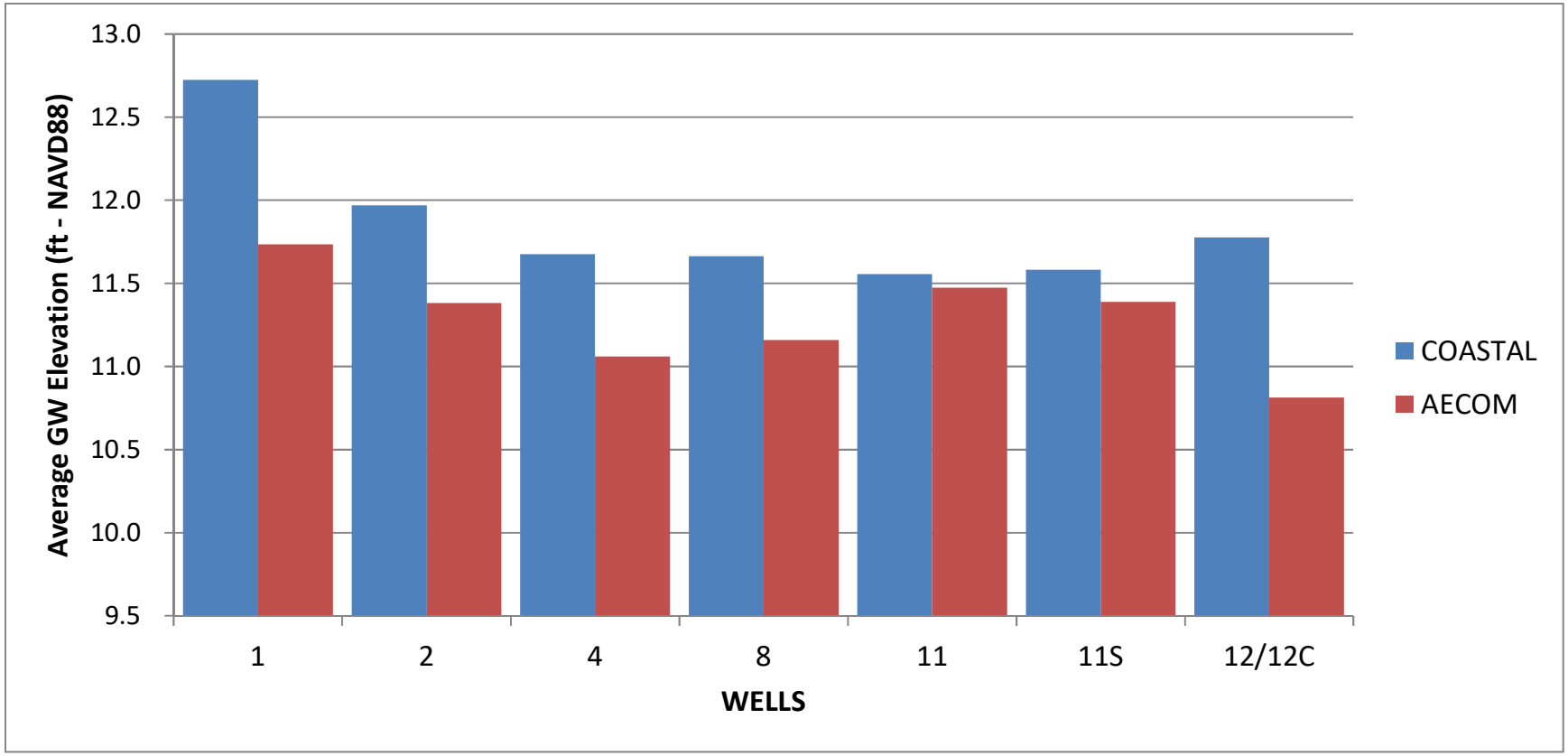

Figure 2. Average groundwater elevations at long-term wells at the Eldredge Park PRB site. All wells included except MW-12C are far-field wells. Coastal Engineering measurements occurred quarterly between June 2012 and December 2015 (n=15), while AECOM measurements occurred between November 2016 and June 2017 (n=7). Average elevations were highest at MW-1, which is located NW of the PRB, in both set of measurements, although it is more pronounced in the CE dataset. Most of the AECOM averages were lower, but with different decreases at various wells (MW-1 decrease>>MW-11 decrease). None of the averages in the two datasets are significantly different statistically except for the decrease in water levels at MW-12, which is located approximately 20 ft south of the PRB. Overall, the differences in average elevations except MW-1 were relatively small, which is consistent with a relatively flat water table throughout the area and similar effluent impacts. Groundwater flow directions in a flat water table area can be extremely changeable with flowpaths changing depending on slight changes in recharge, either from precipitation, wastewater or stormwater. Examples of the changeable nature were present in the comparison of the individual AECOM study area water table maps.

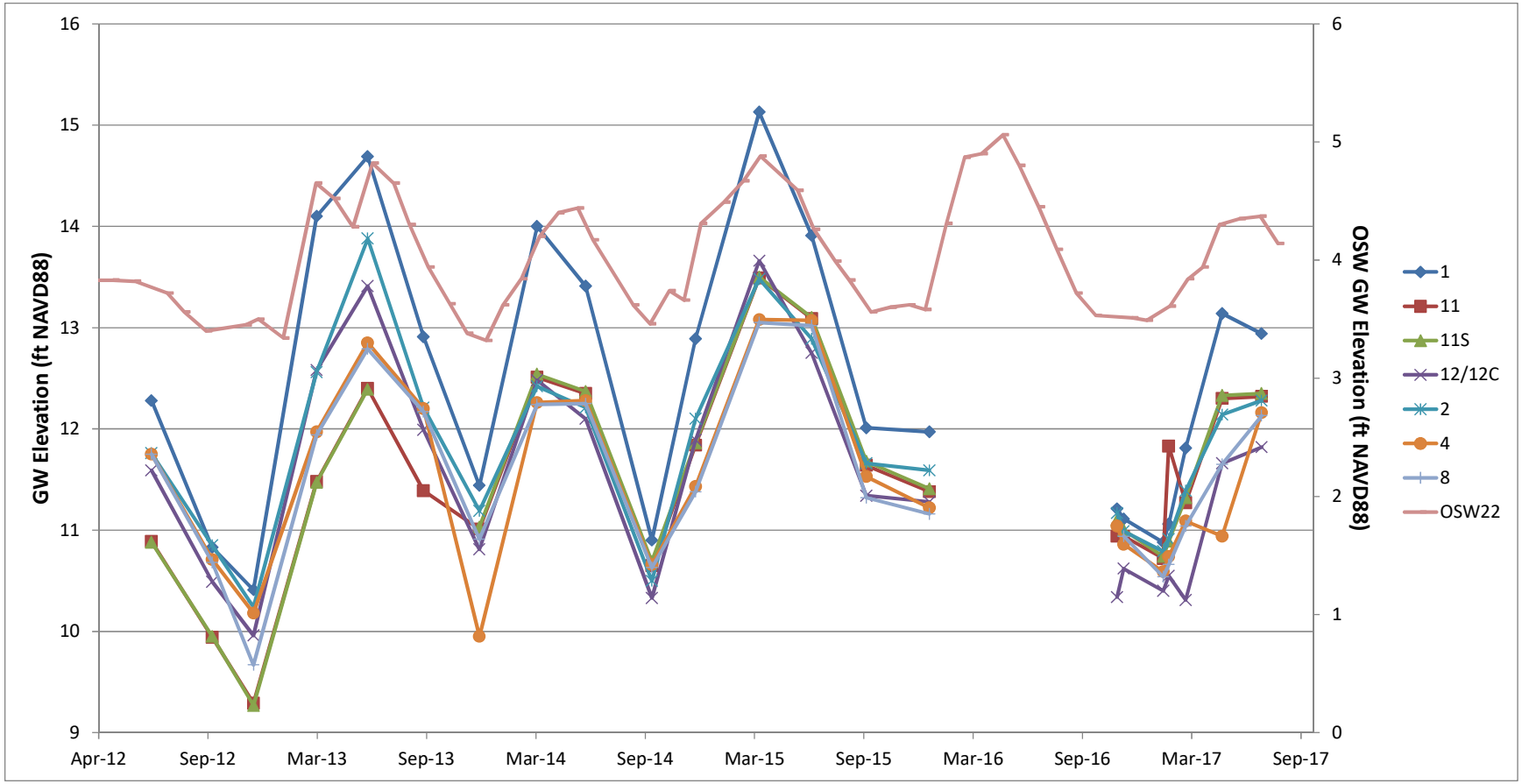

Figure 3. Groundwater elevations at long-term wells at the Eldredge Park PRB site with long-term USGS well. All wells included except MW-12C are far-field wells. Coastal Engineering measurements occurred quarterly between June 2012 and December 2015, while AECOM measurements occurred between November 2016 and June 2017. Fluctuations at the PRB wells generally followed the pattern, but not magnitude, of seasonal fluctuations at the long-term US Geological survey regional groundwater elevation monitoring well (OSW-22). The relative flatness of most of the PRB study area water table is shown by the changing relationships among the well elevations with differing wells having higher elevations relative to others depending on the date of measurements.

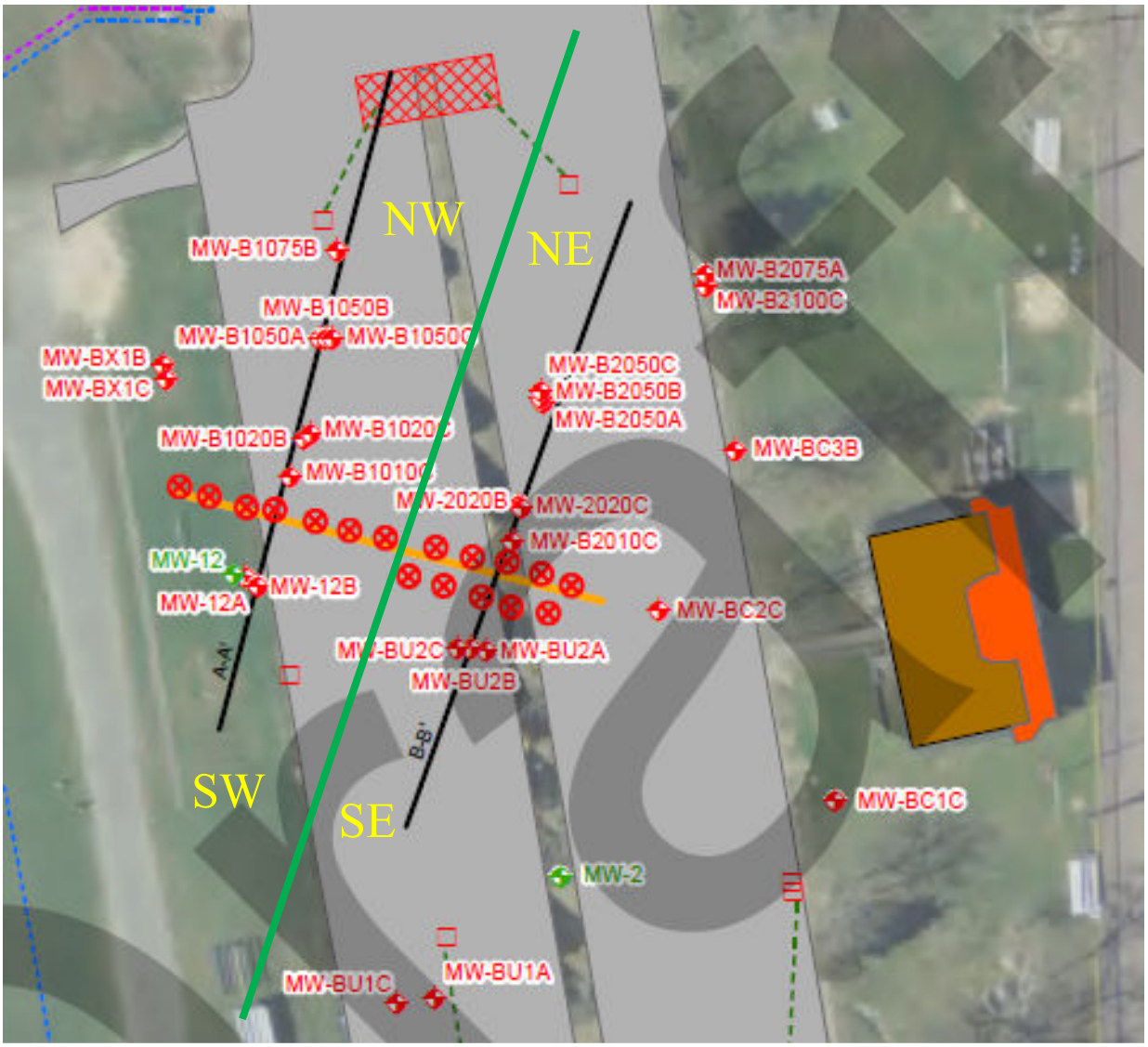

Figure 4. Near-field PRB Wells. For the purposes of evaluating groundwater elevations, flow directions and water quality, CSP/SMAST grouped near-field wells into quadrants using the density of injection points to divide the East and West sections of the PRB and the PRB line to divide North and South sections. Wells thought to be outside of the impact of the PRB *a priori*, such as MW-BC1C, were not included in the analysis groupings. It is notable that well clusters are not distributed evenly among the quadrants: NE and NW have 4 clusters, SE has 3 clusters, and SW has one cluster.

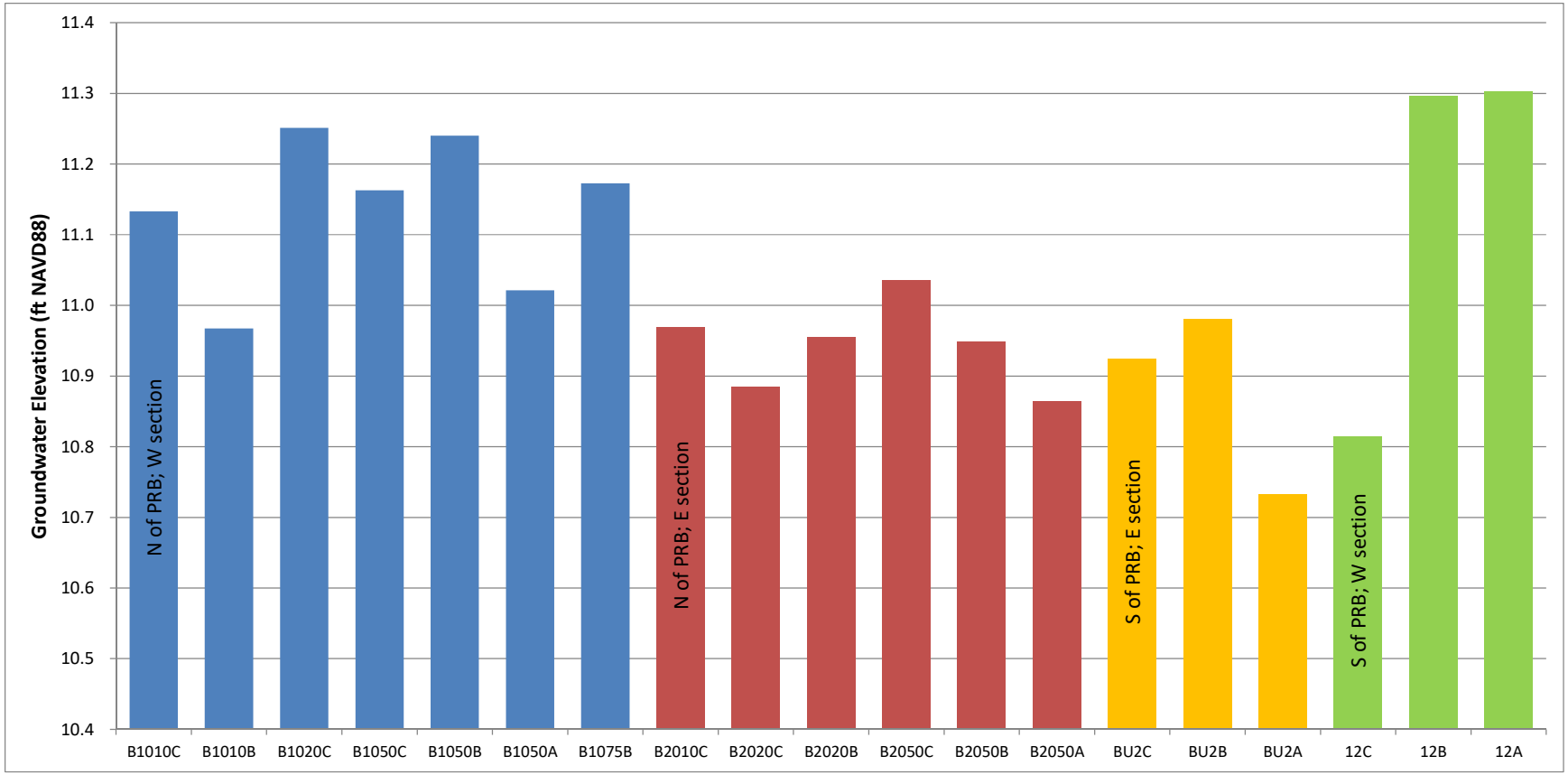

Figure 5. Average groundwater elevations of near-field PRB wells. Wells are grouped by quadrant around the PRB: a) NW quadrant wells are blue bars, b) NE quadrant wells are red bars, c) SE quadrant wells are yellow bars, and d) SW quadrant wells are green bars. Differing numbers of wells are included in each quadrant and depths of screens are indicated by the following AECOM convention: A wells are deepest, B wells are intermediate, and C wells are shallow. Wells to the north of the PRB generally have higher elevations than those south of the PRB, which would indicate groundwater flow from the north to the south. On the western portion of the PRB, shallow wells on the north side were again on average higher than the single well on the south side (MW-12C), but deeper wells in the MW-12 cluster had higher elevations suggesting flow toward the north at depth.

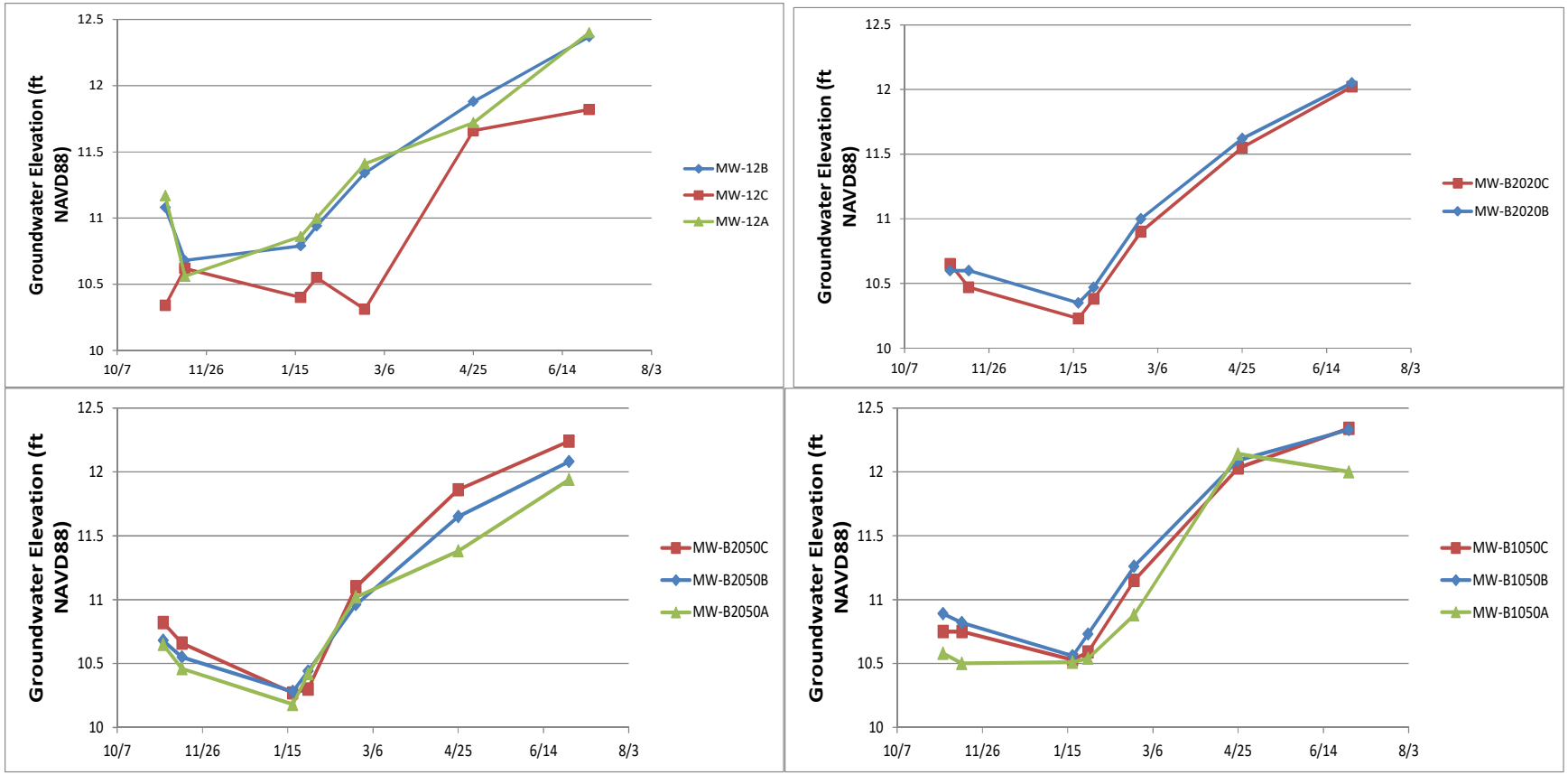

Figure 6. Groundwater elevations of selected near-field well clusters. Groundwater elevations in selected well clusters with screens at shallow ("C" wells), intermediate ("B" wells) and deep ("A" wells) show that elevations tend to be similar at all depths except for those at MW-12. MW-12C, the shallow well, had elevations during the AECOM monitoring that were generally lower than those at the deep and intermediate depths; this difference would tend to indicate a strong downward gradient at this site. This type of gradient would be inconsistent with other cluster and suggest that MW-12 conditions or measurements should be clarified.

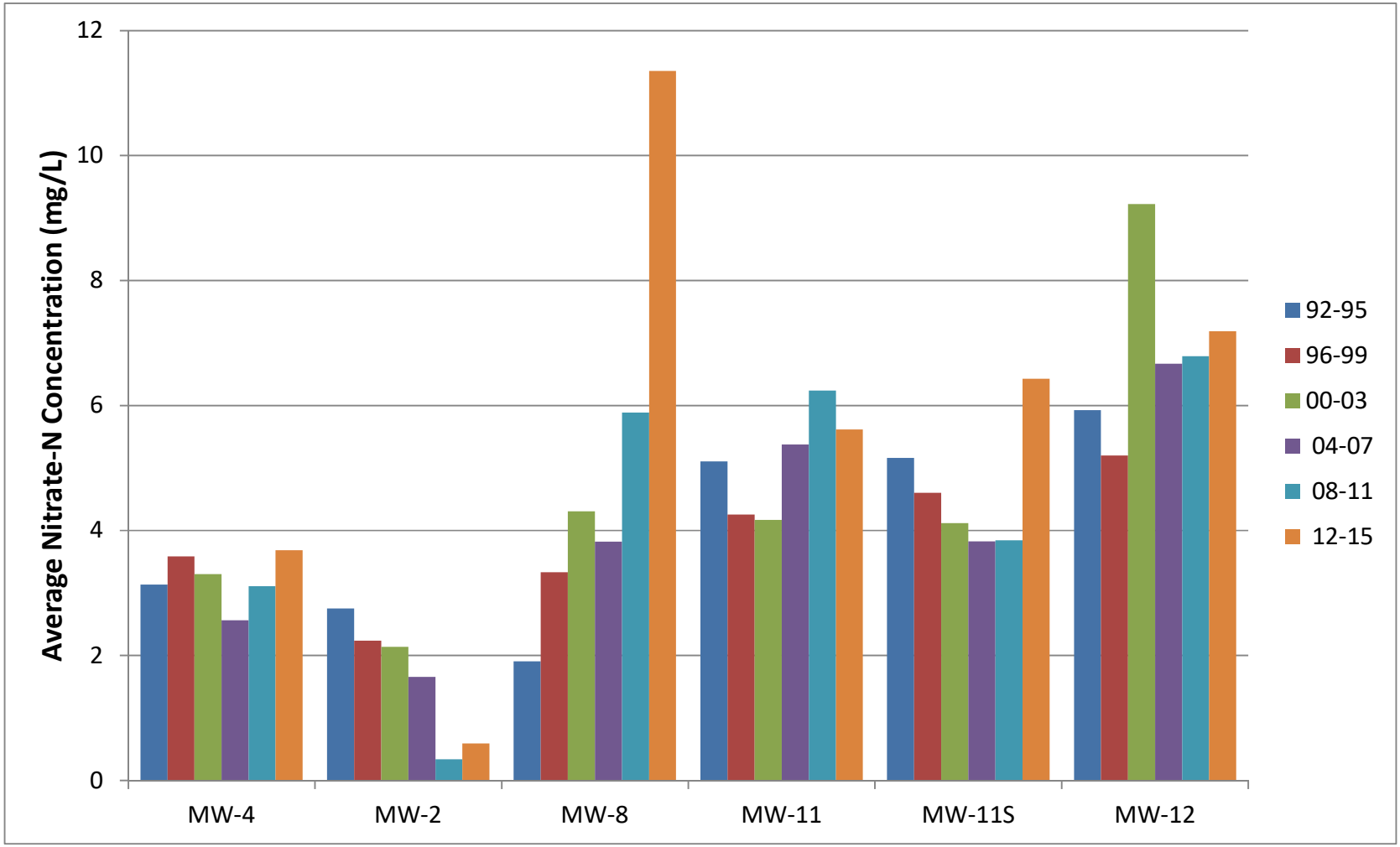

Figure 7. Average nitrate-N concentrations at far-field wells between 1992 and 2015. Concentrations at MW-4, MW-11, MW-11S, and MW-12 have also been relatively consistent, which suggests relatively stable nitrogen sources and groundwater flowpaths. In contrast, concentrations at MW-2 and MW-8 have changed over time with MW-2 concentrations decreasing and MW-8 concentrations increasing. MW-2 concentrations would be consistent with its groundwater elevation readings generally showing it as a high point in the water table, while the gradual increase at MW-8 suggests an increasing proportion of the Middle School leachfields flow was flowing toward the south.

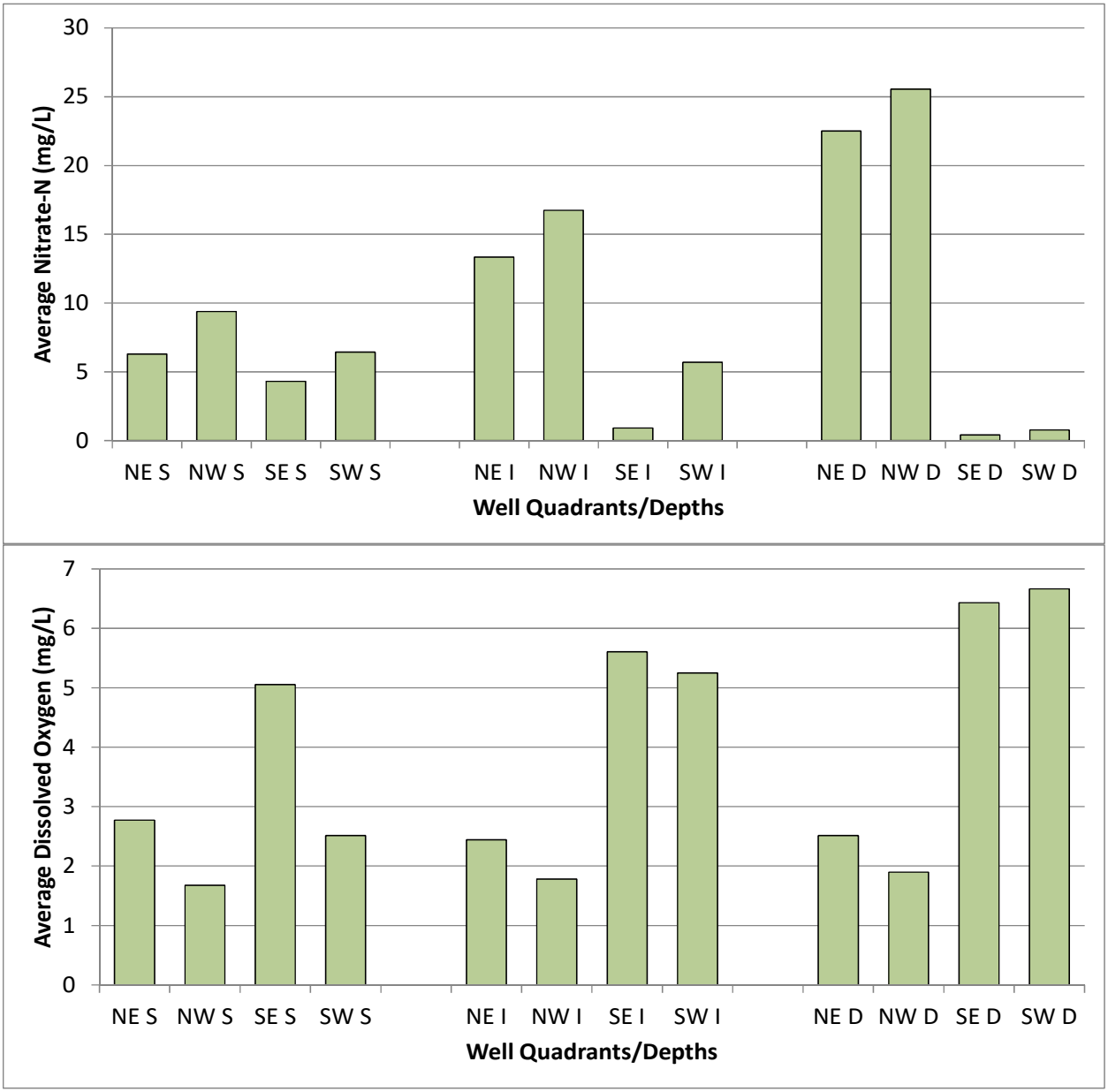

Figure 8. Average nitrate-N concentrations at near-field well quadrants. Averages are based on AECOM monitoring between October 2016 and June 2017. DO readings were generally low, which would be consistent with pervasive wastewater impacts throughout the PRB area. SE quadrant had the highest DO concentrations, which would be consistent with the higher water table and less impact in this area. Review of the nitrate-N water quality lab assays showed lower concentrations in the southern quadrants than the northern quadrants, which suggests average flow toward the south or avoidance of the PRB by the primary wastewater plumes. Review of the northern quadrant nitrate-N concentrations showed decrease from west to east, parallel to the PRB with increasing concentrations with depth. The decrease in average nitrate-N concentrations from north to south would seem to contradict the original conceptualization of flow from south to north. Higher average nitrate-N concentrations at depth in the northern quadrants would seem to suggest an additional nitrogen source.