

Memorandum

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Subject **Town of Orleans, MA**
Water Quality and Wastewater Planning
Task Number 10.1.B.2 – NT Demonstration Projects
Technical Memorandum for Landfill Nitrogen Field Investigation Phase 1 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. Introduction

This Phase 1 Technical Memorandum provides updated information regarding assessment activities implemented starting in January 2017 to investigate nitrogen sources and nitrogen compounds in groundwater at the Orleans Municipal Landfill and former septage lagoons (the landfill) located in the Town Cove/Nauset Marsh Estuarine System watershed. A Phase 2 Technical Memorandum will be prepared with a summary of additional measures to be undertaken to fill data gaps, an evaluation to assess the need for corrective actions to address nitrogen sources and nitrogen flux in groundwater, and a feasibility evaluation and a conceptual design for recommended actions. This investigation was implemented in conjunction with an investigation of 1,4-dioxane in groundwater at the landfill that has been documented in a separate Technical Memorandum.

2. Orleans Landfill Site Description and Background

- A. The landfill consists of approximately 21 acres of Town-owned land located off Lots Hollow Road (Figure 1). The property includes a natural kettle hole that was used for solid waste disposal from the 1950s until 1991. The unlined solid waste fill area was closed and a 13-acre area was capped with a final cover system at a maximum elevation of approximately 110 feet above mean sea level (MSL) in 2005. The landfill property also includes an active solid waste transfer station and yard waste composting and stockpile area (Figure 2). The yard waste composting area is in part located on a land area formerly used for septage waste disposal to lagoons. Six unlined septage lagoons, used between 1950 and 1989, were located just to the north of the capped solid waste area at an approximate elevation of 50 feet above MSL. Landfill drainage and transfer station stormwater are infiltrated along a drainage swale constructed over the former septage disposal area when the landfill was capped in 2005. The septage lagoons were partially excavated to remove sludge, filled and covered with sand in the 1990s. Part of the area over the lagoons has been paved with asphalt (see Figure 2). The landfill property is downgradient (and outside the Zone of Contribution) of the Town of Orleans public well located to the south. Adjacent properties also include the Charles Moore Ice Arena to the west and commercial/industrial properties to the north and east. Plans have been developed by Weston and Sampson for the construction of a new Department of Public Works and Natural Resources (DPW) facility on portions of the landfill property starting in late 2017.

The landfill cap and associated drainage system was installed in 2005 to cap the solid waste and prevent continued infiltration of precipitation. The landfill cap system and transfer station stormwater management system are shown in Figure 3.

The landfill cap includes a subgrade of compacted soil materials on top of waste which is overlain by:

- A gas venting layer consisting of a minimum thickness of six inches of soil with a minimum saturated hydraulic conductivity of 1.2×10^{-3} centimeters per second, overlain by;
- A low permeability layer consisting of a 40 mil textured high-density polyethylene geomembrane, flexible membrane liner, overlain by;
- A drainage layer consisting of soil with a minimum thickness of twelve inches and a minimum saturated hydraulic conductivity of 1.2×10^{-2} cm/sec with a perforated pipe subdrain system constructed within the drainage soil that discharges to the stormwater swales, overlain by;
- A vegetative support layer comprised of a minimum thickness of twelve inches of soil, with a vegetative cover seed mix.

The cover system was completed with a minimum top slope of 5 percent and side-slopes no greater than 3:1. Stormwater runoff controls were constructed to maintain the integrity of the final cover, prevent ponding of water on areas of the final cover, and to control stormwater runoff to prevent off-site flooding impacts. The current stormwater control system includes a perimeter swale around the entire landfill and a 108,000 cubic foot (808,000 gallon) capacity retention basin located in the northeast corner of the site. The retention basin includes a sediment forebay and was designed to fully control the twenty-five year storm event prior to discharge through an emergency spillway. Stormwater system modifications are planned for implementation during construction of the new DPW facility at the landfill in 2017.

- B. Nitrogen compounds (total nitrogen, nitrate, and ammonia) have been detected at significant concentrations in groundwater downgradient of the landfill and former septage lagoons. The Barnstable County Health Department (BCHD) conducts semi-annual groundwater sampling events on behalf of the Town of Orleans. Until recently the nitrogen analyses were limited to nitrate. This long term nitrate monitoring data is included in Appendix A. The highest nitrate concentrations in the long term data set have been observed since the landfill was capped in 2005. Long term monitoring of four monitoring wells (MW-1S, MW-2S, MW-2D, and MW-5S) indicates groundwater nitrate concentrations greater than the Massachusetts Maximum Contaminant Limit of 10 mg/L, with a maximum concentration of 40 mg/L observed at monitoring

well 2S. Landfill monitoring wells were first tested for total nitrogen in May of 2015. Results of testing indicated that total nitrogen concentrations were significantly higher than nitrate concentrations in some of the deeper wells, while nitrate was approximately equal to total nitrogen in shallow wells (data not shown). The 2015 sampling events did not quantify ammonia. However, the significant difference between the concentration of total nitrogen and nitrate in some of the samples was likely due to the presence of ammonia. More recent data from groundwater analyses have confirmed the presence of ammonia which accounts for the difference in total nitrogen and nitrate concentrations in deep groundwater as discussed in detail in Section 4 below.

3. Landfill Groundwater Monitoring Well Network

The following groundwater monitoring wells were in place prior to this assessment:

- MW-1S and 1D on the west side of the landfill property;
- MW-2S and 2D to the north;
- MW-3S and 3D to the east;
- MW-4S and 4D to the south;
- MW-5S and 5D to the northeast; and
- MW-E6B and E6A to the north.

Monitoring well installed prior to this investigation shown on Figure 2 were renamed and identified with a naming convention that included the former name (e.g. MW-2S), and the projected depth interval in feet below ground surface for the screened interval (e.g. MW-2S (84-94)). New monitoring wells installed by AECOM used the same naming convention.

Four of the shallow landfill water table monitoring wells originally identified as MW-1S through MW-4S, were installed in 1992 as part of an assessment associated with the septage lagoon closure. Deeper screened monitoring wells originally identified as MW-1D, MW-2D, MW-3D, and MW-4D) were installed as part of the 1994 landfill Comprehensive Site Assessment, completing the well couplets at these locations. One additional couplet (MW-5S and MW-5D) was also installed in 1994. Monitoring well couplet MW-E6B and MW-E6A was installed by AECOM in 2016 for nitrogen assessment.

4. Initial Conceptual Site Model Prior to the Current Assessment

A. Conceptual Site Model

A Conceptual Site Model (CSM) is a tool used to provide a framework of information to help understand and communicate what is known about a potential problem, visualize available information, identify gaps in data, and prioritize response actions. The following paragraphs provide a narrative version of the CSM for the landfill concerning potential sources of nitrogen and nitrogen in groundwater.

B. Potential Sources of Nitrogen in Groundwater

Municipal operations at the landfill, starting in the 1950s. Operations included operation of septage lagoons until 1989 and solid waste disposal until 1991. Periodically during operations and at closure septage sludge was excavated from the lagoons with material disposed in the solid waste landfill and other unknown areas on and off the landfill property. The remaining mass of nitrogen in the former septage lagoon soil is unknown. Current operations include a transfer station and stockpiling and composting of yard wastes. All these operations may have released nitrogen in the past or may be continuing to release nitrogen compounds to groundwater.

The solid waste landfill was capped with an impermeable cover in 2005, reducing the infiltration of water through solid waste material. While the cap minimizes infiltration, the landfill is expected to generate leachate that will infiltrate to groundwater as the landfill settles over time. Drainage structures constructed to manage runoff from the cap include an unlined rip rap swale that passes directly over part of the former septage lagoon area. The runoff from the landfill cap infiltrating through the former septage lagoons area may be intensifying the release of nitrogen compounds from residual material in the former septage lagoons. Leachate from compost operations and stormwater runoff from the transfer station is also infiltrated in the vicinity of the former septage lagoons.

C. Groundwater Flow and Potential Contaminant Transport

Nitrogen compounds are soluble in groundwater. Nitrate is generally transported with groundwater flow by advection with little retardation. Ammonium, the ionized form of ammonia in groundwater however is likely to be transported at less than the rate of groundwater flow due to physical and biogeochemical processes. Studies conducted at the United States Geological Survey (USGS) Cape Cod Tracer Test Site located on a wastewater plume in Falmouth, MA found that ammonium was moving downgradient at a rate about 0.25 times the groundwater velocity (Bohlke, 2006). There is also a potential for natural attenuation of nitrogen compounds under specific conditions. Under aerobic groundwater conditions ammonia may be converted to nitrate. In the presence of sufficient carbon, nitrate may be attenuated to nitrogen gas under anoxic denitrifying conditions.

Regional groundwater contour maps prepared by the USGS with the Cape Cod Commission and previous assessment reports associated with the landfill indicate groundwater flow to the north northwest, north, and northeast toward Town Cove (Walter et. al., 2004 and Coastal Engineering, 1999).

Boring logs for landfill monitoring wells show subsurface sediments that consist of glacial outwash sands and gravel with thin layers of more silty sand, silt and clay. The depth to groundwater varies significantly with location due to land surface elevation differences associated with the topography of the kettle hole.

Groundwater elevation measurements, characterization of the aquifer sediments, and aquifer tests were used by Coastal Engineering to estimate groundwater velocity and flow direction in the vicinity of the landfill (Coastal Engineering, 1999). The hydraulic conductivity of aquifer materials was determined from aquifer testing at various locations. The hydraulic conductivity determined at shallow screen locations ranged from 5.6 feet/day at MW-1S to 70.88 feet/day at MW-2S. In general, a higher hydraulic conductivity indicates the potential for faster groundwater flow, depending on the gradient. The hydraulic conductivity determined at deeper screen locations ranged from 14.14 feet/day at MW-3D to 147.74 feet/day at MW-1D (Coastal Engineering, 1999). The methods used to test hydraulic conductivity provided information for the immediate vicinity of well screens.

The slope of the potentiometric surface (the water table) derived from water elevation measurements were used to determine the hydraulic gradient and flow direction. According to the Comprehensive Site Assessment prepared for landfill closure by Coastal Engineering in 1999, there is the potential for divergent flow (groundwater flow in more than one direction) from the landfill area. The shallow screen wells indicated a consistent gradient of 0.012 to the northeast while deeper screen wells showed variation in flow direction including flow to the north and north northwest. Measurements indicated an average gradient of 0.003 to the north 0.0006 to the northwest respectively. The 1990s data also indicated vertical gradients at all monitoring well couplets (downward at MW-1, MW-2, MW-3, and MW-4 and upward at MW-5). The variation in the vertical gradient and divergent groundwater flow direction could be the due to local mounding effects from stormwater, differences in sediment permeability, and the location of the landfill in a recharge area of the groundwater system. A downward vertical gradient indicates groundwater flow deeper into the aquifer. The porosity was estimated by Coastal Engineering at 0.30 from soil samples collected during soil boring installation. Based on these data, Coastal Engineering calculated the horizontal groundwater velocity at a range of 0.029 feet/day to 2.84 feet/day.

The groundwater velocity estimate is highly variable from point to point, and can be expected to vary along the long flow path from groundwater recharge to surface water discharge. Slower flow is more likely in low permeability silty sand layers as compared to groundwater in more permeable medium sand layers. Town Cove is located approximately 5,450 feet downgradient on a heading of 40 degrees northeast, consistent with the direction of shallow groundwater flow at the site. The travel time for groundwater from the landfill to Town Cove has been estimated to range up to 50 years (USGS, 2004).

D. Contaminant Assessment - Nitrogen in Groundwater

Landfill monitoring well nitrate data have been collected for more than 20 years between September 1994 and March 2016 (Appendix A). The 1990s data (September 1994 through December 2000) were collected during assessments related to closure of the septage lagoons and solid waste landfill. A gap in data collection occurred during the landfill capping operations and semi-annual monitoring conducted by the Barnstable County Health Department was resumed starting in March 2005. More limited test data are available for MW-1D and MW-3S as they were sampled less frequently.

A reference background nitrate concentration of 0.46 mg/L was previously reported for Cape Cod by the USGS (LeBlanc, 1984). Earlier data from Frimpter and Gay (1979) indicate uncontaminated groundwater may have less than 0.1 mg/L nitrate nitrogen. At the landfill, the lowest nitrate concentrations were observed in the upgradient deep screened monitoring well MW-4D located south of the landfill and were consistent with background Cape Cod groundwater. All other wells tested showed nitrate concentrations above background.

The historical analyses have mainly included testing for nitrate-nitrogen alone. Nitrate-nitrogen analyses provide only a partial assessment of total nitrogen concentrations. Total nitrogen is the sum of total kjeldahl nitrogen (ammonia and organic nitrogen) plus nitrate-nitrogen and nitrite-nitrogen. Recent 2016 BCHD data collection has included groundwater analyses for additional nitrogen compounds. These data show the absence of nitrate but the presence of ammonia in some of the deeper landfill monitoring wells, including MW-2D (124-134) with nitrate at 0.5 mg/L and ammonia at 10 mg/L, MW-3D (84-94) with nitrate at <0.01 mg/L and ammonia at 5.6 mg/L, and MW-5D (124-134) with nitrate at <0.01 mg/L and ammonia at 14 mg/L.

Four of the monitoring wells (MW-1S, MW-2S, MW-2D, and MW-5S) had nitrate concentrations above the Massachusetts Drinking Water Maximum Contaminant Level (MMCL) of 10 mg/L on one or more sampling dates. MW-5S has shown a consistent elevated nitrate concentration over the sampling period (pre- and post-landfill capping), with the nitrate concentration ranging from 6.6 mg/L to 22 mg/L. Other wells including MW-1S, MW-2S, MW-2D, and MW-4S showed a marked increase in nitrate concentration with renewed post-capping groundwater monitoring starting in March 2005 compared to the 1990s data (see Appendix A). One shallow monitoring well, MW-2S, has shown a generally increasing, but highly variable, trend in nitrate concentration starting when post-capping groundwater sampling was resumed. The concentration of nitrate at MW-2S reached a maximum concentration of 40 mg/L in September 2009 and was reported at 34 mg/L in March of 2014 and 22 mg/L in September 2016. MW-5S has shown a fairly steady elevated concentration of nitrate.

Landfill groundwater monitoring data also included limited measurements of dissolved oxygen that indicate oxygen levels are low in deeper groundwater. Shallow groundwater is generally aerobic (>1 - 2 mg/L dissolved oxygen). Biological attenuation of nitrate in groundwater by denitrification is inhibited under aerobic conditions in shallow groundwater and attenuation is unlikely in shallow groundwater during migration from the landfill to Town Cove. In the potential nitrate source areas, the significant depth to groundwater may be limiting migration of organic carbon from below the former septage lagoons and from composting operations to groundwater while allowing for conversion of infiltrating ammonia in runoff to nitrate under aerobic conditions. Ammonia is generated during composting of high nitrogen materials such as fresh grass clippings. The breakdown of residual organic matter in the unsaturated zone below the former septage lagoons may also be a source of ammonia nitrogen.

It is likely the ammonia in deep groundwater comes from below the unlined landfill. Landfill leachate is a common source of ammonia in groundwater. The deeper groundwater is generally anoxic and therefore would not support the conversion of ammonia to nitrate.

Due to the limited number and location of monitoring wells, the extent of nitrogen compounds in groundwater both vertically and horizontally was unknown. Assessment of the horizontal and vertical extent of nitrogen compounds in groundwater immediately downgradient of the landfill and septage lagoons was therefore necessary to refine the estimate of nitrogen flux at the landfill. Assessment was also necessary to confirm the sources of nitrogen compounds in groundwater and to facilitate evaluation of necessary response actions.

E. Initial Conceptual Site Model Summary

The CSM indicates that there is the potential for groundwater with significant concentrations of nitrogen compounds at the landfill to contribute to the nitrogen load to Town Cove. In this report the mass flux of nitrogen in groundwater at the landfill is defined as the approximate mass that continuously passes through a cross sectional area located immediately downgradient of the landfill and is expected to be persistent given current conditions. Based on information available prior to this investigation, the area with elevated nitrogen concentrations at the landfill appeared to extend up to 800 feet cross-gradient (between MW-1 to the west and MW-3/MW-5 to the east). Elevated nitrogen concentrations were also known to extend to at least 40 feet below the water table with deeper groundwater contaminated by ammonia rather than nitrate. The full horizontal and vertical extent was unknown. The cross-section area and groundwater flow data indicate there may be a significant mass flux of nitrate from the landfill. Elevated concentrations of nitrate have been present in groundwater at the landfill for at least 23 years, a period of time extending at least to the start of regular groundwater monitoring in 1994.

Historical landfill and septage lagoon operations, beginning around 1950 were likely sources of nitrogen to groundwater at one or more locations. The location of septage disposal may have changed over time and septage sludge was excavated and placed at other locations at the landfill. With an estimated groundwater travel time of 50 years to Town Cove, it is likely that nitrogen from the landfill property may already be contributing nitrogen loading to Town Cove. The mass flux from the landfill actually reaching Town Cove will likely be affected by hydrogeologic and biogeochemical factors including dispersion, retardation and degradation. Given current conditions and without corrective action, sources of nitrogen will continue to contribute a nitrogen load to the groundwater at the landfill over the long term.

Yard waste composting operations may be a potential source of nitrogen leaching to groundwater. Current infiltration of Transfer Station stormwater and runoff from the top of the capped landfill through the former septage lagoon area may also be adding significant nitrogen to groundwater.

The infiltration of aerobic runoff may have converted a historical ammonia plume to a plume with nitrate as the dominant nitrogen compound in shallow groundwater while ammonia remains present in deeper anaerobic groundwater.

5. Phase 1 Assessment

- A. Phase 1 Assessment plans included actions to define groundwater contaminant sources and the horizontal and vertical extent of nitrogen compounds in groundwater immediately downgradient of the landfill and septage lagoons.
- B. Completed Phase 1 assessment activities include:
 - An evaluation of the landfill cap drainage design and stormwater management systems in the vicinity of the transfer station and material composting areas to determine if runoff from the landfill surface or transfer station stormwater is recharging groundwater through the former septage lagoons;
 - Assessment of the concentration of nitrogen compounds in landfill stormwater and groundwater at recharge locations;

- Groundwater sampling of selected pre-existing groundwater monitoring wells for nitrogen;
- Installation and sampling of new groundwater monitoring wells placed near potential contaminant source areas and adjacent, upgradient, crossgradient, and downgradient of MW-2S(84-94) and MW-2D(124-134), including some with multi-level screen intervals. Note that values in parentheses have been added to show the depth of the screen in feet below ground surface;
- Groundwater monitoring including measuring groundwater elevations based on surveyed top of well casing elevations and depth to groundwater, collection of groundwater field parameters, and collection of groundwater samples for laboratory analyses nitrogen compounds, and other parameters in groundwater;
- An evaluation of groundwater hydrogeology and groundwater flow in the vicinity of the landfill based on data collected;
- Collection and analyses of sub-surface soil samples from the unsaturated zone at and below the former septage lagoon area for total nitrogen, nitrate and total volatile solids to quantify nutrients and organic material; and
- Installation of new monitoring wells downgradient of the landfill closer to Town Cove as necessary.

Monitoring wells were sampled and groundwater samples analyzed for field parameters, nitrogen compounds, and selected anions, elements, and dissolved organic carbon.

Source area and nearfield downgradient monitoring well locations are shown on Figure 2. Downgradient watershed sampling locations are shown on Figure 4.

6. Results of Phase 1 Assessment

A. Evaluation of Landfill Cap Drainage Design, Stormwater Management Systems, and Associated Potential Sources of Nitrogen to Groundwater Including the Former Septage Lagoons

1) General

The landfill cap and drainage system was installed in 2005 to contain the solid waste and prevent continued infiltration of precipitation and manage landfill and transfer station stormwater. The landfill cap system and transfer station stormwater management system are shown in Figure 3.

According to the Massachusetts Department of Environmental Protection, the final cover system includes:

- A subgrade of compacted soil materials on top of waste which is overlain by;
- A gas venting layer consisting of a minimum thickness of six inches of soil with a minimum saturated hydraulic conductivity of 1.2×10^{-3} centimeters per second, overlain by;
- A low permeability layer consisting of a 40 mil textured high-density polyethylene geomembrane, flexible membrane liner, overlain by;
- A drainage layer consisting of soil with a minimum thickness of twelve inches and a minimum saturated hydraulic conductivity of 1.2×10^{-2} cm/sec with a perforated pipe subdrain system constructed within the drainage soil that discharges to the stormwater swales, overlain by;
- A vegetative support layer comprised of a minimum thickness of twelve inches of soil, with a vegetative cover seed mix.

The cover system was completed with a minimum top slope of 5% and side-slopes no greater than 3:1. Stormwater runoff controls were constructed to maintain the integrity of the final cover, prevent ponding of water on areas of the final cover, and to control stormwater runoff to prevent off-site flooding impacts. The stormwater control system includes a perimeter swale around the entire landfill and a 108,000 cubic foot (808,000 gallon) capacity retention basin located in the northeast corner of the site. The retention basin includes a sediment forebay and was designed to fully control the twenty-five year storm event prior to discharge through an emergency spillway.

Drainage pipes were installed across the side slope to collect stormwater accumulated within the sand drainage layer. Side slope pipes connect to a header installed down the side slopes leading to stone riprap lined perimeter swales. Pre-cast catch basins were installed in the paved areas at the transfer station to direct stormwater runoff to the riprap swale leading to the stormwater detention basin (MassDEP October, 2013).

Sources of nitrogen associated with the stormwater management and landfill cap system include general transfer station runoff and the potential mobilization of nitrogen from the former septage lagoon area by infiltrating stormwater and landfill cover drainage water in the unlined riprap swale located to the north of the landfill cap. A sample of general transfer station runoff was collected from Stormdrain-1 located adjacent to the Gift Shop building (Figure 2). Stormwater test results are included in Table 1. Laboratory results for the stormwater sample indicated mainly the presence of organic nitrogen with total nitrogen measured at 4.5 mg/L, nitrate-nitrogen at 0.42 mg/L, and ammonia-nitrogen measured at 0.67 mg/L.

A soil boring was completed at the location of monitoring well MW-7 installed adjacent to the northwest end of the unlined riprap swale on January 18th and 19th, 2017. Soil sampling results indicated the presence of soil with a high nitrogen and organic content with septage odor at approximately 12 feet below ground surface. Test results for soil samples collected at 12 to 13 feet, 13.5 to 14.5 feet, 15 to 17 feet, 42 to 44 feet, and 57 to 58 feet below ground surface indicated that high concentrations of nitrogen and organic material were limited to the 12 to 13 feet range. The concentration of total nitrogen in this residual material was measured at 1,440 mg/kg or 0.14 percent (Table 2). Visual observations at depths less than 12 feet indicated the presence of relatively clean sand.

2) Results of Evaluation

Transfer station stormwater is a source of nitrogen that is infiltrated to groundwater without treatment. A concentration of 4.5 mg/L total nitrogen was measured in the surface water runoff sample collected although the stormwater nitrogen concentration is likely to be highly variable. The section of the unlined riprap perimeter swale to the north of the landfill cap receives runoff from the landfill cap drainage layer on the north and west sides of the landfill as well as stormwater from the transfer station catch basins. This section of swale is located above the former septage lagoons. Based on landfill drawings and observation, landfill drainage and stormwater infiltrates through the swale and does not flow east to the retention basin except during significant storm events. This results in a significant recharge to groundwater through the residual organic material with a high concentration of total nitrogen in the septage lagoon area and potentially a high mass loading to groundwater.

B. Assessment of Nitrogen in Runoff from Composting Operations

1) General

The landfill composting operation processes yard waste that includes leaves, brush, garden, and landscape trimmings. Generally yard waste includes green waste and brown waste. Green waste is primarily fresh plant material such as grass clippings and garden waste that contains appreciable amounts of nitrogen, phosphorus, and mineral nutrients. Brown waste includes dry leaves, hay, and brush that contain primarily carbon, with a high carbon/nitrate (C/N) ratio (Chatterjee et. al., 2013).

Compost operations include the maintenance of aerated windrows of yard waste in an area to the north of the capped landfill on both paved and unpaved surface. An assessment of the concentration of nitrogen compounds in stormwater originating from an area of paved surface that includes yard waste composting operations was completed. Samples of runoff from the paved composting area were collected for nitrogen analyses at Stormdrain-2, located in the paved area near the east end of the riprap swale (Figure 2). The results of analyses were compared to general transfer Station runoff samples that were collected from Stormdrain -1 located adjacent to the Gift Shop. The results of stormwater analyses are included in Table 1 and a comparison of nitrogen compound concentrations in the stormwater samples is presented in Chart 1.

2) Results of Evaluation

Significantly higher nitrogen concentrations were detected in the sample from the Stormdrain-2 location, which is more associated with the composting operation than general transfer station runoff. Total nitrogen concentrations from transfer station and composting area stormwater runoff were 4.5 mg/L and 27.1 mg/L respectively. A comparison of the test results is included in Chart 1. These data indicate composting operations are a likely significant source of nitrogen to groundwater. The compost is located on both paved and unpaved surfaces and a portion of the leachate from compost directly infiltrates to groundwater through sandy soil, while a portion is recharged to groundwater through the stormwater management system.

C. Groundwater Assessment

1) General

Phase 1 groundwater monitoring wells, including single and multi-screen wells, were installed on the landfill property and in public roadways immediately downgradient of the landfill property to assess the nearfield horizontal and vertical extent of nitrogen compounds in groundwater. As noted above, monitoring wells were identified with a naming convention that included the location (e.g. MW-2), and the projected depth interval in feet below ground surface (e.g. MW-2 (84-94)). Monitoring well locations and screen depth were selected based on previously available assessment data and available information regarding the direction of groundwater flow. The objective was to install new monitoring wells in potential source areas (e.g, septage lagoons) to estimate the extent of existing nitrate sources, in deeper groundwater at locations of known shallower contamination (nitrogen compounds in groundwater) to assess vertical distribution, and cross gradient from wells with known contamination to determine the lateral extent of contaminants. The monitoring wells were installed at selected locations with the intention of installing additional monitoring wells in Phase 2 once initial analyses were complete and a clearer picture of the extent of contaminants was available. In addition, monitoring well locations were selected to assess the extent of groundwater contamination around existing monitoring wells MW-2S (84-94) and MW-2D(124-134), where the highest concentrations of nitrogen compounds had been previously detected. Monitoring wells installed during Phase 1 included:

- MW-2 (140-150) adjacent to and deeper than MW-2S (84-94) and MW-2D (124-134),
- MW-7S (55-65), MW-7D (115-125) upgradient of MW-2S (84-94) and MW-2D (124-134), adjacent to the north side of the capped landfill and the drainage swale over the septage lagoons,
- MW-8 (36-46) located cross gradient of MW-2S (84-94) and MW-2D (124-134), to the east and downgradient of the east side of the landfill on Giddiah Hill Road,
- MW-9 (92-102), located cross gradient to the west of MW-2S (84-94) and MW-2D (124-134), adjacent to Lots Hollow Road, and
- MW-10 (85-95) located downgradient of MW-2S (84-94) and MW-2D (124-134), on Finlay Road (Figure 2).

The depth to groundwater at monitoring wells varies depending on location. Surveyed top of casing elevations and well construction details including screen elevations are included in Table 3. During the field effort landfill MW-1D (99-109) was reconstructed to repair a bent and obstructed well casing. All new monitoring wells are 2-inch PVC wells with 10-foot screens installed with hollow stem auger drilling by Desmond Well Drilling Inc. using a CME-75rig mounted on a GMC 7500.

The new and selected previously existing monitoring wells were developed by pumping and sampled using the US EPA low flow methodology between February 6 and February 8, 2017 for field parameters, nitrogen compounds and selected anions, elements and, dissolved organic carbon (DOC). The results of Phase 1 groundwater analyses are included in Table 4.

Water table elevations were recorded prior to purging wells for sampling and are recorded in Table 5. Groundwater elevations on the north side of the landfill generally indicate flow to the northeast as indicated on Figure 2. Variations in groundwater elevation at cluster well locations also indicate the potential for a steep downward vertical gradients.

2) Results of Evaluation

Groundwater data indicates the presence of a two layer nitrogen plume emanating from the landfill and transfer station property. Shallow groundwater is contaminated with nitrate-nitrogen to a depth of approximately 20 feet below the water table. Ammonia-nitrogen is the dominant form of nitrogen in deeper groundwater. The maximum concentration of nitrate observed in February 2017 groundwater samples was 20.2 mg/L detected in MW-9 (92-102), located cross gradient to the west of MW-2S (84-94) (Figure 2). A concentration of 18.8 mg/L was measured at MW-2S (84-94). The maximum concentration of ammonia observed in February 2017 groundwater samples was 12.7 mg/L, measured at MW-5D (124-134) located east of MW-2D (124-134). A concentration of 11.9 mg/L ammonia was measured at MW-2D (124-134).

Based on the Phase 1 assessment additional monitoring wells are necessary to refine the Conceptual Site Model and assess the flux of nitrogen from the landfill.

7. Phase 2 Assessment Plan and Status

The following Phase 2 monitoring wells have been installed and sampled to fill data gaps: MW-2(161-171), MW-5(140-150), MW-7(90-100), MW-8(84-94), MW-13(74-84). Locations of Phase 2 monitoring wells are shown on Figure 5. Two deep screened monitoring wells MW-11 (91-101) and MW-12 (97-97) were also installed in the watershed between the landfill and Town Cove (see Figure 4). Selected monitoring wells sampled in Phase 1 have been resampled in Phase 2 to confirm results of analyses.

The additional data collected during Phase 2 will be used to confirm the nearfield nature and extent of groundwater contamination and assess sources of groundwater contamination. The Phase 2 Technical Memorandum will include a summary of additional measures to be undertaken to fill data gaps, an evaluation to assess the need for corrective actions to address nitrogen sources and nitrogen flux in groundwater, and a feasibility evaluation and a conceptual design for recommended actions.

8. References

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Tables

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Table 1 Orleans Landfill Stormwater Analyses

Sample ID	Stormwater 1	Stormwater 2
Sample Description	Transfer Station Runoff	Compost Runoff
Sampling Date	2/8/2017	2/8/2017
Laboratory Analyses		
Nitrogen		
Nitrate as N (mg/L)	0.424	10.5
Nitrite as N (mg/L)	0.026	0.15
Ammonia (mg/L)	0.67	2.92
Total Kjeldahl Nitrogen (TKN) (mg/L)	4.05	16.4
Total Nitrogen (mg/L)	4.5	27.1
Anions		
Chloride (mg/L)	455	188
Sulfate (mg/L)	<5	5.9
Organic Compounds		
DOC (mg/L)	39.6	175

Notes:

Bold - detected above the Minimum
Detection Limit

Table 2 Orleans Landfill Septage Lagoon Soil Analyses

Sample ID	MW-7/12-13'	MW-7/13.5-14.5'	MW-7/15-17'	MW-7/42-44'	MW-7/57-58'
Sampling Date	01/18/2017	01/18/2017	01/19/2017	01/19/2017	01/19/2017
Laboratory Analyses					
Nitrogen					
Nitrate/Nitrite as N	0.32	<0.25	<0.24	0.76	<0.23
Total Kjeldahl Nitrogen as N	1440	<93.2	160	<78	<86.7
Total Nitrogen	1440	<93.5	160	<78.2	<86.9
Other					
Total Volatile Solids	4	<1	<1	<1	<1

Notes:

Bold - detected above the Minimum

Detection Limit

Table 3 Orleans Landfill Monitoring Well Construction Details

Location	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	Address
MW-1S (56-66)	83.3	85.18	66.0	56.00	66.00	27.30	17.30	22.30	10.0	existing	Landfill
MW-1D (99-109)	83.3	85.11	109.0	99.00	109.00	-15.70	-25.70	-20.70	10.0	existing	Landfill
MW-2S (84-94)	101.3	101.49	94.0	84.00	94.00	17.30	7.30	12.30	10.0	existing	Landfill
MW-2D (124-134)	101.6	101.42	134.0	124.00	134.00	-22.40	-32.40	-27.40	10.0	existing	Landfill
MW-2 (140-150) *	101.3	102.80	150.0	140.00	150.00	-38.70	-48.70	-43.70	10.0	1/18/2017	Landfill
MW-2 (161-171)	101.4	102.9	171.0	161.00	171.00	-59.60	-69.60	-64.60	10.0	March 2017	Landfill
MW-3S (50-60)	68.6	70.32	60.0	50.00	60.00	18.60	8.60	13.60	10.0	existing	Landfill
MW-3D (84-94)	68.8	69.74	94.0	84.00	94.00	-15.20	-25.20	-20.20	10.0	existing	Landfill
MW-5S (78-88)	102.1	103.91	88.0	78.00	88.00	24.10	14.10	19.10	10.0	existing	Powerline ROW
MW-5D (124-134)	102.0	103.89	134.0	124.00	134.00	-22.00	-32.00	-27.00	10.0	existing	Powerline ROW
MW-5 (140-150)	101.7	103.6	150.0	140.00	150.00	-38.30	-48.30	-43.30	10.0	March 2017	Powerline ROW
MW-6A (64-74)	71.6	71.22	74.0	64.00	74.00	7.60	-2.40	2.60	10.0	1/21/2016	Landfill
MW-6B (54-64)	71.8	71.40	64.0	54.00	64.00	17.80	7.80	12.80	10.0	1/21/2016	Landfill
MW-6C (52-62)	71.9	71.55	62.0	52.00	62.00	19.90	9.90	14.90	10.0	1/21/2016	Landfill
MW-E6 (88-98) *	72.2	71.91	98.0	88.00	98.00	-15.80	-25.80	-20.80	10.0	1/17/2017	Landfill
MW-7S (55-65) *	69.8	71.64	65.0	55.00	65.00	14.80	4.80	9.80	10.0	1/19/2017	Landfill
MW-7D (115-125) *	69.9	71.66	125.0	115.00	125.00	-45.10	-55.10	-50.10	10.0	1/20/2017	Landfill
MW-7 (90-100)	69.7	71.4	100.0	90.00	100.00	-20.30	-30.30	-25.30	10.0	3/2/2017	Landfill
MW-8 (36-46) *	59.1	58.80	46.0	36.00	46.00	23.10	13.10	18.10	10.0	1/25/2017	Giddiah Hill Road
MW-8 (84-94)	59.2	58.8	94.0	84.00	94.00	-24.80	-34.80	-29.80	10.0	3/1/2017	Giddiah Hill Road
MW-9 (92-102) *	105.5	107.32	102.0	92.00	102.00	13.50	3.50	8.50	10.0	1/25/2017	Landfill
MW-10 (85-95) *	94.0	93.69	95.0	85.00	95.00	9.00	-1.00	4.00	10.0	1/26/2017	Finlay Road
MW-13 (74-84)	57.0	59.3	84.0	74.0	84.0	-17.00	-27.00	-22.00	10.0	March 2017	Landfill
MW-11 (91-101)	49.4	48.97	101.0	91.0	101.0	-41.60	-51.60	-46.60	10.0	March 2017	Elementary School
MW-12 (87-97)	NA	NA	97.0	87.0	97.0	NA	NA	NA	10.0	March 2017	Snow Library

Notes: TOC = Top of Casing
bgs = below
ground surface
NA = Not
Available

All new wells constructed with 2-inch Schedule 40 PVC threaded flush joint casings, 10 ft screens with Schedule 40 PVC .010" 10 slot well screen

Table 4 Orleans Landfill Groundwater Analyses

Sample ID	MW-1S (56-66)		MW-1D (99-109)		MW-2S (84-94)			MW-2D (124-134)			
Top of Screen Elevation (ft)	27.30		-15.70		17.30			-22.40			
Bottom of Screen Elevation (ft)	17.30		-25.70		7.30			-32.40			
Sampling Date	2/8/2017	3/29/2017	2/8/2017	3/29/2017	2/26/2016	02/06/2017	3/28/2017 ¹	2/26/2016	02/06/2017	02/06/2017(D UP)	3/28/2017 ¹
Field Measurements											
pH (SU)	5.3	4.7	5.6	4.9	4.9	4.8	4.5	4.7	6.0	6.0	5.6
Temperature (°C)	14.1	13.4	13.7	12.6	13.2	16.0	15.0	12.4	15.5	15.5	15.1
Dissolved Oxygen (DO; mg/L)	3.0	1.1	4.2	4.4	1.4	1.6	0.8	0.8	0.1	0.1	0.0
Dissolved Oxygen (DO; %)	-	10.5	-	38.6	-	16.2	7.5	-	0.6	0.6	0.2
Redox Potential (ORP; mV)	120.2	149.8	138.3	143.4	193.6	129.8	144.7	144.9	54.5	54.5	106.0
Specific Conductivity (µS/cm) ^c	137.0	127.0	172.0	173.0	942.0	751.0	777.0	886.0	800.0	800.0	828.0
Laboratory Analyses											
Nitrogen											
Nitrate as N (mg/L)	3.6	2.56	3.28	4.12	24.7	18.8	1.05	9.26	0.208	0.18	2.32
Nitrite as N (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	0.0	<0.01	0.065	0.014	<0.01	<0.01
Ammonia (mg/L)	<0.1	0.11	0.51	0.43	0.25	0.14	<0.1	0.34	11.5	11.2	10.9
Total Kjeldahl Nitrogen (TKN) (mg/L)	1.24	-	1.21	-	-	2.13	2.3	-	13.7	14.7	12.1
Total Nitrogen (mg/L)	4.8	4.26	4.5	4.86	27.1	21.0	3.34	11.1	13.9	14.8	14.5
Alkalinity											
Total Alkalinity (mg/L)	-	-	-	-	-	-	-	-	-	-	-
Bicarbonate Alkalinity (mg/L)	-	-	-	-	-	-	-	-	-	-	-
Anions											
Chloride (mg/L)	13.2	15	32.5	30.7	131.0	88.8	94.8	152.0	97.7	99.2	134
Sulfate (mg/L)	6.7	5.4	8.7	8.2	66.0	77.0	81	51.6	52.5	52.0	51
Elements											
Dissolved Iron (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.11	0.107
Dissolved Manganese (mg/L)	0.37	0.454	0.08	0.059	0.60	0.55	0.528	1.10	5.12	5.10	4.48
Boron (mg/L)	-	-	-	-	0.22	0.28	-	0.16	0.26	0.25	-
Organic Compounds											
DOC (mg/L)	-	-	-	-	9.5	9.5	-	4.5	7.2	8.6	-
Methane	-	-	-	-	-	-	-	-	-	-	-

Notes:

Bold - detected above the Minimum Detection Limit

1. TKN and Total Nitrogen data from re-run analysis reported on E. Data point appears to be in error (124-134)-Well screen depth below land surface

Table 4 Orleans Landfill Groundwater Analyses

Sample ID	MW-2 (140-150)		MW-3S (50-60)		MW-3D (84-94)		MW-5S (78-88)		
Top of Screen Elevation (ft)	-38.70		18.60		-15.20		24.10		
Bottom of Screen Elevation (ft)	-48.70		8.60		-25.20		14.10		
Sampling Date	02/06/2017	3/28/2017	2/8/2017	3/29/2017	2/8/2017	3/29/2017	2/26/2016	2/6/2017	3/29/2017
Field Measurements									
pH (SU)	6.0	6.3	5.25	4.41	6.12	5.63	5.7	5.5	5.1
Temperature (°C)	15.2	16.9	15.07	13.85	13.99	12.87	13.5	14.0	14.2
Dissolved Oxygen (DO; mg/L)	0.1	0.2	4.45	4.22	0.11	0.02	5.0	2.4	1.9
Dissolved Oxygen (DO; %)	0.8	2.2	-	42.1	-	0.2	-	23.2	18.6
Redox Potential (ORP; mV)	65.1	97.7	100.8	170.8	-56.1	-29.6	169.7	58.3	139.3
Specific Conductivity (µS/cm) ^c	637.0	6341.0	918	2139	632	709	477.0	523.0	494.0
Laboratory Analyses									
Nitrogen									
Nitrate as N (mg/L)	<0.03	<0.03	0.601	0.299	<0.03	<0.03	0.03	17.3	18.6
Nitrite as N (mg/L)	<0.01	<0.01	<0.01	<0.01	0.014	0.043	<0.050	<0.01	<0.01
Ammonia (mg/L)	11.9	11.2	<0.1	<0.1	-	4.36	0.10	0.12	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	12.8	-	0.61	-	5.75	-	-	2.19	-
Total Nitrogen (mg/L)	12.8	17.2	1.2	0.75	5.8	5.35	1.8	19.5	18.9
Alkalinity									
Total Alkalinity (mg/L)	-	-	-	-	-	-	-	-	-
Bicarbonate Alkalinity (mg/L)	-	-	-	-	-	-	-	-	-
Anions									
Chloride (mg/L)	49.0	46.1	324.0	774	159.0	147	53.1	63.5	64.4
Sulfate (mg/L)	62.0	63.5	5.0	<5	14.1	18.1	27.9	55.0	49
Elements									
Dissolved Iron (mg/L)	0.11	0.908	<0.1	1.27	34.6	34.5	-	0.10	0.12
Dissolved Manganese (mg/L)	5.46	5.12	0.18	0.669	2.66	2.78	-	0.11	0.075
Boron (mg/L)	0.28	-	<0.05	-	<0.05	-	-	0.11	-
Organic Compounds									
DOC (mg/L)	7.0	-	-	-	-	-	-	-	-
Methane	-	-	-	-	-	-	-	-	-

Notes:

Bold - detected above the Minimum Detection Limit

1. TKN and Total Nitrogen data from re-run analysis reported on E. Data point appears to be in error (124-134)-Well screen depth below land surface

Table 4 Orleans Landfill Groundwater Analyses

Sample ID	MW-5D (124-134)			MW-E6-A (64-74)			MW-E6-B (54-64)			MW-6 (88-98)	
Top of Screen Elevation (ft)	-22.00			7.60			17.80			-15.80	
Bottom of Screen Elevation (ft)	-32.00			-2.40			7.80			-25.80	
Sampling Date	2/26/2016	2/6/2017	3/29/2017	2/10/2016	2/6/2017	3/28/2017	2/10/2016	2/6/2017	3/28/2017 ¹	02/06/2017	3/28/2017 ¹
Field Measurements											
pH (SU)	6.1	5.9	5.6	5.9	5.6	5.8	5.5	5.4	5.2	6.5	6.6
Temperature (°C)	13.5	13.9	13.8	13.3	14.9	15.6	12.5	14.9	15.4	14.0	14.7
Dissolved Oxygen (DO; mg/L)	2.4	0.2	0.0	0.46	0.15	0.11	1.82	1.45	1.06	0.12	0.15
Dissolved Oxygen (DO; %)	-	1.9	0.0	-	1.5	1.1	-	14.5	10.5	1.2	1.5
Redox Potential (ORP; mV)	87.5	29.4	89.8	100.0	56.4	85.5	72.4	71.2	119.2	-82.1	-36.0
Specific Conductivity (µS/cm) ^c	437.0	441.0	445.0	672.0	1069.0	1186.0	847.0	743.0	793.0	900.0	991.0
Laboratory Analyses											
Nitrogen											
Nitrate as N (mg/L)	11.4	0.05	0.058	11.6	7.2	2.61	20.8	16.3	8.27	0.1	<0.03
Nitrite as N (mg/L)	<0.050	<0.01	<0.01	<0.050	<0.01	<0.01	<0.050	<0.01	<0.01	<0.01	<0.01
Ammonia (mg/L)	15.3	12.7	14	0.10	<0.1	<0.1	0.10	0.11	<0.1	0.12	22.6
Total Kjeldahl Nitrogen (TKN) (mg/L)	-	13.9	-	-	1.7	-	-	1.50	1.3	24.10	25.0
Total Nitrogen (mg/L)	26.8	13.9	16	12.6	8.9	3.94	21.2	17.8	9.60	24.2	25.0
Alkalinity											
Total Alkalinity (mg/L)	-	-	-	-	-	-	-	-	-	-	-
Bicarbonate Alkalinity (mg/L)	-	-	-	-	-	-	-	-	-	-	-
Anions											
Chloride (mg/L)	61.2	66.1	70.1	143.0	280.0	331	115.0	151.0	167	173.0	196
Sulfate (mg/L)	45.2	24.0	23.8	55.5	34.4	27.8	52.5	41.5	43.5	22.5	21.5
Elements											
Dissolved Iron (mg/L)	-	0.62	0.608	0.05	0.15	0.107	0.05	0.16	<0.1	18.40	13.5
Dissolved Manganese (mg/L)	-	0.52	0.584	0.02	0.05	0.05	0.02	0.04	0.026	2.49	2.39
Boron (mg/L)	-	0.06	-	0.14	0.10	-	0.14	0.11	-	0.24	-
Organic Compounds											
DOC (mg/L)	-	-	-	7.6	8.1	-	7.6	6.7	-	8.8	-
Methane	-	-	-	-	-	-	-	-	-	-	-

Notes:

Bold - detected above the Minimum Detection Limit

1. TKN and Total Nitrogen data from re-run analysis reported on E. Data point appears to be in error (124-134)-Well screen depth below land surface

Table 4 Orleans Landfill Groundwater Analyses

Sample ID	MW-7S (55-65)			MW-7D (115-125)		MW-8 (36-46)		MW-9 (92-102)		MW-10 (85-95)	
Top of Screen Elevation (ft)	14.80			-45.10		23.10		13.50		9.00	
Bottom of Screen Elevation (ft)	4.80			-55.10		13.10		9.00		-1.00	
Sampling Date	02/06/2017	02/06/2017 (DUP)	3/28/2017	02/06/2017	3/28/2017 ¹	2/8/2017	3/27/2017	2/8/2017	3/29/2017	2/8/2017	3/28/2017
Field Measurements											
pH (SU)	5.7	5.7	5.2	6.2	6.3	4.5	4.0	5.0	4.4	5.6	5.4
Temperature (°C)	12.7	12.7	13.4	12.7	12.9	14.6	13.8	15.9	15.5	14.6	15.9
Dissolved Oxygen (DO; mg/L)	0.69	0.69	0.04	0.2	0.2	2.1	2.9	7.4	7.8	9.4	8.5
Dissolved Oxygen (DO; %)	6.5	6.5	0.4	1.9	2.2	20.5	28.5	-	76.1	-	81.5
Redox Potential (ORP; mV)	39.4	39.4	115.1	-64.1	2.0	175.6	179.8	139.1	185.6	118.9	117.8
Specific Conductivity (µS/cm) ^c	665.0	665.0	1229.0	510.0	482.0	397.0	351.0	297.0	327.0	175.0	176.0
Laboratory Analyses											
Nitrogen											
Nitrate as N (mg/L)	8.7	12.8	4.96	<0.03	<0.03	5.5	3.83	20.2	6.37	2.4	2.5
Nitrite as N (mg/L)	<0.01	<0.01	0.012	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ammonia (mg/L)	0.34	0.13	0.15	2.74	2.59	0.11	0.18	0.34	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen (TKN) (mg/L)	1.92	2.38	-	3.17	3.2	2.03	-	2.83	-	0.85	-
Total Nitrogen (mg/L)	10.6	15.2	8.67	3.2	3.2	7.6	4.84	23.0	6.65	3.3	2.83
Alkalinity											
Total Alkalinity (mg/L)	-	-	-	-	-	-	-	-	-	-	-
Bicarbonate Alkalinity (mg/L)	-	-	-	-	-	-	-	-	-	-	-
Anions											
Chloride (mg/L)	127.0	124.0	369	55.3	57.2	55.1	66.4	65.5	60.8	42.9	39.1
Sulfate (mg/L)	29.6	33.6	15.5	36.2	34.2	37.8	24.3	15.5	34.6	<5	6.1
Elements											
Dissolved Iron (mg/L)	0.34	0.27	0.216	18.30	17.5	<0.1	<0.1	<0.1	<0.1	<0.1	0.375
Dissolved Manganese (mg/L)	0.02	0.02	0.031	3.21	2.72	0.10	0.301	0.49	0.052	0.07	0.028
Boron (mg/L)	0.08	0.08	-	0.14	-	0.09	-	<0.05	-	<0.05	-
Organic Compounds											
DOC (mg/L)	-	-	-	-	-	4.4	-	1.6	-	<0.5	-
Methane	-	-	<2	-	<2	-	-	-	-	-	-

Notes:

Bold - detected above the Minimum Detection Limit

1. TKN and Total Nitrogen data

from re-run analysis reported on

E. Data point appears to be in error

(124-134)-Well screen depth below

land surface

Table 5 Orleans Landfill Groundwater Elevations

Well ID	Location	TOC Elevation (ft)	Depth to Water (ft)				GW Elevation (ft)	Notes
			2/3/2017	2/6/2017	2/28/2017	03/27/2017-03/29/2017		
MW-1S (56-66)	Landfill	85.18	61.95	62.0	61.88	-	23	Perched Water
MW-1D (99-109)	Landfill	85.11	70.60	70.5	70.33	-	15	
MW-2S (84-94)	Landfill	101.49	87.90	-	87.63	-	14	
MW-2D (124-134)	Landfill	101.42	88.42	88.4	88.20	-	13	
MW-2 (140-150) *	Landfill	102.80	89.82	-	89.60	89.38	13	
MW-2 (161-171)	Landfill	101.40	NI	NI	NI	89.57	12	
MW-3S (50-60)	Landfill	70.32	54.20	55.3	54.94	-	15	
MW-3D (84-94)	Landfill	69.74	54.90	55.0	54.66	-	15	
MW-5S (78-88)	ROW	103.91	90.28	-	89.94	-	14	
MW-5D (124-134)	ROW	103.89	89.90	-	89.67	-	14	
MW-5 (140-150)	ROW	101.68	NI	NI	NI	89.50	12	
MW-6A (64-74)	Landfill	71.22	56.35	56.4	56.41	-	15	
MW-6B (54-64)	Landfill	71.40	56.40	56.5	56.33	-	15	
MW-6C (52-62)	Landfill	71.55	NS	NS	NS	-	NA	
MW-E6 (88-98)*	Landfill	71.91	57.77	57.8	57.51	-	14	
MW-7S (55-65) *	Landfill	71.64	66.50	56.6	56.22	56.31	15	
MW-7D (115-125) *	Landfill	71.66	57.30	57.3	57.03	56.92	15	
MW-7 (90-100)	Landfill	69.70	NI	NI	NI	56.66	13	
MW-8 (36-46)*	Giddiah Hill Rd	58.80	35.05	34.9	34.62	34.45	24	Perched Water
MW-8 (84-94)	Giddiah Hill Rd	NA	NI	NI	NI	43.07	NA	
MW-9 (92-102)*	Landfill	107.32	93.50	93.3	93.11	-	14	
MW-10 (85-95)*	Finlay Rd	93.69	81.12	82.1	80.95	-	13	
MW-13 (74-84)	Landfill	57.00	NI	NI	NI	44.07	13	
MW-11 (91-101)	Elementary School	48.97	NI	NI	NI	37.58	11	
MW-12 (87-97)	Snow Library	NA	NI	NI	NI	35.67	NA	

NS- no sampled
 NI- not installed
 NA- not available

Figures

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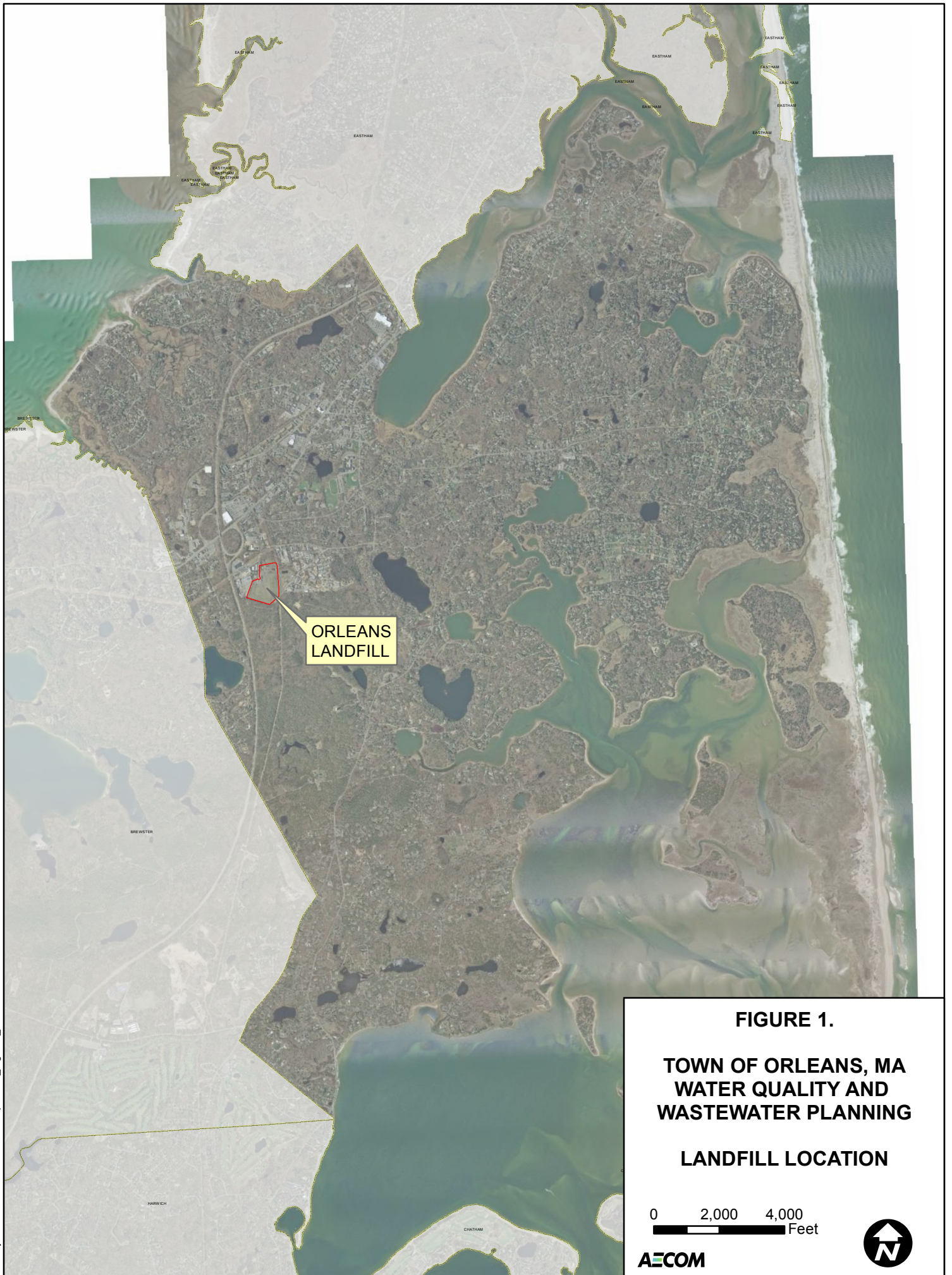


FIGURE 1.

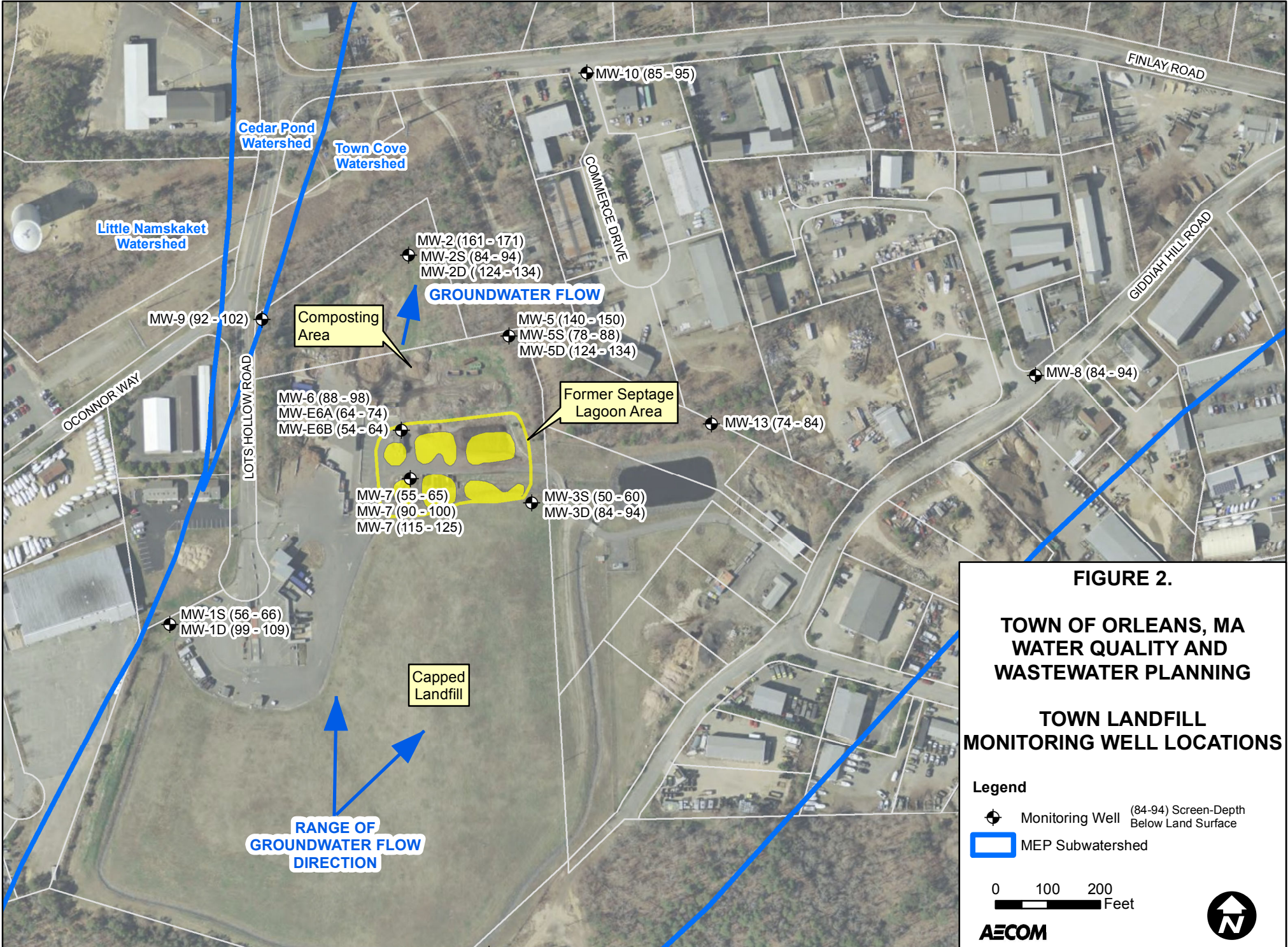
**TOWN OF ORLEANS, MA
WATER QUALITY AND
WASTEWATER PLANNING**

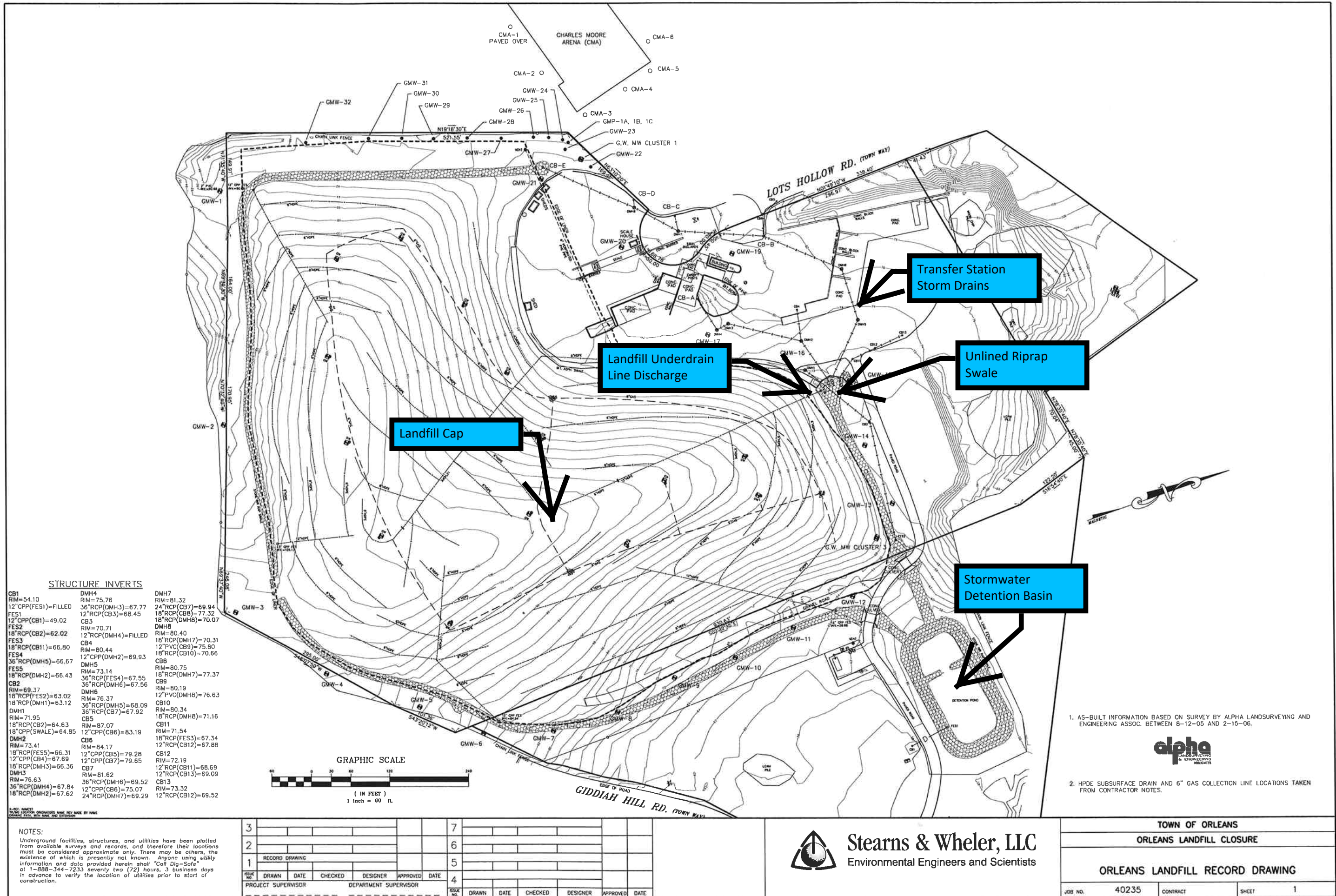
LANDFILL LOCATION

0 2,000 4,000
Feet

AECOM

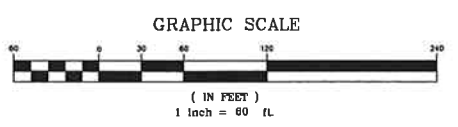






STRUCTURE INVERTS

CB1 RIM=54.10 12"CPP(FES1)=FILLED FES1 12"CPP(CB1)=49.02 FES2 18"RCP(CB2)=62.02 FES3 18"RCP(CB11)=66.80 FES4 36"RCP(DMH5)=66.67 FES5 18"RCP(DMH2)=66.43 CB2 RIM=69.37 18"RCP(FES2)=63.02 18"RCP(DMH1)=63.12 DMH1 RIM=71.95 18"RCP(CB2)=64.63 18"CPP(SWALE)=64.85 DMH2 RIM=73.41 18"RCP(FES5)=66.31 12"CPP(CB4)=67.69 18"RCP(DMH3)=66.36 DMH3 RIM=76.63 36"RCP(DMH4)=67.84 18"RCP(DMH2)=67.62	DMH4 RIM=75.76 36"RCP(DMH3)=67.77 CB3 RIM=70.71 12"RCP(DMH4)=FILLED CB4 RIM=80.44 12"CPP(DMH2)=69.93 DMH5 RIM=73.14 36"RCP(FES4)=67.55 36"RCP(DMH6)=67.56 DMH6 RIM=76.37 36"RCP(DMH5)=68.09 36"RCP(CB7)=67.92 CB5 RIM=87.07 12"CPP(CB6)=83.19 CB6 RIM=84.17 12"CPP(CB5)=79.28 12"CPP(CB7)=79.85 RIM=81.62 36"RCP(DMH6)=69.52 12"CPP(CB6)=75.07 24"RCP(DMH7)=69.29	DMH7 RIM=81.32 24"RCP(CB7)=69.94 18"RCP(CB8)=77.32 18"RCP(DMH8)=70.07 DMH8 RIM=80.40 18"RCP(DMH7)=70.31 12"RCP(CB9)=75.80 18"RCP(CB10)=70.66 CB8 RIM=80.75 18"RCP(DMH7)=77.37 CB9 RIM=80.19 12"RCP(DMH8)=76.63 CB10 RIM=80.34 18"RCP(DMH8)=71.16 CB11 RIM=71.54 18"RCP(FES3)=67.34 12"RCP(CB12)=67.88 CB12 RIM=72.19 12"RCP(CB11)=68.69 12"RCP(CB13)=69.09 CB13 RIM=73.32 12"RCP(CB12)=69.52
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- AS-BUILT INFORMATION BASED ON SURVEY BY ALPHA LANDSURVEYING AND ENGINEERING ASSOC. BETWEEN 8-12-05 AND 2-15-06.
- HPDE SUBSURFACE DRAIN AND 6" GAS COLLECTION LINE LOCATIONS TAKEN FROM CONTRACTOR NOTES.



NOTES:
Underground facilities, structures, and utilities have been plotted from available surveys and records, and therefore their locations must be considered approximate only. There may be others, the existence of which is presently not known. Anyone using utility information and data provided herein shall "Call Dig-Safe" at 1-888-344-7233 seventy two (72) hours, 3 business days in advance to verify the location of utilities prior to start of construction.

3						7					
2						6					
1	RECORD DRAWING					5					
NO. 1	DRAWN	DATE	CHECKED	DESIGNER	APPROVED	DATE	4				
	PROJECT SUPERVISOR										
	DEPARTMENT SUPERVISOR										
NO. 2	DRAWN	DATE	CHECKED	DESIGNER	APPROVED	DATE	NO. 3				

Stearns & Wheler, LLC
Environmental Engineers and Scientists

TOWN OF ORLEANS		
ORLEANS LANDFILL CLOSURE		
ORLEANS LANDFILL RECORD DRAWING		
JOB NO. 40235	CONTRACT	SHEET 1

Figure 3 - Landfill Stormwater Management System

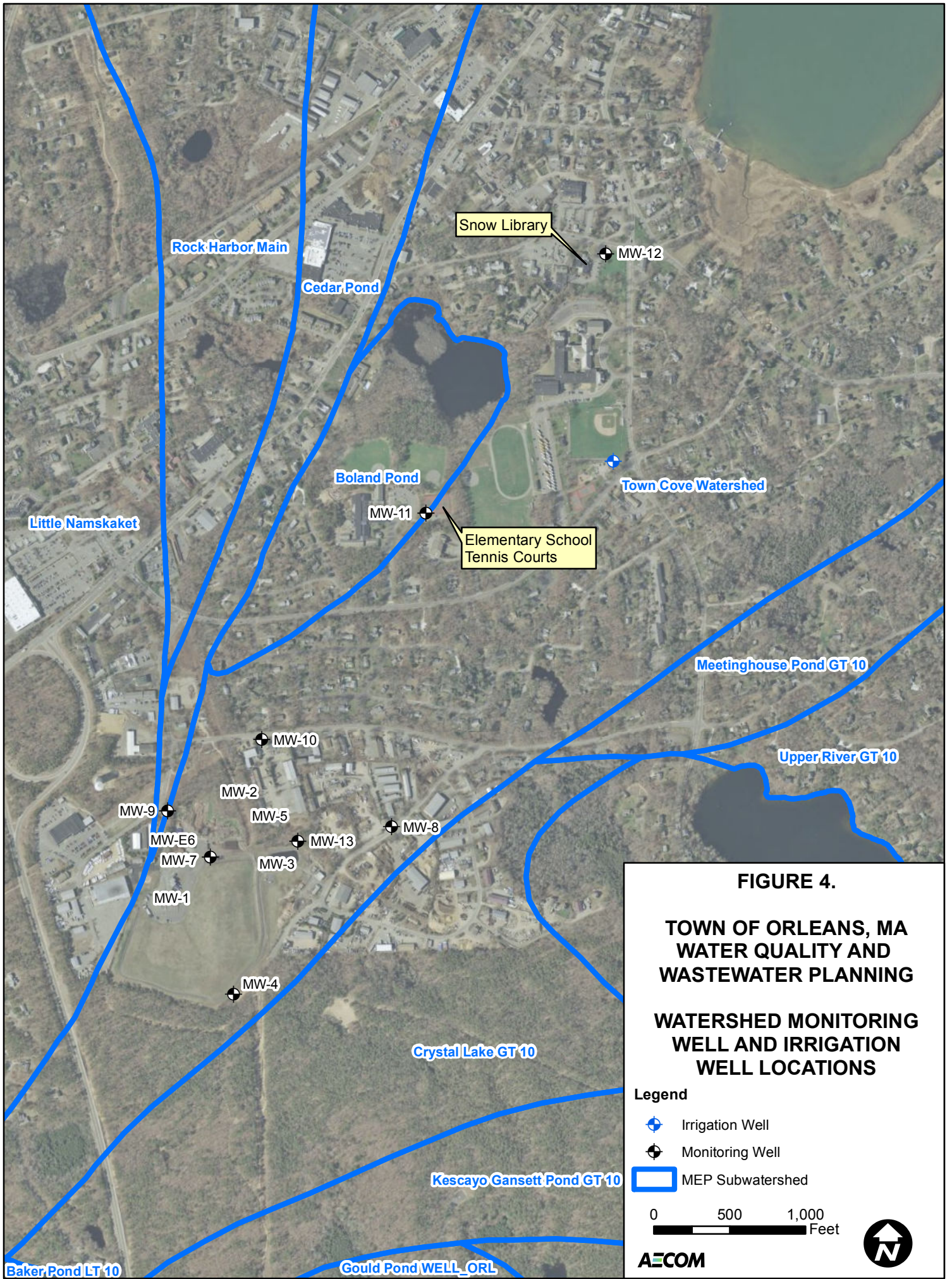


FIGURE 4.
TOWN OF ORLEANS, MA
WATER QUALITY AND
WASTEWATER PLANNING
WATERSHED MONITORING
WELL AND IRRIGATION
WELL LOCATIONS

Legend

- Irrigation Well
- Monitoring Well
- MEP Subwatershed

0 500 1,000 Feet

AECOM

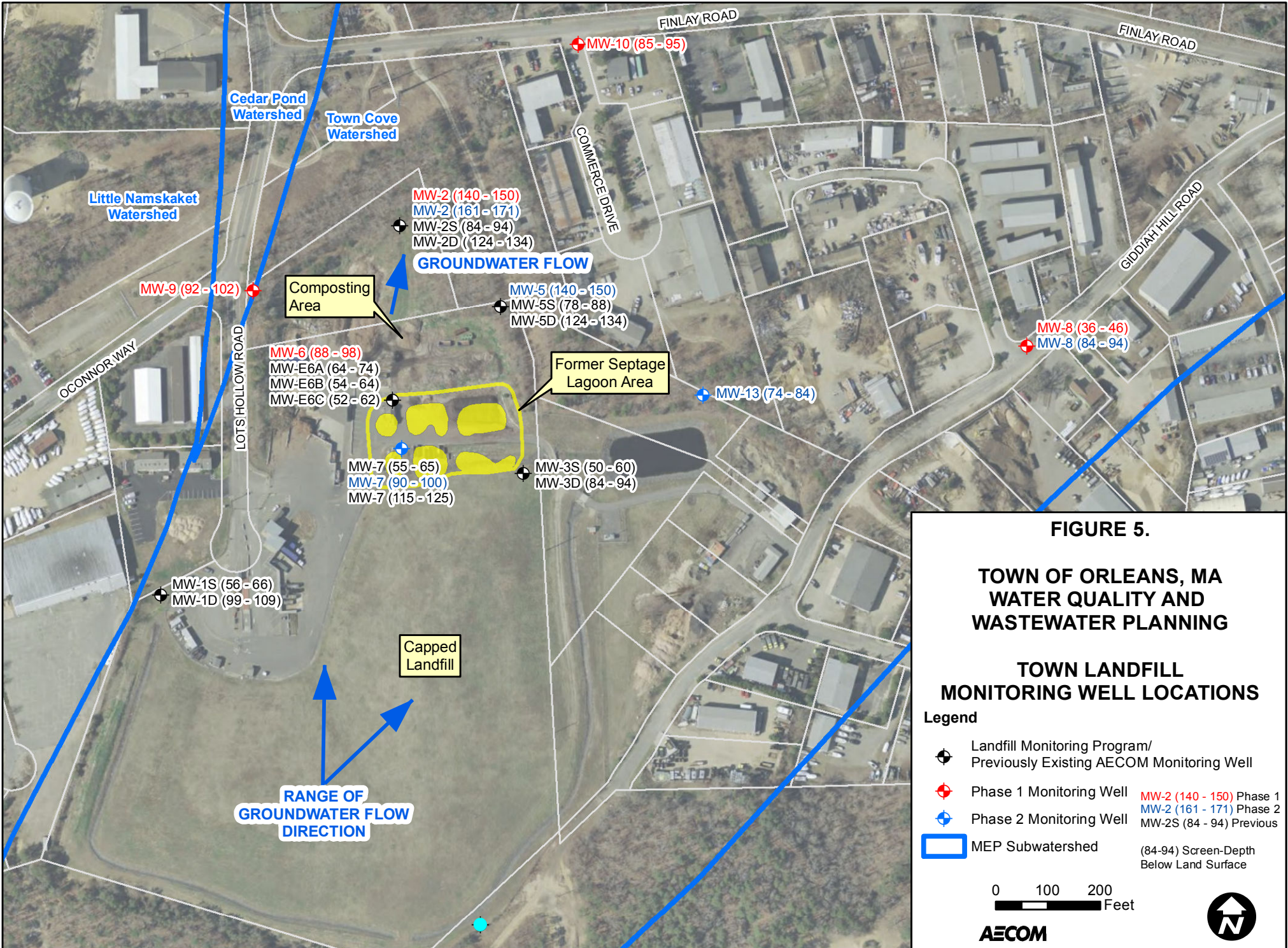
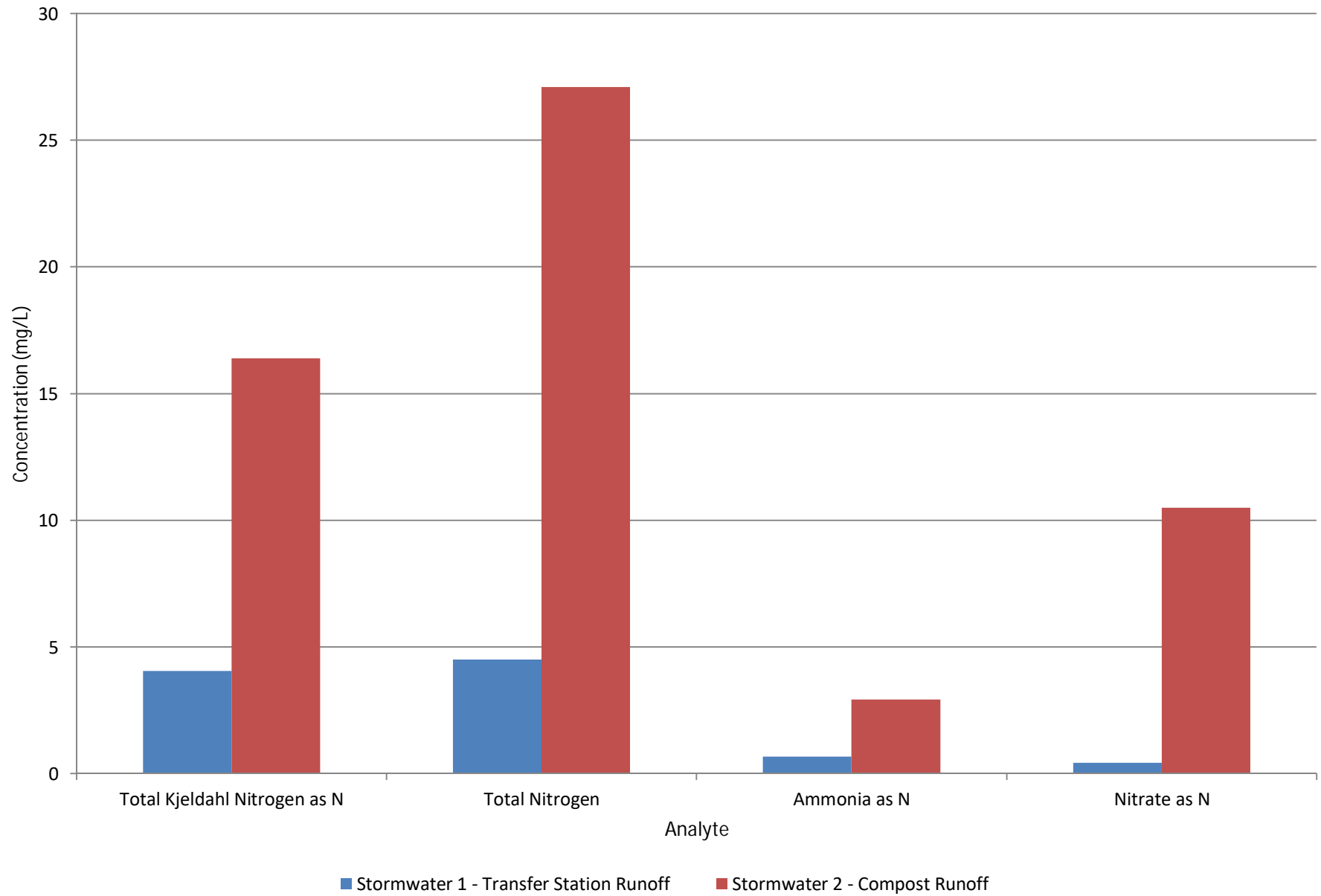


Chart 1: Transfer Station Runoff vs. Compost Runoff



Appendix A

Barnstable County Health Department Historical Nitrate Data

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Appendix A - Summary of Landfill Monitoring Wells Nitrate Data (BCHD)

	MW-1S	MW-1D	MW-2S	MW-2D	MW-3S	MW-3D	MW-4S	MW-4D	MW-5S	MW-5D
Date	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Sep-94	5.15	NS	2.40	2.10	0.15	0.10	NS	0.03	6.60	0.1
Jan-95	<.1	NS	5.40	3.20	0.13	0.13	NS	0.02	10.30	0.22
May-95	0.20	NS	9.50	4.60	0.19	0.20	<.02	<.02	9.30	0.3
Aug-95	<.1	NS	0.90	1.70	0.30	<.02	<.02	<.02	12.90	0.40
Jul-98	<.02	NS	4.60	1.50	<.02	<.02	<.02	<.02	17.00	<.02
Aug-99	<.02	NS	4.80	1.50	0.09	<.02	0.09	0.02	15.00	<.02
Apr-00	0.07	NS	3.90	0.20	0.06	0.05	<.01	<.01	9.60	<.02
Dec-00	NS	NS	3.70	0.40	1.00	<.01	<.01	<.01	10.00	<.01
Mar-05	0.03	NS	1.90	11.00	7.70	NS	0.05	NS	9.80	<.01
Jul-05	4.50	NS	18.00	1.00	NS	0.98	<.01	<.01	10.00	7.90
Feb-06	0.22	NS	11.00	11.00	NS	0.67	<.01	0.11	18.00	1.00
Sep-06	0.46	2.10	19.00	15.00	NS	0.32	0.93	<.01	14.00	0.21
Mar-07	0.25	3.00	16.00	7.30	NS	ND	5.60	<.01	12.00	<.01
Oct-07	1.90	NS	31.00	4.30	NS	ND	2.70	<.01	12.00	<.01
Apr-08	2.20	NS	32.00	8.90	NS	ND	5.50	0.1	15.00	<.01
Sep-08	16.00	NS	8.90	9.00	NS	ND	2.80	<.01	13.00	<.01
May-09	1.80	NS	30.00	2.00	NS	ND	3.60	<.01	21.00	<.01
Sep-09	13.00	NS	40.00	1.20	NS	0.53	2.50	<.01	12.00	0.30
Apr-10	2.60	NS	17.00	5.60	NS	0.20	4.20	<.01	10.00	0.10
Sep-10	13.00	NS	28.00	0.66	NS	0.25	2.40	<.01	22.00	0.15
Mar-11	1.80	NS	28.00	0.73	NS	0.39	4.00	<.01	12.00	0.19
Jun-11	1.50	NS	26.00	0.71	NS	0.26	1.40	0.15	8.40	0.51
Mar-12	0.54	NS	27.00	1.30	0.9	0.44	1.60	<.01	9.70	0.28
Sep-12	10.00	NS	27.00	<.02	<.01	<.01	1.40	<.01	12.00	<.01
Apr-13	3.30	NS	38.00	4.10	0.67	0.60	6.60	0.18	17.00	0.38
Sep-13	1.60	NS	37.00	12.00	<.01	0.01	2.90	<.01	8.70	0.73
Mar-14	1.80	NS	34.00	8.10	1.70	1.20	1.00	0.12	14.00	3.80
Oct-14	5.70	NS	23.00	1.80	2.70	1.40	2.00	<.01	12.00	<.01
May-15	2.20	NS	20.00	4.20	<.01	0.94	2.70	<.01	9.50	<.01
Oct-15	5.00	NS	25.00	0.94	0.36	0.27	1.10	<.01	11.00	0.14
Mar-16	1.70	NS	22.00	3.80	7.3	<.01	1.40	<.01	12.00	<.01

Notes: Concentration Greater than Groundwater Standard of 10 mg/L in Bold
 NS = Not Sampled