FINAL

HYDROGEOLOGIC EVALUATION
OVERLAND WAY SITE
TOWN OF ORLEANS, MASSACHUSETTS

Prepared for:
Town of Orleans
19 School Road
Orleans, Massachusetts 02653

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Project No. 60476644

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1. INTRODUCTION AND BACKGROUND

The Hydrogeologic Evaluation Technical Memorandum documents the approach used to evaluate the Overland Way site (Figure 1) for a groundwater discharge from the proposed Downtown Area wastewater treatment facility (WWTF). This Memorandum includes the following:

- Description of the initial steps taken in the process of evaluating groundwater discharge sites;
- Summary of existing data that is available to help with the Overland Way site evaluation;
- Summary of field investigations conducted at the Overland Way site;
- Evaluation of field investigations and other available data;
- Results of groundwater flow modeling and groundwater mounding analysis; and
- Recommended maximum discharge capacity for the Overland Way site.

The purpose of this document is to provide a transparent and objective assessment of the Overland Way Site for the discharge of WWTF effluent. If the Town chooses to use the site for a groundwater discharge, a Hydrogeologic Evaluation will be submitted to the Massachusetts Department of Environmental Protection (MassDEP) as part of the Groundwater Discharge Permit (GWDP) application process.


CHASE LANE
SALTY RIDGE ROAD
OLD COLONY WAY
Overland Way Site
MID CAPE HIGHWAY
6
WEST ROAD
MID CAPE HIGHWAY
BAY RIDGE LANE
OAK RIDGE LANE
RAMP-RT 6 WB TO RT 6A
G:\Projects\MUNI\60476644ORL\Maps\GWD_OverlandWay_Figure1.mxd
FIGURE 1
OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING
LOCUS MAP
0 150 300
Feet
AECOM

2. PROPOSED COLLECTION, TREATMENT, AND DISCHARGE FACILITIES

2.1. Collection Area and WWTF

MEP estimates that approximately 7,000 kilograms per year (kg/yr) nitrate load of the nitrate load from existing and future septic load will need to be removed from the Town Cove Watershed to meet the nutrient load reduction target for Town Cove. The OWQAP evaluated traditional and non-traditional nutrient reduction technologies for nitrate removal within the watershed. Due to the significant nitrate load removal within the Town Cove Watershed, the OWQAP proposed to manage a significant portion of the nitrate load through the construction of wastewater collection, treatment, and disposal facilities in the Consensus Plan. Flow from the collection area will be primarily residential and commercial. Flows are estimated at 260,000 gallons per day (gpd). The proposed collection area is shown on Figure 2. The method of treatment is also being evaluated although a sequencing batch reactor (SBR) facility is considered likely. The location of proposed discharge site is shown on Figure 3.

2.2. Discharge Sites Considered

Nine potential locations for groundwater discharge of wastewater treatment facility effluent were considered including:

- Overland Way (Parcels 1/1A);
- Route 6 Interchange (Exit 12) Cloverleaf;
- Thayer Property (Orleans Market Place);
- Old Colony Apartments (Old Colony Way);
- Hole in One Restaurant Parking (Cranberry Highway);
- Depot Square (Old Colony Way);
- Orleans Elementary (46 Eldredge Park Way);
- Nauset Regional Middle School (70 Eldredge Park Way); and
- Orleans Firebirds Baseball Field (80 Eldredge Park Way).

2.3. Site Suitability Criteria and Analysis

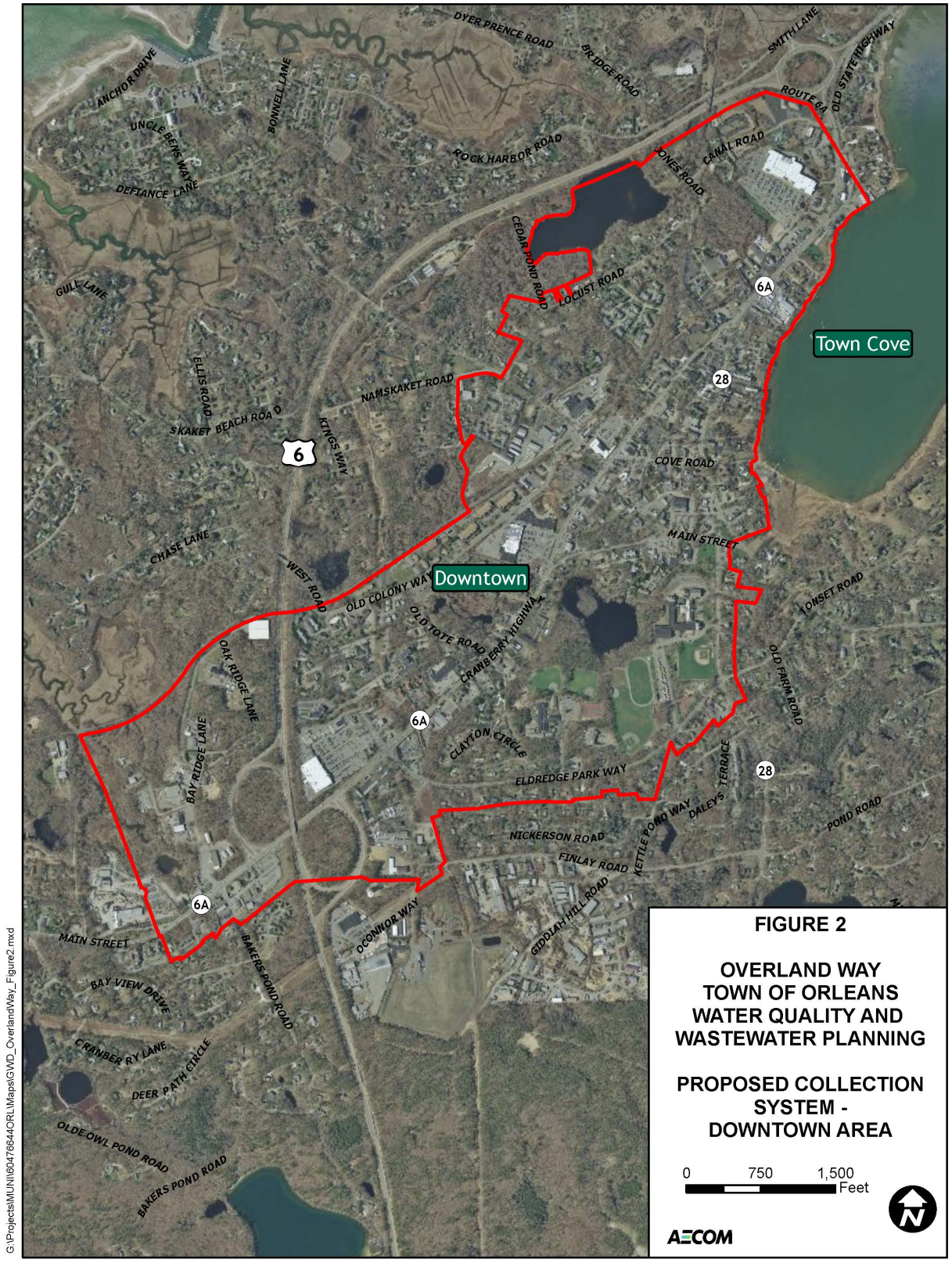
A Site Selection Matrix was developed for objective evaluation of selected discharge sites. The Matrix includes criteria for Site Suitability, Permitting, Project Evaluation and Other/Overriding Considerations. These criteria address environmental, land use and implementation features of the proposed discharge locations. Permitting criteria assess regulatory requirements and potential conflicts related to the proposed discharge locations. Project evaluation criteria evaluate the benefits gained from a proposed discharge site. The site selection screening was based on data available at the time of the screening process.

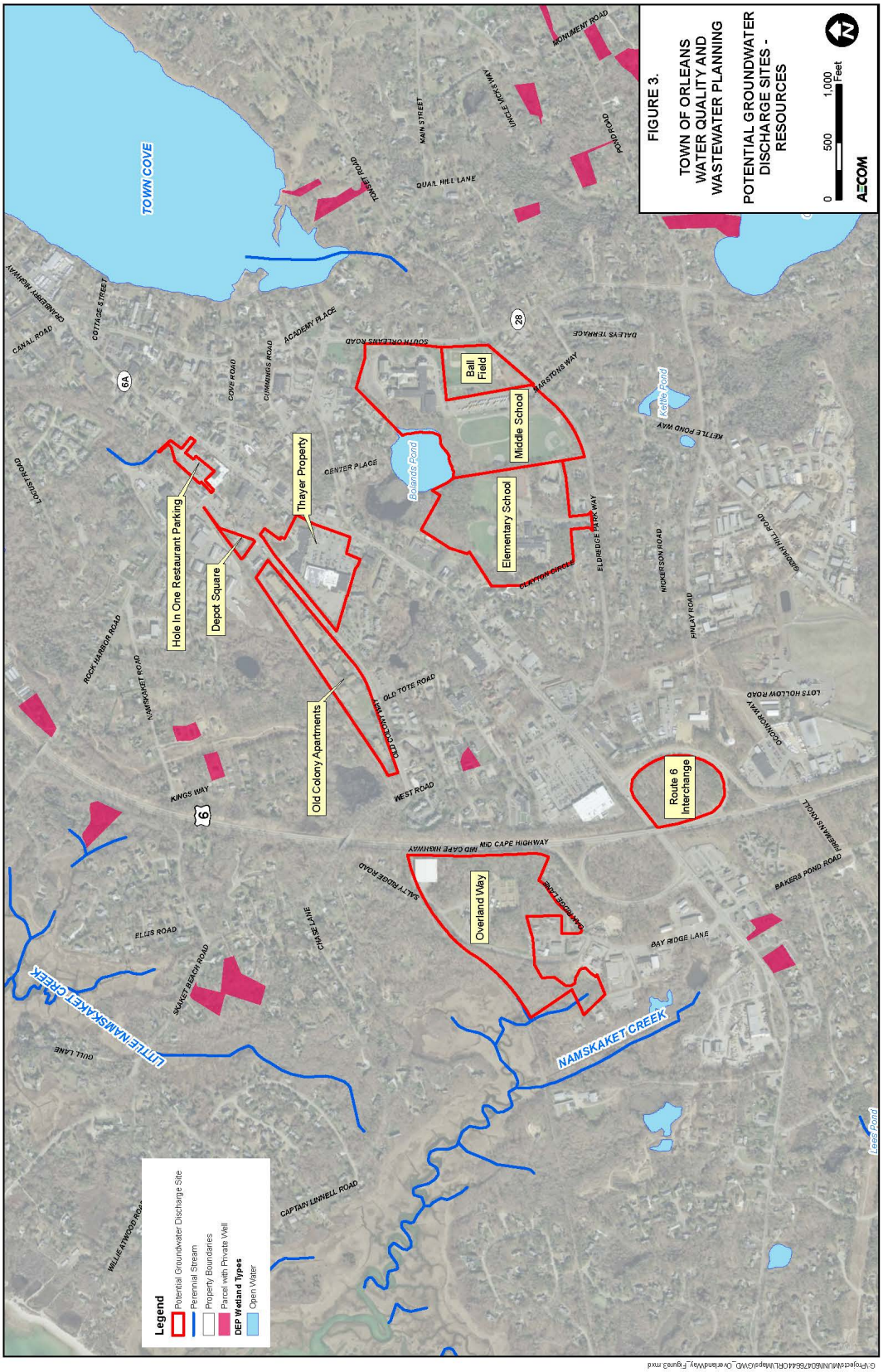
AECOM collected site specific information for each, conducted site visits, and evaluated the potential performance effectiveness. A rating system was then developed to quantify how well each site met a specific criterion. The point-based system used is as follows.

The Site Selection Matrix includes the following criteria that can be understood from currently available information and excluding hydrogeology which will be the subject of the investigations:

A. Site Suitability

- Property Ownership – Town owned, open space, privately owned, and developed, undeveloped.
- Distance from wastewater treatment facility – The length of the force main and route it would follow must be installed significantly affecting overall costs.


DYER PRENCE ROAD
BRIDGE ROAD
SMITH LANE
OLD STATE HIGHWAY
ROUTE 6A
ANCHOR DRIVE
UNCLE BENS WAY
BOWNELL LANE
ROCK HARBOR ROAD
JONES ROAD
CANAL ROAD
DEFIANCE LANE
CEDAR POND ROAD
LOCUST ROAD
GULL LANE
6A
Town Cove
ELLIS ROAD
NAMSKAKET ROAD
28
SKAKET BEACH ROAD
KINGS WAY
6
COVE ROAD
CHASE LANE
MAIN STREET
WEST ROAD
OLD COLONY WAY
Downtown
TONSET ROAD
OLD TOTE ROAD
CRANBERRY HIGHWAY
OAK RIDGE LANE
OLD FARM ROAD
6A
BAY RIDGE LANE
CLAYTON CIRCLE
ELDREDGE PARK WAY
28
DALEY'S TERRACE
KETTLE POND WAY
POND ROAD
NICKERSON ROAD
FINLAY ROAD
GIDDIAH HILL ROAD
6A
O'CONNOR WAY
MAIN STREET
BAKERS POND ROAD
BAY VIEW DRIVE
CRANBERRY LANE
DEER PATH CIRCLE
OLDE OWL POND ROAD
BAKERS POND ROAD
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FIGURE 2
OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING
PROPOSED COLLECTION
SYSTEM -
DOWNTOWN AREA
0
750
1,500
Feet
AECOM


FIGURE 3.
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING
POTENTIAL GROUNDWATER
DISCHARGE SITES -
RESOURCES
0
500
1,000
Feet
AECOM
TOWN COVE
MONUMENT ROAD
MAIN STREET
UNCLE NICKS WAY
POND ROAD
TONSET ROAD
QUAIL HILL LANE
CANAL ROAD
COTTAGE STREET
ACADEMY PLACE
SOUTH ORLEANS ROAD
CUMMINGS ROAD
COVE ROAD
DALEYS TERRACE
BARSTONS WAY
Ball Field
Middle School
Kettle Pond
KETTLE POND WAY
Bolands Pond
CENTER PLACE
Thayer Property
Elementary School
ELDRIDGE PARK WAY
CLAYTON CIRCLE
NICKERSON ROAD
GIBSON HILL ROAD
FINLAY ROAD
LOCUST ROAD
Hole In One Restaurant Parking
Depot Square
ROCK HARBOR ROAD
NAMSKAKET ROAD
OLD TOTE ROAD
OLD COLONY WAY
Old Colony Apartments
WEST ROAD
KINGS WAY
6
6A
28
OCONNOR WAY
LOTS HOLLOW ROAD
Route 6 Interchange
MID CAPE HIGHWAY
SALTY RIDGE ROAD
Overland Way
CAMBRIDGE LANE
BAKERS POND ROAD
OBERMAN KNOLL
BAY RIDGE LANE
ELLIS ROAD
SKAKET BEACH ROAD
CHASE LANE
LITTLE NAMSKAKET CREEK
NAMSKAKET CREEK
OULL LANE
CAPTAIN LINNELL ROAD
Legend
Potential Groundwater Discharge Site
Perennial Stream
Property Boundaries
Parcel with Private Well
DEP Wetland Types
Open Water
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- Ease of Access/Use of Property – Whether the discharge area is in an open area, under an existing parking lot, or in a developed area can affect the size and cost of the discharge area as well as installation and maintenance costs.
- Site Topography - Significant changes in elevation may affect construction and monitoring.
- Present Use of Site – Developed sites may be difficult to gain an easement agreement or right-of-way for a groundwater discharge.
- Potential Use of Site – Sites that are zoned or slated for future development may be more difficult to get permission to access and can impact the purchase price of parcel or alter the value of Town owned land.
- Depth to Groundwater - Deeper water table increases costs and may affect feasibility.
- Subsurface Soils Profile – Finer, lower transitivity soils (silt and clay) between the ground surface and 20 feet or so below the groundwater table can limit the amount of groundwater that can be discharged as well as the method of discharge (open bed, subsurface, wick, etc.).
- Area Available for Groundwater Discharge – Smaller discharge areas limit the amount of groundwater discharge potentially requiring discharge infrastructure at several locations.
- Downgradient Water Use – Public water supply or potable water supply wells are located nearby or down gradient.

B. Permitting

- Potential for Watershed/Estuary Impacts - Distance from surface water and wetland resource areas/ water use considerations.
- Potential Impacts to an ACEC.
- Presence of Rare and Endangered species.

C. Project Evaluation

- Watershed total maximum daily load (TMDL) – Discharging to a watershed with a nitrate total maximum daily load may require higher treatment levels at the wastewater treatment facility significantly increasing capitol and O&M costs.
- Conclusion of Previous Studies – The quality and conclusion of previous studies can impact the tasks necessary to perform the required MassDEP Hydrogeologic Evaluation.
- Required Effluent Discharge Quality – Site specific and surrounding conditions can impact required wastewater treatment facility discharge quality such as disinfection, nitrate levels, etc.
- Groundwater Discharge Method(s) – Capital and O&M costs for groundwater discharge methods vary. Site conditions can impact what discharge methods can be used.

2.4. Findings and Recommendations

The site suitability evaluation process resulted in the following ranking of sites:

- Overland Way (Parcels 1/1A) – 13 Points
- Route 6 Interchange (Exit 12 Cloverleaf) – 8 Points
- Depot Square (Old Colony Way) – 5 Points
- Old Colony Apartments (Old Colony Way) – 5 Points

- Thayer Property (Orleans Market Place) – 1 Point
- Hole in One Restaurant Parking (Cranberry Highway) – 1 Point

2.5. Site Review and Shortlisted Sites

The initial groundwater discharge sites were reviewed by the Selectmen at an open meeting on Wednesday December 14, 2016. Two locations were initially shortlisted for hydrogeologic evaluation; Route 6A (Exit 12) Cloverleaf and the Overland Way.

The Overland Way site (Parcels 1/1A) was considered for two primary reasons. First, the site is located next to the proposed WWTF at Overland Way. Second, the site is located outside the Town Cove Watershed allowing for the complete removal of the nitrate load from the nitrate impacted watershed. Preliminary model runs of the USGS Monomoy Lens Groundwater Model indicated that most if not all of the discharge up to 150,000 gpd would flow under the Namskaket and Little Namskaket Marshes discharging to Cape Cod Bay, outside of an estuary where the effluent nitrate could be a potential issue. Flows of 150,000 gpd or greater indicated that a small percentage of the discharge could enter the outer reaches of the Namskaket and Little Namskaket Marshes near the mouth of the streams. The focus of this report is the hydrogeologic evaluation that was performed at the Overland Way site including the groundwater model results resulting from the calibrated groundwater model.

The Overland Way site is located in west Orleans along Overland Way (Figure 4). The site is owned by the Town of Orleans and is the location of the Tri Town Septage Treatment Facility (STF). The facility has not been in use since June 2016 and is scheduled for demolition beginning fall of 2017. In March 2017, a hydrogeologic evaluation commenced to evaluate the site for a groundwater discharge.

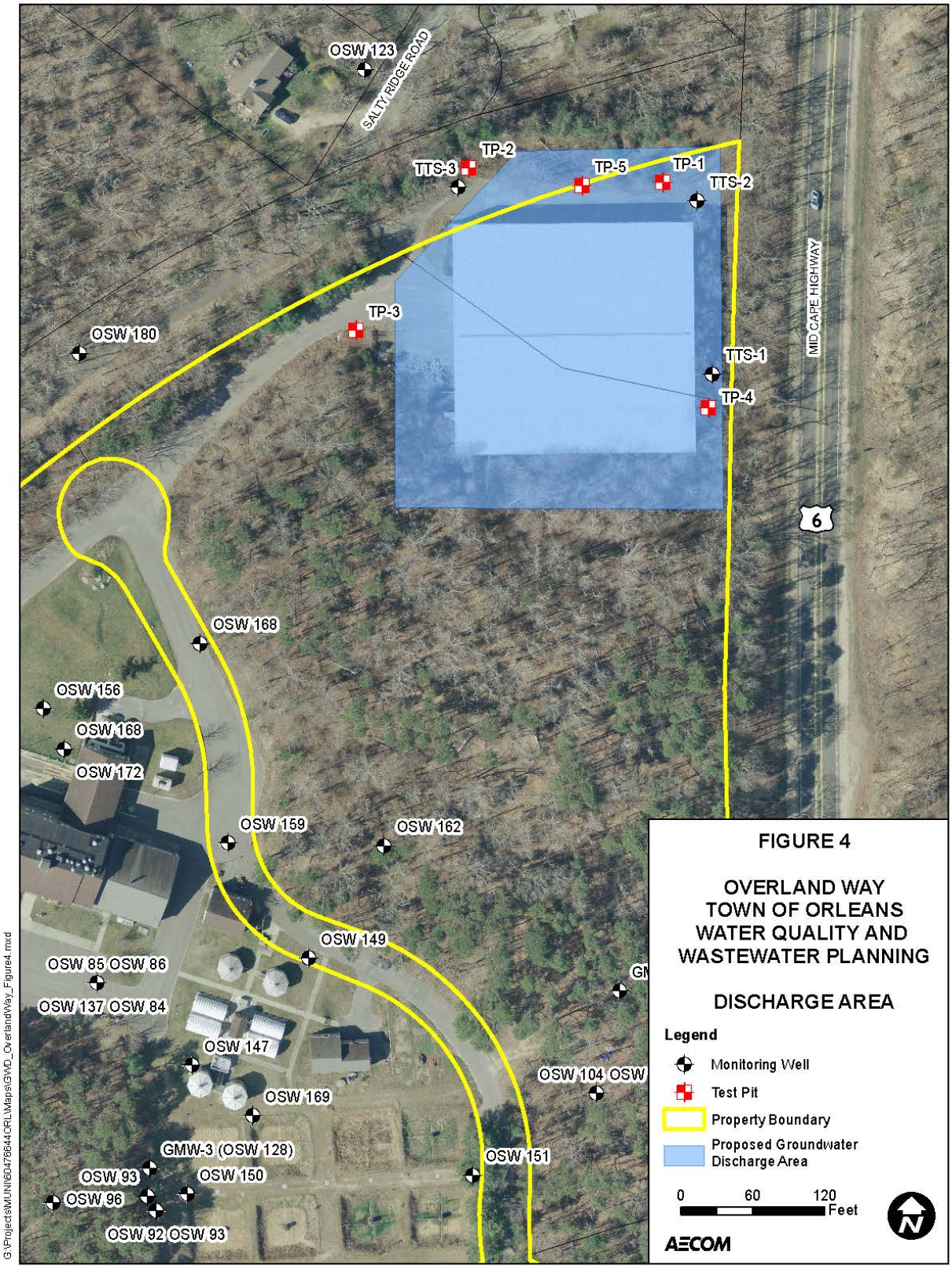
On December 15, 2016, a proposed scope of work to conduct a Hydrogeologic Site Evaluation was submitted to MassDEP for review and comment. The notification of the proposed scope of work was published in Volume 87, Issue 4 on December 21, 2016 of the Environmental Monitor and was open to public comment. The Proposed Hydrogeologic Site Evaluation was approved by MassDEP on May 16, 2017. Copies of the proposed Hydrogeologic Evaluation scope of work, Environmental Monitor Notification and MassDEP approval letter are provided in Appendix A. The following Technical Memorandum reports on the scope of work, methodology, findings, conclusions, and recommendations of the Overland Way Hydrogeologic Evaluation.

2.6. Effluent Disposal – Primary and Reserve Discharge Areas

The potential discharge area at Overland Way (Parcels 1/1A) is shown on Figure 4. The potential discharge area is in excess of 50,000 square feet (sqft). The discharge area could be expanded by approximately 50,000 sqft by the cleared area behind the existing STF office building as additional discharge area.

At this time the location of the primary and reserve discharge areas have not been determined. Several options exist. The primary discharge could take place in the vicinity of the shed at Parcels 1/1A while the reserve discharge would be designated for a site other than the Overland Way site. There is also the possibility that the reserve discharge could be designated for the area behind the STF office building.

Based on the soils investigations performed by AECOM, the primary and potentially reserve discharge facilities will be designed using a percolation rate less than 2 minutes per inch. This percolation rate has been verified by percolation tests conducted on March 29, 2017. If the primary discharge area were to be limited to the shed area of Parcels 1/1A, an open bed, wicks or subsurface leaching trench discharge would be required to obtain a discharge rate above 100,000 gpd.


OSW 123
SALTY RIDGE ROAD
TP-2
TTS-3
TP-5
TP-1
TTS-2
MID CAPE HIGHWAY
TP-3
OSW 180
TTS-1
TP-4
6
OSW 168
OSW 156
OSW 168
OSW 172
OSW 159
OSW 162
OSW 149
OSW 85 OSW 86
OSW 137 OSW 84
OSW 147
OSW 104 OSW
OSW 169
GMW-3 (OSW 128)
OSW 151
OSW 93
OSW 150
OSW 96
OSW 92 OSW 93
G:\Projects\MUNI\60476644\GRL\Maps\GWD_OverlandWay_Figure4.mxd
FIGURE 4
OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING
DISCHARGE AREA
Legend
Monitoring Well
Test Pit
Property Boundary
Proposed Groundwater Discharge Area
0
60
120
Feet
AECOM

3. HYDROGEOLOGIC INVESTIGATION

Results of the hydrogeologic investigation are included in the following sections. AECOM's investigations included the excavation of test pits, performing Title 5 percolation tests, the installation of soil borings and monitoring wells, grain-size analysis of soil samples. The data obtained were used to evaluate subsurface conditions, estimate the groundwater flow direction and calculate aquifer characteristics. Results of the field investigations and data analysis were incorporated into a numerical groundwater flow model to simulate groundwater flow across the site and estimate groundwater mounding under various discharge scenarios. A summary of these investigations follows.

3.1. Previous Subsurface Investigations

The US Geological Survey (USGS) has conducted numerous investigations at the Overland Way site, focusing primarily in the vicinity of and downgradient of the former STF discharge lagoons. Investigations began in the mid- to late 1980s, prior to the startup of the STF. Since 1986, the investigations have included:

- The installation of numerous groundwater monitoring wells at various locations and depths;
- Collection and analysis or baseline groundwater samples to establish water quality at numerous locations and depths prior to the Tri Town Septage Treatment Facility (STF) being brought on line;
- Long-tern groundwater sampling and data analysis to establish changes in groundwater quality during the operation of the Tri Town STF;
- Borehole geophysics to evaluate the locations of a subsurface clay layer and the discharge from the STF;
- Estimate the locations of the groundwater plume from the STF; and
- Reports with supporting data, figures, tables, and appendices.

In addition, the CCC investigated soils, water level and water quality data across the Town of Orleans in the early 1990s. The CCC gathered existing soil boring and water level data from numerous previous investigations. The CCC also had numerous additional soil borings and monitoring wells installed to evaluate soil and groundwater elevations across the Town of Orleans. Once collected, data was summarized in a report titled "Orleans Water Table Mapping Project, Orleans Massachusetts", dated May 1995. Soil boring logs, water level and groundwater elevation data, well location maps, geologic cross-sections and groundwater contour maps are included in the report.

3.2. Test Pit Excavation and Percolation Tests

On March 29, 2017 a total of 5 test pits and 1 percolation test were conducted by AECOM at the proposed discharge site (Figure 4). The test pits were performed to assist in evaluating the overall suitability of the subsurface soils for the proposed discharge. The test pits were excavated to depths of between 132 and 216 inches (11.0 and 18 feet).

The test pits and percolation test was witnessed by MassDEP. All test pits and the percolation test were performed under the direction of a Massachusetts licensed soil evaluator Mr. John Schnaible R.S. of Coastal Engineering Company of Orleans, SE 2166. Mr. Adekunle Teniola of MassDEP SERO was present during the excavations. Copies of the test pit data and Soil Evaluator Forms, including the percolation test results are contained in Appendix B.

3.3. Soil Boring and Monitoring Well Installation

A total of three soil borings and three monitoring wells were installed by AECOM March 9, 2017 through the March 13, 2017. The soil borings (TTS-1, TTS-2, and TTS-3) were installed with a Geoprobe 6600 direct push rig. Core samples were collected for soil type characterization. Continuous soil samples were collected to a depth of approximately 20 feet below the water table at all locations.

Monitoring wells were constructed with 2-inch Schedule 40 PVC casings and 10 foot screens (Schedule 40 PVC .010" 10 slot well screen). The soil borings were advanced at locations TTS-1, TTS-2, and TTS-3 (Figure 4).

Each monitoring well consisted of ten-foot sections of schedule 40 PVC riser pipe attached to 10-foot sections of 10-slot well screen. An artificial sand pack was installed between the well and the formation from the base of the well to approximately 2 feet above the well screen. The sand pack was then capped by approximately 2 feet of bentonite pellets and allowed to hydrate. Bentonite pellets sere then installed to a depth of 5 to 10 feet below the ground surface.

The monitoring wells were used to determine the water table elevation. All wells were surveyed for location and elevation relative to NAVD 1988. Water table elevations were used to estimate groundwater flow patterns (Section 4.0). Copies of the boring logs with monitoring well details are provided in Appendix C. A summary of the well construction details is provided in Table 1.

3.4. Grain-Size Analysis

Soil samples were collected during the installation of the soil borings. Select samples were submitted to a laboratory for grain size analysis. Copies of the grain-size analysis reports are provided in Appendix D. Results of the soils analysis are discussed in Section 4.2.

Table 1

OBSERVATION WELL CONSTRUCTION AND WATER-LEVEL SUMMARY
OVERLAND WAY SITE
ORLEANS, MASSACHUSETTS

Observation Well	Diameter (inches)	Borehole Depth	Depth of Screened Interval	Ground Elevation	Northing	Easting	Top of PVC Elevation (ft msl)	Depth to Water Table (4 25 17)	Groundwater Elevation (ft msl)
TTS-1	**2.0**	**58.1**	**35-45**	43.4	2749750.026	1064129.218	43.07	30.73	12.34
TTS-2	**2.0**	**67.7**	**30-40**	37.2	2749894.443	1064116.400	36.81	24.35	12.46
TTS-3	**2.0**	**53.4**	**30-40**	37.8	2749905.718	1063917.285	37.43	25.29	12.14
TTS-4 (Soil Boring)	**2.0**		-						
					Lat Long (NAD 27)				
OSW-22	**2.0**	**52**	**52**	39	41°47'26"	69°58'16"	39.10	34.64	4.46

Notes
All depths in feet below ground level (bgl)
All elevations in feet mean sea level (msl)
ft = feet

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4. HYDROGEOLOGIC CONDITIONS AND DATA ANALYSIS

4.1. Geology, Groundwater Flow and Boundary Conditions

Orleans is underlain by glacially derived sediments deposited 15,000 or so years ago during the waning stages of continental glaciation. The sediments consist of outwash deposited from the melting of the Cape Cod Bay and South Channel Lobes of the glacier (Wordsworth and Wigglesworth, 1934). The Harwich Outwash Plain deposits were derived from the Cape Cod Bay Lobe, while the Nauset Heights and Eastham plain deposits were derived from the South Channel Lobe (Oldale et.al., 1971).

According to Koteff and Cotton (1962) coarse sand and gravel deposits (Harwich Outwash Plain Deposits) are underlain by coarse sands to clayey silts followed by compact basal till directly overlying bedrock. The relatively thin layer of basal till indicates that the soils were deposited as the result of a single glaciation. Previous seismic investigations in the Orleans beach area indicate the bedrock surface at about 400 feet below sea level (Oldale and Tuttle, 1964).

The Overland Way parcel is underlain by Harwich Outwash Plan Deposits, as mapped by Oldale et.al (1971). According to Oldale, these deposits consist primarily of medium to very course sand and pebble to cobble gravel. In general, these deposits are fairly well sorted and very permeable. Till and boulders can be found shallow or overlying the deposits. Clayey silt can also be found in the deposits.

Due west and north of the site, lake deposits and lake bottom deposits from the Cape Cod Bay proglacial lake are mapped by Oldale et.al. (1971). The deposits due west of the site are described as being gravely sand, pebble and gravel cobble gravel. Clayey silt and till can also be found. Deposits further to the northwest and north of the outwash deposits are described as being more gravely and clayey silt

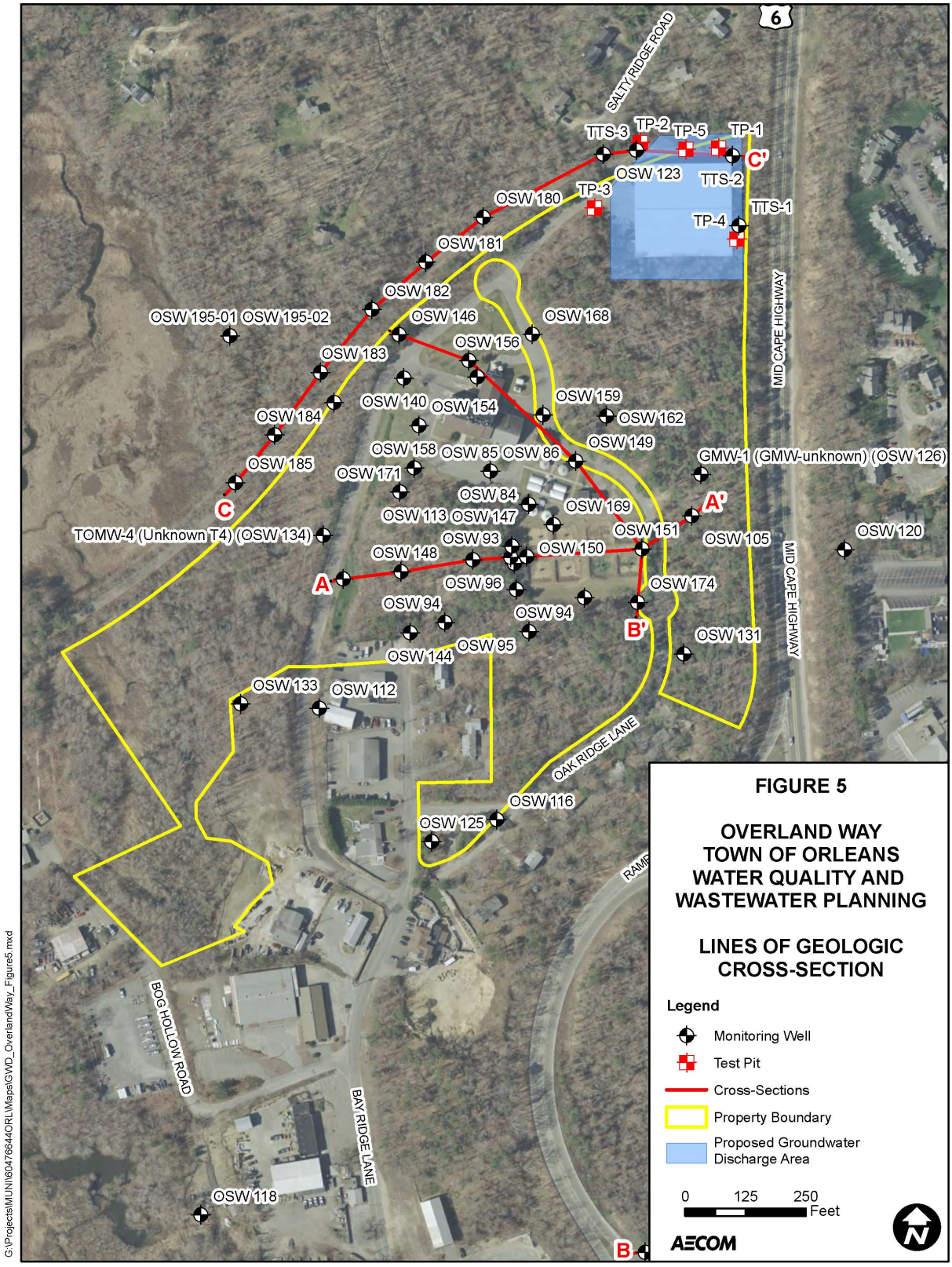
Geologic conditions found at the Overland Way in the vicinity of shed at Parcels 1/1A through AECOM's field investigations are consistent with the deposits described above. Test Pit excavations generally revealed fine or fine to medium sands (loamy sand) extending to depths between 11 to 14.5 feet below the ground surface. A course to medium sand was excavated at TP -2.

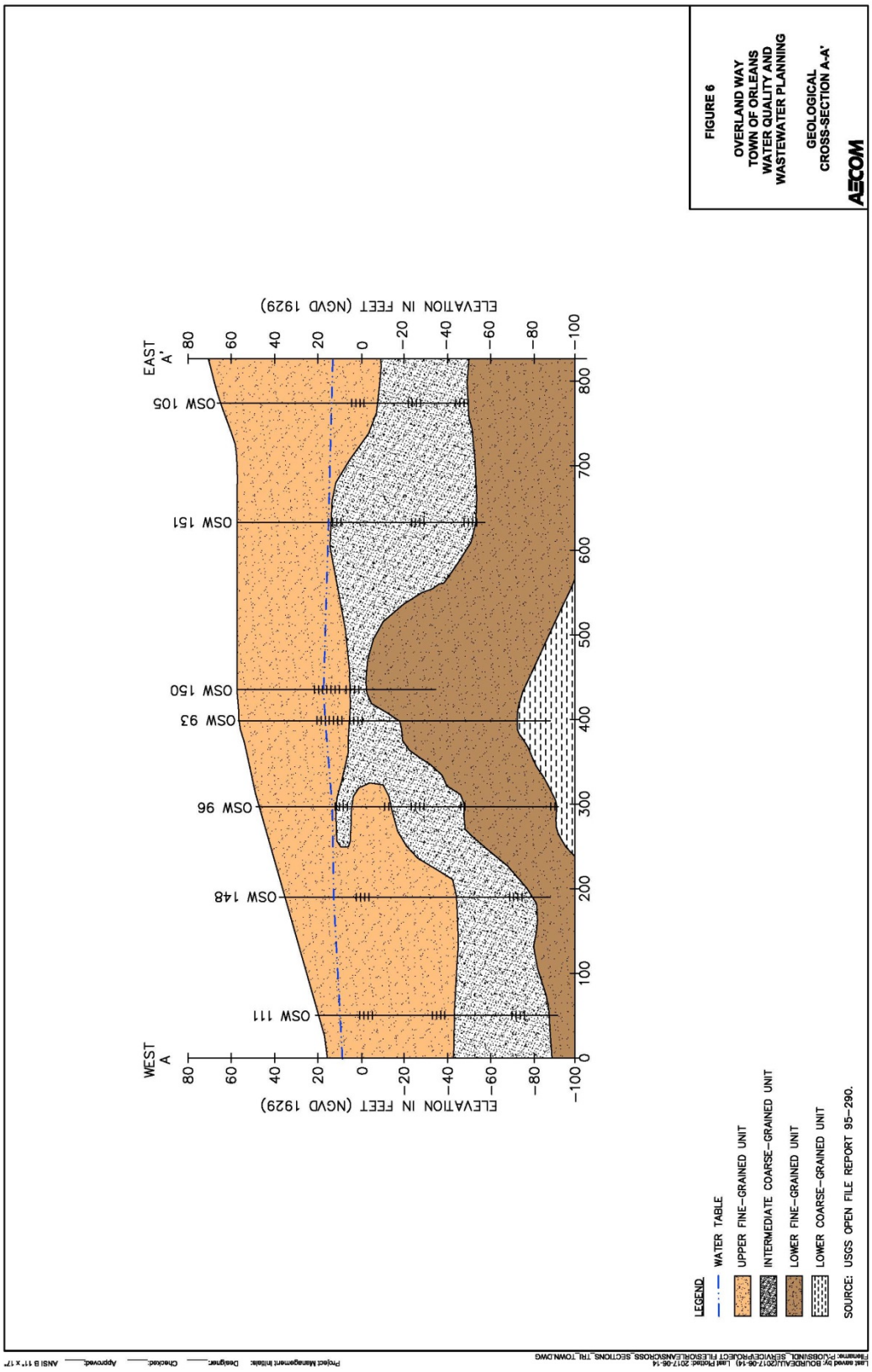
Percolation tests were performed in the medium to fine sands at TP-1 and the fine sands at TP-2. After saturation, the percolation rate at both locations was less than 2 minutes per inch indicating that the underlying shallow sands are suitable for a groundwater discharge system. Copies of the soil evaluator forms are provided in Appendix B. Copies of soil boring logs are in Appendix C.

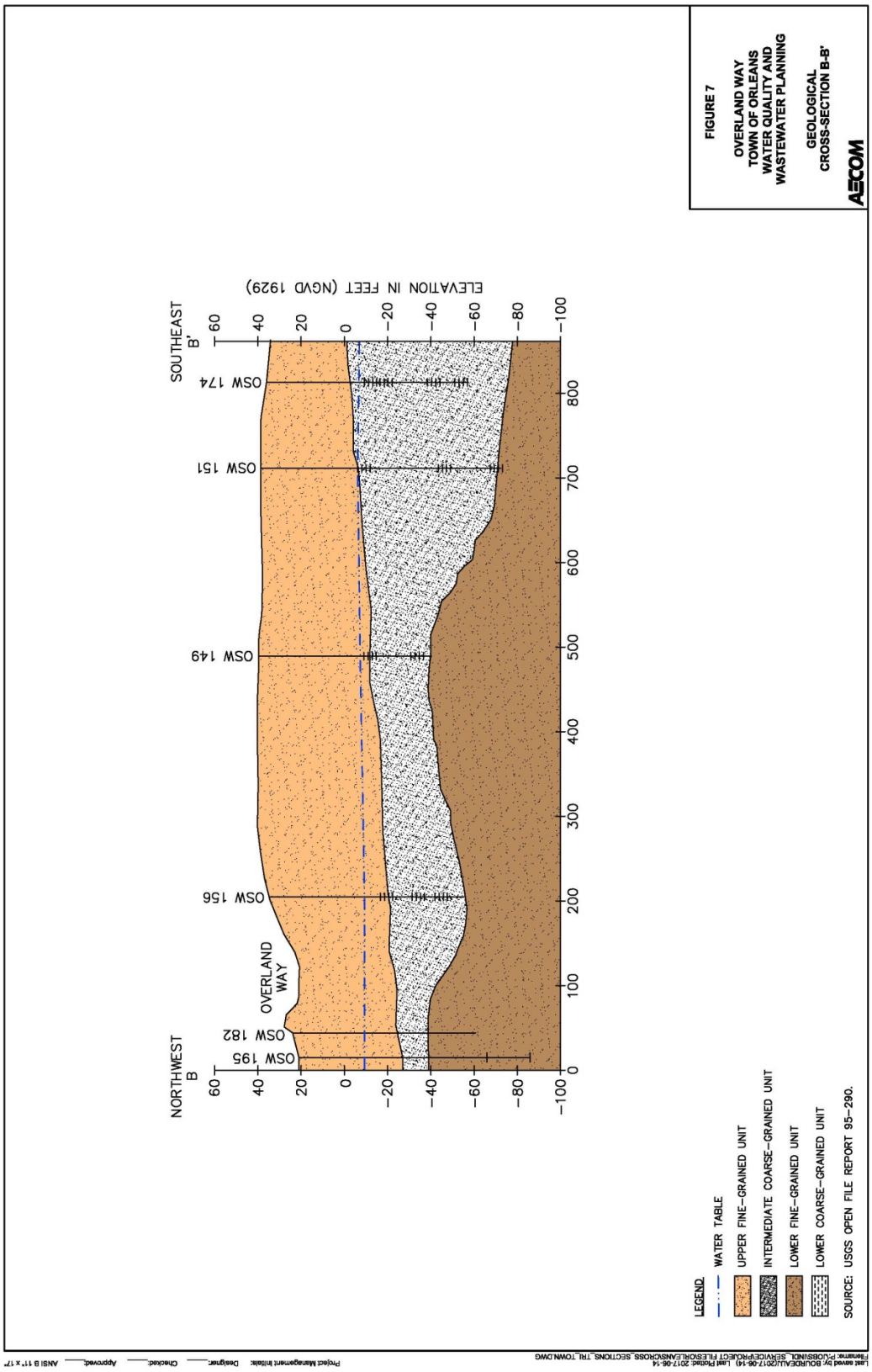
Groundwater was not encountered in any of the test pits, but was measured in the monitoring wells at a depth of approximately 65 to 75 feet below ground surface.

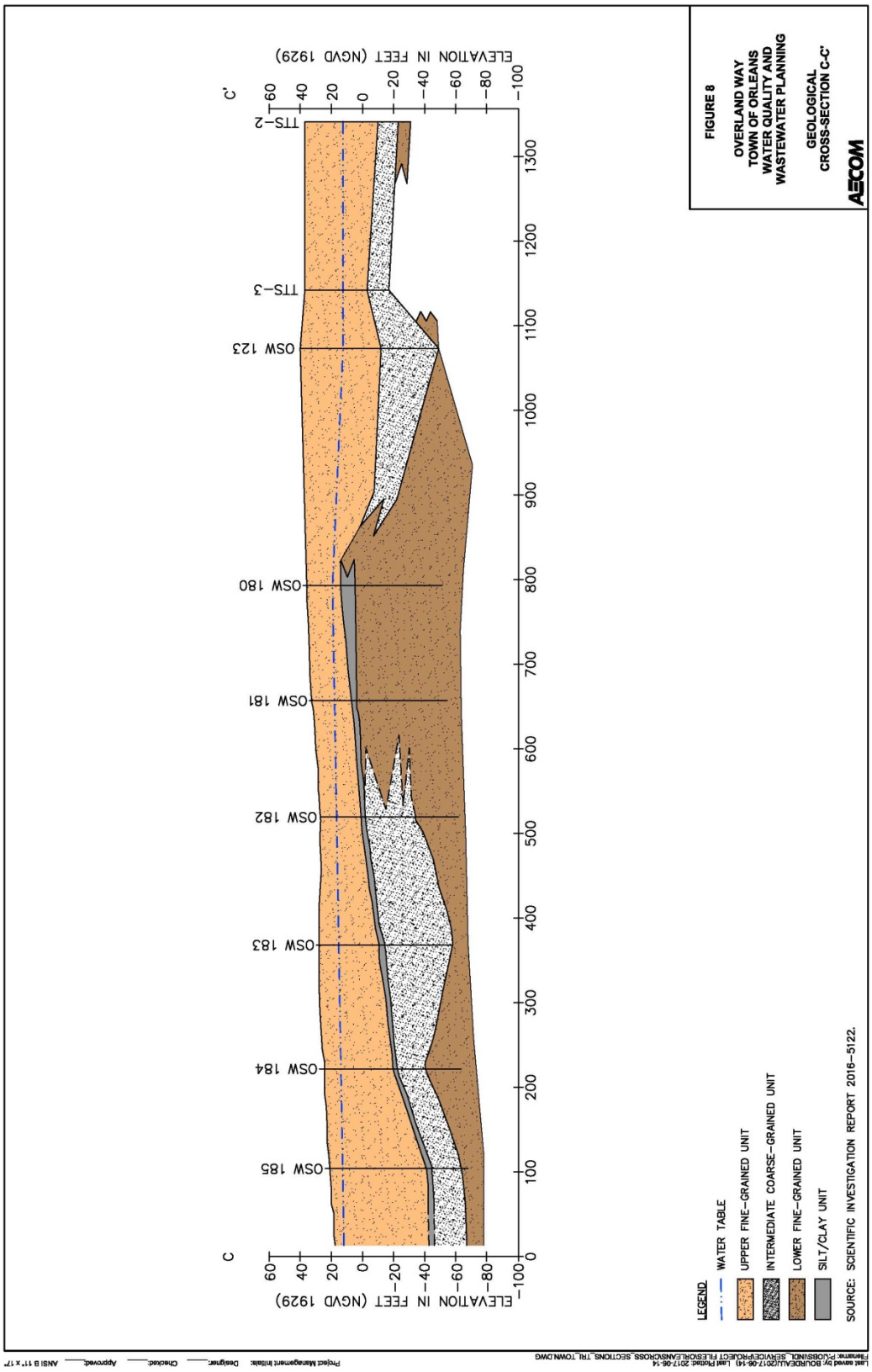
The lines of geologic cross-section are shown on Figure 5. The geologic cross-sections A-A' and B-B' (Figure 6, Figure 7, and Figure 8, respectively) graphically depict geologic conditions locally and regionally. Well logs used to construct the geologic cross- section are in Appendix C.

According to USGS and CCC water table maps, groundwater flows north northwesterly across the site toward the Namskaket and Little Namskaket Marshes (USGS, 2005). The drainage divide to Namskaket and Little Namskaket Marshes is located approximately 50 to 110 feet southwest of the discharge.


6
SALTY RIDGE ROAD
TTS-3
TP-2
TP-5
TP-1
C'
OSW 123
TTS-2
OSW 180
TP-3
TTS-1
TP-4
OSW 181
OSW 182
OSW 195-01
OSW 195-02
OSW 146
OSW 168
OSW 156
OSW 183
MID CAPE HIGHWAY
OSW 140
OSW 154
OSW 159
OSW 184
OSW 162
OSW 149
OSW 158
OSW 85
OSW 86
GMW-1 (GMW-unknown) (OSW 126)
OSW 185
OSW 171
OSW 84
C
A'
OSW 169
OSW 113
OSW 147
TOMW-4 (Unknown T4) (OSW 134)
OSW 151
OSW 105
OSW 120
OSW 93
OSW 150
OSW 148
A
OSW 96
OSW 174
OSW 94
OSW 94
B'
OSW 131
OSW 144
OSW 95
OSW 133
OSW 112
OAK RIDGE LANE
OSW 116
OSW 125
RAMP
BOG HOLLOW ROAD
BAY RIDGE LANE
OSW 118
B
FIGURE 5
OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING
LINES OF GEOLOGIC
CROSS-SECTION
Legend
Monitoring Well
Test Pit
Cross-Sections
Property Boundary
Proposed Groundwater
Discharge Area
0
125
250
Feet
AECOM
G:\Projects\MUNI\60476644ORL\Maps\GWD_OverlandWay_Figure5.mxd


FIGURE 6
OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING
GEOLOGICAL
CROSS-SECTION A-A'
AECOM
WEST
A
EAST
A'
ELEVATION IN FEET (NGVD 1929)
OSW 111
OSW 148
OSW 96
OSW 93
OSW 150
OSW 151
OSW 105
LEGEND
WATER TABLE
UPPER FINE-GRAINED UNIT
INTERMEDIATE COARSE-GRAINED UNIT
LOWER FINE-GRAINED UNIT
LOWER COARSE-GRAINED UNIT
SOURCE: USGS OPEN FILE REPORT 95-290.


FIGURE 7
OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING
GEOLOGICAL
CROSS-SECTION B-B'
AECOM
ELEVATION IN FEET (NGVD 1929)
NORTHWEST
B
SOUTHEAST
B'
OSW 195
OSW 182
OVERLAND
WAY
OSW 156
OSW 149
OSW 151
OSW 174
60
40
20
0
-20
-40
-60
-80
-100
0
100
200
300
400
500
600
700
800
LEGEND
WATER TABLE
UPPER FINE-GRAINED UNIT
INTERMEDIATE COARSE-GRAINED UNIT
LOWER FINE-GRAINED UNIT
LOWER COARSE-GRAINED UNIT
SOURCE: USGS OPEN FILE REPORT 95-290.


FIGURE 8
OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING
GEOLOGICAL
CROSS-SECTION C-C'
AECOM
C
C'
ELEVATION IN FEET (NGVD 1929)
TTS-2
TTS-3
OSW 123
OSW 180
OSW 181
OSW 182
OSW 183
OSW 184
OSW 185
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
LEGEND
WATER TABLE
UPPER FINE-GRAINED UNIT
INTERMEDIATE COARSE-GRAINED UNIT
LOWER FINE-GRAINED UNIT
SILT/CLAY UNIT
SOURCE: SCIENTIFIC INVESTIGATION REPORT 2016-5122.

4.2. Calculated Aquifer Values

Aquifer characteristics were estimated through laboratory grain-size analysis described as follows.

Samples collected from selected soil boring and test pit excavations were submitted to a laboratory for grain-size analysis. In total, 6 soil samples were submitted for grain-size analysis, four samples each from soil borings at TTS-1, TTS-2 and TTS-3.

Hydraulic conductivity (K) and porosity (n) values for each of the 6 samples were estimated using several numerical methods including Kozeny-Carman (Carman, 1937), Shepards (1989), Hazen (1892), and Slitcher (1992).

The calculated hydraulic conductivity values from the grain-size analysis was 117 ft/day for sand samples. Average conductivity values for samples containing sand and silt range from 2.5 to 33.5 ft/day while the average value for the silt sample was 0.28 ft/day. Including the results of the finer soils, the calculated averages at TTS-1, TTS-2, and TTS-3, were 18.0, 65.2, and 0.3 ft/day, respectively. Averaging the results from all of the samples at all locations, results in a conductivity of 28.4 ft/day. The calculated hydraulic conductivity values estimated from the grain-size analysis are summarized in Table 2. Laboratory reports for the soils analysis are provided in Appendix D. The hydraulic conductivity approximation reports are provided in Appendix E.

4.3. Groundwater

The study area is located in a watershed that discharges to the Namskaket, Little Namskaket or Cape Cod Bay Watersheds. Locally, groundwater flows northwest. Water levels measured on April 25, 2017, from over 45 monitoring wells were used to estimate the groundwater flow direction across the study area. Each well was surveyed relative to NAVD 1988. Using the survey data, the water levels obtained at each location were converted to elevation in feet msl. A summary of groundwater elevation data is provided in Table 1.

The static groundwater elevations were plotted on a map and approximated contours of the potentiometric surface were drawn. The resulting contours are shown on Figure 9. Contours were inferred between monitoring well locations. Based on the contours, groundwater flow across the site is generally to the east. The hydraulic gradient between the 11.0 and 12.0 foot contour was calculated at 0.006 ft/ft in the vicinity of monitoring wells OSW 129 and OSW 148. Between the 10.5 and 12.5 foot contour near wells OSW 146 and OSW 168, the gradient was shallower at 0.003 ft/ft. The groundwater contours are shown on Figure 9.

To evaluate whether the groundwater mound resulting from the discharge would cause the water table to rise to within four feet of the bottom of the discharge, high groundwater levels were estimated for the site. High groundwater levels were estimated by comparing water levels collected across the Overland Way site with water level data at a USGS reference well on the same day. The USGS long-term reference well selected was OSW-22. Reference Well OSW-22 is a USGS well located approximately 9,500 feet west of the Overland Way site in Orleans, which has been monitored since 1967. The well is screened in a similar formation with a similar hydrogeologic setting as the Overland Way site.

Water Levels were collected at the Overland Way site and the reference well site on the same day: April 25, 2017. The observed groundwater level at OSW-22 was the compared to the historic high water level for that site. The high water level on record was 1.80 feet higher than observed on April 25, 2017. Using the method developed by Frimpter, the 1.80 feet difference was added to the Overland Way water table elevations measured on the same date, adjusting the Overland Way site water table elevations to simulate high water level conditions (Frimpter, 1980).

4.4. Surface Water

The nearest surface water body is the upper reaches of Namskaket Marsh. At its closest point, Namskaket Marsh is located approximately 950 feet due west of the proposed discharge area. However, groundwater flow is to the north northwest towards Little Namskaket Marsh where the marsh is closer to 1,975 feet from the discharge (Figure 1).

Table 2

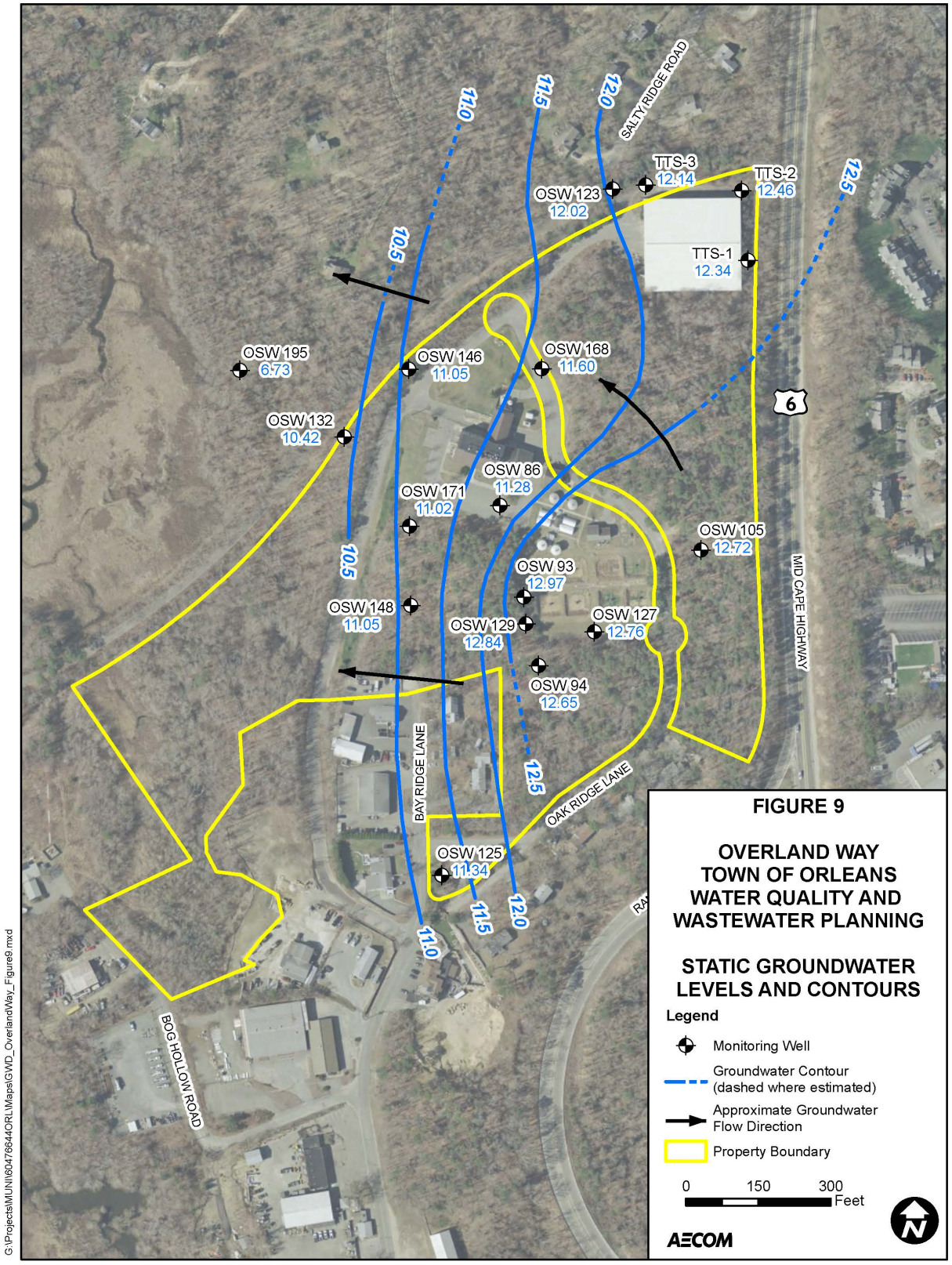
Summary of Aquifer Charactistics - Grain-size Analysis

Soil sample	Depth (ft)	D10 (mm)	D50 (mm)	D60 (mm)	U(d60/d10)	n (porosity)	Classification	Fines(%)	Kozeny-Carman Ksat (ft/day)	Sheperds Ksat (ft/day)	Hazen Ksat (ft/day)	Slitcher Ksat (ft/day)	Sample Average (FT/day)
TTS-1-TP 10-15	10-15.0	0.0963	0.2044	0.2319	2.41	0.42	Poorly graded SAND with Silt	0.06	45.83	34.00	39.71	14.57	**33.53**
TTS-1 45-46.5	45-46.5	0.0056	0.0823	0.1225	21.7	0.26	Silty SAND	0.47		7.58	0.05	0.01	**2.55**
TTS-2-TP 10-15	10-15.0	0.1632	0.5646	0.7039	4.31	0.37	Poorly graded SAND	0.04	77.44	181.76	92.58		**117.26**
TTS-2 21-21.5	21-21.5	0.0124	0.1754	0.2763	22.32	0.26	Silty SAND	0.33		26.41		0.05	**13.23**
TTS-3 15-16.5	15-16.5	0.0035	0.0168	0.021	5.91	0.34	SILT	0.98		0.55		0.01	**0.28**
TTS-4 15.5-16.5	15.5-16.5	0.0032	0.0798	0.1482	46.95	0.26	Silty SAND	0.49		7.20		0.00	**3.60**

Grain size outside the equation applicability range

Insufficient grain size data

Based on average K value for Silt


SALTY RIDGE ROAD
MID CAPE HIGHWAY
BAY RIDGE LANE
OAK RIDGE LANE
BOG HOLLOW ROAD
11.0
11.5
12.0
12.5
10.5
TTS-3
12.14
TTS-2
12.46
TTS-1
12.34
OSW 123
12.02
OSW 195
6.73
OSW 146
11.05
OSW 168
11.60
OSW 132
10.42
OSW 86
11.28
OSW 171
11.02
OSW 105
12.72
OSW 93
12.97
OSW 148
11.05
OSW 129
12.84
OSW 127
12.76
OSW 94
12.65
OSW 125
11.34
6
FIGURE 9
OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING
STATIC GROUNDWATER
LEVELS AND CONTOURS
Legend
Monitoring Well
Groundwater Contour
(dashed where estimated)
Approximate Groundwater
Flow Direction
Property Boundary
0
150
300
Feet
AECOM
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5. GROUNDWATER MODELING EVALUATION

Groundwater modeling was performed by AECOM as a part of the evaluation of disposal options to provide feedback on potential designs; this feedback can then be used to help make design decisions. Specifically for this project, numerical groundwater flow modeling was used by AECOM to predict changes in groundwater elevations and flow directions based on the volume of discharge.

More specifically, the purpose of the groundwater modeling was to: (a) evaluate the potential impacts of the groundwater discharge on ambient groundwater flow and water levels; (b) evaluate where the effluent originating from the Overland Way Discharge; and (c) estimate the nitrate load discharging to each watershed.

5.1. Modeling Method

A regional three-dimensional groundwater flow model of the Monomoy Lens was developed by the USGS as a tool for understanding the groundwater flow system and water budget (USGS, 2004). This regional groundwater flow model formed the basis of the model modified by AECOM for the purpose of performing groundwater discharge simulations.

MODFLOW was used by AECOM for this analysis (MacDonald and Harbaugh, 1988). The three-dimensional groundwater flow model was coupled with a particle tracking model called MODPATH (Pollack, 2004) in order to illustrate the potential movement of groundwater over time. Both of these models were used on the GMS platform, Version 10.0.

5.2. Conceptual Model of the Aquifer System

A conceptual site model (CSM) of a groundwater flow system is a representation of how an aquifer functions based on available data. Geologic maps and cross-sections, groundwater flow maps, and the generalized water balance (the volume of water entering and leaving the aquifer) are common elements of a conceptual aquifer model. AECOM's understanding of how the Town of Orleans groundwater flow system functions is based on the geological and hydrological data presented in Sections 3.0 and 4.0; additionally the CSM is based on the work done and reported on by the USGS (2004).

The CSM for hydrogeology and groundwater flow in the Monomoy Lens is well documented in the USGS (2004) report. Overall, the CSM documented in the USGS (2004) report is the same as is used for AECOM's modeling effort. However, AECOM's investigation of the Overland Way site completed in December 2015-January 2016 was used to verify the USGS's CSM. AECOM's work included new wells and hydraulic testing of the aquifer (to estimate K). These results of the investigation and data analysis are discussed in Sections 3.0 and 4.0 of this document.

In general, the aquifer in the Town of Orleans is a relatively simple water table aquifer composed of relatively homogeneous deposits of sand with trace amounts of gravel and silt. The bottom of the aquifer is assumed to coincide with the bottom of the numerical model, around -350 feet elevation below sea level.

According to the USGS's CSM, water enters the aquifer system primarily in the form of rainfall recharge. Rainfall recharge is expected to be around 29 inches per year except in wetlands, lakes, oceans where it may be low or zero. Groundwater then leaves the aquifer system through surface water features, such as lakes, streams, wetlands, marshes and the ocean.

5.3. Model Design and Updates

The numerical groundwater flow modeling was completed using the USGS numerical groundwater flow model of the Monomoy Lens as a basis. This model is documented in "Simulated Water Sources and Effects of Pumping on Surface and Ground Water, Sagamore and Monomoy Flow Lenses, Cape Cod, Massachusetts" (USGS, 2005). Modeling files were received from the USGS and were imported into the GMS 10.0 platform. GMS is a pre- and post-processor for MODFLOW-2000 that facilitates data input, and depiction and interpretation of output.

5.3.1. Model Design

The model prepared by the USGS, and modified by AECOM, is structured as follows:

- The USGS model runs as a steady-state model, which incorporates long-term average conditions and does not include shorter-term (i.e., transient) changes in storage.
- The USGS model domain included the entire Monomoy Lens; a map of this domain is included in Appendix 1 (USGS, 2004) Figure 1-1A. The model domain updated by AECOM is bounded primarily by surface water features (streams, marshes, inlets, estuaries, and ocean). The southwestern limit of the model domain was adjusted from the full regional model; a no flow boundary was assigned there to coincide with the groundwater divide.
- The original USGS model and AECOM modified model are both 20 layers. In this area of the Monomoy Lens, the groundwater table is low enough such that many of the upper layers go dry. The first layer that is wet over the entire model domain is layer 8. The bottom updated model domain ranges from approximately -300 to -400 feet elevation below sea level. With the exception of the lowest model layer, the model layers are uniform thickness across the model domain, see Appendix 1 (USGS, 2004. Figure 1-1B.
- USGS assigned a uniform model grid or 400 feet by 400 feet across the model domain. AECOM refined the model grid across the area of interest to 100 feet by 100 feet. Figure 10 shows AECOM's updated model grid, general head boundaries and drain nodes.
- USGS assigned rainfall recharge using a variable array for the model domain. The rainfall recharge rate ranges (0 to 33.7 in/year, with a model wide average of 22.9 inches per year. Lesser rates or zero rainfall recharge rates were assigned to wetlands, open water, and/or oceans. The distribution of recharge is shown in Figure 11. Figure 11 shows rainfall recharge distribution across the model domain. In the calibration process, AECOM increased the recharge, discussed below in the calibration section.
- USGS simulated surface water features in a variety of ways:
    - Streams, wetlands, marshes, estuaries and other drainages were simulated using the drain (DRN) package;
    - The Atlantic Ocean and Cape Cod Bay were simulated with a general head boundary (GHB);
    - Lakes were simulated with horizontal flow boundaries (HFB) and high hydraulic conductivity; and
    - The original model included using the stream (STR) package for some surface water drainages, but when the model domain was made smaller, those features were excluded. Therefore, the updated model does not use the stream package.
- The original USGS model included groundwater extraction consistent with water usage using the well (WEL) package. Extraction rates are summarized in Table 1-3 of Appendix 1 of the USGS (2004) report. AECOM made no changes to the well rates for the updated model domain. AECOM used the WEL package to simulate the groundwater discharge at the Overland Way site. This is discussed in the Simulations section, below.

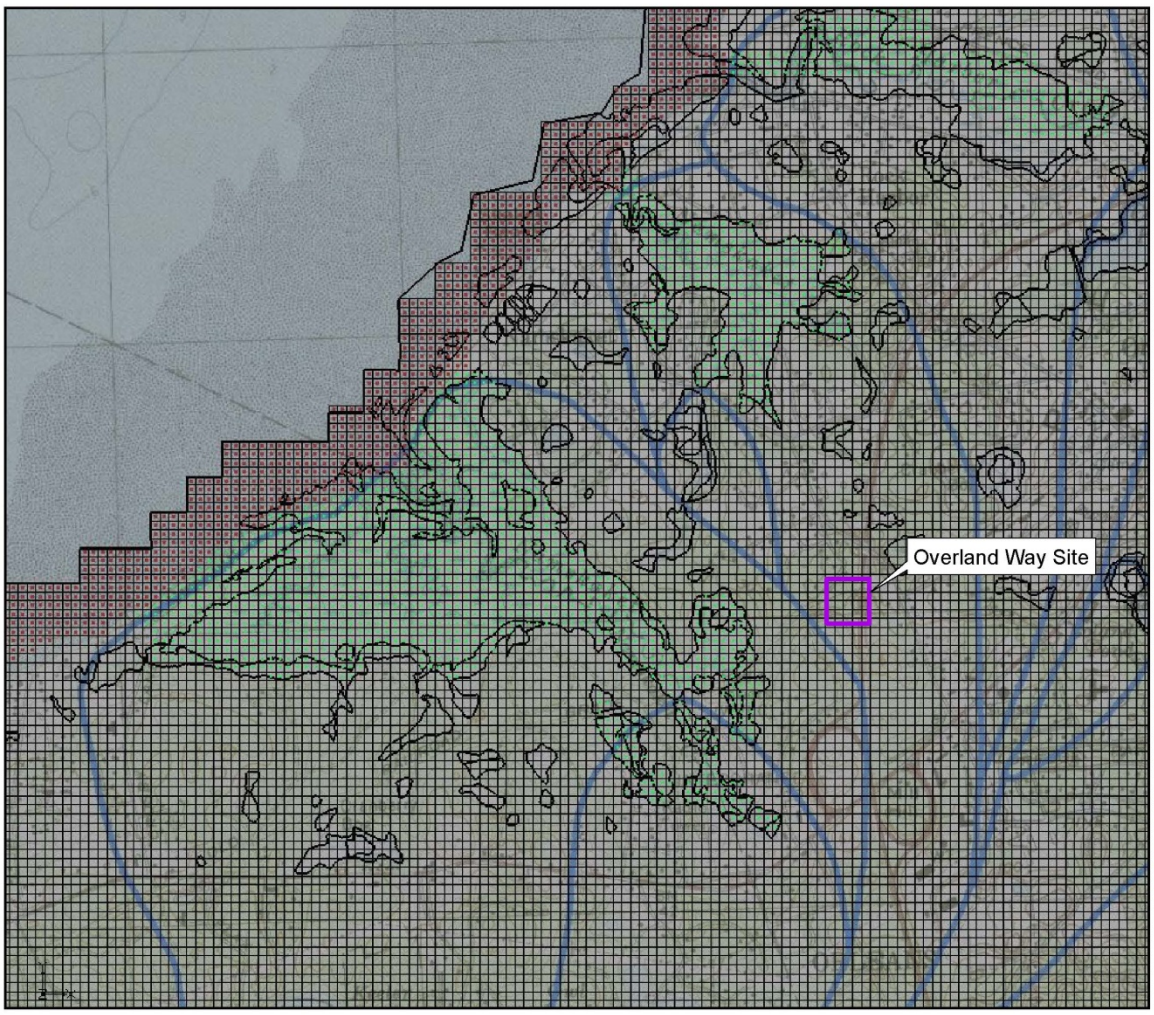


FIGURE 10

**OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING**

MODEL GRID AND LOCATION OF GENERAL HEAD BOUNDARIES AND DRAIN NODES

Legend

- Model Drain Nodes
- Boundary of Model Domain
- General Head Boundary

AECOM

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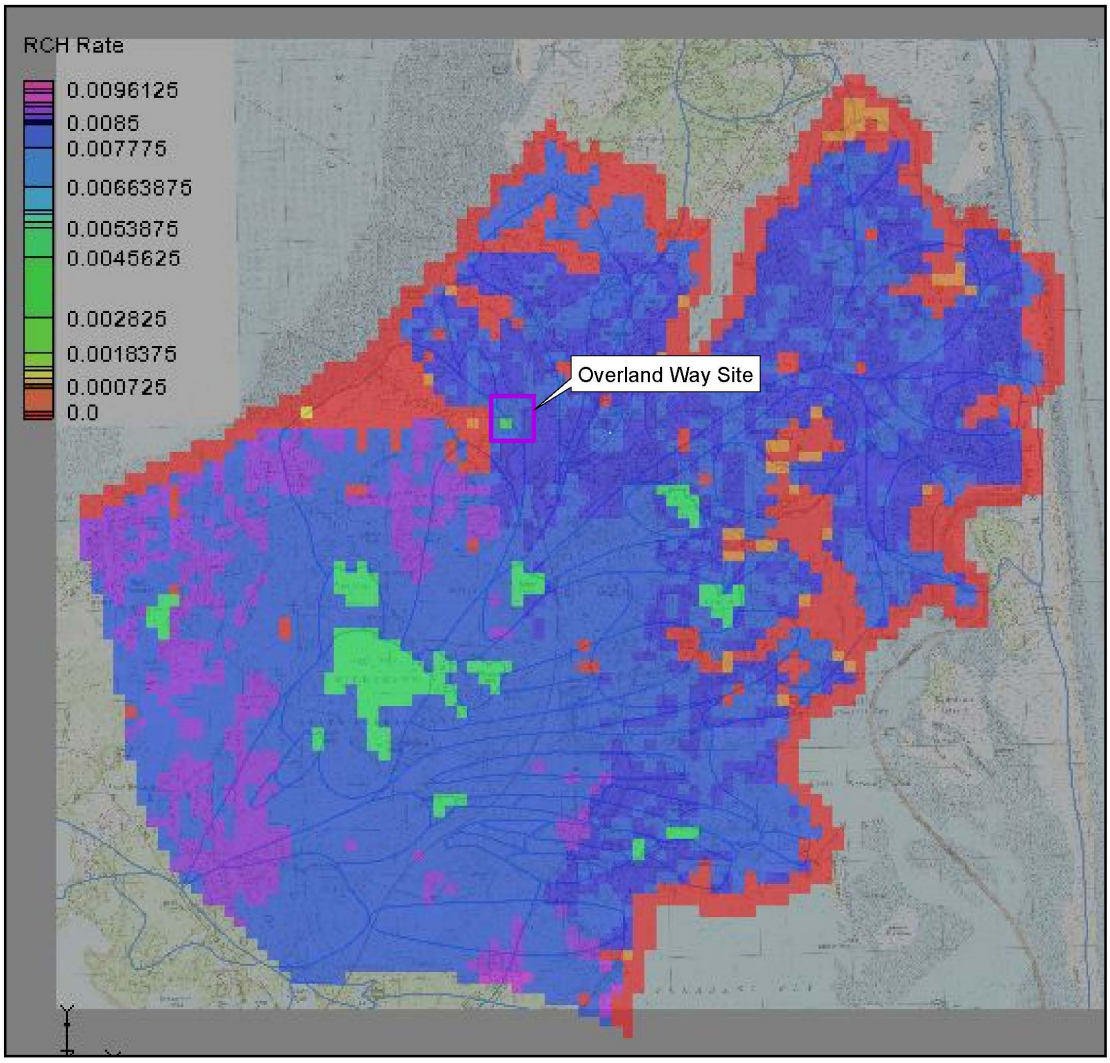


FIGURE 11

OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING

MODEL RECHARGE DISTRIBUTION

Legend

RCH Rate (in. per yr.)	
0	15.99
2.54	27.24
3.62	29.78
9.9	30.88
	31.61

AECOM

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5.3.2. AECOM Model Updates

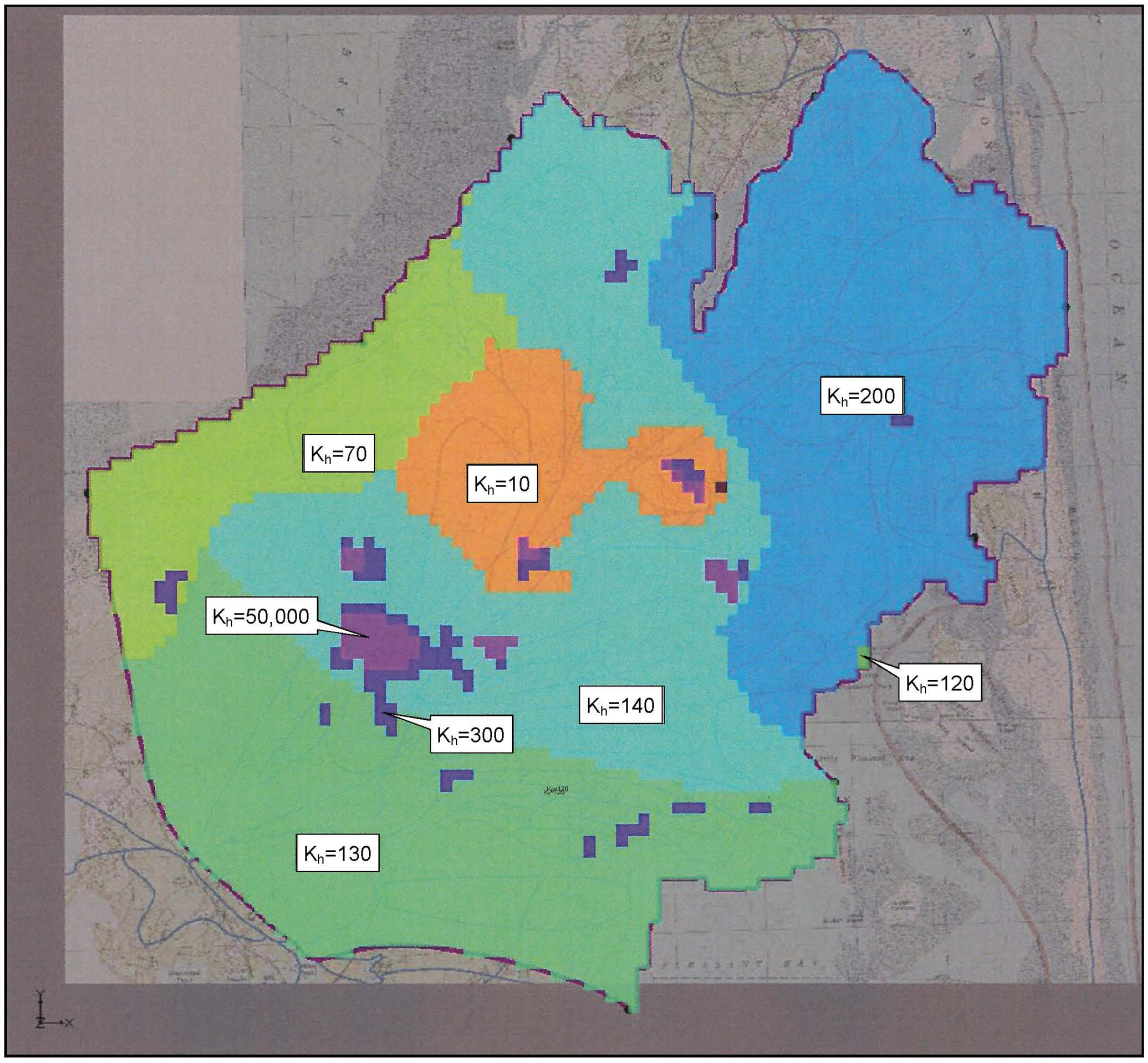
AECOM made a number of changes to the model by to meet model objectives. They are as follows:

- AECOM converted the solver package to the PCG2 package from the LMG package based on a recommendation from the USGS in the model documentation that accompanied the model files ("…due to licensing restrictions, the USGS is no longer able to publicly distribute the Algebraic Multi-Grid (AMG) solver, on which the Link-AMG (LMG) Package relies. There are two possible solutions: 1) use a standard solver publicly available from USGS, such as SIP or PCG2 or 2) obtain the AMG/LMG solver from Fraunhofer-Institute for Algorithms and Scientific Computing (SCAI)").
- AECOM refined the grid around the Overland Way site. The USGS model used a grid size of 400 feet by 400 feet over the entire model domain. AECOM adjusted the grid to 100 by 100 feet. This was completed to provide better resolution on the model inputs (i.e., discharge areas) and outputs.
- In refining the grid, AECOM updated some model features:
    - Drain cell conductances were adjusted to reflect the new dimensions of the grid cells;
    - General head boundary conductances were adjusted to reflect the new dimensions of the grid cells; and
    - Horizontal flow barrier segments were added as needed to encompass the ponds/lakes in the model domain.

Figure 10 shows AECOM's updated model grid, general head boundaries and drain nodes. The distribution of recharge is shown in Figure 11. The hydraulic conductivity values used by the USGS and AECOM are shown in Figure 12.

After AECOM made the changes above, the model was verified to be an adequate representation of the original USGS model in the following ways:

- A comparison of predicted groundwater elevations was made in select cells/areas to demonstrate that AECOM's new version of the model predicted groundwater elevations similar to that predicted by the USGS model. Generally, the differences were less than 0.5 feet and lower in many instances. There are a handful of cells where AECOM model predictions are greater than 1 foot, but these are far from the areas of interest and so should not impact model predictions;
- A comparison of groundwater flow directions as demonstrated with particle tracking. Particles were seeded in select areas to verify that groundwater flow paths and divides are similar as those mapped by the USGS. Generally speaking the AECOM version of the model was the same or similar to the particle tracking under ambient conditions from the USGS version of the model;
- AECOM made a comparison of mass balance generated by the two models. More specifically, recharge, well, general head boundary, drain boundary volumes were compared to verify that the water balances were the same or similar to the USGS model. Table 3 summarizes the comparison. The percent differences on the water budget components are very small; most differences can be attributed, in part, to the regridding and resulting changes to conductances of the drain and general head boundaries; and
- The change in model solver (from LMG to PCG2), which results in a slightly different solution.



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FIGURE 12

OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING

MODEL HYDRAULIC CONDUCTIVITY VALUES (FT/DAY), K_h, IN MODEL LAYER 8

Legend

Boundary of Model Domain

AECOM

In summary, AECOM made a number of changes to the original USGS model domain and structure to better meet the project objectives. Despite the changes, the AECOM model replicated the USGS output adequately; differences can be explained and are not expected to impact model predictions. Overall, AECOM considers this model a good tool to complete a preliminary evaluation of effluent disposal scenarios.

5.4. Model Calibration

USGS calibrated the full Monomoy Lens model and this process is described in Appendix 1 of the USGS report (2004). In accordance with our scope, AECOM verified that the calibration was maintained after the domain and grid were updated as discussed above. In summary:

- Simulated groundwater elevations from the USGS model compared favorably to the simulated groundwater elevations generated in the AECOM model;
- Simulated groundwater flow paths from the USGS model compared favorably to the simulated groundwater flow paths generated in the AECOM model; and
- The water budget of the USGS model (for the area of interest) compared favorably with the water budget for the AECOM model.

Regionally, the updated model was able to reproduce the results from the original USGS model very closely.

On April 25, 2017, groundwater levels were measured at the Overland Way monitoring wells (TTS-1 through TTS-3) and numerous other wells in Orleans. An estimate of high groundwater levels at Overland Way and across the model domain were made based on the differences observed between high and current groundwater levels at OSW-22. The simulated groundwater levels at the target locations predicted by the model indicating that the USGS calibrated model was simulating groundwater levels below the estimated high water table elevations. Therefore, the model was further calibrated to better simulate the estimated high water table conditions.

Numerous model runs were performed varying several parameters, including rainfall recharge, hydraulic conductivity values, the location of the model drain nodes used to simulate the Namskaket and Little Namskaket Marshes, the drain node elevation, and the drain node elevations. At the conclusion of the calibration process, the following changes were made:

- Rainfall recharge was increased by 25 percent, from 22.9 inches to 28.6 inches;
- The location of the Namskaket Marsh drain nodes, those within approximately 2,700 feet east of the discharge, were changed to better simulate the geometry of the march boundary;
- The Namskaket Marsh drain node elevations and conductivity values within 2,700 feet of the discharge were made consistent; and
- The elevation of the Namskaket Marsh drain node elevations and conductivity values within 2,700 feet of the discharge were made consistent.

At the conclusion of the calibration process, the model was considered a good tool for conducting predictive simulations. The simulated groundwater elevations compared favorably to estimates for high groundwater elevation conditions. The results of the calibrated steady-state model output (water table levels) are shown in Figure 13. In the simulated contours are for Layer 8 of the model. Table 4 summarizes the estimated high water table and model simulated elevations. Table 4 also summarizes the comparison between the calculated high water level conditions and the model simulated groundwater levels.

TABLE 3
COMPARISON OF MASS BALANCE
TOWN OF ORLEANS
WATER QUALITY AND WASTEWATER PLANNING

	SUBSET OF REGIONAL[1]	UPDATED MODEL[2]	DIFFERENCE	% DIFFERENCE FROM ORIGINAL
IN (ft^3/day):				
CONSTANT HEAD	0.00	0.00		
WELLS	0.00	0.00		
DRAINS	0.00	0.00		
GENERAL HEAD	0.00	0.00		
RECHARGE	3,899,661.85	3,906,112.50	-6,450.64	-0.17%
STREAM LEAKAGE	0.00	NA		
OUT (ft^3/day):				
CONSTANT HEAD	0.00	0.00		
WELLS	239,703.00	239,703.00	0.00	
DRAINS	2,137,289.64	2,152,853.94	-15,564.31	-0.73%
GENERAL HEAD	1,472,953.97	1,513,555.55	-40,601.58	-2.76%
RECHARGE	0.00	0.00		
STREAM LEAKAGE	0.00	NA		
Notes:				
1 - Using Zonebudget, calculated based on approximate same domain as the Updated Model				
2 - Using Zonebudget.				

5.5. Predictive Simulations

AECOM's calibrated groundwater flow model was used to simulate nine discharge scenarios to predict groundwater mounding and the flow of groundwater from the discharge sites. The Overland Way (Parcels 1/1A) site is proposed to be the primary discharge area for the groundwater discharge. The entire discharge from the WWTF is proposed to be discharged in the vicinity of the shed on Parcels 1/1A.

AECOM ran a base case run with zero discharge. The resulting groundwater contours and residuals are shown on Figure 13. The model generated contours represent high water table conditions across the modeled area. The monitoring well locations shown on the figure are locations where water level data was collected on April 25 and high water table conditions were estimated (Section 5.4). The residual are the calculated difference between the model simulated and the estimated high water table condition at each monitoring well location.

Well locations where the model predicted water table elevation is within 0.5 feet of the estimated high water table elevation is indicated by dark green. Lighter green symbols indicate that the simulated water table elevation is between 0.5 and on 1.0 feet of the calculated high water table. Light and dark red symbols represent locations where the residual is between 1.0 and 2.0 feet, and is greater than 2.0 feet, respectively. Monitoring well symbols with a "+" are locations where the model simulated water table elevation is higher than the estimate water table conditions for that site. A negative ("-") indicated that the simulated water table is lower than the estimated high water table elevation.

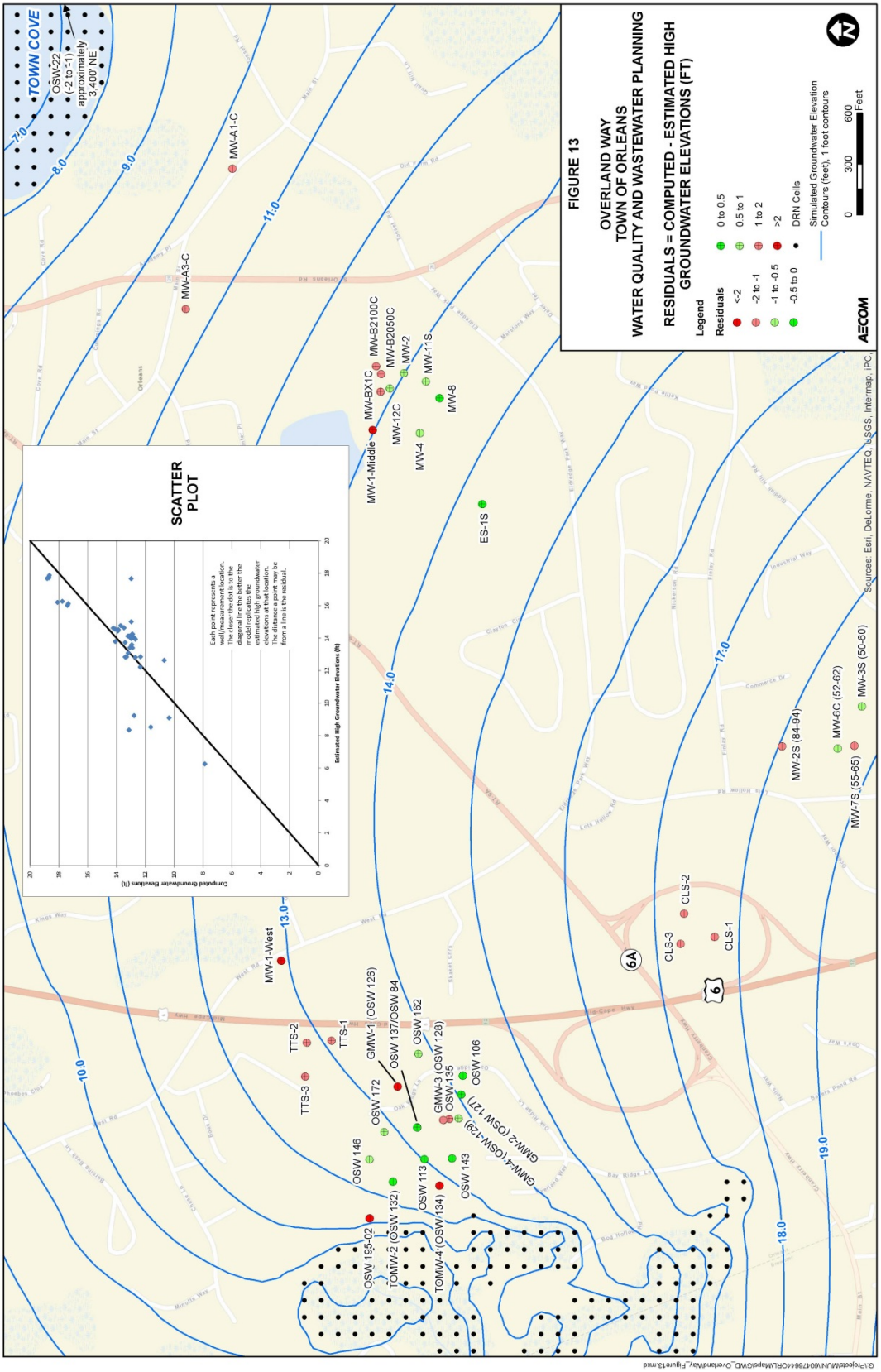
Also shown on Figure 13 is a graph plotting model simulated and estimated high water table elevations at each monitoring well location. The residual at each location is the distance between the diagonal line and point plotted. The closer the point to the diagonal line, the lower the residual and the closer the model is simulation high water table conditions. As indicated by the scatter plot, the points are fairly evenly distributed above and below the diagonal line and the residuals are also relatively close to the line. Both indicate that the model is reasonable calibrated to the estimated high water table conditions.

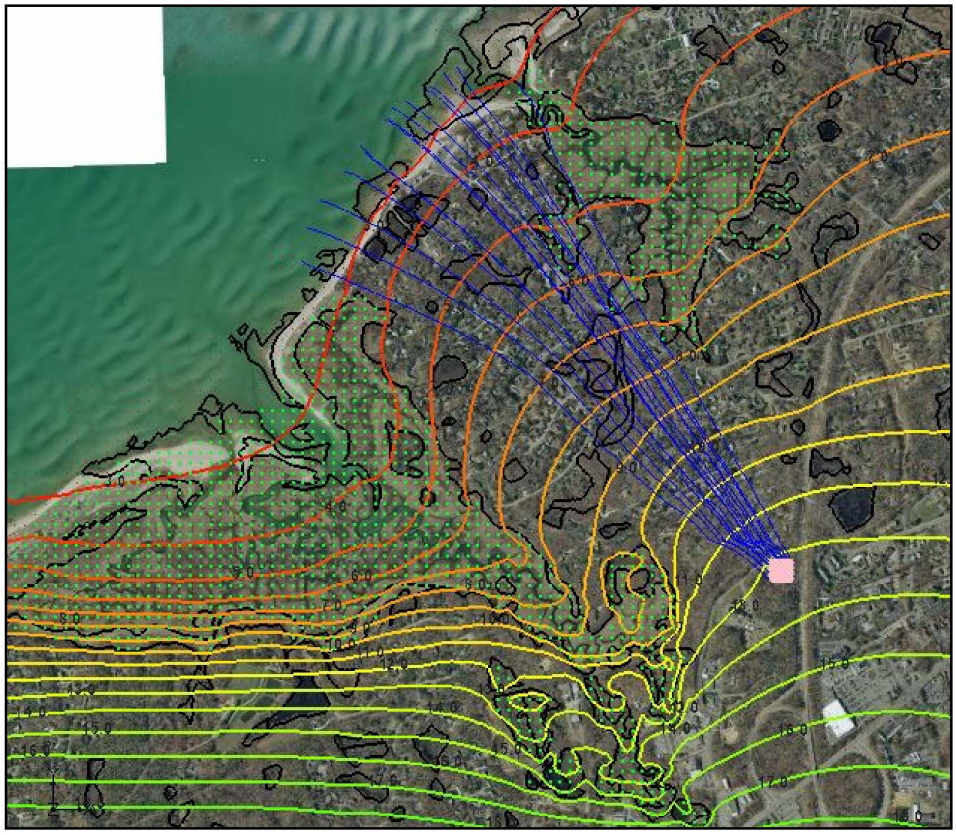
Additionally, eight separate discharge simulations (Simulations A through H) were modeled using the calibrated model. Each simulation scenario assumes a different discharge rate (between no discharge and a flow of 500,000 gpd) under the high water-table conditions described above. The simulation results are illustrated in Figure 14 through Figure 21.

- Based on particle tracking travel times, the model predicts that groundwater in the discharge area will reach Cape Cod Bay in approximately 65 years.
- Simulation A – 25,000 gpd - Figure 14 shows the simulated paths of groundwater flow as determined by the particle-tracking module. The ultimate discharge points of groundwater are shown by the particle track endpoints. The modeling indicates that all of the groundwater will flow northwest and discharge into Cape Cod Bay. There are no particle traces indicating discharge into Namskaket Marsh. The baseline groundwater elevation near the center of the discharge area is 13.0 feet; with a 25,000 gpd discharge, the groundwater elevation at the same location is 13.7 feet, indicating 0.7 feet of mound.
- Simulation B – 50,000 gpd - Figure 15 shows the results of Simulation B, treated effluent being discharged at a rate of 50,000 gpd. The maximum mound elevation is predicted to be approximately 14.36 feet indicating 1.36 feet of mounding above the ambient groundwater levels. The top of the mound would be approximately 25 feet the below ground surface. No WWTF effluent appears to discharge into Namskaket although a single particle trace exiting at Little Namskaket Marsh indicates that some of the groundwater discharge is beginning to enter Little Namskaket Marsh.
- Simulation C – 100,000 gpd - Simulation C (Figure 16) shows the simulated paths of groundwater flow as estimated by the groundwater model. At 100,000 gpd, the model predicts that a majority of the groundwater will discharge northwest to Cape Cod Bay. The model predicts a small amount of groundwater discharge to the Namskaket and Little Namskaket Marshes. The groundwater elevation at the top of the mound is approximately 15.5 feet, or 2.5 feet of mounding. The overall distribution of the distribution continues to widen as the groundwater discharge increases.
- Simulation D – 150,000 gpd - Figure 17 also shows the simulated paths of groundwater flow as determined by the particle-tracking module for a discharge rate of 150,000 gpd. The model results indicate that most of the groundwater will continue to discharge to Cape Cod bay, with smaller amounts discharge to Namskaket and Little Namskaket Marshes. The overall distribution of applied groundwater continues to widen with successive discharge rates. The groundwater elevation below the discharge is approximately 16.6 feet from a 3.6 foot mound.

Table 4
Comparison of High Water Table Conditions

Location	Estimated High Groundwater Elevations (feet)	Computed Groundwater Elevations (feet)	Residuals (feet)	Average Residual
MW-2S (84-94)-Shallow	16.21	18.10	-1.89	-0.002
MW-3S (50-60)-Shallow	17.72	18.68	-0.96	
MW-6C (52-62) -Shallow	17.87	18.66	-0.79	
MW-7S (55-65)-Shallow	17.68	18.81	-1.13	
MW-1-Middle-Shallow	15.01	12.99	2.02	
MW-2-Shallow	13.99	12.99	1.00	
MW-4-Shallow	12.84	13.41	-0.57	
MW-8-Shallow	13.74	13.41	0.33	
MW-11S-Shallow	14.13	13.21	0.92	
MW-12C-Shallow	13.6	12.95	0.65	
MW-B2050C-Shallow	14.02	12.81	1.21	
MW-BX1C-Shallow	14.24	12.89	1.35	
MW-B2100C-Shallow	13.98	12.73	1.25	
ES-1S-Shallow	14.62	14.24	0.38	
CLS-1-Shallow	16.27	17.76	-1.49	
CLS-2-Shallow	16.02	17.40	-1.38	
CLS-3-Shallow	16.13	17.34	-1.21	
TTS-1-Shallow	14.14	13.13	1.01	
TTS-2-Shallow	14.26	12.91	1.35	
TTS-3-Shallow	13.94	12.69	1.25	
OSW 137-Shallow	13.08	13.19	-0.11	
OSW 84-	13.41	13.08	0.33	
OSW 135-Shallow	14.64	13.49	1.15	
OSW 146-Shallow	12.85	12.34	0.51	
OSW 143-Shallow	12.85	13.31	-0.46	
OSW 162-Shallow	8.35	13.13	-4.78	
OSW 172-Shallow	13.4	12.89	0.51	
OSW 113-Shallow	12.82	12.70	0.12	
OSW 106-Shallow	13.8	14.09	-0.29	
OSW 195-02-Shallow	8.53	11.63	-3.10	
OSW 132- Shallow	12.22	12.36	-0.14	
OSW 134-Shallow	9.23	12.79	-3.56	
GMW-2 (OSW 127)-Shallow	14.56	14.12	0.44	
GMW-3 (OSW 128)-Shallow	14.77	13.72	1.05	
GMW-4 (OSW 129)-Shallow	14.45	13.91	0.54	
OSW 126-Shallow	14.52	13.88	0.64	
MW-1-West-Shallow	17.67	12.98	4.69	
MW-A1-C-Shallow	9.09	10.35	-1.26	
MW-A3-C-Shallow	12.64	10.70	1.94	
OSW-22-Shallow	6.26	7.88	-1.62	


FIGURE 13
OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND WASTEWATER PLANNING
RESIDUALS = COMPUTED - ESTIMATED HIGH GROUNDWATER ELEVATIONS (FT)
Legend
Residuals
<-2
-2 to -1
-1 to -0.5
-0.5 to 0
0 to 0.5
0.5 to 1
1 to 2
>2
DRN Cells
Simulated Groundwater Elevation Contours (feet), 1 foot contours
0
300
600
Feet
AECOM
SCATTER PLOT
Computed Groundwater Elevations (ft)
Estimated High Groundwater Elevations (ft)
Each point represents a well/measurement location. The closer the data is to the diagonal line the better the model replicates the estimated high groundwater elevations at that location. The distance a point may be from a line is the residual.
TOWN COVE
OSW-22
(-2 to -1)
approximately 3,400 feet
MW-A1-C
MW-A3-C
MW-B2100C
MW-B2050C
MW-2
MW-11S
MW-8
MW-BX1C
MW-12C
MW-4
MW-1-Middle
ES-1S
MW-1-West
TTS-2
TTS-1
TTS-3
GMW-1 (OSW 126)
OSW 137/OSW 84
OSW 162
GMW-3 (OSW 128)
OSW 135
OSW 106
OSW 172
GMW-4 (OSW 139)
GMW-2 (OSW 127)
OSW 146
OSW 113
OSW 143
OSW 195-02
TOMW-2 (OSW 132)
TOMW-4 (OSW 134)
CLS-3
CLS-2
CLS-1
6A
6
MW-2S (84-94)
MW-6C (52-62)
MW-7S (55-65)
MW-3S (50-60)
7.0
8.0
9.0
10.0
11.0
13.0
14.0
17.0
18.0
19.0
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC,
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Groundwater Mounding

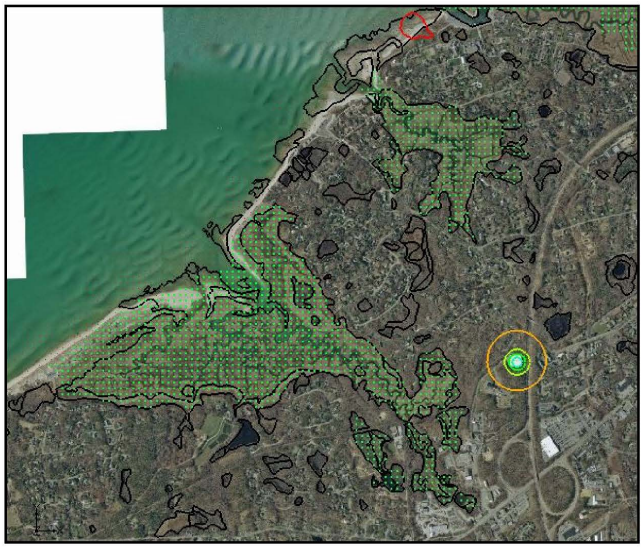


FIGURE 14

**OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING**

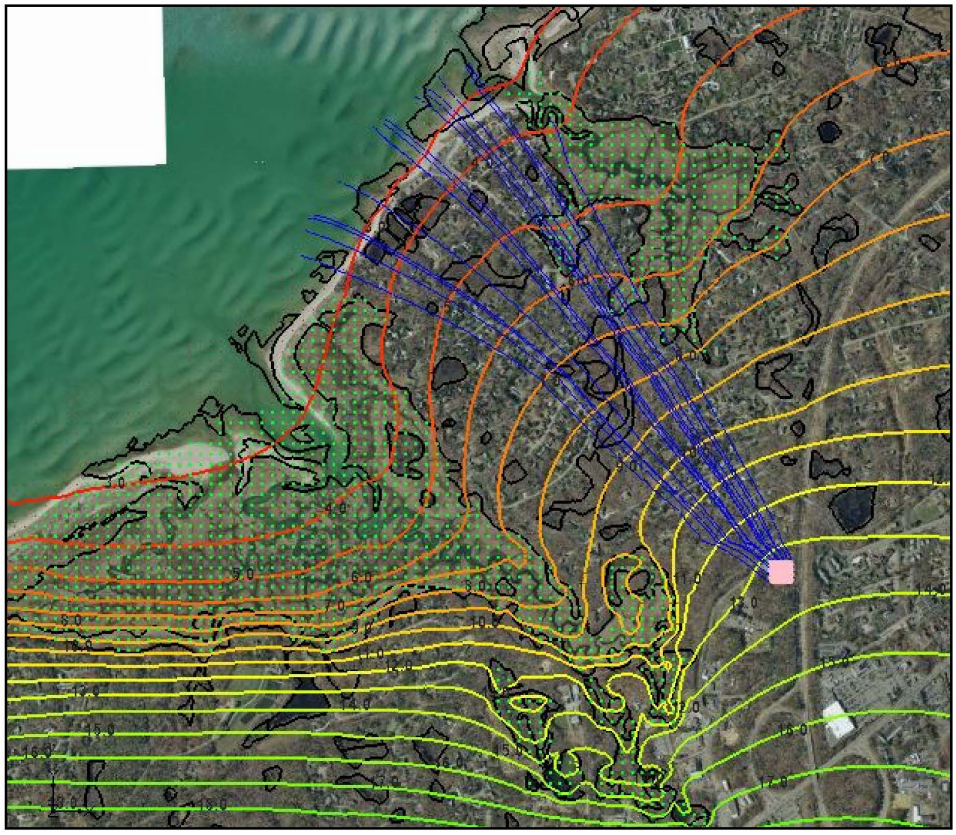
SIMULATION A - 25,000 gpd

Legend

- Groundwater Discharge Area
- Model Drain Nodes
- Simulated Groundwater Discharge Flow Path
- 5.0 Simulated Groundwater Contours (ft)
- Groundwater Mound Contour (contour interval 0.1 ft)

AECOM

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Groundwater Mounding

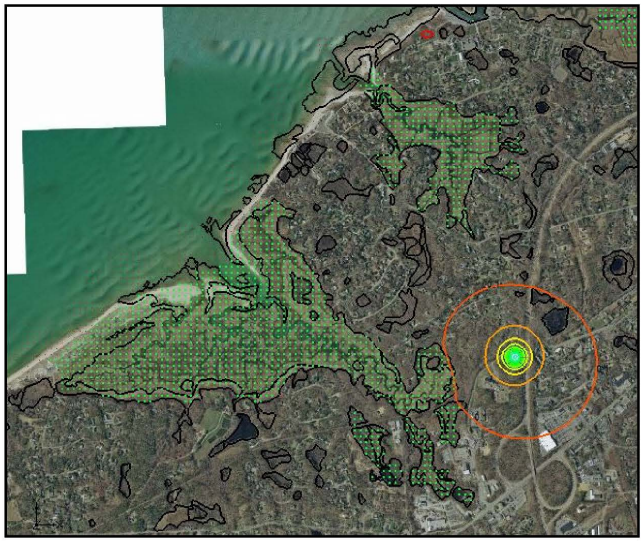


FIGURE 15

OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING

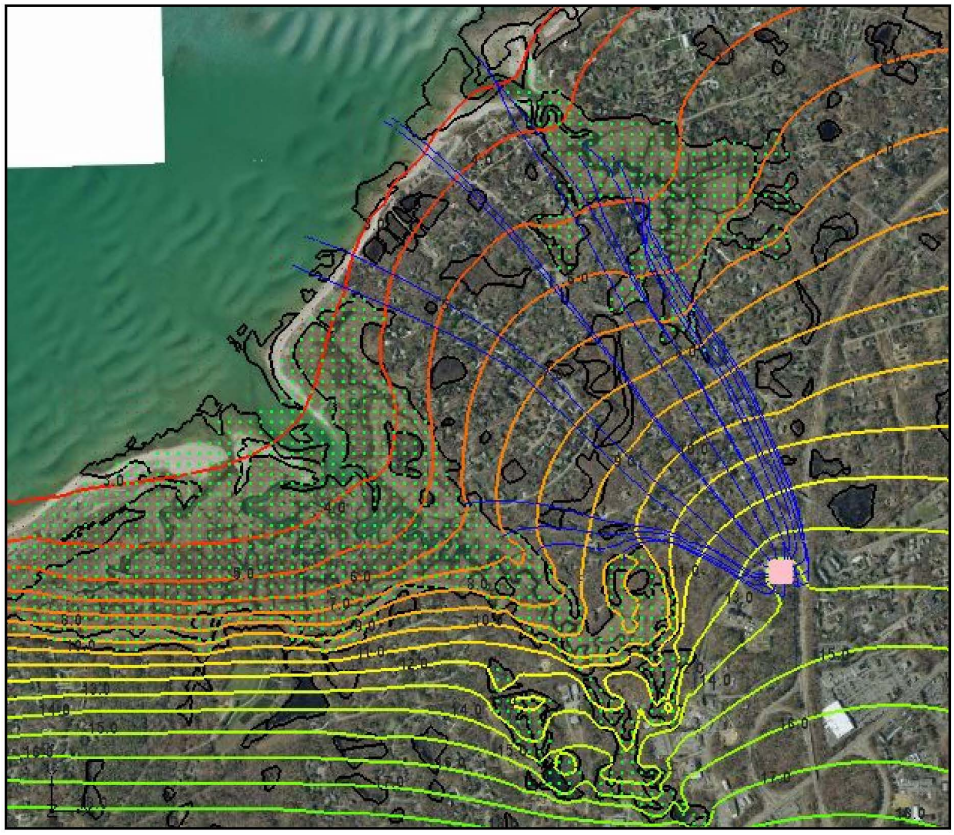
SIMULATION B - 50,000 gpd

Legend

- Groundwater Discharge Area
- Model Drain Nodes
- Simulated Groundwater Discharge Flow Path
- 5.0 Simulated Groundwater Contours (ft)
- Groundwater Mound Contour (contour interval 0.1 ft)

AECOM

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Groundwater Mounding

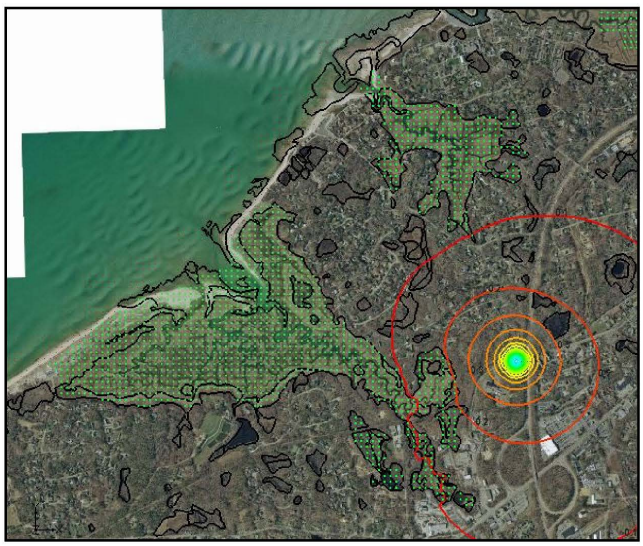


FIGURE 16

OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING

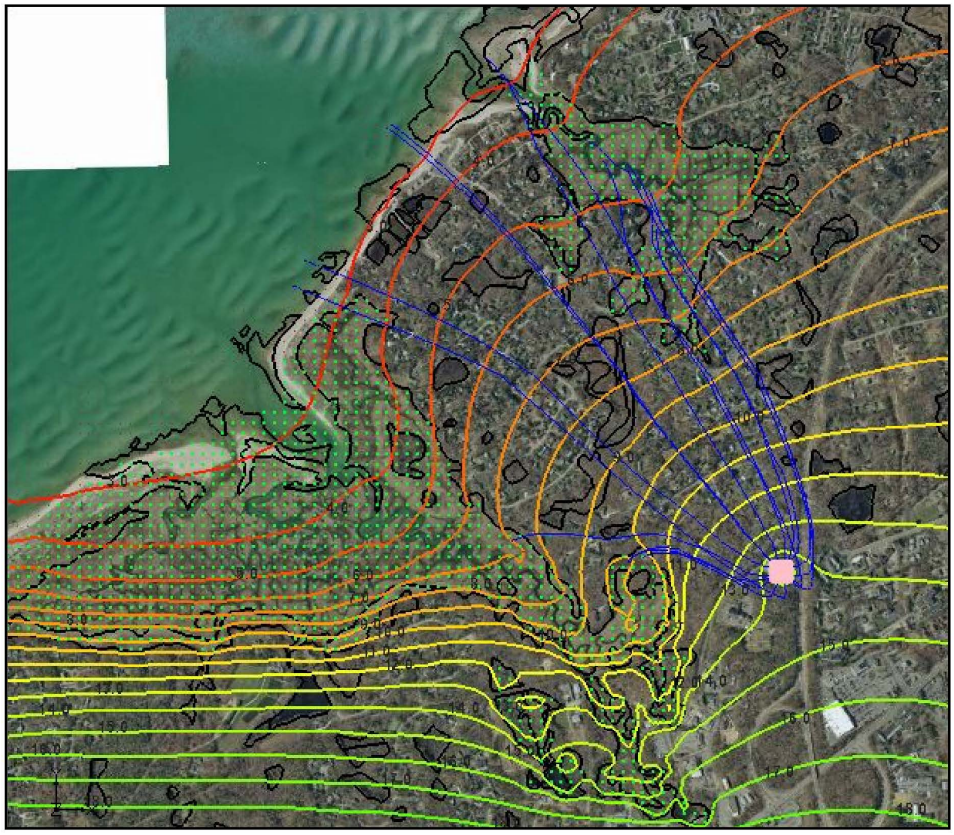
SIMULATION C - 100,000 gpd

Legend

- Groundwater Discharge Area
- Model Drain Nodes
- Simulated Groundwater Discharge Flow Path
- 5.0 Simulated Groundwater Contours (ft)
- Groundwater Mound Contour (contour interval 0.1 ft)

AECOM

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Groundwater Mounding

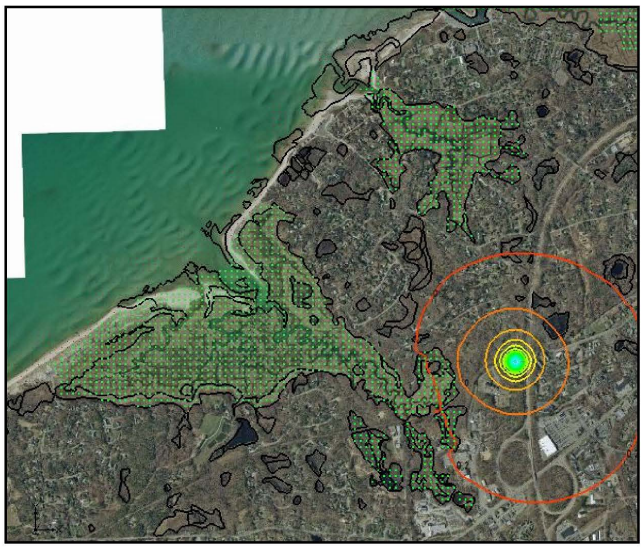


FIGURE 17

OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING

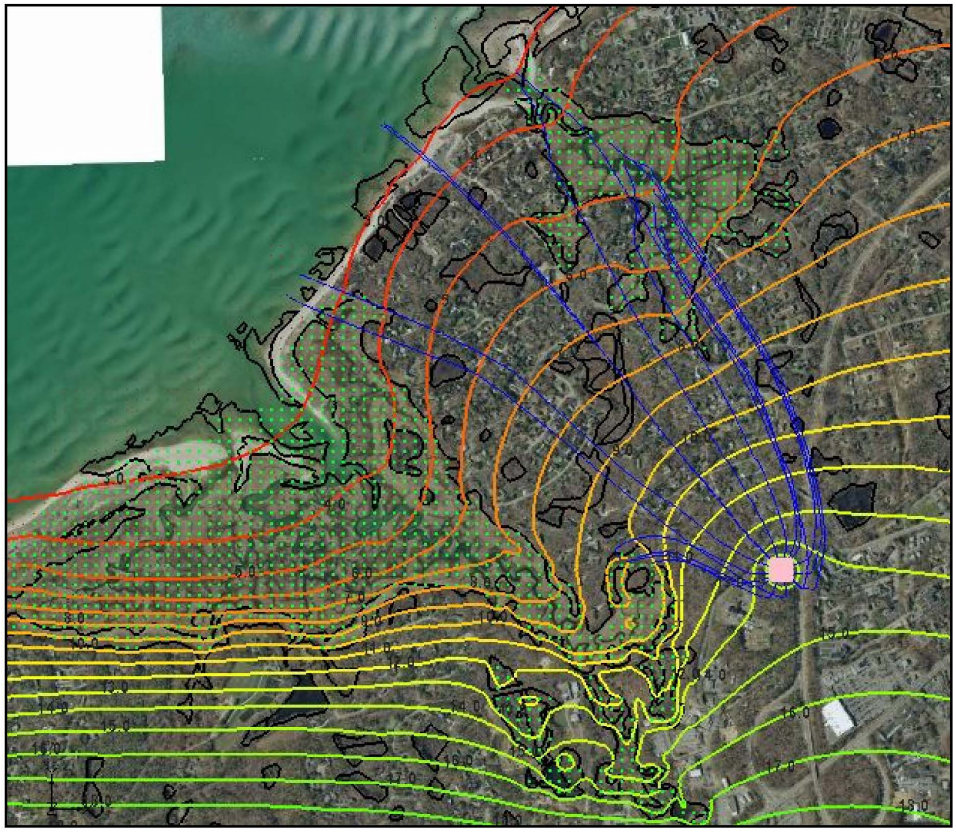
SIMULATION D - 150,000 gpd

Legend

- Groundwater Discharge Area
- Model Drain Nodes
- Simulated Groundwater Discharge Flow Path
- 5.0 Simulated Groundwater Contours (ft)
- Groundwater Mound Contour (contour interval 0.1 ft)

AECOM

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Groundwater Mounding

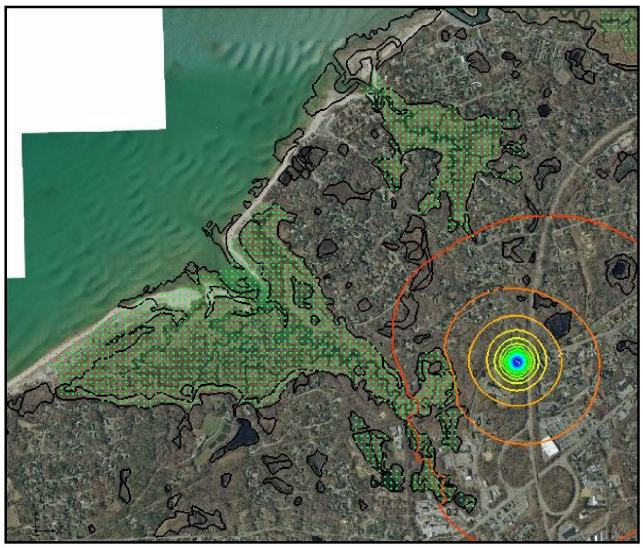


FIGURE 18

OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING

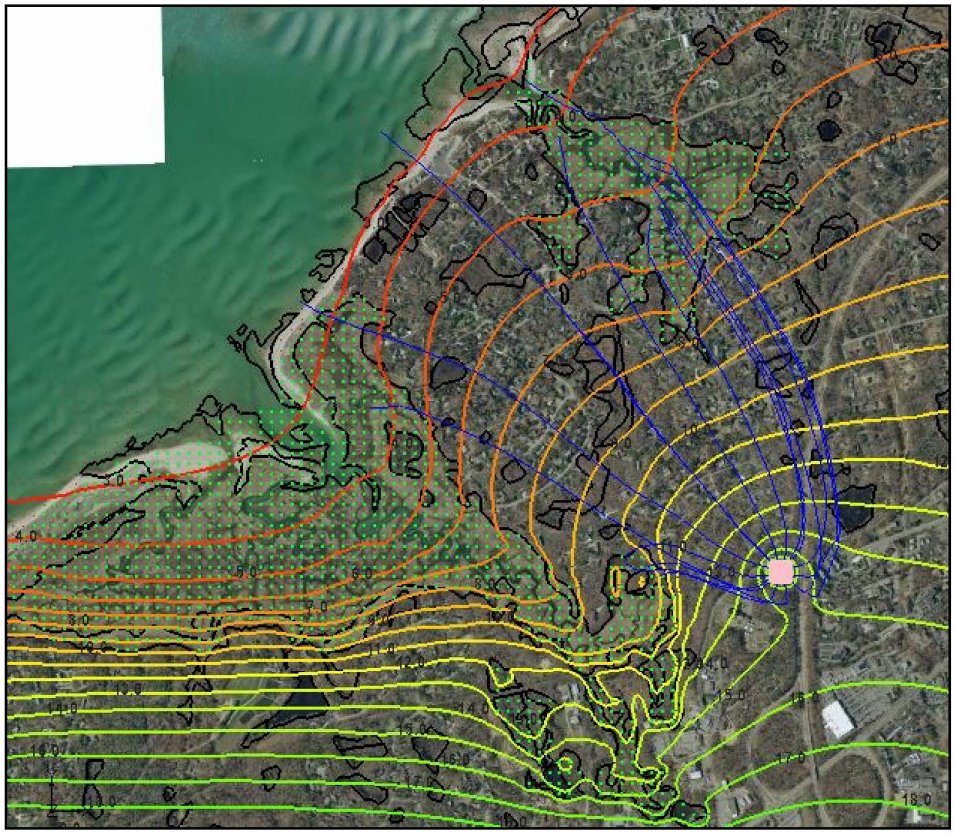
SIMULATION E - 200,000 gpd

Legend

- Groundwater Discharge Area
- Model Drain Nodes
- Simulated Groundwater Discharge Flow Path
- 5.0 Simulated Groundwater Contours (ft)
- Groundwater Mound Contour (contour interval 0.2 ft)

AECOM

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Groundwater Mounding

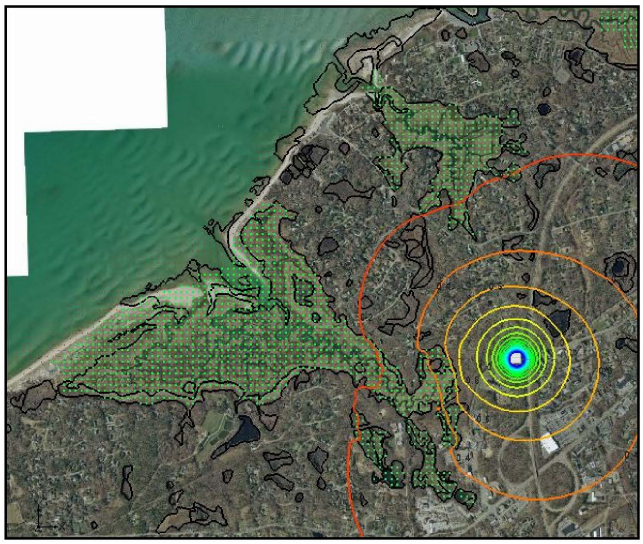


FIGURE 19

OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING

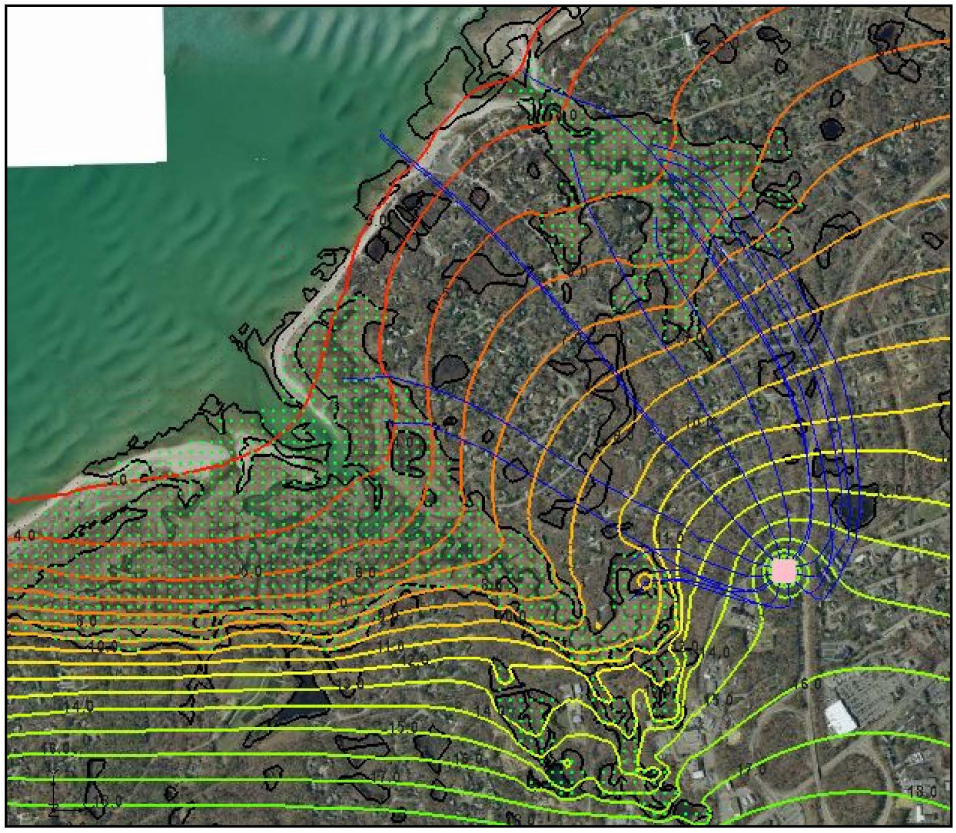
SIMULATION F - 300,000 gpd

Legend

- Groundwater Discharge Area
- Model Drain Nodes
- Simulated Groundwater Discharge Flow Path
- 5.0 Simulated Groundwater Contours (ft)
- Groundwater Mound Contour (contour interval 0.2 ft)

AECOM

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Groundwater Mounding

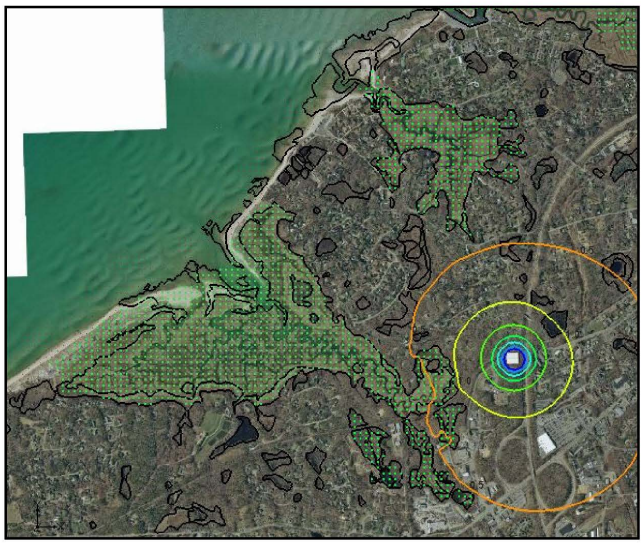


FIGURE 20

OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING

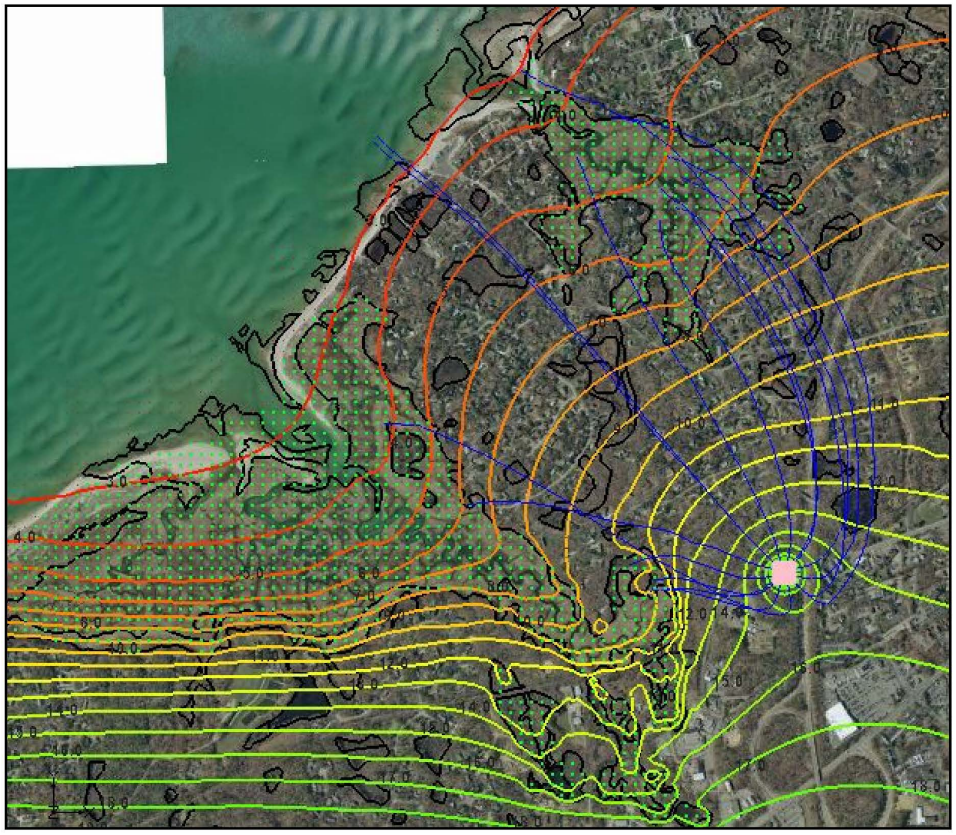
SIMULATION G - 400,000 gpd

Legend

- Groundwater Discharge Area
- Model Drain Nodes
- Simulated Groundwater Discharge Flow Path
- 5.0 Simulated Groundwater Contours (ft)
- Groundwater Mound Contour (contour interval 0.5 ft)

AECOM

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Groundwater Mounding

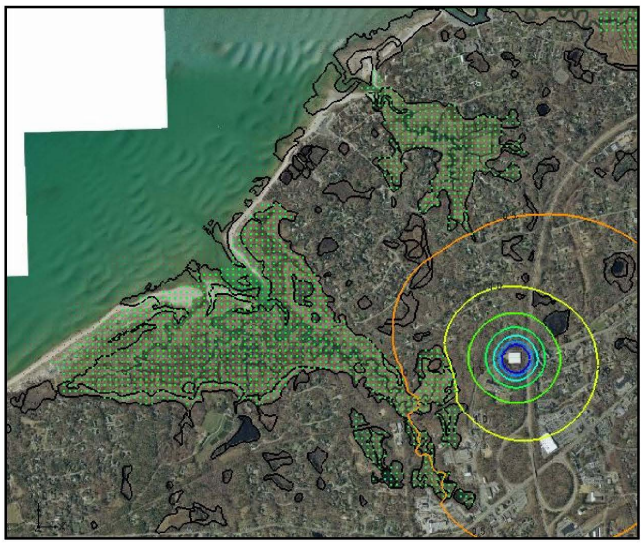


FIGURE 21

OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING

SIMULATION H - 500,000 gpd

Legend

- Groundwater Discharge Area
- Model Drain Nodes
- Simulated Groundwater Discharge Flow Path
- 5.0 Simulated Groundwater Contours (ft)
- Groundwater Mound Contour (contour interval 0.5 ft)

AECOM

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- Simulation E – 200,000 gpd - Model Simulation E, simulates a groundwater discharge of 200,000 gpd. Figure 18 shows the model results of Scenario Simulation E. The maximum mound height directly below the discharge is predicted to be approximately 17.7 feet above the ambient groundwater levels. This is approximately 22 feet below ground surface. MassDEP requires a four-foot separation between the bottom of the infiltration beds and the high water table.
- Simulation F – 300,000 gpd – In this simulation, a groundwater discharge of 300,000 gpd was modeled. Figure 19 shows the model results of Simulation F. The maximum mound height, is approximately 19.7 feet above the ambient groundwater levels or approximately 20 feet below ground surface. In this scenario, the groundwater discharge flows to Namskaket and Little Namskaket Marshes with most of the WWTF effluent discharging to Cape Cod Bay.
- Simulation G – 400,000 gpd - In this simulation, a groundwater discharge of 400,000 gpd was modeled. Figure 20 shows a majority of the WWTF discharge flowing below the Namskaket and Little Namskaket marshes. Model results of Simulation G indicate mound heights of approximately 8.7 feet above the ambient groundwater levels.
- Simulation H – 500,000 gpd - In this simulation, a groundwater discharge of 500,000 gpd was modeled. As with simulation G, particle traces indicate that discharge from the site flows into Cape Cod Bay, Namskaket and Little Namskaket Marshes. Figure 21 shows the model results. The maximum mound height, directly below the discharge, is approximately 10.5 feet or approximately 17 feet below ground surface.

A higher rate of discharge above 500,000 gpd was not simulated.

5.6. Estimated Nitrate Load

MODFLOW was used to simulate groundwater mounding and gradients from the proposed groundwater discharge location (Section 5.5). MODPATH was used to depict groundwater flow paths from the discharge location to demonstrate where groundwater may discharge into surface water bodies (i.e. Namskaket Marsh, Little Namskaket Marsh, Cape Cod Bay). In order to calculate the concentration and mass flux of nitrate (nitrate load) into surface water bodies, AECOM used MT3DMS in conjunction with the MODFLOW groundwater flow field.

MT3DMS is a three-dimensional fate and transport model developed by the US Army Corps of Engineers (Zheng, et al., 1999) that simulates source term characteristics, dispersion, retardation, and degradation in order to predict attenuation of dissolved phase constituents in the groundwater. AECOM completed this modeling using the pre/post-processor GMS 10.2.5 (Aquaveo, 2017).

To estimate the mass loading in the surface water bodies for this project, the following assumptions were made:

- Degradation was not considered a significant attenuation process for the simulations. In other words, nitrate dies not degrade in groundwater, a conservative assumption;
- Longitudinal dispersion was assumed to be 10 ft and transverse and vertical dispersion were assumed to be one-tenth and one-hundredth of the longitudinal dispersion, respectively;
- A discharge concentration of 10 mg/L of nitrate; and
- Travel times from disposal to discharge were estimated using particle tracking. Steady state was not quite achieved in Cape Cod Bay and the deep layers of the model for the Overland Way site until approximately 100,000 days (almost 274 years).

The model was run for three discharge simulations, 100,000, 200,000, and 400,000 gpd. The MT3DMS output is an estimated concentration at each model cell. For each surface water body, an array of cells was defined. In general these distributions of concentrations are similar to the particle pathlines shown in Figures 16, 18, and 20.

In order to calculate the nitrate load to each surface water body, the concentrations within the array of cells defined for each water body was multiplied by the groundwater discharging from each model cell with a drain (marsh) or general head (ocean) boundary condition. The fluxes are provided by the cell-by-cell flow file generated in the MODFLOW run.

USGS Monomoy Lens Model, general head boundaries were used to represent Cape Cod Bay. For Cape Cod Bay, the mass flux for all cells representing Cape Cod Bay were summed and converted to kg/year. For Namskaket Marsh, Little Namskaket Marsh, and Rock Harbor, the drain boundary was used to estimate the nitrate load discharged to each. To do so, an additional step was needed to determine which model cells (and fluxes) were assigned to each of these water bodies. Once assigned, the fluxes could be summed over all cells representing each of the three tributaries to Cape Cod Bay. There are drain cells in the model domain that represent other water bodies and are considered "other" in the summary of results discussed below.

In order to calculate the flow to each of the boundaries, we used the USGS calibrated model and "flow budget" tool included in the GMS pre and post processer. This tool reports on the flow in and out of selected cells and boundary conditions. For example, a set of cells were selected to represent Namskaket Marsh and the flow budget tool was used it reported the flow through those drain cells. This was completed separately for the drain cells representing Little Namskaket and Rock Harbor. Flow through the general head boundary cells, representing Cape Cod flow into Cape Cod Bay, was similarly used using the flow budget tool.

Table 5 summarizes the nitrate loading to each of the estuaries after 100,000 days of WWTF loading at flow rate of 150,000 gpd. Also summarized in Table 5 is the combined watershed load with the estimated WWTF load. In all watersheds at all three loading rates, the total nitrate load is below the nitrate threshold load for the respective watershed.

Table 5
Estimate of Watershed Load From Overland Way Site
Discharge Rate - 150,000 gpd

Estuary	Present Nitrate Load[1]	Present Nitrate Threshold Load[1]	Estimated WWTF Nitrate Load (kg/yr)	Watershed Load with WWTF[3]	Percent of Watershed Load with WWTF
Namskaket Marsh	3,446	16,750	316	3,762	22
Little Namskaket Marsh	2,797	4,650	421	3,218	69
Rock Harbor	ND	ND	0	ND	ND
Cape Cod Bay	ND	ND		ND	ND

Notes:
[1] Present and Threshold Loads from Draft and Final MEP Reports for Namskaket Marsh, Little Namskaket Marsh, and Rock Harbor. Tri Town WWTF Loads Removed.
[2] Watershed Load = Threshold Load - Present Load
[3] Estimated Watershed Load with WWTF = Present Nitrate Load + Estimated WWTF Load
[4] Threshold Load From Draft MEP Report for Rock Harbor - 1,951 kg/yr (Subject to Change)

gpd = gallons per day
kg/day = kilograms per day
kg/yr = kilograms per year

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6. WATER QUALITY

On May 4, 2017, baseline water quality sampling was performed at the Overland Way site. Groundwater samples were collected from all three wells installed by AECOM, TTS-1, TTS-2, and TTS-3. The samples were submitted to a Massachusetts certified analytical laboratory for select inorganic and organic analyses. In addition, in-situ water quality sampling was performed in the field using an YSI water quality meter. In general, the water quality results indicate that the groundwater quality results meet Massachusetts's drinking water quality standards. Nitrate and phosphorous levels are relatively low. Chloride levels in groundwater from Monitoring Well TTS-2 are slightly elevated compared to Monitoring Wells TTS-1 and TTS-3. No VOCs were detected in any of the groundwater samples. Results of the field and laboratory testing are summarized in Table 5. Copies of the laboratory reports are provided in Appendix F.

TABLE 6
SUMMARY OF LABORATORY WATER-QUALITY RESULTS

Parameter	Units	MRL	Drinking Water Standard[1]	Monitoring Well TTS-1	Monitoring Well TTS-2	Monitoring Well TTS-3
Sample Date:				5/4/17	5/4/17	5/4/17
Field Results:						
pH	S.U.	NA	6.5-8.5[2]	5.15	5.36	6.29
Specific Conductance	μmho/cm	0	NE	79	330	234
Turbidity	NTU	0.25	NE	11.2	5.89	979
Temperature	^{0}C	0.01	NE	11.55	10.59	12.88
ORP	mV	0.1	NE	225.10	205.6	166.8
Dissolved Oxygen	mg/L	2.50	NE	10.71	10.21	6.58
Laboratory Results:						
Sodium	mg/L	2.500	20[3]	9.47	37.0	26.1
Chloride	mg/L	3.0	250[2]	14.0	94.6	20.4
Nitrate-N	mg/L	0.110	10	1.66	0.611	0.897
Nitrite-N	mg/L	0.010	1	ND	ND	0.010
Ammonia as N	mg/L	0.10	NE	1.66	0.611	0.907
Total Phosphorus as P	mg/L	0.10	NE	ND	ND	0.37
Ortho Phosphorus as P	mg/L	0.10	NE	ND	ND	ND
VOCs	μg/L	Various	1	ND	ND	ND

NA = not applicable
ND = not detected
NE = not established
NTU = Nephelometeric turbidity units
μg/L = microgram per liter
S.U. = standard units
VOCs = Volatile Organic Compounds

1Mass. Maximum Contaminant Level
2Mass. Secondary Maximum Contaminant Level
3Mass. DEP Office Research and Standards Goal
mg/L = milligram per liter
μmho/cm = micromho per centimeter
MRL = Minimum Reporting Limit

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7. POTENTIAL IMPACTS

The potential impacts resulting from the proposed groundwater discharge fall into two general categories: 1) potential water quality impacts and 2) potential groundwater mounding impacts. Although the discharge will be treated to high levels, the discharge may contain slightly higher levels of nutrients and other constituents compared to the ambient groundwater. Potential mounding impacts include: one, the discharge of groundwater in areas where groundwater does not presently discharge, and second the rise of groundwater levels under surrounding properties.

As described, the groundwater model was used to simulate potential mounding and nutrient loading impacts at several groundwater discharge flow rates between 25,000 and 500,000 gpd. Groundwater mounding results at each of the discharge rates are shown on Figure 13 through Figure 20. Tables summarizing the results of the nitrate loading to estuaries are provided in Appendix G.

When estimating potential groundwater mounding and water quality impacts were modelled, conservative model parameters were used to generate the scenarios. These include:

- The groundwater model simulations used to estimate potential mounding impacts were performed under high water table conditions (Section 4.3);
- The groundwater model was used to simulate potential mounding impacts and nutrient loading impacts at several flow rates up to 500,000 gpd. WWTF discharge flows are not expected to exceed 250,000 gpd for the downtown area at buildout. The Meetinghouse Pond sewer area is not expected to exceed a flow of 110,000 gpd and may be discharged at another location. If both sewer areas are treated at the proposed WWTF and discharged at the Overland Way Site, the maximum flows at buildout are not expected to exceed 360,000 gpd at Buildout;
- The groundwater model simulations used to estimate nutrient loading to estuaries had a model input concentration of 10 mg/L of nitrogen. The expected discharge concentration would likely be less than 5 mg/L, less than half the model input;
- The groundwater model simulations indicate that a majority of the WWTF effluent will flow deep in the aquifer, taking tens of years for the discharge to reach Cape Cod Bay, Namskaket Marsh and Little Namskaket Marsh estuaries. It is likely that a significant portion of the nitrate load will be removed through natural attenuation due to the significant amount of time the effluent will flow through the deeper, low oxygen aquifer. The nitrate attenuation (reduction) is not accounted for in the model simulations;
- USGS soil boring data indicates a significant clay layer in the aquifer in the vicinity of the bike path west of the former Tri Town Septage Treatment Facility (Weiskal, et.al., 2016); and
- There is the possibility that this clay layer extends west and northward under Namskaket Marsh into Cape Cod Bay. If this is the case, the clay layer could reduce groundwater mounding in the marsh area as well as the amount of nitrate load that would reach the marsh. The clay layer may also extend north and northwestward under portions of Little Namskaket and Rock Harbor Estuaries, again decreasing mounding and nitrate load impacts to theses marsh area. As the extent of the clay layer is not presently known, this clay layer and its potential mitigating impacts were not included in the model design.

The following should also be kept in mind when considering potential groundwater discharge impacts:

- Groundwater model results indicate that it will take 3 to 4 years for the Overland Way discharge to reach the nearest wetland. It will take between 4 to over 100 years for the discharge to reach of Namskaket, Little Namskaket, and Cape Cod Bay Estuaries;
- It will likely take in excess of 10 to 20 years for the town to reach buildout conditions and for WWTF flows to reach the modeled discharge flows; and

- Sea level rise will increase over time, increasing flow in and out of the estuaries and potentially offsetting some of the potential impacts discussed in this section. Sea level rise was not considered in the groundwater modeling simulates.

7.1. Potential Groundwater Mounding Impacts

The location of proposed discharge is at the northern extend of the Overland Way: Parcels 1/1A (Figure 5). The extent of the discharge area would be roughly the area of the former sludge drying shed (Figure 5). Based on the model simulations previously described, groundwater mounding would not impact any structures at the Overland Way site, or any nearby properties. In general, the average or high water level elevations from groundwater mounding is insignificant compared to the surrounding ground elevations.

At this time, the Town proposes to discharge approximately 150,000 gpd within the discharge area. The model simulations indicate that groundwater may rise approximately one to two inches on the eastern edge of Namskaket March. This relatively small increase is expected to have little, if any, effect on the extent of the marsh or its plant community for a few reasons. First, this increase is within the range of seasonal and annual variations in groundwater elevations that occur under current conditions. Second, the groundwater mounding predicted by the model is likely overly conservative as the model is not a spatially fine scaled model. Finally, the proposed discharge is approximately 560 feet from the previous Tri-Town discharge. Although the previous discharge was less than the currently proposed discharge, modelling evaluations simulated that the previous discharge resulted in a groundwater mound of 0.5 to one inch below the eastern edge of the marsh. SMAST monitoring of the plant community in Namskaket Marsh during the time period of the previous discharge between 1995 and 2015 indicated that although some shift in plant species distribution occurred, no increase in Phragmites cover occurred, and no decrease in salinity occurred. The relatively small increase in the extent of the groundwater mounding under the currently proposed discharge is expected to result in a similar, undetectable, effect on the marsh plant community.

The currently proposed discharge is located further form the Namskaket Marsh than the previous Tri Town discharge. The discharge is also located further downgradient and in a separate watershed than the previous discharge. However, because the proposed discharge has a slightly higher discharge rate, it is possible, although not expected, that the discharge would have a larger effect on salinity in the rooting zone of marsh species, and therefore species distribution, with a possible expansion in extent of Phragmites. Monitoring of the plant species distribution within the eastern boundary of Namskaket Marsh is recommended once the discharge commences, in order to document any unexpected shifts in plant cover from salt water to freshwater species, including Phragmites. Similar to the previous study conducted by SMAST, it is recommended that long-term permanent monitoring plots be established in the eastern portion of Namskaket Marsh to annually monitor plant community composition, and thereby document any changes over time. If any changes to the salt marsh community were to occur, such as expansion in Phragmites cover, mitigation measures such as restoration or replication of a salt marsh in the vicinity or payment to the Commonwealth's in-lieu fee administered by the Massachusetts Department of Fish and Game should occur.

It is possible that floodplains at the eastern/southeastern boundary of Namskaket Marsh may be slightly affected as the water table may rise slightly in the low elevation areas around the marshes. Thus, it is possible that the extent of the floodplain may increase slightly as a result of the predicted groundwater mounding. However, any increase would be unlikely to raise the floodplain elevation by a half foot or more which would trigger a modification to the mapped floodplain. In addition, as mentioned above, any increase is likely to be dwarfed by predicted sea level rise.

It should be noted that a recent study conducted by USGS (USGS, 2016) indicated that as a result of sea level rise, groundwater levels on Cape Cod are predicted to rise as high as 2.11 feet, with a more nominal rise of 0.1 foot near inland streams. Given these predictions, it is likely that any effect of the groundwater mounding would be dwarfed by the changes in sea level rise.

7.2. Potential Water Quality Impacts

The elimination of the Tri Town Septage Treatment Facility and septic systems will result in long-term improvements in groundwater quality that is flowing into Namskaket Marsh. No significant short-term impacts on surface water quality are expected from the WWTF effluent discharge. It is likely that the overall improvement in the groundwater quality will eventually lead to better surface water quality to the marsh.

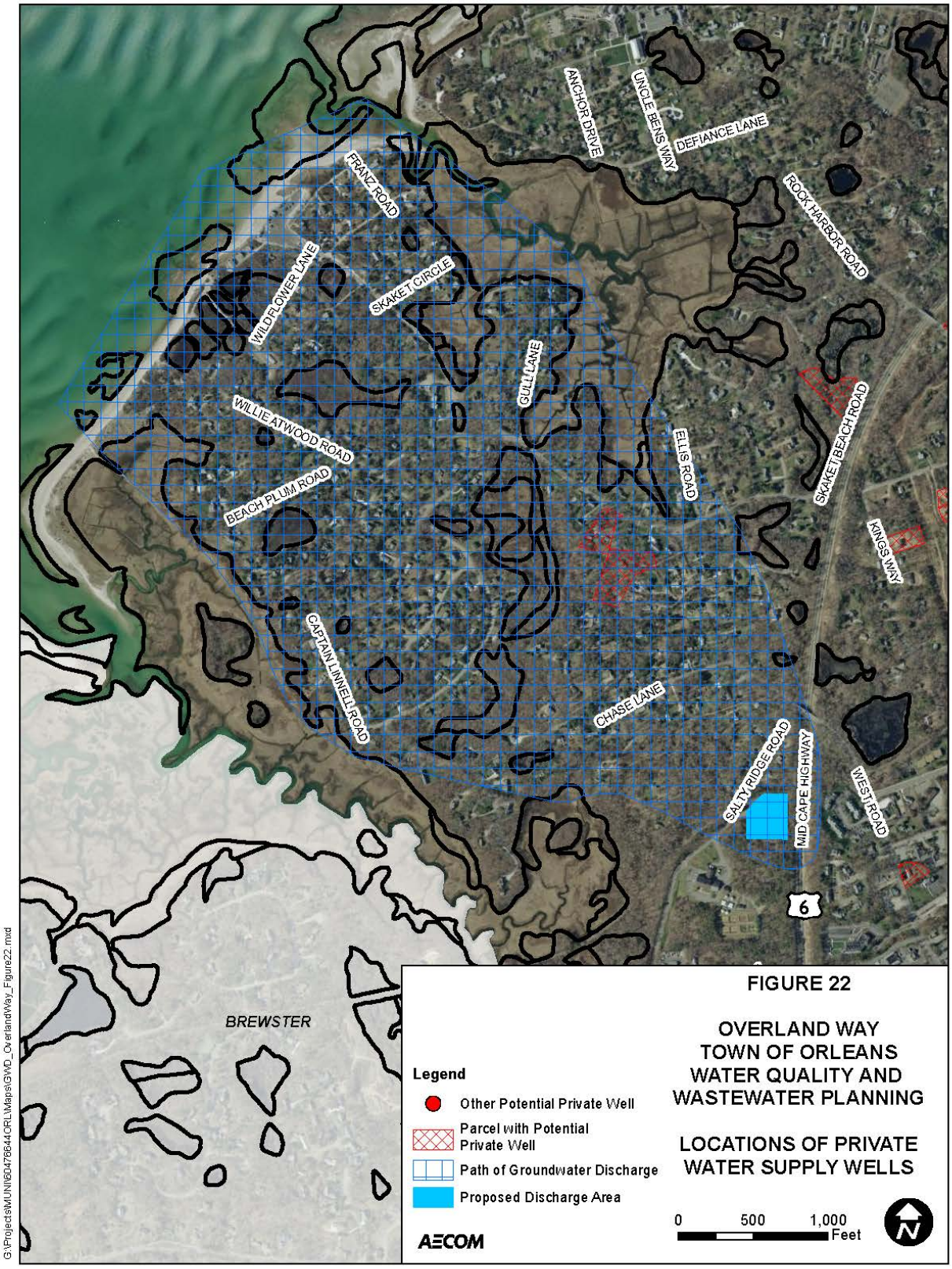
The groundwater model estimates that it will take ten or so years after the initiation of the groundwater discharge for the effluent mixed with groundwater to emerge in Cape Cod Bay and Little Namskaket Marsh system. When most of the groundwater discharge eventually emerges, it would likely do so sufficiently offshore or in sufficiently well-mixed areas (i.e. stream channels) that the water quality would not impact Cape Cod Bay or the Namskaket and Little Namskaket Marsh areas.

Cape Cod Bay has not been evaluated by the Massachusetts Estuaries Project (MEP), but Namskaket and Little Namskaket Marsh and Rock Harbor are all evaluated in MEP reports that identify nitrogen loading thresholds based on hydrodynamic and water quality modelling of these estuarine systems (Howes et. al. 2007a, b and c). The MEP modelling analysis of both the Namskaket and Little Namskaket marsh systems indicates that the marshes are still able to assimilate additional nitrogen without adverse water quality and benthic habitat impacts. The residual nitrogen remaining after treatment at the Overland Way site will increase the nitrogen loading to both Namskaket Marsh and Little Namskaket Marsh, but only to approximately 22% and 69% of their respective MEP nitrogen load target (Table 5).

Because Cape Cod Bay experiences a tremendous amount of daily flushing, it is not anticipated that the additional nitrogen loading to the Bay would result in adverse water quality or benthic habitat impacts, particularly when coupled with lowered nitrogen loading from the former Tri Town Septage Treatment Facility and septic systems proposed to be taken offline.

Cape Cod Bay, Namskaket Creek (MA 96-27), and Little Namskaket Creek (MA 96-26) are not identified as impaired for nitrogen in either the MassDEP 2014 303(d) list of impaired waters, nor in the draft 2016 303(d) list of impaired waters. Namskaket Creek and Little Namskaket Creek are all listed as impaired for fecal coliform, and covered under a TMDL for this water quality constituent. The proposed groundwater discharge from the WWTF is expected to be within water quality standards set by the Commonwealth and would therefore comply with the TMDL requirements.

There are no known sensitive receptors directly downgradient of the discharge with the exception of potential private water supply wells. According to Town records, two properties are located within the area where the WWTF discharge is predicted to flow (Figure 22). If the wells are for drinking water or irrigation supply, the Town should consider connecting the property to the public water supply as the private well may be located within the influence of the proposed discharge. Address and parcel information for the identified sites are provided in Appendix H.


ANCHOR DRIVE
UNCLE BENS WAY
DEFIANCE LANE
FRANZ ROAD
ROCK HARBOR ROAD
WILDFLOWER LANE
SKAKET CIRCLE
GULL LANE
WILLIE ATWOOD ROAD
SKAKET BEACH ROAD
ELLIS ROAD
BEACH PLUM ROAD
KINGS WAY
CAPTAIN LINNELL ROAD
CHASE LANE
SALTY RIDGE ROAD
MID CAPE HIGHWAY
WEST ROAD
6
BREWSTER
G:\Projects\MUNI\60476644\GRL\Maps\GWD_OverlandWay_Figure22.mxd
FIGURE 22
OVERLAND WAY
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING
LOCATIONS OF PRIVATE
WATER SUPPLY WELLS
Legend
Other Potential Private Well
Parcel with Potential Private Well
Path of Groundwater Discharge
Proposed Discharge Area
AECOM
0
500
1,000
Feet
N

7.3. Potential Impacts to Coastal Resources

Coastal resources in the area of groundwater mounding and eventual effluent discharge include beaches and associated swimming areas, commercial and recreational shellfishing areas, and marine/estuarine habitat. The groundwater mound and effluent discharge would occur within the Inner Cape Cod Bay Area of Critical Environmental Concern (ACEC), which includes Cape Cod Bay, and both Namskaket and Little Namskaket marshes up to the 10-foot ground elevation contour. Because a majority of the WWTF effluent will travel deep beneath these coastal resources and discharge sufficiently offshore or within stream channels where substantial tidal flushing will occur, the potential for nitrate impacts to the marshes is significantly lessened. As discussed in Section 7.2, the discontinued use of the septage treatment facility, the mixing of natural groundwater with the highly treated WWTF effluent, and taking numerous on-site septic systems offline, the water quality to coastal resources is expected to be an overall improvement. Thus the discharge is not expected to adversely affect the ACEC functions.

7.4. Potential Impacts to Wetlands

As discussed above in Section 1.1, although the far western extent of the simulated groundwater mound will intercept with the eastern boundary of Namskaket Marsh, the mound is expected to have little if any effect on the wetland plant community. The area where the mound intercepts Namskaket Marsh is currently a mix of salt marsh vegetation and *Phragmites* (SMAST, 2016) and is expected to remain the same; although coverage of species may shift it is not expected that *Phragmites* would expand in coverage due to the groundwater discharge. As described in Section 7.1, monitoring of Namskaket Marsh is recommended to document the long-term plant community stability as well as any potential changes, and if adverse changes are documented, compensatory mitigation can be implemented.

7.5. Potential Impacts to Rare and Endangered Species

According to the MassGIS data layers, Cape Cod Bay, and the area of Namskaket and Little Namskaket Marshes are mapped as Priority Habitat (Figure 3). The Massachusetts Natural Heritage and Endangered Species Program (NHESP) has not been contacted to determine which species are present in the areas of Cape Cod Bay, Namskaket Marsh, and Little Namskaket Marsh where groundwater mounding and eventual effluent discharge may occur. However, as discussed in Section 7.2, no adverse water quality impacts are anticipated to occur to any of these receiving waters. Therefore, water quality is not expected to impact any of the protected species.

As previously discussed (Section 7.1), the proposed discharge would result in a groundwater mound that may intercept the eastern edge of Namskaket Marsh. During consultation with NHESP as part of the preparation and submittal of the 2010 Comprehensive Wastewater Management Plan (CWMP), it was determined that Priority Habitat for four species protected under the Massachusetts Endangered Species Act (MESA) was present at the former Tri-Town Septage Treatment Facility site. The four species identified were: the Eastern Box Turtle (Terrapene carolina), the Diamond-backed Terrapin (Malaclemys terrapin), Salt Reedgrass (Spartina cynosuroides), and Mitchell's Sedge (Carex mitchelliana). During more recent discussions pertaining to the demolition of the compost shed associated with the former Tri-Town site, MA NHESP indicated that the area west of the site was potential habitat for two state listed plant species. Thus, the estimated mound from a discharge at the Overland Way site may extend to areas that include habitat for these and potentially others species.

Additional consultation with NHESP is needed to determine the species potentially present at the discharge site. Mitigation measures could include pre-discharge surveys to document the location of protected plant species and ongoing monitoring to evaluate any impacts on these species. As discussed above, no adverse impacts on water quality and minimal impacts on wetland hydrology due to groundwater mounding are anticipated. However, monitoring may be necessary to confirm the presence and any impacts on protected species. Salt Reedgrass occurs at the upper fringes of salt marsh, while Mitchell's sedge occurs in freshwater areas adjacent to salt marsh. Similarly, the eastern box turtle may utilize wetland habitat, and diamond-backed terrapin utilizes salt marsh habitat. Thus, additional consultation with NHESP is necessary to confirm if any mitigation measures would be necessary.

7.6. Summary of Potential Impacts and Discharge Capacity of the Site

As described in this section, the groundwater model was used to simulate potential groundwater mounding and nutrient loading impacts at flow rates between 25,000 and 500,000 gpd. Based on model results, nutrient loading to the Namskaket, Little Namskaket, and Cape Cod Bay estuaries would be well within each estuary's capacity to assimilate the additional nitrate load. This is particularly true when considering that the Former Tri Town Facility is no longer contributing nitrate to the Namskaket Marsh and numerous septic systems will be taken offline once the WWTF goes online.

The far western extent of the simulated groundwater mound will intercept with the eastern boundary of Namskaket Marsh, the mound is expected to have little if any effect on the wetland plant community. Long-term permanent monitoring plots could be established in this area for annual plant community monitoring. If changes are documented over time, mitigation measures would need to be taken. Similar monitoring could occur within areas identified as Priority Habitat or Rare and Endangered Species.

Based on the evaluation of the soils underlying the site, groundwater modeling simulations and results, and evaluation of potential mounding and water quality impacts, the Overland Way site is suitable for a groundwater discharge rates up to 500,000 gpd. In order to discharge in excess of 150,000 gpd, additional discharge areas would need to be identified and evaluated outside of Site 1/1A.

As required by MassDEP, a conventional reserve discharge area equal to the proposed discharge at Site 1/1A may need to be identified and approved prior to allowing a discharge at the site. The need for and/or size of the reserve discharge area would need to be discussed and confirmed with the MassDEP as part of the Groundwater Discharge Permit application process.

8. GROUNDWATER MONITORING PLAN

A groundwater monitoring plan will be implemented to assess both baseline and compliance groundwater quality in the vicinity of the proposed primary discharge. The location of the proposed monitoring wells, baseline water quality parameters and compliance water quality parameters are discussed in the following sections.

8.1. Compliance Monitoring

Once the WWTF is operational, groundwater samples will be collected and analyzed to demonstrate that the groundwater quality meets the standards set by MassDEP. Groundwater monitoring will be performed at the three monitoring well locations (TTS-1, TTS-2, and TTS-3) outlined above. The proposed sampling frequency and parameters are as follows:

- Monthly Sampling – Water quality analysis for pH and conductivity will be analyzed on a monthly basis. In addition, a round of water levels will be collected and recorded;
- Quarterly Sampling – In addition to the monthly sampling, total nitrogen, total phosphorus, nitrate-nitrogen, sodium and fecal coliform will be sampled and analyzed quarterly;
- Twice Annual Sampling. In addition to the monthly and quarterly sampling, VOCs will be sampled and analyzed twice annually; and
- Groundwater samples collected during each round will be sent to a MassDEP certified laboratory for analysis. Groundwater sampling will be conducted in accordance with MassDEP's "Standard References for Monitoring Wells". After each round of sampling, the water level data and water quality results will be summarized and submitted to the MassDEP for review.

8.2. Replacement Monitoring Well Installation

Should any of the monitoring wells become damaged or need to be replaced, the MassDEP will be notified prior to replacing the well. The installation of the replacement well(s) will be as follows.

For each replacement well, one soil boring will be drilled to a depth of approximately 10 to 15 feet below the water table. At a minimum, split spoon samples will be collected every five feet to the total depth of the boring. The soil borings will be drilled in accordance with MassDEP's "Standard References for Monitoring Wells".

Once the soil boring is completed, a single monitoring well with ten feet of 10-slot well screen will be installed. The bottom of the well screen will be installed approximately 15 feet below the water table. The two-inch diameter PVC monitoring wells will be installed and developed in accordance with MassDEP's "Standard References for Monitoring Wells".

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Appendix A

Correspondence

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Commonwealth of Massachusetts
Executive Office of Energy & Environmental Affairs

Department of Environmental Protection

Southeast Regional Office • 20 Riverside Drive, Lakeville MA 02347 • 508-946-2700

Charles D. Baker
Governor

Karyn E. Polito
Lieutenant Governor

Matthew A. Beaton
Secretary

Martin Suuberg
Commissioner

May 16, 2017

Mr. Mark Owen
AECOM
9 Jonathan Bourne Drive
Pocasset, MA 02559

RE: ORLEANS – Overland Way,
Approval of Hydrogeologic Evaluation
Scope of Work

Dear Mr. Owen:

The Massachusetts Department of Environmental Protection (MassDEP) has completed its review of the hydrogeologic evaluation scope of work prepared and submitted by your office (i.e., AECOM) to support a future groundwater discharge application for a wastewater treatment facility at the above referenced site in Orleans, Massachusetts. The document is dated December 15, 2016 and outlines the tasks that will be completed to assess the soil and groundwater conditions at the proposed discharge location. The information gathered during this investigation will be used to determine the suitability of the site for the discharge of 360,000 gallons per day of treated sanitary effluent.

A pre-application/pre-scoping meeting to discuss the proposed project and scope of work was conducted at the Southeast Regional Office on March 1, 2017. In addition, a public notice announcing the preparation of the scope of work and its submission to MassDEP was published in *Environmental Monitor* on December 21, 2016. As of this date, MassDEP has not received any public comments regarding the submitted scope of work.

MassDEP has determined that the AECOM submission is complete and hereby approves its scope of work subject to the following comments and recommendations:

- Upon the completion of the activities outlined in the approved scope of work, AECOM shall prepare and submit a hydrogeologic evaluation report to MassDEP. A MassDEP Transmittal Form and a complete BRPWP 83 application shall accompany the report. The report shall comply with the requirements outlined in the Hydrogeologic Evaluation Report Guidance that accompanies the BRPWP 83 application packet. AECOM shall contact MassDEP to discuss hydrogeologic report requirements that may not be applicable to this project.

This information is available in alternate format. Call Michelle Waters-Ekanem, Diversity Director, at 617-292-5751. TTY# MassRelay Service 1-800-439-2370
MassDEP Website: www.mass.gov/dep

Printed on Recycled Paper

- AECOM shall identify the downgradient sensitive receptors that may be impacted by the proposed discharge and assess the current groundwater quality downgradient of the proposed discharge. Additionally, AECOM shall discuss any anticipated impacts to these downgradient receptors and to overall downgradient groundwater quality.

    - AECOM's hydrogeological evaluation report documenting the results of the proposed investigation shall include a surveyed site plan prepared and stamped by a professional engineer. At a minimum, the surveyed site plan will identify and document:

        - The locations/footprints of the primary and reserve disposal areas,

        - The locations of all test pits and percolation tests conducted as part of the hydrogeological investigation,

        - The locations and top-of-casing/top-of-PVC elevations of all borings/monitoring wells installed as part of the investigation and of all existing on-site monitoring wells used in the investigation, and

        - The proposed locations of monitoring wells to be installed as part of the approved groundwater monitoring plan.

      This surveyed site plan, along with an approved maximum daily discharge volume, will be referenced in MassDEP's Site Approval Letter. Any soil absorption system installed at the site shall be constructed within the footprint indicated on the plan and the discharge volume limited to that contained within the Site Approval Letter.

    - A groundwater monitoring well plan capable of identifying and assessing any impacts to groundwater flow and quality resulting from a discharge of effluent at the approved location. Monitoring wells installed as part of the site investigation may be utilized provided they are appropriately located and constructed in accordance with MassDEP's *Standard References for Monitoring Wells.* Additional well locations shall be proposed if needed to monitor impacts to nearby sensitive receptors.

- AECOM shall notify the Southeast Regional Office at least one week prior to conducting any significant, on-site field work so that a MassDEP representative may be present if necessary.

If you have questions regarding the comments and conditions of this approval, please contact Kermit Studley of this office at 508-946-2803.

Sincerely,

Brian Dudley
Bureau of Water Resources

D/AT

Ecc: Christos Dimisioris, MassDEP-BWR: christos.dimisioris@state.ma.us

cc: Mr. John Kelly
Town Administrator,
Town of Orleans,
19 School Road,
Orleans, MA 02653

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Appendix B

Test Pit Data and Soil Evaluator Forms

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COASTAL engineering co.

260 Cranberry Highway
Orleans, MA 02653
508.255.6511 P 508.255.6700 F
Orleans | Sandwich | Nantucket
coastalengineeringcompany.com

CEC File No: C18470.00

Date: 03/29/17

COMMONWEALTH OF MASSACHUSETTS
ORLEANS, MASSACHUSETTS

Soil Suitability Assessment for On-site Sewage Disposal

Performed by: *John G. Schnaible, R.S.*
Witnessed by: *Adekunle Teniola, DEP-SERO*

Location Address or **Lot #:** *Map 39 Parcel 07 & Map 32 Parcel 103* *Overland Drive* *Orleans, MA*	**Owner's Name** *Town of Orleans* *c/o AECOM* *Attn: Thomas Parece* **Address:** *usapimaging@aecom.com* *tom.parece@aecom.com*

New Construction ☒ Repair ☐

Office Review

Published Soil Survey Available: No ☐ Yes ☒
Year Published: *1993* Publication Scale: *1:25000* Soil Map Unit: CoB Carver-Hinesburg
Drainage Class: *Well Drained* Soil Limitations: *Poor Filter*

Surficial Geologic Report Available: No ☐ Yes ☒
Year Published: *1971* Publication Scale: *1:24000*
Geologic Material (Map Unit): *Harwich Outwash Plains*
Landform: *Outwash Plain*

Flood Insurance Rate Map:
Above 500 year flood boundary No ☐ Yes ☒
Within 500 year flood boundary No ☒ Yes ☐
Within 100 year flood boundary No ☒ Yes ☐

Wetland Area:
National Wetland Inventory (map unit) *Upland*
Wetlands Conservancy Program Map (map unit) --

Current Water Resource Conditions (USGS): Month: *April*
Range: Above Normal ☐ Normal ☒ Below Normal ☐
Other References Reviewed: *USGS Quad Maps and Groundwater Maps*

On-site Review

Deep Hole Number: 1 Date: 03/29/17 Time: 9:15 Weather: Cloudy

Location (identify on site plan) Near Salt Shed

Land Use: Institutional Slope (%): 3-8 Surface Stones: No

Vegetation: Oak Trees and PineTrees

Landform: Outwash Plain

Position on landscape (sketch on the back): See Sketch

Distances from:

Open Water Body 200+ feet
Possible Wet Area 200+ feet
Drinking Water Well 100+ feet
Drainageway 50+ feet
Property Line 50+ feet
Other

DEEP OBSERVATION HOLE LOG					
Depth from Surface (Inches)	Soil Horizon	Soil Texture (USDA)	Soil Color (Munsell)	Soil Mottling	Other (Structure, Stones, Boulders, Consistency, % Gravel)
0" – 48"	Fill				
48" – 144"	C	Sand	10 YR 5/6		Fine to Medium Sand, Loose

Parent Material (geologic) Proglacial Outwash Depth to Bedrock: 200'+
Depth to Groundwater: Standing Water in the Hole: None Weeping from Pit Face: None
Estimated Seasonal High Ground Water: 40'±

On-site Review

Deep Hole Number: *2* Date: *03/29/17* Time: *9:45* Weather: *Cloudy*

Location (identify on site plan) *Near Salt Shed*

Land Use: *Institutional* Slope (%): *3-8* Surface Stones: *No*

Vegetation: *Oak Trees and Pine Trees*

Landform: *Outwash Plain*

Position on landscape (sketch on the back): *See Sketch*

Distances from:

Open Water Body *200+* feet
Possible Wet Area *200+* feet
Drinking Water Well *100+* feet
Drainageway *50+* feet
Property Line *50+* feet
Other

DEEP OBSERVATION HOLE LOG

Depth from Surface (Inches)	Soil Horizon	Soil Texture (USDA)	Soil Color (Munsell)	Soil Mottling	Other (Structure, Stones, Boulders, Consistency, % Gravel)
0" – 60"	*Fill*				*Sand and Sandy Loam Mix*
60" – 66"	*A*	*Loamy Sand*	*10 YR 3/2*		
66" – 84"	*B*	*Loamy Sand*	*10 YR 6/4*		
84" - 156"	*C1*	*Sand*	*10 YR 7/4*		*Fine sand, Loose*
156" – 204"	*C2*	*Silt Loam*	*2.5Y 5/2*		*Dense*
204" – 216"	*C3*	*Clay*	*Gley 5/10B*		

Parent Material (geologic) *Proglacial Outwash* Depth to Bedrock: *200'+*
Depth to Groundwater: Standing Water in the Hole: *None* Weeping from Pit Face: *None*
Estimated Seasonal High Ground Water: *40'±*

On-site Review

Deep Hole Number: *3* Date: *03/29/17* Time: *10:30* Weather: *Cloudy*

Location (identify on site plan) *Near the Salt Shed*

Land Use: *Institutional* Slope (%): *3-8* Surface Stones: *No*

Vegetation: *Oak Trees and Pine Trees*

Landform: *Outwash Plain*

Position on landscape (sketch on the back): *See Sketch*

Distances from:

Open Water Body *200+* feet
Possible Wet Area *200+* feet
Drinking Water Well *100+* feet
Drainageway *100+* feet
Property Line *100+* feet
Other

DEEP OBSERVATION HOLE LOG

Depth from Surface (Inches)	Soil Horizon	Soil Texture (USDA)	Soil Color (Munsell)	Soil Mottling	Other (Structure, Stones, Boulders, Consistency, % Gravel)
0" – 84"	*Fill*				*Tight Silts with some Sand*
84" – 96"	*E*	*Sand*	*10 YR 6/1*		*Medium Sand*
96" – 108"	*C1*	*Sand*	*7.5YR 3/3*		*Manganese, Hardpan, Cemented*
108" – 204"	*C2*	*Silt Loam*	*2.5Y 5/4*		*Dense*

Parent Material (geologic) *Proglacial Outwash* Depth to Bedrock: *200'+*
Depth to Groundwater: Standing Water in the Hole: *None* Weeping from Pit Face: *96"*
Estimated Seasonal High Ground Water: *96 inches±*

On-site Review

Deep Hole Number: *4* Date: *03/29/17* Time: *11:15* Weather: *Cloudy*

Location (identify on site plan) *Between Salt Shed and Highway*

Land Use: *Institutional* Slope (%): *3-8* Surface Stones: *No*

Vegetation: *Oak Trees and Pine Trees*

Landform: *Outwash Plain*

Position on landscape (sketch on the back): *See Sketch*

Distances from:

Open Water Body *200+* feet
Possible Wet Area *200+* feet
Drinking Water Well *100+* feet
Drainageway *100+* feet
Property Line *25+* feet
Other

DEEP OBSERVATION HOLE LOG					
Depth from Surface (Inches)	Soil Horizon	Soil Texture (USDA)	Soil Color (Munsell)	Soil Mottling	Other (Structure, Stones, Boulders, Consistency, % Gravel)
0" – 54"	*Fill*				
54" – 56"	*A*	*Loamy Sand*	*10 YR 3/2*		
56" – 78"	*B*	*Loamy Sand*	*10 YR 5/8*		
78" – 156"	*C*	*Sand*	*10YR 5/6*		*Fine to Medium Sand, Loose*

Parent Material (geologic) *Proglacial Outwash* Depth to Bedrock: *200'+*
Depth to Groundwater: Standing Water in the Hole: *None* Weeping from Pit Face: *None*
Estimated Seasonal High Ground Water: *45'±*

On-site Review

Deep Hole Number: *5* Date: *03/29/17* Time: *Noon* Weather: *Cloudy*

Location (identify on site plan) *Near Salt Shed*

Land Use: *Institutional* Slope (%): *8-15* Surface Stones: *No*

Vegetation: *Oak Trees and Pine Trees*

Landform: *Outwash Plain*

Position on landscape (sketch on the back): *See Sketch*

Distances from:

Open Water Body *200+* feet
Possible Wet Area *200+* feet
Drinking Water Well *100+* feet
Drainageway *50+* feet
Property Line *50+* feet
Other

DEEP OBSERVATION HOLE LOG					
Depth from Surface (Inches)	Soil Horizon	Soil Texture (USDA)	Soil Color (Munsell)	Soil Mottling	Other (Structure, Stones, Boulders, Consistency, % Gravel)
0" – 44"	*Fill*				
44" – 132"	*C*	*Sand*	*10 YR 6/6*		*Medium to Fine Sand, Loose*

Parent Material (geologic) *Proglacial Outwash* Depth to Bedrock: *200'+*
Depth to Groundwater: Standing Water in the Hole: *None* Weeping from Pit Face: *None*
Estimated Seasonal High Ground Water: *40'±*

Location Address or Lot No. *Overland Drive*

COMMONWEALTH OF MASSACHUSETTS
Orleans, Massachusetts

PERCOLATION TEST*		
Date: 03/29/17		Time: 9-noon
Observation Hole #	*1*	
Depth of Perc	*66"*	
Start Pre-soak	*0:00*	
End Pre-soak	*15:00*	
Time at 12"	*0:00*	
Time at 9"	*4:19*	
Time at 6"	*9:30*	
Time (9" - 6")	*5:11*	
Rate Min./Inch	*<2*	

**** Minimum of 1 percolation test must be performed on both the primary area AND reserve area.***

Site Passed ☐ Site Failed ☐
Further testing required to determine extent of suitable soils

Performed by: *John G. Schnaible CEC*

Witnessed by: *Adekunle Teniola DEP*

Comments: *The C layer in DOH #1, #4, & #5 and the C1 layer in DOH #2 are considered suitable for the subsurface disposal of sewage. No suitable soils were found in DOH#3.*

COASTAL engineering co.

260 Cranberry Highway
Orleans, MA 02653
508.255.6511 P 508.255.6700 F
Orleans | Sandwich | Nantucket
coastalengineeringcompany.com

Job C18470.00
Sheet No 8 Of 9
Calculated by: JGS Date: 03/29/17
Scale See Attached Plan

SKETCH PLAN SHOWING DEEP OBSERVATION HOLE LOCATIONS:

See Attached Plan

Determination for Seasonal High Water Table

Method Used: N/A

- ☐ Depth observed standing in observation hole _____inches
- ☐ Depth weeping from side of observation hole_____inches
- ☐ Depth to soil mottles _____inches
- ☐ Ground water adjustment_____feet

Index Well Number_____Reading Date_____Index well level_____

Adjustment Factor_____Adjusted ground water level_____

Depth of Naturally Occurring Pervious Material

Does at least four feet of naturally occurring pervious material exist in all areas observed throughout the area proposed for the soil absorption system?

Yes

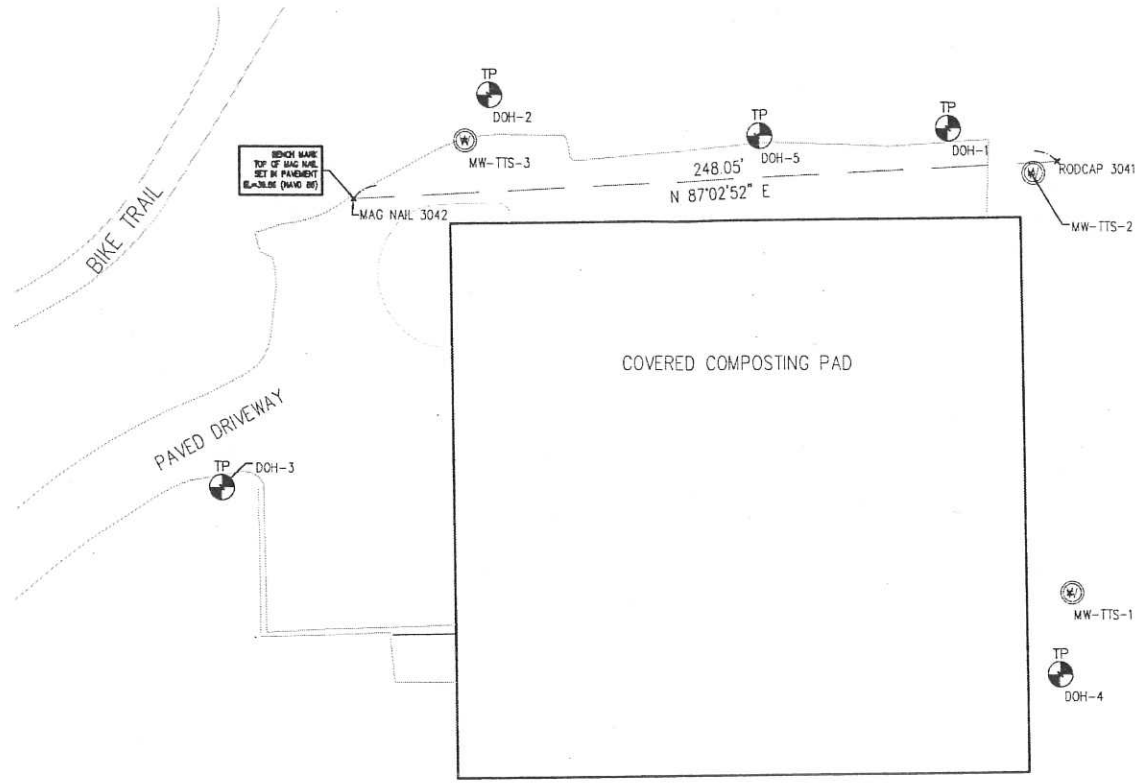
If not, what is the depth of naturally occurring pervious material?

Certification

I certify that on *April 1995* I have passed the examination approved by the Department of Environmental Protection and that the above analysis was performed by me consistent with the required training, expertise and experience described in 310 CMR 15.017.

Signature_____SE 2166 Date *03/29/17*

JGS/jgs



ROUTE 6 – STATE HIGHWAY

MASS. COORD. SYSTEM NAD 1983 MAINLAND ZONE

DATUM NOTE:

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

Point	Northing	Easting	Elevation (Top of Casing)	Elevation (Ground)
MW-TTS-1	2749750.026	1064129.218	43.07	43.4
MW-TTS-2	2749894.443	1064116.400	36.81	37.2
MW-TTS-3	2749905.718	1063917.285	37.43	37.8
DOH-1	2749909.865	1064087.541		36.3
DOH-2	2749921.466	1063925.785		37.1
DOH-3	2749786.346	1063831.320		44.2
DOH-4	2749721.686	1064125.806		42.5
DOH-5	2749907.251	1064020.207		36.5
MAG NAIL 3042	2749885.644	1063878.075		39.86
RODCAP 3041	2749898.419	1064125.794		38.84
USGS MW 156	2749463.416	1063583.242		54.005 (CAP)
HYD-TAG 470	2749539.626	1063661.872		49.54

PLAN

40 20 0 40 120

1 inch = 40 ft.

F:\SD\SKPROJ\C18000\C18470\C18470-00_TriTown-CL\C18470-TT-CL.dwg Apr 20, 2017 - 6:02pm

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

NO.	DATE	REVISION	BY

SEAL

PROJECT
AECOM
TRI-TOWN TREATMENT FACILITY
ORLEANS, MA

SHEET TITLE
WELL PLAN OF LAND SHOWING
MONITOR WELL AND SOIL TEST LOCATIONS

SCALE: AS NOTED
DRAWING FILE: C18470-TT-CL.dwg
DATE: 4/20/2017
DRAWN BY: BPM
CHECKED BY:

SKC-7

1 OF 1 SHEETS

PROJECT NO. C17470.00

Coastal Engineering Co., Inc. © 2017

Appendix C

Soil Boring Logs

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Project Number: 60476644
Client: Town of Orleans

Site Location: Overland Way, Tri-town Orleans, MA

AECOM
250 Apollo Drive
Chelmsford, Massachusetts
(978) 905-2100

Project Manager: Mark Owen | Field Tech: C Hayden | Started: 3/13/2017
Drill Contractor: NE Geotech | Driller: Hayes | Date Completed: 3/13/2017

Boring: TTS-1 cont.

Boring Number:
Sheet: 2 of 3
Surface Elevation (ft-asl):
Equipment: Geoprobe 6620
Inside Diameter: 2"

Well Data

Boring Depth: 40 ft
Screen Depth: 30 - 40 ft
Screen length: 10 ft

Depth	Sample Identification	Rec (ft)	Sorting	Moisture	PID (ppm)	Field Identification	Description	Fill Mat.	Tube	Fill Mat.	Depth
31	30 ft to 35 ft	3 ft		moist		30 to 31 ft: Tan fine sand, little medium sand					31
32				wet		31 to 31.8 ft: red/orange medium sand, trace coarse sands					32
33				wet		31.8 to 32 ft: Fine/medium sand to silt / clay varve sequences					33
34				wet		32 to 32.2 ft: Light brown fine/medium sand					34
35				wet		32.2 to 33 ft: Light brown fine sand, trace medium sands					35
36	35 ft to 40 ft	3.6 ft		wet		35 to 36 ft: Grey fine/medium sand, little coarse sand					36
37						36 - 36.2 ft: Grey silt/clay fining/coarsening/fining sequence					37
38						36.2 to 37.1 ft: Tan fine sand, some medium sand 36.4-36.7					38
39						37.1 to 38.6 ft: Tan medium to coarse sand, trace fine sand					39
40											40
41	40 ft to 45 ft	3.9 ft		wet		40 to 42 ft: Tan medium to coarse sand, trace fines, Fe-stained					
42						42 to 42.5 ft: Grey coarse sand, little medium sand					
43						42.5 to 43.2 ft: Tan medium to coarse sand, trace fines					
44						43.2 to 43.9 ft: Tight grey Fe-stained mottled fine sand					
45											
46	45 ft to 50 ft	3.8 ft		wet		45 to 47.5 ft: Tight grey Fe-stained mottled fine sand					
47						47.5 to 48.5 ft: Tan/grey medium to coarse sand, some fine gravel					
48											
49											
50											
51	50 ft to 55 ft	3 ft		wet		50 to 53 ft: Light tan medium sand, some coarse sand, trace gravel					
52											
53											
54											
55											
56	55 ft to 60 ft	2.8 ft		wet		55 to 57 ft: Light tan medium sand, some coarse sand, trace gravel, FE stain at 57ft					
57						57 to 58.1 ft: Tight grey Fe-Stained mottled fine sand					
58											
59											
60											

Project Number: 60476644
Client: Town of Orleans

Site Location: Overland Way, Tri-Town Orleans, MA

AECOM
250 Apollo Drive
Chelmsford, Massachusetts
(978) 905-2100

Boring: TTS-2

Boring Number:
Sheet: 1 of 3
Surface Elevation (ft-asl):
Equipment: Geoprobe 6620

Project Manager: Mark Owen
Field Tech: C Hayden
Date Started: 3/9/2017
Drill Contractor: NE Geotech
Driller: Hayes
Date Completed: 3/10/2017
Inside Diameter: 2"

Well Data

Boring Depth: 40 ft
Screen Depth: 30 - 40 ft
Screen length: 10 ft

Depth	Sample Identification	Rec (ft)	Sorting	Moisture	PID (ppm)	Field Identification	Description	Fil Mat	Tube	Fill Ma	Depth
1-5	0 ft to 5 ft					Pre-Cleared to 5 ft on 03/07/2017 4" of asphalt, 2" of road gravel, 6"-60" fine to medium orange sand					1-5
6-10	5 ft to 10 ft	4 ft		dry		5 to 6 ft: Brown fine-medium sand, trace coarse sands 6-9 ft: Tan, orange-molted fine sand					6-10
11-15	10 ft to 15 ft	3.5 ft		Dry		10 to 11 ft: Tan, orange-mottled fine sand 11 ft: Broken large gravel 11.1 to 12 ft: Grey Iron-stained fine to medium sand with silt lenses 12 to 13 ft: Grey Iron-mottled silt, firm 13 to 13.5 ft: Grey Iron-stained fine to medium sand with silt lenses					11-15
16-20	15 ft to 20 ft	4 ft		dry		15 to 16 ft: Alternating brown silt - orange fine to medium sand lenses 16 to 17.1 ft: Tan fine to medium sand (coarse sand at 11.4-11.6) 17.1 to 17.6 ft: Tan/Orange medium sand, little fine sands 17.6 to 18.3 ft: Alternating brown silt - orange fine to medium sand lenses 18.3 to 19 ft: Tan/Orange fine to medium sand					16-20
21-25	20 ft to 25 ft	3.5 ft		dry moist		20 to 21 ft: Tan fine sand, intermittent light Iron staining 21 to 21.1 ft: Orange medium sand lense 21.1 to 21.6 ft: Brown silt and fine sand, very firm 21.6 to 23.5 ft: Tan/light orange fine to medium sand, coarsening to fine to medium sand with little coarse sand at 22.7 ft					21-25
26-30	25 ft to 30 ft	3.1		wet		25 to 26 ft: Medium sand and coarse sand, trace gravel 26 to 26.5 ft: Tan fine sand, some medium sand 26.5 to 27.5 ft: tan fine sand, iron stained 27-27.4 27.5 to 28.1 ft: Mottled brown silt, soft					26-30

Project Number: 60476644 Client: Town of Orleans Site Location: Overland Way, Tri-town Orleans, MA	AECOM 250 Apollo Drive Chelmsford, Massachusetts (978) 905-2100	**Boring: TTS-2** Boring Number: Sheet: 2 of 3 Surface Elevation (ft-asl): Equipment: Geoprobe 6620 Inside Diameter: 2"

Well Data

Boring Depth: 40 ft
Screen Depth: 30 - 40 ft
Screen length: 10 ft

Project Manager: Mark Owen	Field Tech: C.Hayden	Date Started: 3/9/2017
Drill Contractor: NE Geotech	Driller: Hayes	Date Completed: 3/10/2017

Depth	Sample Identification	Rec (ft)	Sorting	Moisture	PID (ppm)	Field Identification	Description	Fill Mat.	Tube	Fill Mat.	Depth
31	30 ft to 35 ft	3.6 ft		wet		30 to 30.9 ft: Brown fine to medium sand					31
32						30.9 to 31.5 ft: Brown fine sand					32
33						31.5 to 32 ft: Brown fine sand, some medium sand, trace coarse sand					33
34						32 to 32.9 ft: Brown fine sand, light brown mottling					34
35						32.9 to 33.6 ft: Brown fine sand, some medium sand					35
36	35 ft to 40 ft	4 ft		wet		35 to 36.8 ft: Brown-tan fine sand, coarsening to fine to medium orange sand at 36.4					36
37						36.8 ft: Silty grey clay					37
38						36.8 to 37.9 ft: Iron-stained mottled tan fine sand					38
39						37.9 to 38 ft: Grey mottled silt into 1/4" clay					39
40						38 to 39 ft: Brown fine sand, trace medium sand (38-38.3 Iron stain mottled)					40
41	40 ft to 45 ft	4 ft		wet		40 to 40.5 ft: Light brown, iron-stained fine to medium sand					
42						40.5 to 42.6 ft: Light brown fine sand					
43						42.6 to 43 ft: Grey/tan mottled fine sand, firm					
44						43 to 44 ft: Tan fine sand (1/8" clay at 43.2', 2" clay pocket from 43.6-43.7') very firm					
45											
46	45 ft to 50 ft	3.8 ft		wet		45 to 46.7 ft: Tan fine sand, very firm					
47						46.7 to 48.8 ft: Brown/light brown medium sand, little coarse sand					
48											
49											
50											
51	50 ft to 55 ft	3 ft		wet		50 to 51 ft: Brown/light brown medium sand, little coarse sand					
52						51 to 51.5 ft: Orange/brown medium to coarse sand					
53						51.5 ft: Brown silt / clay					
54						51.6 to 53 ft: Tan fine sand, some medium sand					
55											
56	55 ft to 60 ft	2.8 ft		wet		55 to 56.3 ft: Tan fine to medium sand					
57						56.3 to 56.4 ft: Red/orange medium to coarse sand					
58						56.4 to 57.8 ft: Tan fine sand, trace iron-stained mottling					
59											
60											

Project Number: 60476644
Client: Town of Orleans

Site Location: Overland Way, Tri-town
Orleans, MA

AECOM
250 Apollo Drive
Chelmsford, Massachusetts
(978) 905-2100

Boring: TTS-2

Boring Number:
Sheet: 3 of 3
Surface Elevation (ft-asl):
Equipment: Geoprobe 6620
Inside Diameter: 2"

Well Data

Boring Depth: 40 ft
Screen Depth: 30 - 40 ft
Screen length: 10 ft

Project Manager: Mark Owen | Field Tech: C.Hayden | Date Started: 3/9/2017
Drill Contractor: NE Geotech | Driller: Hayes | Date Completed: 3/10/2017

Depth	Sample Identification	Rec (ft	Sorting	Moist	PID (ppm)	Field Identification	Description	Fill Mat.	Tube	Fill Mat.	Depth
60											
61	60 ft to 65 ft	2.8 ft		wet		60 to 60.8 ft: Tan fine sand					31
62						60.8 to 61.4 ft: Inter-layered tan fine sand; grey silt					32
63						61.4 to 62 ft: Tan fine sand					33
64						62 to 62.8 ft: Inter-layered tan fine sand; grey silt					34
65											35
66	65 ft to 70 ft	2.7 ft		wet		65 to 65.3 ft: Tan fine sand					36
67						65.3 to 66.4 ft: Alternating fine sand and silt - fine to coarse sand layers, brown					37
68											38
69						66.4 to 67.7 ft: Very dense fine sand, little medium sand, trace large gravel					39
70						-------- End of Boring --------					40

Project Number: 60476644
Client: Town of Orleans

Site Location: Overland Way, Tri-Town
Orleans, MA

AECOM
250 Apollo Drive
Chelmsford, Massachusetts
(978) 905-2100

Boring: TTS-3

Boring Number:
Sheet: 1 of 2
Surface Elevation (ft-asl):
Equipment: Geoprobe 6620

Well Data

Boring Depth: 40 ft
Screen Depth: 30 - 40 ft
Screen length: 10 ft

Project Manager: Mark Owen
Field Tech: C Hayden
Date Started: 3/13/2017
Inside Diameter: 2"

Drill Contractor: NE Geotech
Driller: Hayes
Date Completed: 3/13/2017

Depth	Sample Identification	Rec (ft)	Sorting	Moist	PID (ppm)	Field Identification	Description	Fill Mat.	Tube	Fill Ma	Depth
1	0 ft to 5 ft					Pre-Cleared to 5 ft on 03/07/2017 4" of asphalt, 2" of road gravel, 6"-60" fine to medium brown sand					1
2											2
3											3
4											4
5											5
6	5 ft to 10 ft	3.6 ft				5 to 6 ft: Brown fine-medium sand, trace broken cobble					6
7				dry		6-8.6 ft: Tan, orange-molted fine sand					7
8											8
9											9
10											10
11	10 ft to 15 ft	3.7 ft				10 to 12.1 ft: Tan, orange-mottled fine sand (fine sand and silt at 11-11.5 light brown)					11
12				Dry		12.1 to 13.7 ft: Brown fine sand and silt (trace cobble at 12.3 to 12.7 and 13 to 13.2) 12.1 to 12.2 Iron-stained					12
13											13
14											14
15											15
16	15 ft to 20 ft	4.8 ft		wet		15 to 18 ft: Silt with some clay (15 - 16 brown, 16 to 16.6 brown with iron staining, 16.6 - 17.1 grey, 17.1 to 18 brown with iron-staining) all semi-plastic					16
17											17
18						18 to 18.7 ft: Grey clay, trace silts, plastic					18
19						18.7 to 19.2 ft: Orange/red/yellow Fe-stained fine sand and silt					19
20				dry dry		19.2 to 19.5 ft: Tan fine to medium sand 19.5 to 19.8 ft: Tan silt, some fine sand					20
21	20 ft to 25 ft	3.5 ft		dry		20 to 23.5 ft: Brown/light grey fine sand, mottled with Iron-staining					21
22				moist		- Medium sand lenses; 22 ft, 22.5ft, 23.3 ft - silt lenses; 20.6 ft, 22.4 ft, 22.6 ft					22
23				dry		- Red/dark orange medium sand and gravel, 20.3 to 20.5					23
24											24
25											25
26	25 ft to 30 ft	3.5 ft		wet		25 to 28.5 ft: Brown/light grey fine sand					26
27						- medium sand lenses; 26.1, 26.4-26.6, 27.3 - Iron-mottling; 26.3, 27.5, 28-28.5					27
28											28
29											29
30											30

t Number: 60476644
Town of Orleans

ocation: Overland Way, Tri-town
Orleans, MA

AECOM
250 Apollo Drive
Chelmsford, Massachusetts
(978) 905-2100

Boring: TTS-3

Boring Number:
Sheet 2 of 2
Surface Elevation (ft-asl):
Equipment: Geoprobe 6620

Well Data

Boring Depth: 40 ft
Screen Depth: 30 - 40 ft
Screen length: 10 ft

t Manager: Mark Owen
Field Tech: C Hayden
Date Started: 3/9/2017
ontractor: NE Geotech
Driller: Hayes
Date Completed: 3/10/2017
Inside Diameter: 2"

Sample Identification	Rec (ft	Sortin	Moistu	PID (ppm)	Field Identification	Description	Fil Mat	Tube	Hill Mat	Depth
30 ft to 35 ft	4.3 ft		wet		30 to 33.5 ft: Light grey fine sand, with some silt, Iron-stained mottling throughout - medium sand, 30.5-31.5, 31.8, 32.4-32.8 - silt, 33-34.3					31 32 33 34 35
35 ft to 40 ft	4.1 ft		wet		35 to 39.1 ft: Light grey/light brown fine sand, little silt, Iron-stained mottling throughout - little medium sand, 37.8, 38-38.4, 38.6 - Iron-stained, 39-39.2					36 37 38 39 40
40 ft to 45 ft	3.2 ft		wet		40 to 43.2 ft: Brown medium sand with little fine sand, little gravel - Brown medium to coarse sand and gravel, 41.6 to 43.2					
45 ft to 50 ft	3.4 ft		wet		45 to 47 ft: Brown fine to medium sand, trace coarse sand and gravel 47 to 48.4 ft: Brown fine sand, some medium sand					
50 ft to 55 ft	3.4 ft		wet		50 to 51.7 ft: Tan fine sand, trace coarse sand and fine gravel sand ---------- End of Boring ----------					

Appendix D

Laboratory Reports - Soils

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CERTIFICATE OF ANALYSIS

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

RE: Orleans MA (60476644 T10.1B)
ESS Laboratory Work Order Number: 1704795

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 12:03 pm, May 09, 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.

Subcontracted Analyses

CTS - Cranston, RI	Grain Size Analysis, Hydrometer Analyses

CERTIFICATE OF ANALYSIS

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

ESS Laboratory Work Order: 1704795

SAMPLE RECEIPT

The following samples were received on April 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
1704795-01	CLS-1 70-72	Soil	§
1704795-02	CLS-1 86-88	Soil	§
1704795-03	CLS-1 95.5-96	Soil	§
1704795-04	CLS-1 108-110	Soil	§
1704795-05	CLS-2 21-24	Soil	§
1704795-06	CLS-2 64.66	Soil	§
1704795-07	CLS-2 74-76	Soil	§
1704795-08	CLS-2 80-82	Soil	§
1704795-09	CLS-3 65-69	Soil	§
1704795-10	CLS-3 73-77	Soil	§
1704795-11	CLS-3 87-95	Soil	§
1704795-12	CLS TP-3 15-15	Soil	§
1704795-13	CLS TP-7 10-15	Soil	§
1704795-14	TTS-1-TP 10-15	Soil	§
1704795-15	TTS-1 45-46.5	Soil	§
1704795-16	TTS-2-TP 10-15	Soil	§
1704795-17	TTS-2 21-21.5	Soil	§
1704795-18	TTS-3 15-16.5	Soil	§
1704795-19	TTS-4 15.5-16.5	Soil	§

CERTIFICATE OF ANALYSIS

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

ESS Laboratory Work Order: 1704795

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: 1704795

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

ESS Laboratory Work Order: 1704795

Classical Chemistry

Client Sample ID: CLS-1 70-72
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-01
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS-1 86-88
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-02
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS-1 95.5-96
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-03
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

Client Sample ID: CLS-1 108-110
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-04
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS-2 21-24
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-05
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

CERTIFICATE OF ANALYSIS

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

ESS Laboratory Work Order: 1704795

Classical Chemistry

Client Sample ID: CLS-2 64.66
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-06
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS-2 74-76
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-07
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

Client Sample ID: CLS-2 80-82
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-08
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS-3 65-69
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-09
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS-3 73-77
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-10
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

CERTIFICATE OF ANALYSIS

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

ESS Laboratory Work Order: 1704795

Classical Chemistry

Client Sample ID: CLS-3 87-95
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-11
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS TP-3 15-15
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-12
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS TP-7 10-15
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-13
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: TTS-1-TP 10-15
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-14
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: TTS-1 45-46.5
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-15
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

CERTIFICATE OF ANALYSIS

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

ESS Laboratory Work Order: 1704795

Classical Chemistry

Client Sample ID: TTS-2-TP 10-15
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-16
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: TTS-2 21-21.5
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-17
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

Client Sample ID: TTS-3 15-16.5
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-18
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

Client Sample ID: TTS-4 15.5-16.5
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-19
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

CERTIFICATE OF ANALYSIS

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

ESS Laboratory Work Order: 1704795

Notes and Definitions

Z-08	See Attached
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: 1704795

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

LABORATORY TESTING DATA SHEET (1 of 2)

Project Name **Orleans - GWDP** Location Overland Way, MA Reviewed By

Project No. **1704795** Assigned By T. Parece

Project Manager T. Parece Report Date 05.08.17 Date Reviewed *05.08.17*

Boring/ Test Pit No.	Sample No.	Depth ft.	Lab No.	Identification Tests						Corrosivity					Laboratory Log and Soil Description
				Water Content %	LL %	PL %	Gravel %	Sand %	Fines (<#200) %	pH	Sulfate (mg/kg)	Chloride (mg/kg)	Resistivity (Mohms-cm)	GTL Resist	
CLS-1		70-72	17-S-560				0.1	98.0	1.9						Light Brown-White poorly graded sand
CLS-1		86-88	17-S-561				0.0	97.3	2.7						Brown poorly graded sand
CLS-1		95.5-96	17-S-562				0.0	56.4	43.6						Brown silty sand
CLS-1		108-110	17-S-563				0.0	94.3	5.7						Brown poorly graded sand with silt
CLS-2		21-24	17-S-564				0.0	4.4	95.6						Light Brown silt
CLS-2		64-66	17-S-565				0.0	53.0	47.0						Light White-Brown silty sand
CLS-2		74-76	17-S-566				0.0	41.8	58.2						Light Brown sandy silt
CLS-2		80-82	17-S-567				0.0	89.0	11.0						Light Brown poorly graded sand with silt
CLS-3		65-69	17-S-568				0.0	85.6	14.4						Strong Brown silty sand
CLS-3		73-77	17-S-569				0.0	57.3	42.7						Brown silty sand
CLS-3		87-95	17-S-570				0.0	89.6	10.4						Brown poorly graded sand with silt
CLS TP-3		15-15	17-S-571				2.0	96.1	1.9						Red-Brown poorly graded sand

THIELSCH ENGINEERING
195 Frances Avenue
Cranston, RI 02910 401-467-6454

LABORATORY TESTING DATA SHEET (2 of 2)

Project Name **Orleans - GWDP** Location Overland Way, MA Reviewed By

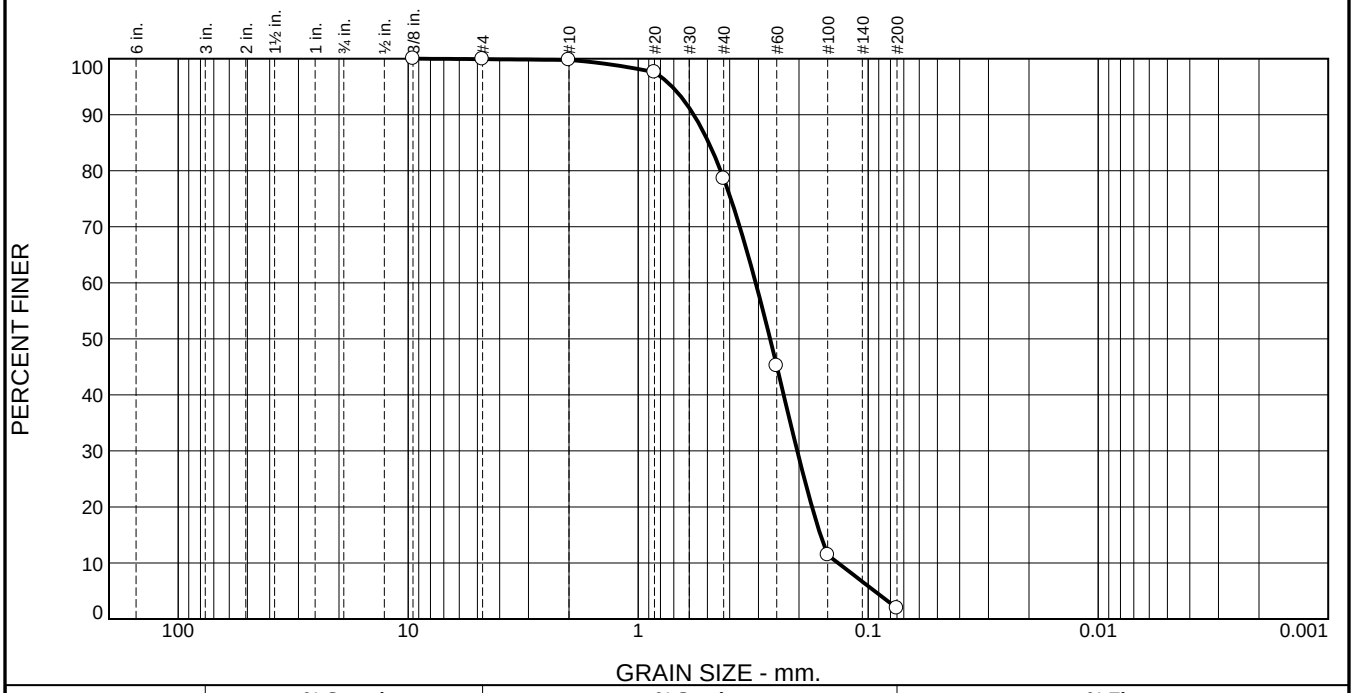
Project No. **1704795** Assigned By T. Parece

Project Manager T. Parece Report Date 05.08.17 Date Reviewed *05.08.17*

Boring/ Test Pit No.	Sample No.	Depth ft.	Lab No.	Identification Tests						Corrosivity					Laboratory Log and Soil Description
				Water Content %	LL %	PL %	Gravel %	Sand %	Fines (<#200) %	pH	Sulfate (mg/kg)	Chloride (mg/kg)	Resistivity (Mohms-cm)	GTL Resist	
CLS-TP-7		10-15	17-S-572				3.3	92.6	4.1						Brown poorly graded sand
TTS-1-TP		10-15	17-S-573				0.1	94.1	5.8						Red-Brown poorly graded sand with silt
TTS-1		45-46.5	17-S-574				0.0	53.0	47.0						Brown silty sand
TTS-2-TP		10-15	17-S-575				14.1	81.8	4.1						Light Brown poorly graded sand
TTS-2		21-21.5	17-S-576				0.0	66.9	33.1						Brown silty sand
TTS-3		15-16.5	17-S-577				0.0	2.5	97.5						Brown silt
TTS-4		15.5-16.5	17-S-578				0.0	51.2	48.8						Brown silty sand

THIELSCH ENGINEERING
195 Frances Avenue
Cranston, RI 02910 401-467-6454

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.1	0.1	21.2	76.7	1.9	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
.375	100.0		
#4	99.9		
#10	99.8		
#20	97.6		
#40	78.6		
#60	45.2		
#100	11.4		
#200	1.9		

* (no specification provided)

Material Description

Light Brown-White poorly graded sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** A-3

Coefficients

D_{90}= 0.5736 D_{85}= 0.4934 D_{60}= 0.3084
D_{50}= 0.2670 D_{30}= 0.2035 D_{15}= 0.1612
D_{10}= 0.1351 C_u= 2.28 C_c= 0.99

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 70-72' **Date Sampled:**

Sample Number: CLS-1

Thielsch Engineering Inc.

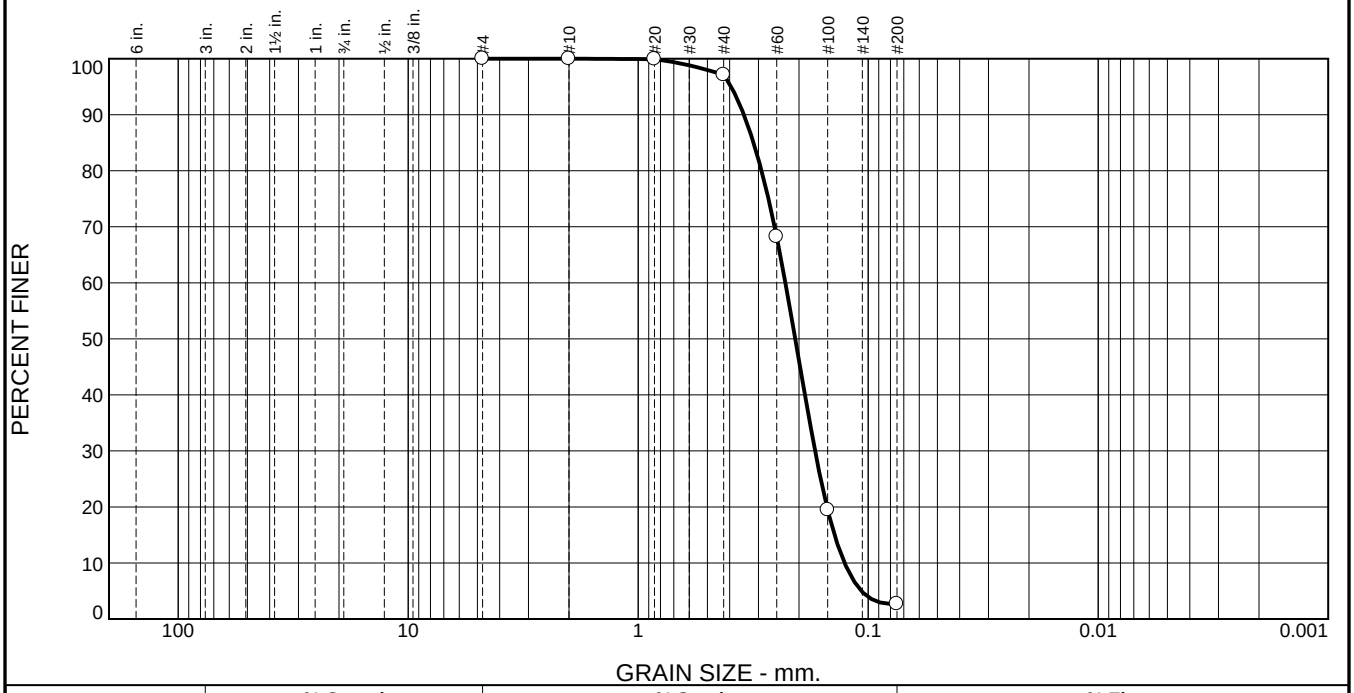
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-560

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	2.9	94.4	2.7	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	100.0		
#20	99.9		
#40	97.1		
#60	68.2		
#100	19.5		
#200	2.7		

* (no specification provided)

Material Description

Brown poorly graded sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** A-3

Coefficients

D_{90}= 0.3470 D_{85}= 0.3150 D_{60}= 0.2291
D_{50}= 0.2076 D_{30}= 0.1701 D_{15}= 0.1401
D_{10}= 0.1267 C_u= 1.81 C_c= 1.00

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 86-88' **Date Sampled:**

Sample Number: CLS-1

Thielsch Engineering Inc.

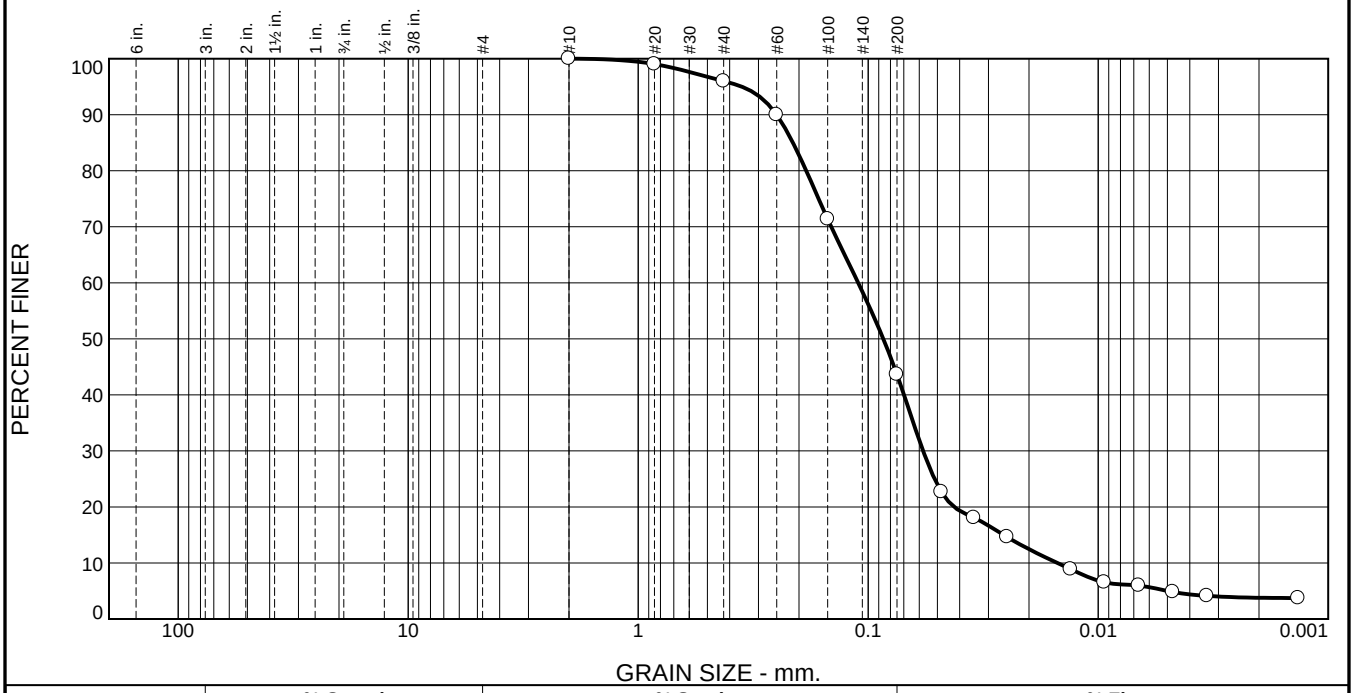
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-561

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	4.0	52.4	39.8	3.8

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#10	100.0		
#20	99.0		
#40	96.0		
#60	90.0		
#100	71.4		
#200	43.6		
0.0481 mm.	22.7		
0.0347 mm.	18.1		
0.0249 mm.	14.6		
0.0132 mm.	8.9		
0.0094 mm.	6.5		
0.0067 mm.	6.0		
0.0047 mm.	4.8		
0.0034 mm.	4.1		
0.0013 mm.	3.7		

* (no specification provided)

Material Description

Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.2502 D_{85}= 0.2124 D_{60}= 0.1106
D_{50}= 0.0860 D_{30}= 0.0577 D_{15}= 0.0257
D_{10}= 0.0150 C_u= 7.35 C_c= 2.00

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 95.5-96' **Date Sampled:**

Sample Number: CLS-1

Thielsch Engineering Inc.

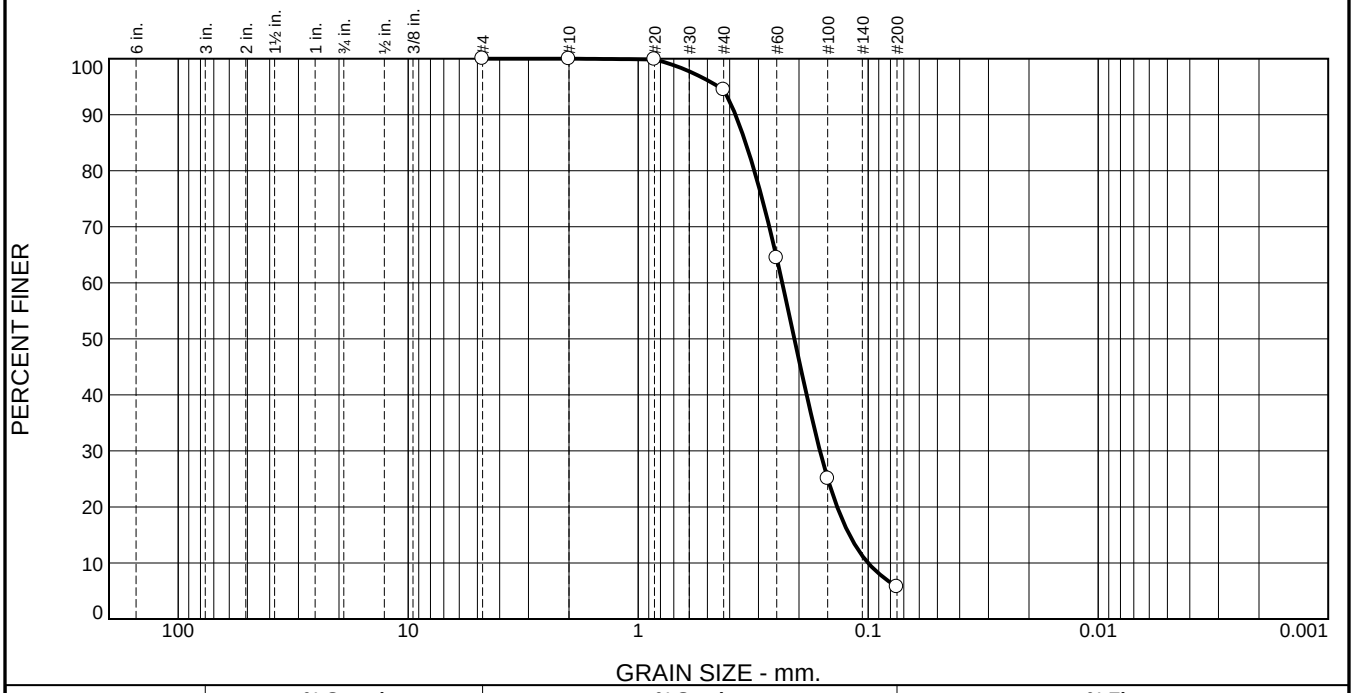
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-562

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	5.5	88.8	5.7	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	100.0		
#20	99.9		
#40	94.5		
#60	64.4		
#100	25.0		
#200	5.7		

* (no specification provided)

Material Description

Brown poorly graded sand with silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP-SM **AASHTO (M 145)=** A-3

Coefficients

D_{90}= 0.3778 D_{85}= 0.3410 D_{60}= 0.2364
D_{50}= 0.2093 D_{30}= 0.1620 D_{15}= 0.1206
D_{10}= 0.1001 C_u= 2.36 C_c= 1.11

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 108-110' **Date Sampled:**

Sample Number: CLS-1

Thielsch Engineering Inc.

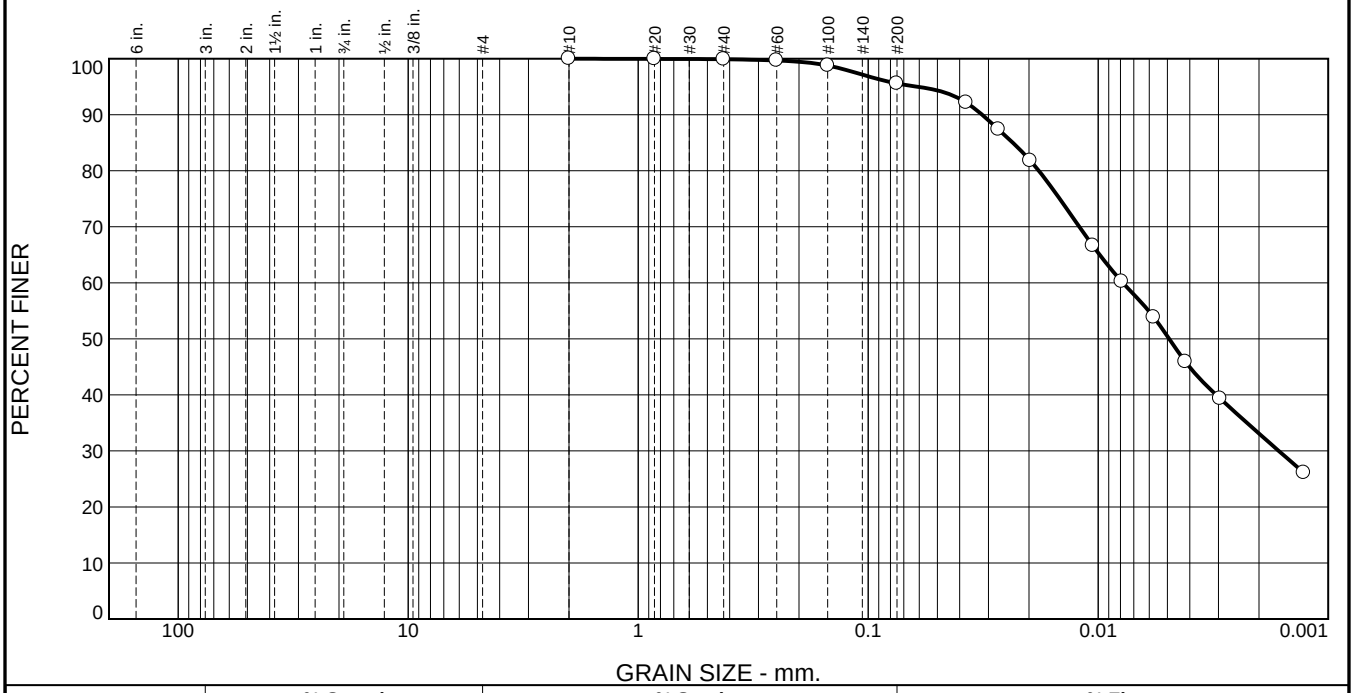
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-563

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.1	4.3	62.5	33.1

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#10	100.0		
#20	100.0		
#40	99.9		
#60	99.7		
#100	98.8		
#200	95.6		
0.0375 mm.	92.2		
0.0272 mm.	87.4		
0.0197 mm.	81.8		
0.0106 mm.	66.6		
0.0079 mm.	60.3		
0.0057 mm.	53.9		
0.0042 mm.	45.9		
0.0030 mm.	39.4		
0.0013 mm.	26.1		

* (no specification provided)

Material Description

Light Brown silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= ML **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.0320 D_{85}= 0.0235 D_{60}= 0.0078
D_{50}= 0.0049 D_{30}= 0.0016 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 21-24' **Date Sampled:**

Sample Number: CLS-2

Thielsch Engineering Inc.

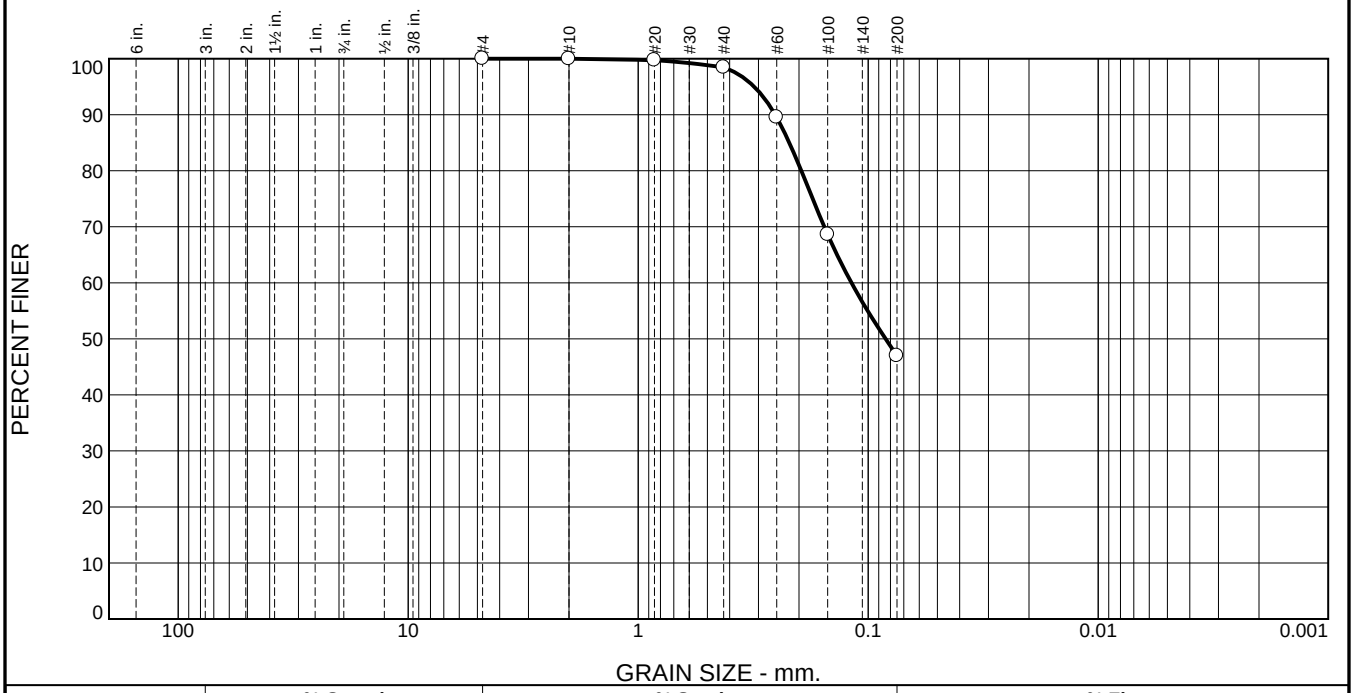
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-564

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	1.5	51.5	47.0	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	100.0		
#20	99.7		
#40	98.5		
#60	89.5		
#100	68.6		
#200	47.0		

* (no specification provided)

Material Description

Light White-Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.2537 D_{85}= 0.2203 D_{60}= 0.1183
D_{50}= 0.0840 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 64-66' **Date Sampled:**

Sample Number: CLS-2

Thielsch Engineering Inc.

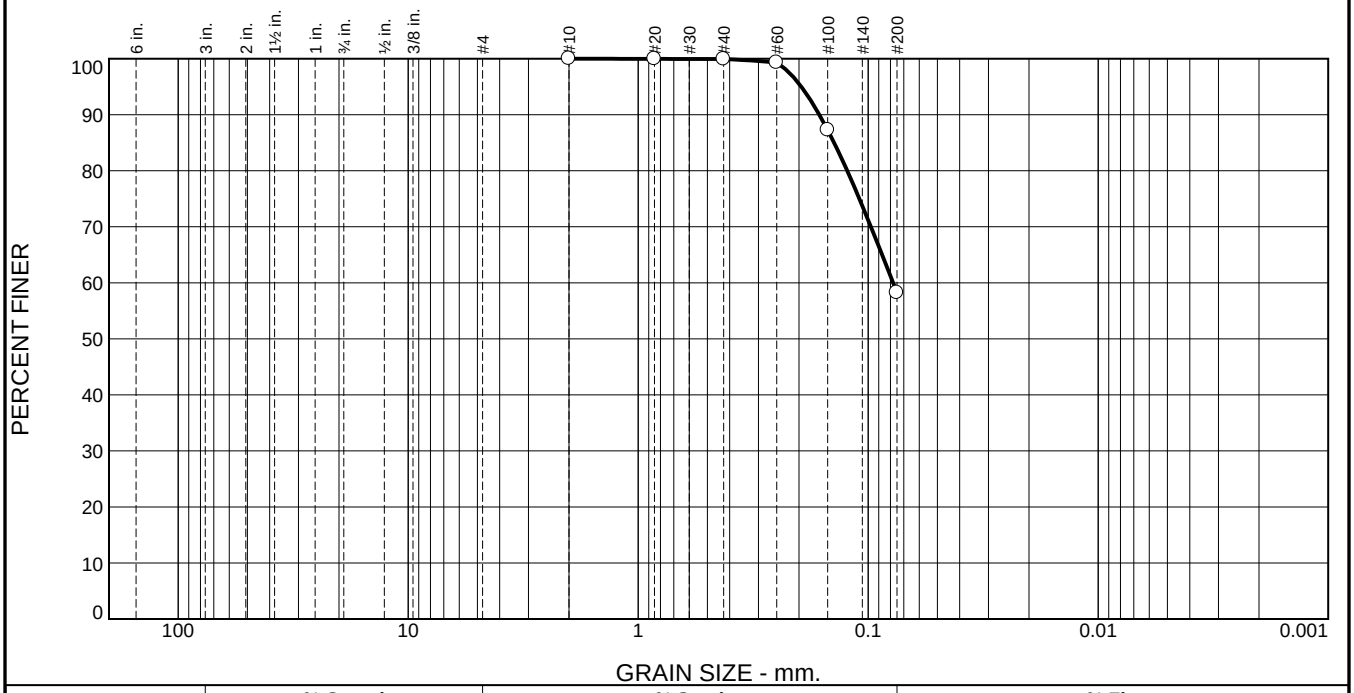
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-565

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.1	41.7	58.2	

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#10	100.0		
#20	100.0		
#40	99.9		
#60	99.3		
#100	87.3		
#200	58.2		

* (no specification provided)

Material Description

Light Brown sandy silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= ML **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.1630 D_{85}= 0.1407 D_{60}= 0.0779
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 74-76' **Date Sampled:**

Sample Number: CLS-2

Thielsch Engineering Inc.

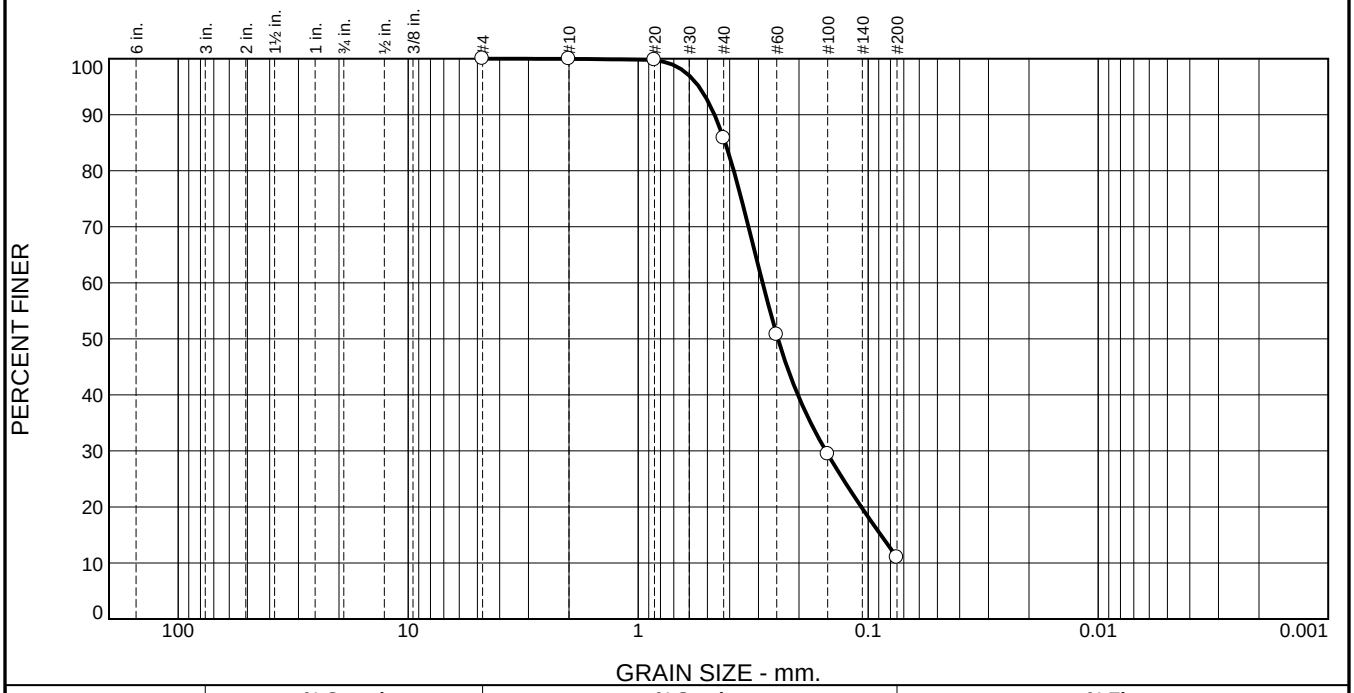
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-566

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	14.2	74.8	11.0	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	100.0		
#20	99.8		
#40	85.8		
#60	50.7		
#100	29.5		
#200	11.0		

* (no specification provided)

Material Description

Light Brown poorly graded sand with silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP-SM **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 0.4656 D_{85}= 0.4184 D_{60}= 0.2878
D_{50}= 0.2469 D_{30}= 0.1527 D_{15}= 0.0881
D_{10}= C_u= C_c=

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 80-82' **Date Sampled:**

Sample Number: CLS-2

Thielsch Engineering Inc.

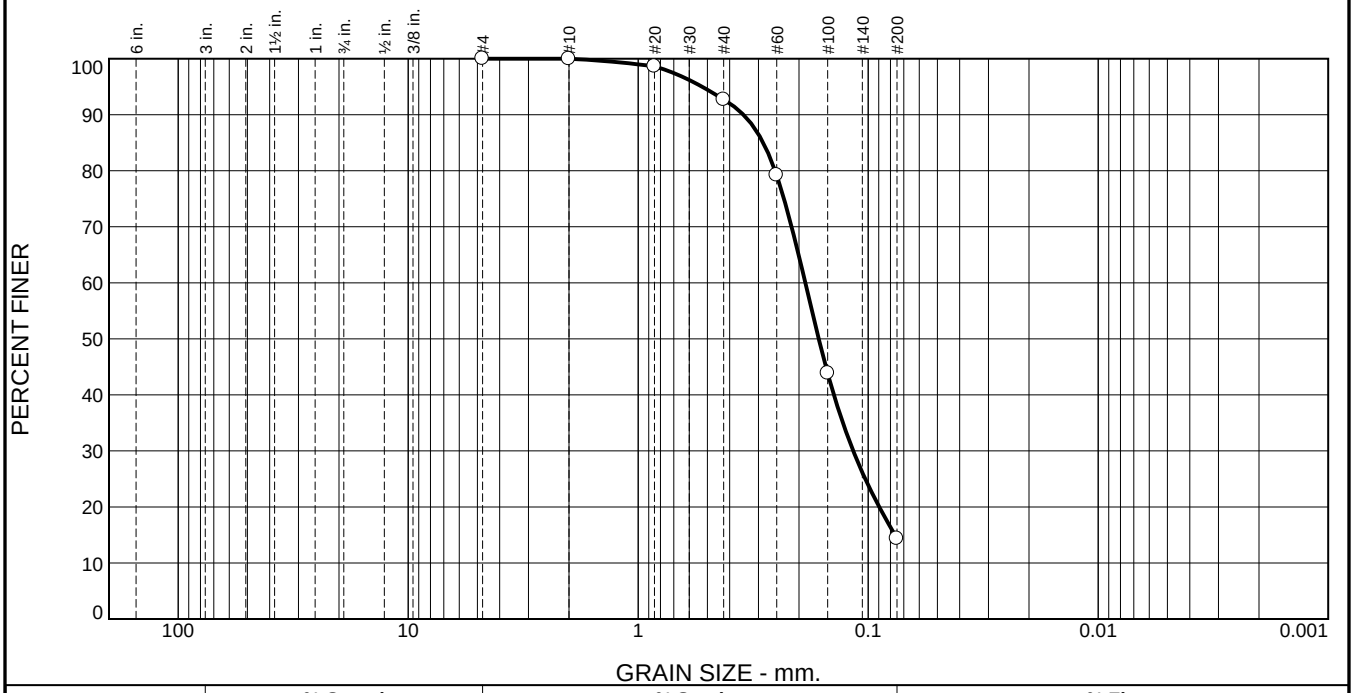
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-567

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	7.3	78.3	14.4	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	100.0		
#20	98.6		
#40	92.7		
#60	79.2		
#100	43.9		
#200	14.4		

* (no specification provided)

Material Description

Strong Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 0.3484 D_{85}= 0.2860 D_{60}= 0.1876
D_{50}= 0.1640 D_{30}= 0.1162 D_{15}= 0.0766
D_{10}= C_u= C_c=

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 65-69' **Date Sampled:**

Sample Number: CLS-3

Thielsch Engineering Inc.

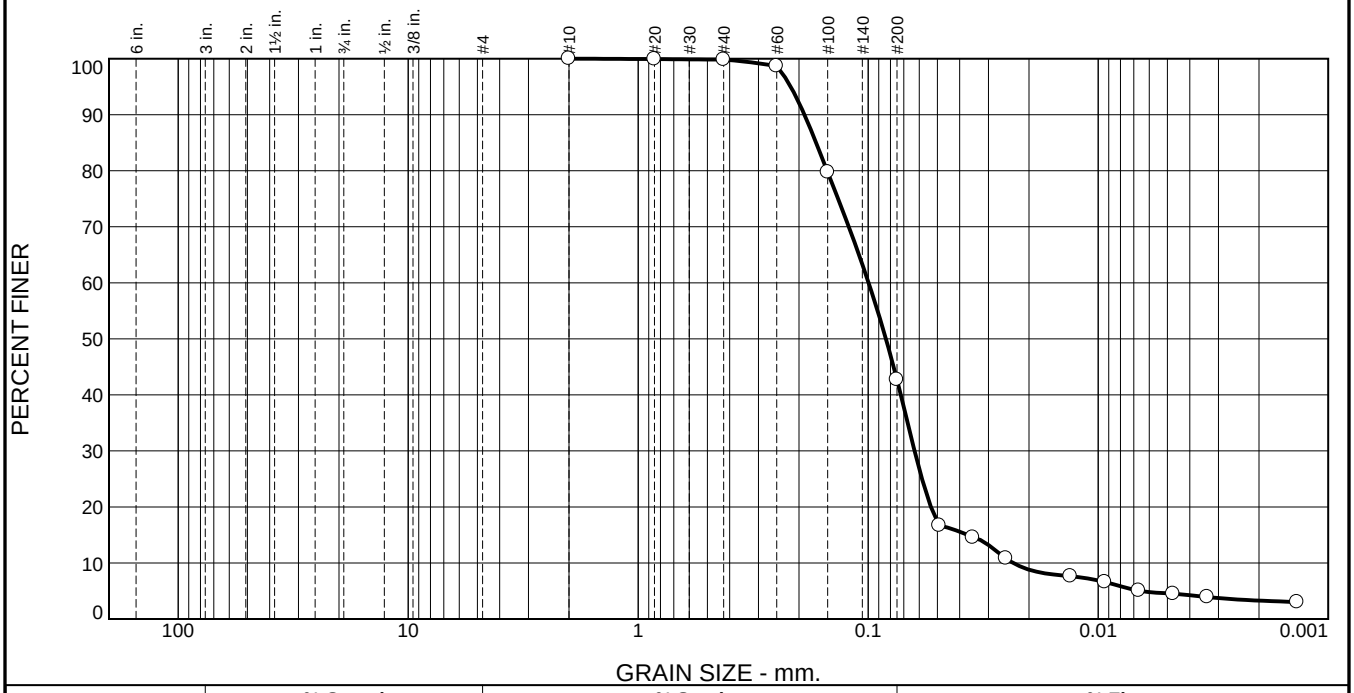
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-568

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.2	57.1	39.4	3.3

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#10	100.0		
#20	99.9		
#40	99.8		
#60	98.7		
#100	79.7		
#200	42.7		
0.0491 mm.	16.7		
0.0351 mm.	14.6		
0.0252 mm.	10.8		
0.0132 mm.	7.6		
0.0094 mm.	6.6		
0.0067 mm.	5.1		
0.0047 mm.	4.5		
0.0034 mm.	3.9		
0.0014 mm.	3.0		

* (no specification provided)

Material Description

Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.1894 D_{85}= 0.1685 D_{60}= 0.0996
D_{50}= 0.0837 D_{30}= 0.0628 D_{15}= 0.0370
D_{10}= 0.0234 C_u= 4.25 C_c= 1.69

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 73-77' **Date Sampled:**

Sample Number: CLS-3

Thielsch Engineering Inc.

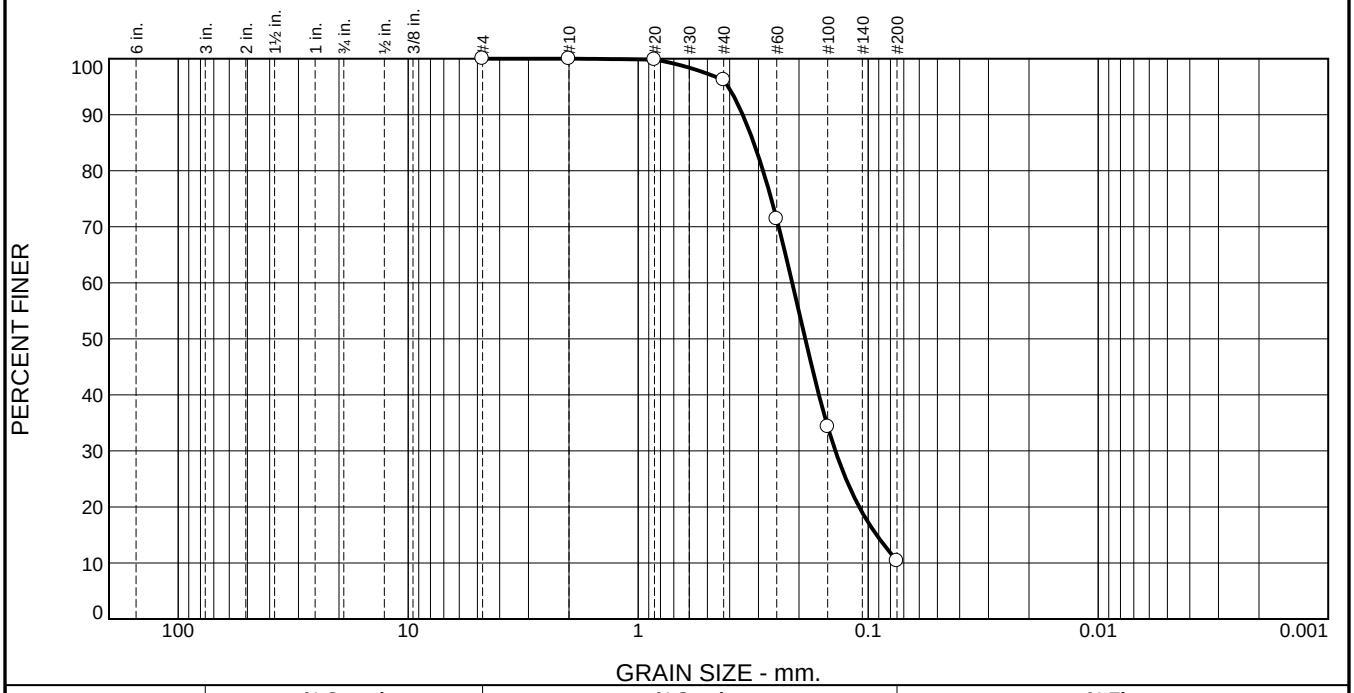
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-569

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	3.8	85.8	10.4	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	100.0		
#20	99.8		
#40	96.2		
#60	71.4		
#100	34.3		
#200	10.4		

* (no specification provided)

Material Description

Brown poorly graded sand with silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP-SM **AASHTO (M 145)=** A-3

Coefficients

D_{90}= 0.3511 D_{85}= 0.3144 D_{60}= 0.2139
D_{50}= 0.1878 D_{30}= 0.1389 D_{15}= 0.0919
D_{10}= C_u= C_c=

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 87-95' **Date Sampled:**

Sample Number: CLS-3

Thielsch Engineering Inc.

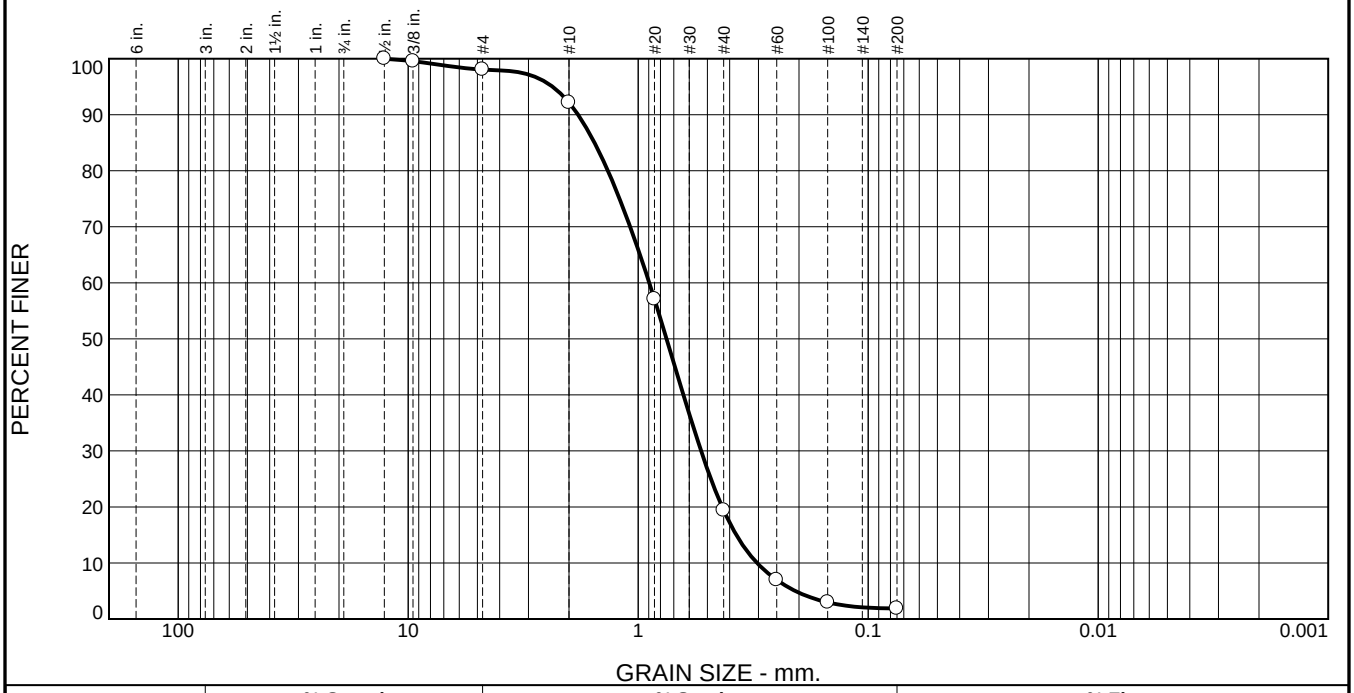
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-570

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	2.0	5.8	72.8	17.5	1.9	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
0.5	100.0		
0.375	99.5		
#4	98.0		
#10	92.2		
#20	57.1		
#40	19.4		
#60	7.0		
#100	3.0		
#200	1.9		

* (no specification provided)

Material Description

Red-Brown poorly graded sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= 1.8256 D_{85}= 1.5482 D_{60}= 0.8950
D_{50}= 0.7526 D_{30}= 0.5327 D_{15}= 0.3744
D_{10}= 0.3043 C_u= 2.94 C_c= 1.04

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 15-15' **Date Sampled:**

Sample Number: CLS-TP-3

Thielsch Engineering Inc.

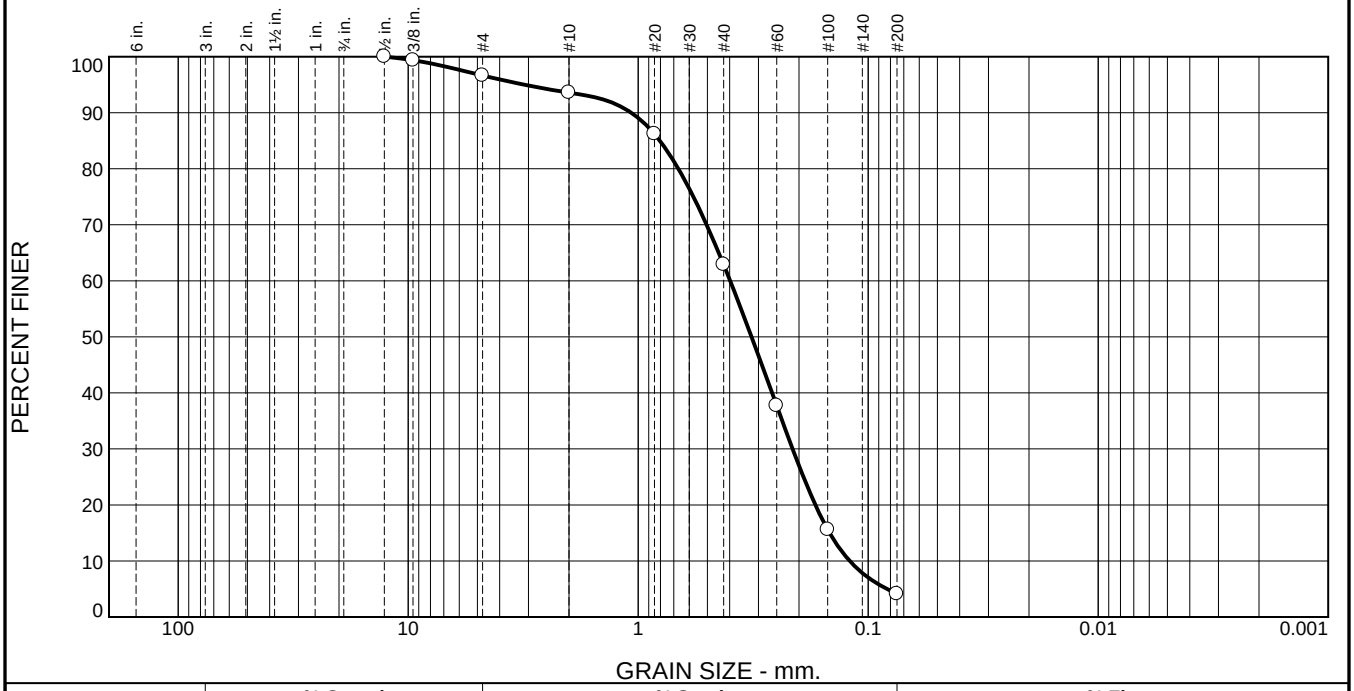
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-571

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	3.3	3.1	30.7	58.8	4.1	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
0.5	100.0		
0.375	99.4		
#4	96.7		
#10	93.6		
#20	86.2		
#40	62.9		
#60	37.7		
#100	15.6		
#200	4.1		

* (no specification provided)

Material Description

Brown poorly graded sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** A-3

Coefficients

D_{90}= 1.0713 D_{85}= 0.8044 D_{60}= 0.3983
D_{50}= 0.3214 D_{30}= 0.2132 D_{15}= 0.1472
D_{10}= 0.1203 C_u= 3.31 C_c= 0.95

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 10-15' **Date Sampled:**

Sample Number: CLS-TP-7

Thielsch Engineering Inc.

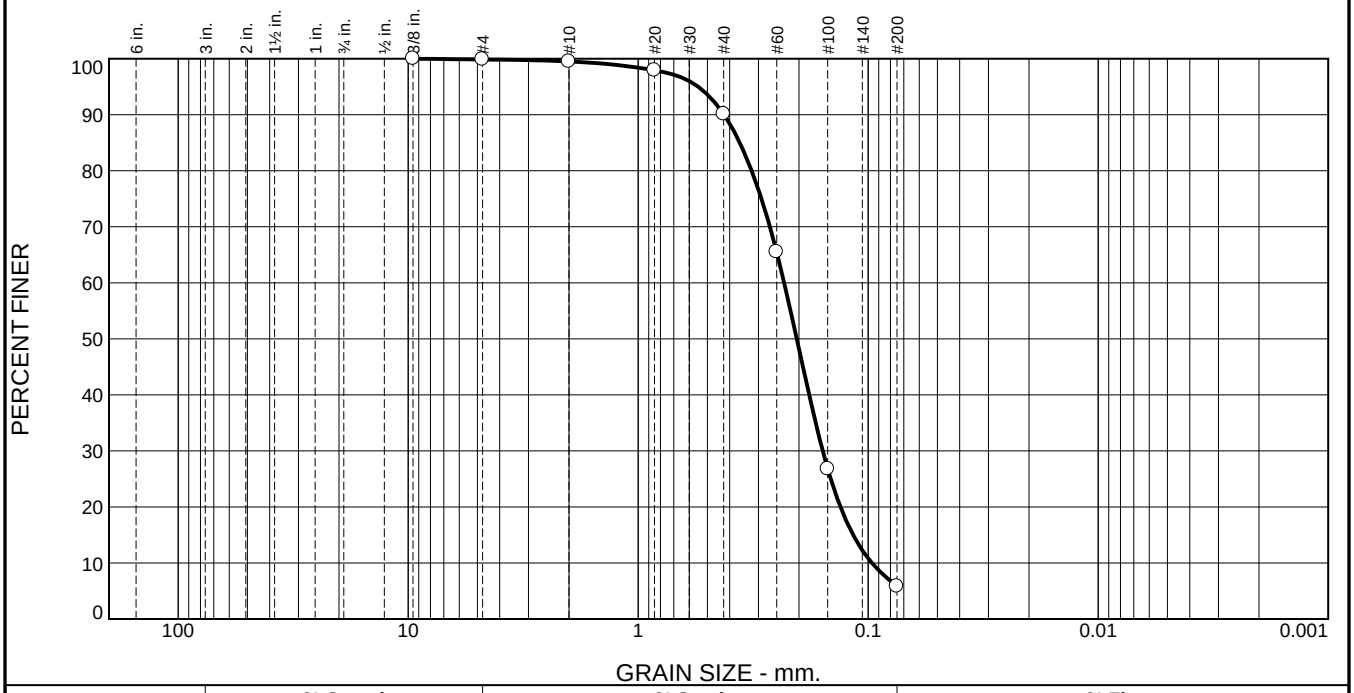
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-572

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.1	0.4	9.4	84.3	5.8	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
0.375	100.0		
#4	99.9		
#10	99.5		
#20	97.9		
#40	90.1		
#60	65.5		
#100	26.8		
#200	5.8		

* (no specification provided)

Material Description

Red-Brown poorly graded sand with silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP-SM **AASHTO (M 145)=** A-3

Coefficients

D_{90}= 0.4233 D_{85}= 0.3617 D_{60}= 0.2319
D_{50}= 0.2044 D_{30}= 0.1576 D_{15}= 0.1163
D_{10}= 0.0963 C_u= 2.41 C_c= 1.11

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 10-15' **Date Sampled:**

Sample Number: TTS-1-TP

Thielsch Engineering Inc.

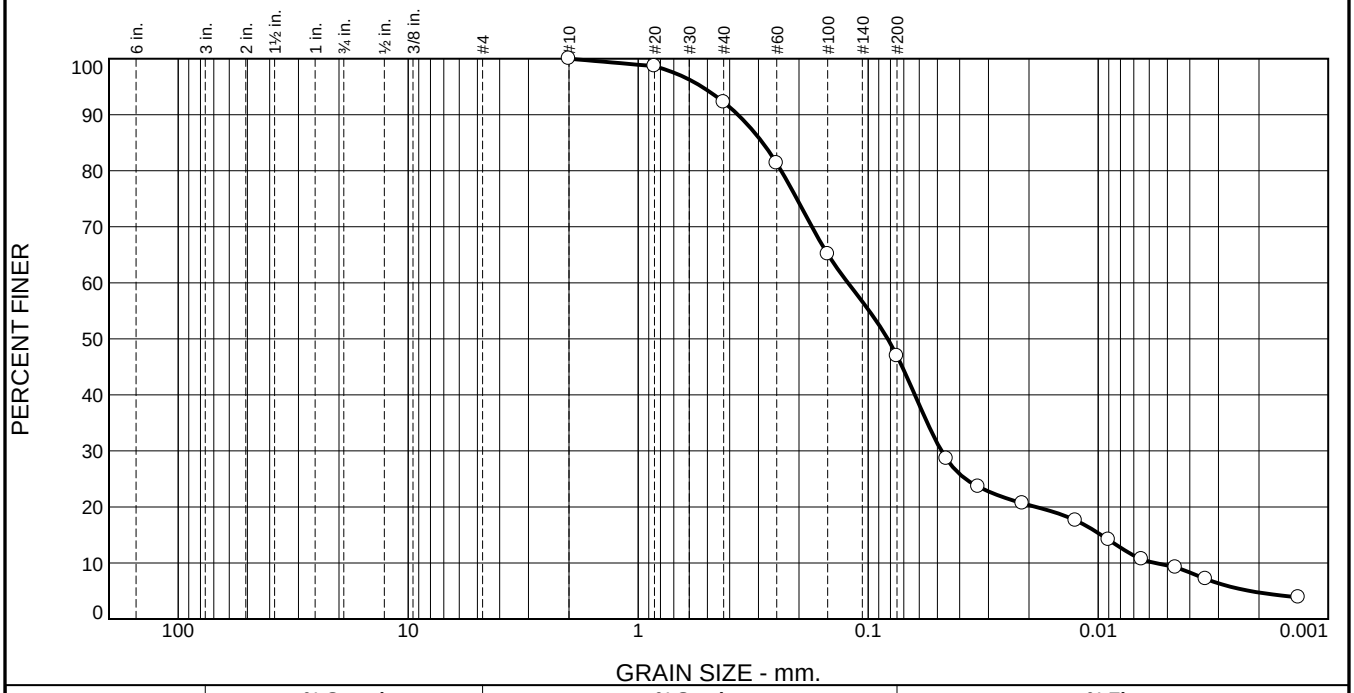
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-573

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	7.8	45.2	42.3	4.7

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#10	100.0		
#20	98.7		
#40	92.2		
#60	81.3		
#100	65.1		
#200	47.0		
0.0457 mm.	28.6		
0.0332 mm.	23.6		
0.0214 mm.	20.7		
0.0126 mm.	17.6		
0.0090 mm.	14.2		
0.0065 mm.	10.7		
0.0046 mm.	9.2		
0.0034 mm.	7.2		
0.0013 mm.	3.9		

* (no specification provided)

Material Description

Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.3684 D_{85}= 0.2876 D_{60}= 0.1225
D_{50}= 0.0823 D_{30}= 0.0480 D_{15}= 0.0097
D_{10}= 0.0056 C_u= 21.70 C_c= 3.33

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 45.46.5' **Date Sampled:**

Sample Number: TTS-1

Thielsch Engineering Inc.

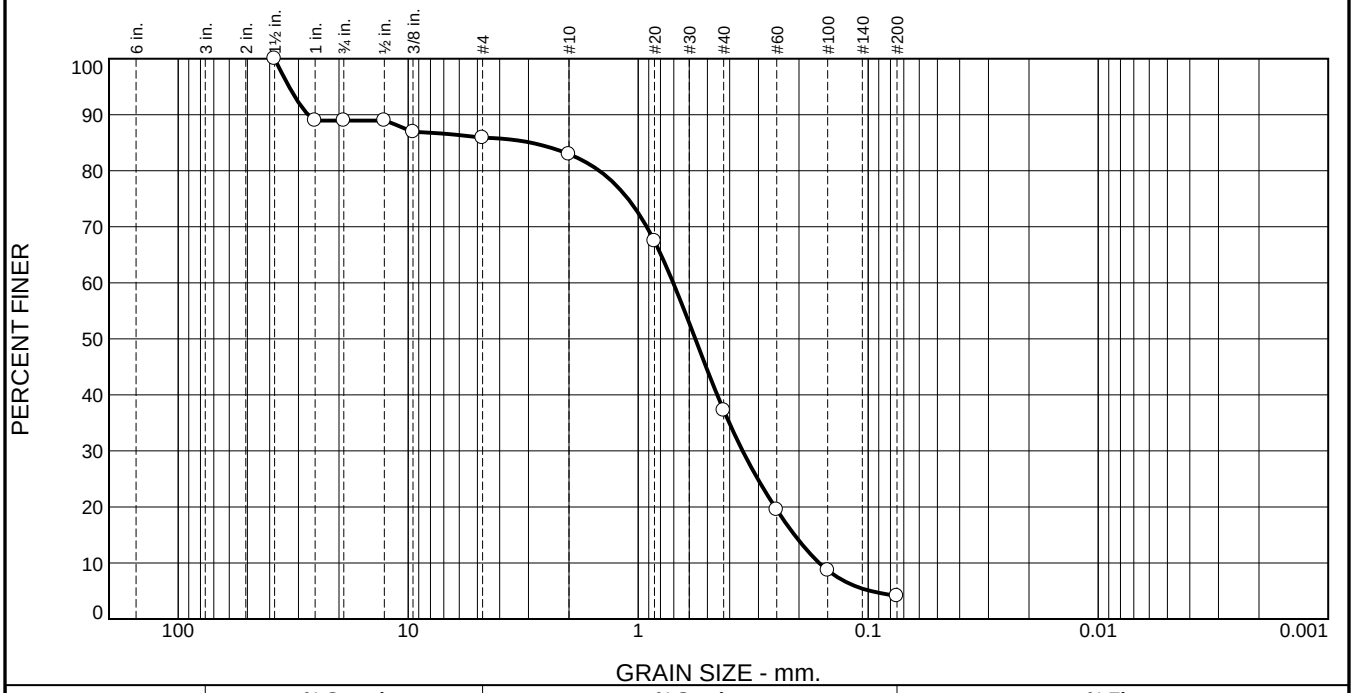
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-574

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	11.0	3.1	2.9	45.7	33.2	4.1	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1.5	100.0		
1	89.0		
.75	89.0		
0.5	89.0		
.375	86.9		
#4	85.9		
#10	83.0		
#20	67.5		
#40	37.3		
#60	19.5		
#100	8.7		
#200	4.1		

* (no specification provided)

Material Description

Light Brown poorly graded sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= 27.2477 D_{85}= 2.9193 D_{60}= 0.7039
D_{50}= 0.5646 D_{30}= 0.3514 D_{15}= 0.2091
D_{10}= 0.1632 C_u= 4.31 C_c= 1.07

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 10-15' **Date Sampled:**

Sample Number: TTS-2-TP

Thielsch Engineering Inc.

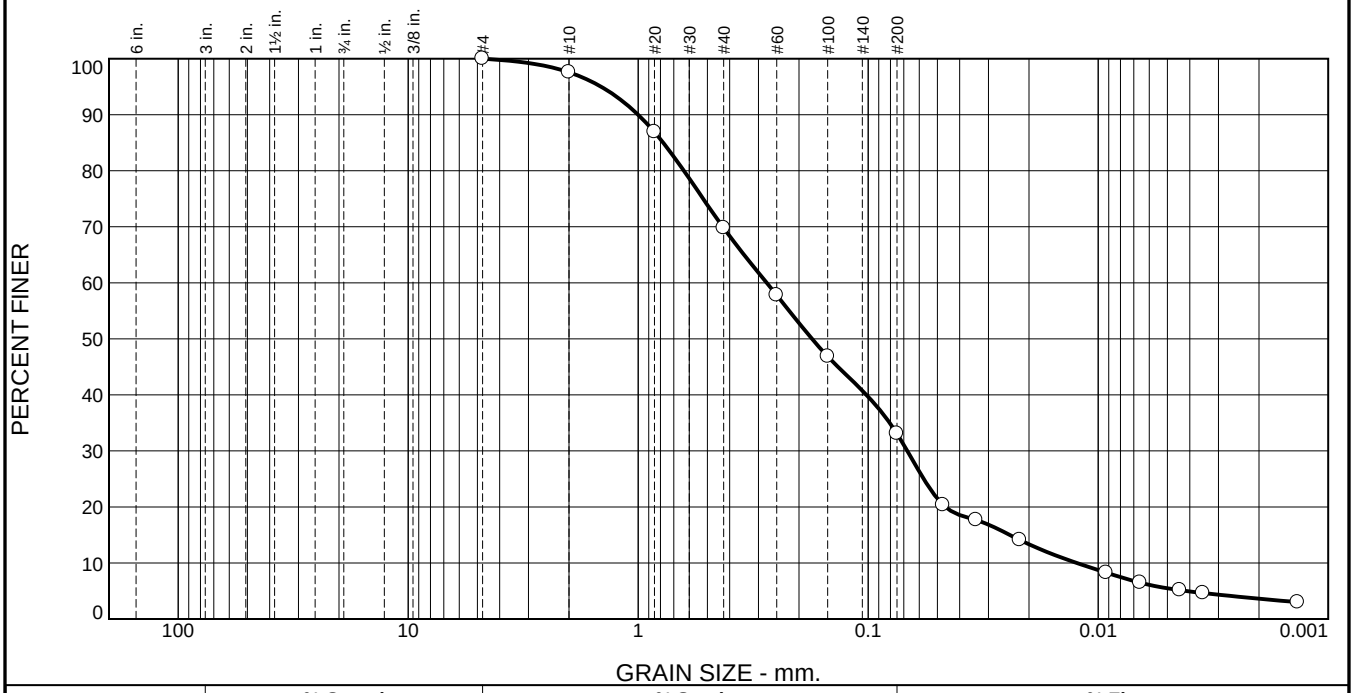
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-575

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	2.4	27.8	36.7	29.5	3.6

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	97.6		
#20	86.9		
#40	69.8		
#60	57.8		
#100	46.9		
#200	33.1		
0.0473 mm.	20.4		
0.0339 mm.	17.7		
0.0219 mm.	14.1		
0.0092 mm.	8.3		
0.0066 mm.	6.5		
0.0044 mm.	5.2		
0.0035 mm.	4.6		
0.0014 mm.	3.0		

* (no specification provided)

Material Description

Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 1.0006 D_{85}= 0.7782 D_{60}= 0.2763
D_{50}= 0.1754 D_{30}= 0.0676 D_{15}= 0.0242
D_{10}= 0.0124 C_u= 22.32 C_c= 1.33

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 21-21.5' **Date Sampled:**

Sample Number: TTS-2

Thielsch Engineering Inc.

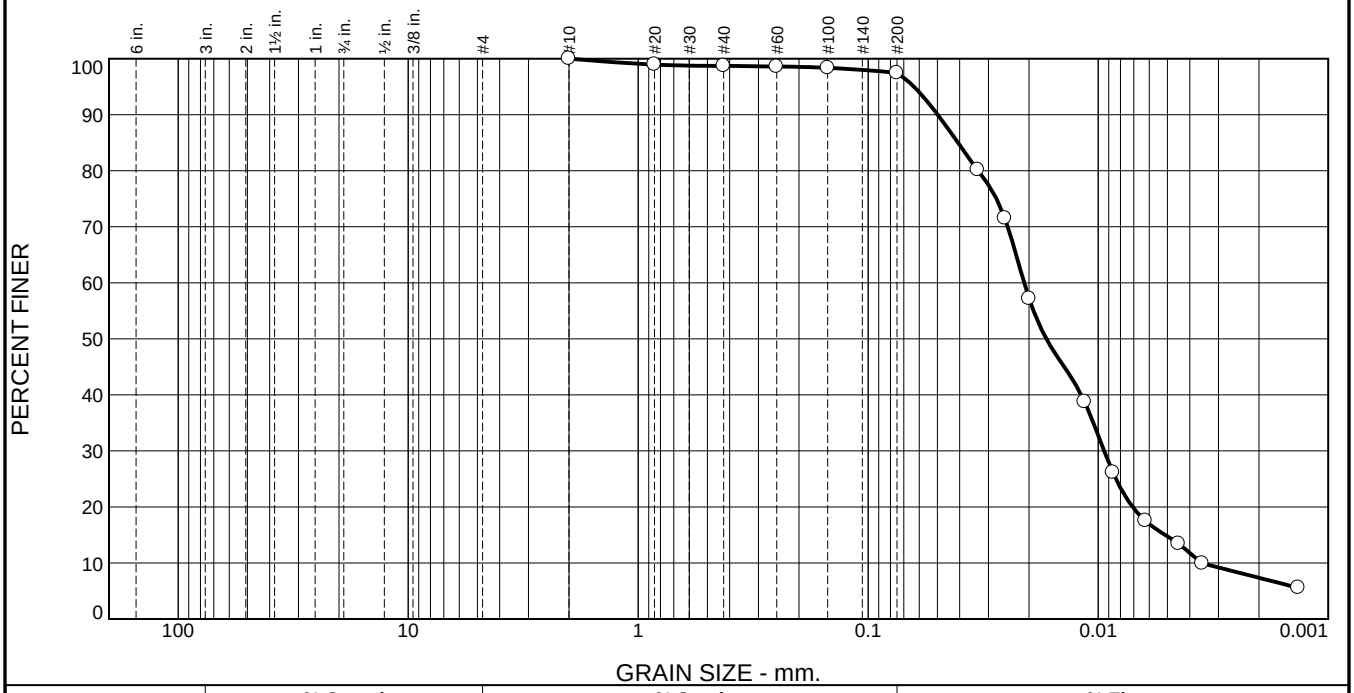
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-576

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	1.3	1.2	90.1	7.4

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#10	100.0		
#20	99.0		
#40	98.7		
#60	98.6		
#100	98.4		
#200	97.5		
0.0335 mm.	80.2		
0.0255 mm.	71.5		
0.0200 mm.	57.2		
0.0115 mm.	38.8		
0.0086 mm.	26.1		
0.0062 mm.	17.5		
0.0045 mm.	13.4		
0.0035 mm.	9.9		
0.0014 mm.	5.6		

* (no specification provided)

Material Description

Brown silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= ML **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.0499 D_{85}= 0.0407 D_{60}= 0.0210
D_{50}= 0.0168 D_{30}= 0.0094 D_{15}= 0.0051
D_{10}= 0.0035 C_u= 5.91 C_c= 1.19

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 15-16.5' **Date Sampled:**

Sample Number: TTS-3

Thielsch Engineering Inc.

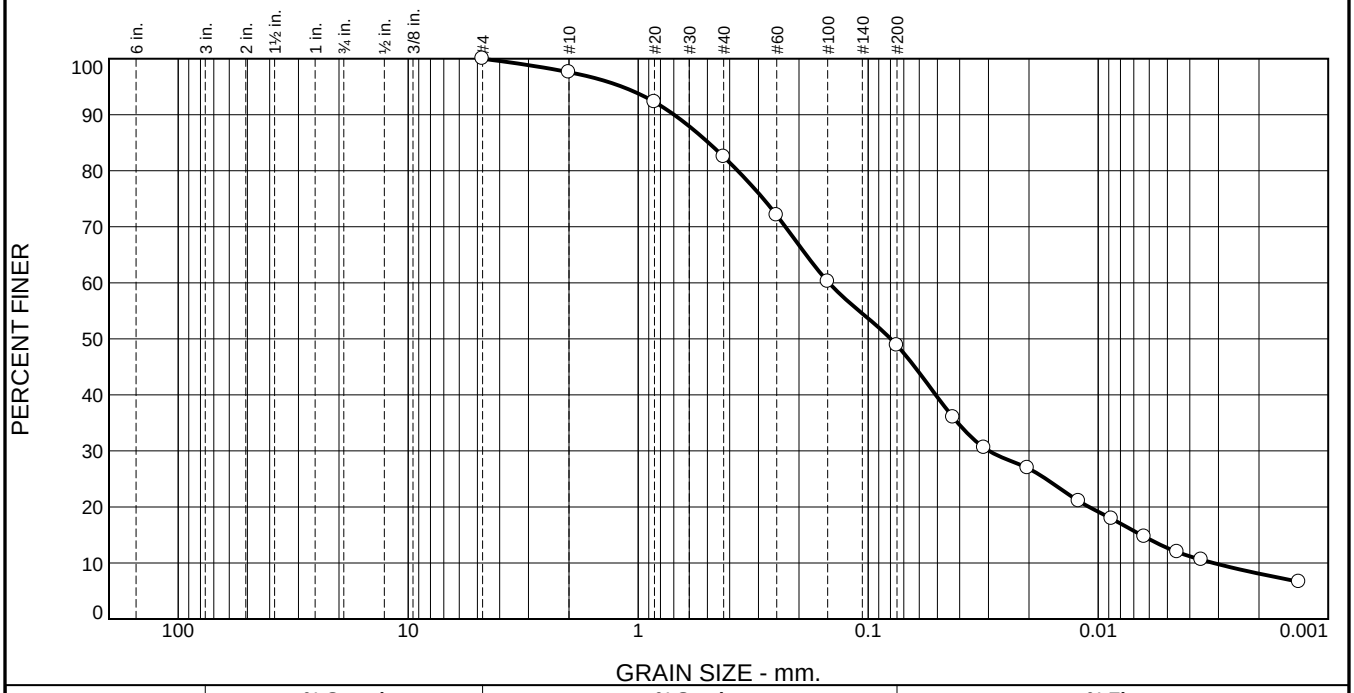
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-577

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	2.4	15.1	33.7	40.7	8.1

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	97.6		
#20	92.3		
#40	82.5		
#60	72.1		
#100	60.2		
#200	48.8		
0.0427 mm.	36.0		
0.0314 mm.	30.6		
0.0203 mm.	27.0		
0.0122 mm.	21.1		
0.0088 mm.	17.9		
0.0063 mm.	14.7		
0.0045 mm.	12.0		
0.0036 mm.	10.6		
0.0013 mm.	6.7		

* (no specification provided)

Material Description

Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.6980 D_{85}= 0.4944 D_{60}= 0.1482
D_{50}= 0.0798 D_{30}= 0.0298 D_{15}= 0.0065
D_{10}= 0.0032 C_u= 46.95 C_c= 1.90

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 15.5-16.5' **Date Sampled:**

Sample Number: TTS-4

Thielsch Engineering Inc.

Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-578

1704794 4/28/17

SOILS LABORATORY TESTING ASSIGNMENT SHEET

THIELSCH ENGINEERING 401-467-6454 195 Frances Ave., Cranston, RI 02910

1704795

Project Name **Orleans - GWDP** Client **Town of Orleans** Assigned By **Mark Owen**

CTS Project No. **60476644.10.1.A** Site Location **Overland Way** Collected By **Mark Owen**

ESS Project No. _____ Date Assigned _____ Received By _____

Project Manager **T. Parece** Date Received _____ Date Required **Norman**

	Sample Information					Lab No.	Identification Tests							Permeability		Compaction			Strength		Consol.	Notes
	Boring/ Test Pit No.	Sample No.	Depth Ft.	Sample Date	ESS SAMPLE ID		Water Cont. %	LL & PL %	Org. %	Sieve -200 %	Hyd -2μ %	G_s	γ_t pcf	Sand	Clay	Mod.	Std.	CBR	Tor-vane	Type Test $\bar{\sigma}_c$ or σ_c	Cc/ 1+eo	
							D2216	D4318	D2974	D422		D854		D2434	D5084	D1557	D698	D1883		D2166/ D4767/ D2850	D2435	#
1	CLS - 1	70-72								X												
2	CLS - 1	86-88								X												
3	CLS - 1	95.5-96								X	X											
4	CLS - 1	108-110								X												
5	CLS - 2	21-24								X	X											
6	CLS - 2	64-66								X												
7	CLS - 2	74-76								X	X											
8	CLS - 2	80-82								X												
9	CLS-3	65-69								X												
10	CLS-3	73-77								X	X											
11	CLS-3	87-95								X												
12	CLS TP-3	15-Gst 15	MH							X												
13	CLS-TP-7	10-15	MH							X												

Notes: MH 2 4-28-17 @ 12:55 TCP 4/28/17 12:55 NOICE 22.1

TCP 2 4/28/17 @ 11:20 4/28/17 1659

1704795

SOILS LABORATORY TESTING ASSIGNMENT SHEET

THIELSCH ENGINEERING 401-467-6454 195 Frances Ave., Cranston, RI 02910

Project Name **Orleans - GWDP** Client **Town of Orleans** Assigned By **Mark Owen**

CTS Project No. **60476644.10.1.A** Site Location **Overland Way** Collected By **Mark Owen**

ESS Project No. _____ Date Assigned _____ Received By _____

Project Manager **T. Parece** Date Received _____ Date Required **Norman**

	Sample Information						Identification Tests							Permeability		Compaction			Strength		Consol.	Notes
	Boring/ Test Pit No.	Sample No.	Depth Ft.	Sample Date	ESS SAMPLE ID	Lab No.	Water Cont. %	LL & PL %	Org. %	Sieve -200 %	Hyd -2μ %	G_s	γ_t pcf	Sand	Clay	Mod.	Std.	CBR	Tor-vane	Type Test $\bar{\sigma}_c$ or σ_c	Cc/ 1+eo	#
							D2216	D4318	D2974	D422		D854		D2434	D5084	D1557	D698	D1883		D2166/ D4767/ D2850	D2435	#
14	TTS - 1	TP	10 - 15							X												
15	TTS - 1		45-46.5							X	X											
16	TTS-2	TP	10 - 15							X												
17	TTS-2		21-21.5							X	X											
18	TTS-3		15-16.5							X	X											
19	TTS-4		15.5-16.5							X	X											

Notes: 4-28-17 @ 12:55 4/25/17 12:55 No 22.1

4/25/17 @ 1420 4/28/17 1659

1704794 4/28/17

SOILS LABORATORY TESTING ASSIGNMENT SHEET

THIELSCH ENGINEERING

401-467-6454

195 Frances Ave., Cranston, RI 02910

1704795

Project Name **Orleans - GWDP** | Client **Town of Orleans** | Assigned By **Mark Owen**

CTS Project No. **60476644.10.1.A** | Site Location **Overland Way** | Collected By **Mark Owen**

ESS Project No. | Date Assigned | Received By

Project Manager **T. Parece** | Date Received | Date Required **Norman**

	Sample Information						Identification Tests							Permeability		Compaction			Strength		Consol.	Notes
	Boring/ Test Pit No.	Sample No.	Depth Ft.	Sample Date	ESS SAMPLE ID	Lab No.	Water Cont. %	LL & PL %	Org. %	Sieve -200 %	Hyd -2μ %	G_s	γ_t pcf	Sand	Clay	Mod.	Std.	CBR	Tor-vane	Type Test $\bar{\sigma}_c$ or σ_c	Cc/ 1+eo	#
							D2216	D4318	D2974	D422		D854		D2434	D5084	D1557	D698	D1883		D2166/ D4767/ D2850	D2435	#
1	CLS - 1	70-72								X												
2	CLS - 1	86-88								X												
3	CLS - 1	95.5-96								X	X											
4	CLS - 1	108-110								X												
5	CLS - 2	21-24								X	X											
6	CLS - 2	64-66								X												
7	CLS - 2	74-76								X	X											
8	CLS - 2	80-82								X												
9	CLS-3	65-69								X												
10	CLS-3	73-77								X	X											
11	CLS-3	87-95								X												
12	CLS TP-3	15-~~Oct~~ 15	MA							X												
13	CLS-TP-7	10-15	MA							X												

Notes: 4-28-17 @ 12:55 4/25/17 12:55 No ICE 22.1

4/25/17 @ 1420 4/28/17 1659

1704795

SOILS LABORATORY TESTING ASSIGNMENT SHEET

THIELSCH ENGINEERING 401-467-6454 195 Frances Ave., Cranston, RI 02910

Project Name **Orleans - GWDP** | Client **Town of Orleans** | Assigned By **Mark Owen**

CTS Project No. **60476644.10.1.A** | Site Location **Overland Way** | Collected By **Mark Owen**

ESS Project No. | Date Assigned | Received By

Project Manager **T. Parece** | Date Received | Date Required **Norman**

	Sample Information						Identification Tests							Permeability		Compaction			Strength		Consol.	
	Boring/ Test Pit No.	Sample No.	Depth Ft.	Sample Date	ESS SAMPLE ID	Lab No.	Water Cont. %	LL & PL %	Org. %	Sieve -200 %	Hyd -2μ %	G_s	γ_t pcf	Sand	Clay	Mod.	Std.	CBR	Tor-vane	Type Test $\bar{\sigma}_c$ or σ_c	Cc/ 1+eo	Notes
							D2216	D4318	D2974	D422		D854		D2434	D5084	D1557	D698	D1883		D2166/ D4767/ D2850	D2435	#
14	TTS - 1	TP	10 - 15							X												
15	TTS - 1		45-46.5							X	X											
16	TTS-2	TP	10 - 15							X												
17	TTS-2		21-21.5							X	X											
18	TTS-3		15-16.5							X	X											
19	TTS-4		15.5-16.5							X	X											

Notes: 4-28-17 @ 12:55 4/25/17 12:55 No 22.1 ICS

4/25/17 @ 1420 4/28/17 1659

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Appendix E

Grain Size Analysis Report

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Hydraulic Conductivity Approximation
Orleans, MA

Summary of Equations:

Vukovic and Soro n=0.255*(1+0.83^u) U=(d60/d10)

$$n = 0.255\left(1 + 0.83^{U}\right)$$

Sheperds

$K_{sat} = b * (d_{50})^{c}$ b and c are read from Sheperds Chart

Hazen Ksat=c(d10)^2; c=1.0 to 1.5; d10 (mm)

$$K = \frac{g}{v} \times 6 \times 10^{-4}\left[1 + 10(n - 0.26)\right] d_{10}^{2}$$

Kozeny-Carman Ksat=g/viscosity*8.3*0.0018[n^3/(1-n)^2]*d10^2

$$K = \frac{g}{v} \times 8.3 \times 10^{-3}\left[\frac{n^{3}}{(1-n)^{2}}\right] d_{10}^{2}$$

Slitcher Ksat=g/viscosity*1*0.01*n^3.287*d10^2

$$K = \frac{g}{v} \times 1 \times 10^{-2}\, n^{3.287}\, d_{10}^{2}$$

g	9.81 m/s^2
viscosity	1.004E-06 m^2/s

Summary of Results

Most widely accepted, fine sand with d10 between 0.1 to 3mm

Wide range of application (see Sheperds Equation chart)

Uniformly graded sand and fine sand with d10 between 0.1 to 3mm, and U<5

Applicable for grain-size between 0.01mm and 5mm

Table 2
Summary of Aquifer Charactistics - Grain-size Analysis

Soil sample	*Depth (ft)*	*D10 (mm)*	*D50 (mm)*	*D60 (mm)*	*U(d60/d10)*	*n (porosity)*	*Classification*	*Fines(%)*	Kozeny-Carman Ksat (ft/day)	Sheperds Ksat (ft/day)	Hazen Ksat (ft/day)	Slitcher Ksat (ft/day)	Sample Average (FT/day)
TTS-1-TP 10-15	10-15.0	0.0963	0.2044	0.2319	2.41	0.42	Poorly graded SAND with Silt	0.06	45.83	34.00	39.71	14.57	**33.53**
TTS-1 45-46.5	45-46.5	0.0056	0.0823	0.1225	21.7	0.26	Silty SAND	0.47		7.58	0.05	0.01	**2.55**
TTS-2-TP 10-15	10-15.0	0.1632	0.5646	0.7039	4.31	0.37	Poorly graded SAND	0.04	77.44	181.76	92.58		**117.26**
TTS-2 21-21.5	21-21.5	0.0124	0.1754	0.2763	22.32	0.26	Silty SAND	0.33		26.41		0.05	**13.23**
TTS-3 15-16.5	15-16.5	0.0035	0.0168	0.021	5.91	0.34	SILT	0.98		0.55		0.01	**0.28**
TTS-4 15.5-16.5	15.5-16.5	0.0032	0.0798	0.1482	46.95	0.26	Silty SAND	0.49		7.20		0.00	**3.60**

Grain size outside the equation applicability range

Insufficient grain size data

Based on average K value for Silt

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Appendix F

Laboratory Reports – Groundwater Quality

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CERTIFICATE OF ANALYSIS

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

RE: Orleans MA (60476644 T10.1B)
ESS Laboratory Work Order Number: 1704795

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 12:03 pm, May 09, 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.

Subcontracted Analyses

CTS - Cranston, RI	Grain Size Analysis, Hydrometer Analyses

CERTIFICATE OF ANALYSIS

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

ESS Laboratory Work Order: 1704795

SAMPLE RECEIPT

The following samples were received on April 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
1704795-01	CLS-1 70-72	Soil	§
1704795-02	CLS-1 86-88	Soil	§
1704795-03	CLS-1 95.5-96	Soil	§
1704795-04	CLS-1 108-110	Soil	§
1704795-05	CLS-2 21-24	Soil	§
1704795-06	CLS-2 64.66	Soil	§
1704795-07	CLS-2 74-76	Soil	§
1704795-08	CLS-2 80-82	Soil	§
1704795-09	CLS-3 65-69	Soil	§
1704795-10	CLS-3 73-77	Soil	§
1704795-11	CLS-3 87-95	Soil	§
1704795-12	CLS TP-3 15-15	Soil	§
1704795-13	CLS TP-7 10-15	Soil	§
1704795-14	TTS-1-TP 10-15	Soil	§
1704795-15	TTS-1 45-46.5	Soil	§
1704795-16	TTS-2-TP 10-15	Soil	§
1704795-17	TTS-2 21-21.5	Soil	§
1704795-18	TTS-3 15-16.5	Soil	§
1704795-19	TTS-4 15.5-16.5	Soil	§

CERTIFICATE OF ANALYSIS

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

ESS Laboratory Work Order: 1704795

PROJECT NARRATIVE

No unusual observations noted.

End of Project Narrative.

DATA USABILITY LINKS

To ensure you are viewing the most current version of the documents below, please clear your internet cookies for www.ESSLaboratory.com. Consult your IT Support personnel for information on how to clear your internet cookies.

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: 1704795

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

ESS Laboratory Work Order: 1704795

Classical Chemistry

Client Sample ID: CLS-1 70-72
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-01
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS-1 86-88
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-02
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS-1 95.5-96
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-03
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

Client Sample ID: CLS-1 108-110
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-04
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS-2 21-24
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-05
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

CERTIFICATE OF ANALYSIS

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

ESS Laboratory Work Order: 1704795

Classical Chemistry

Client Sample ID: CLS-2 64.66
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-06
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS-2 74-76
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-07
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

Client Sample ID: CLS-2 80-82
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-08
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS-3 65-69
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-09
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS-3 73-77
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-10
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

CERTIFICATE OF ANALYSIS

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

ESS Laboratory Work Order: 1704795

Classical Chemistry

Client Sample ID: CLS-3 87-95
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-11
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS TP-3 15-15
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-12
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: CLS TP-7 10-15
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-13
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: TTS-1-TP 10-15
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-14
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: TTS-1 45-46.5
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-15
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

CERTIFICATE OF ANALYSIS

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

ESS Laboratory Work Order: 1704795

Classical Chemistry

Client Sample ID: TTS-2-TP 10-15
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-16
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						

Client Sample ID: TTS-2 21-21.5
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-17
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

Client Sample ID: TTS-3 15-16.5
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-18
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

Client Sample ID: TTS-4 15.5-16.5
Date Sampled: 04/28/17 00:00

ESS Laboratory Sample ID: 1704795-19
Sample Matrix: Soil

All methods used are in accordance with 40 CFR 136.

Analyte	Results	Units	MRL	Method	DF	Analyst	Analyzed
Grain Size	**See Attached**						
Hydrometer	**See Attached**						

CERTIFICATE OF ANALYSIS

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

ESS Laboratory Work Order: 1704795

Notes and Definitions

Z-08	See Attached
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: 1704795

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

LABORATORY TESTING DATA SHEET (1 of 2)

Project Name **Orleans - GWDP** Location Overland Way, MA Reviewed By

Project No. **1704795** Assigned By T. Parece

Project Manager T. Parece Report Date 05.08.17 Date Reviewed *05.08.17*

Boring/ Test Pit No.	Sample No.	Depth ft.	Lab No.	Identification Tests						Corrosivity					Laboratory Log and Soil Description
				Water Content %	LL %	PL %	Gravel %	Sand %	Fines (<#200) %	pH	Sulfate (mg/kg)	Chloride (mg/kg)	Resistivity (Mohms-cm)	GTL Resist	
CLS-1		70-72	17-S-560				0.1	98.0	1.9						Light Brown-White poorly graded sand
CLS-1		86-88	17-S-561				0.0	97.3	2.7						Brown poorly graded sand
CLS-1		95.5-96	17-S-562				0.0	56.4	43.6						Brown silty sand
CLS-1		108-110	17-S-563				0.0	94.3	5.7						Brown poorly graded sand with silt
CLS-2		21-24	17-S-564				0.0	4.4	95.6						Light Brown silt
CLS-2		64-66	17-S-565				0.0	53.0	47.0						Light White-Brown silty sand
CLS-2		74-76	17-S-566				0.0	41.8	58.2						Light Brown sandy silt
CLS-2		80-82	17-S-567				0.0	89.0	11.0						Light Brown poorly graded sand with silt
CLS-3		65-69	17-S-568				0.0	85.6	14.4						Strong Brown silty sand
CLS-3		73-77	17-S-569				0.0	57.3	42.7						Brown silty sand
CLS-3		87-95	17-S-570				0.0	89.6	10.4						Brown poorly graded sand with silt
CLS TP-3		15-15	17-S-571				2.0	96.1	1.9						Red-Brown poorly graded sand

THIELSCH ENGINEERING
195 Frances Avenue
Cranston, RI 02910 401-467-6454

LABORATORY TESTING DATA SHEET (2 of 2)

Project Name **Orleans - GWDP** Location Overland Way, MA Reviewed By

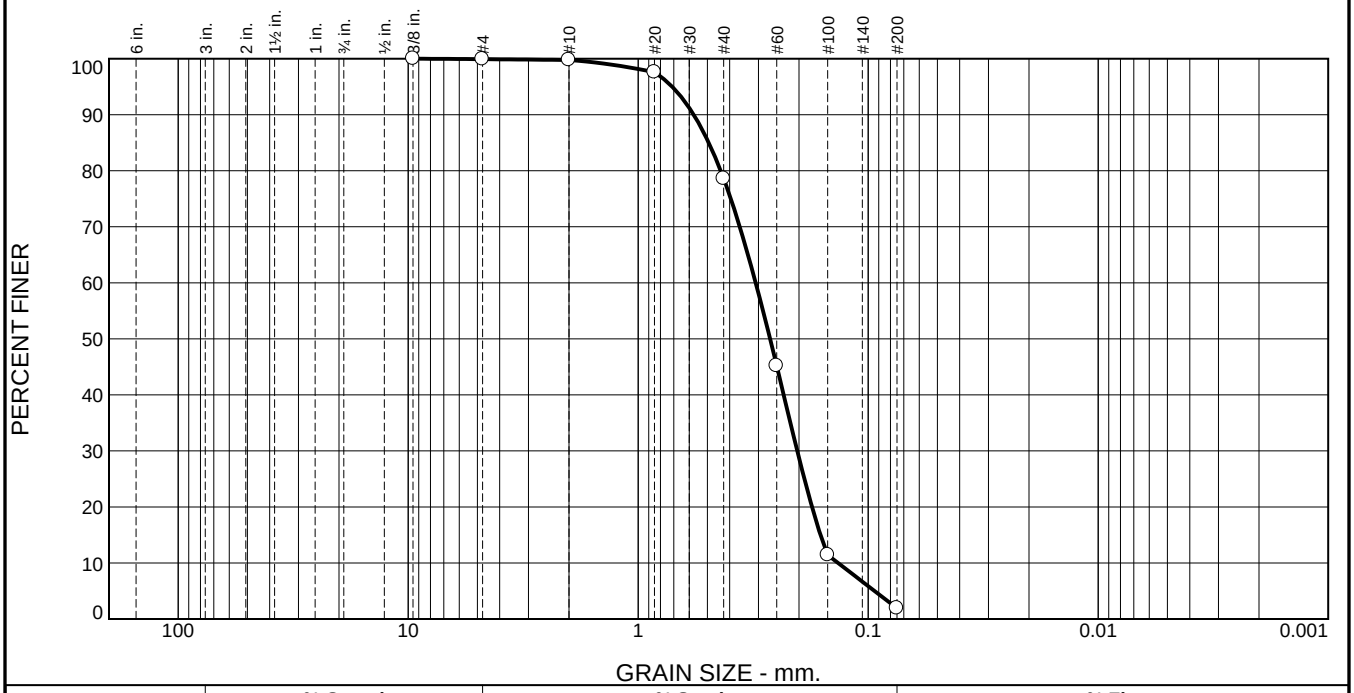
Project No. **1704795** Assigned By T. Parece

Project Manager T. Parece Report Date 05.08.17 Date Reviewed *05.08.17*

Boring/ Test Pit No.	Sample No.	Depth ft.	Lab No.	Identification Tests						Corrosivity					Laboratory Log and Soil Description
				Water Content %	LL %	PL %	Gravel %	Sand %	Fines (<#200) %	pH	Sulfate (mg/kg)	Chloride (mg/kg)	Resistivity (Mohms-cm)	GTL Resist	
CLS-TP-7		10-15	17-S-572				3.3	92.6	4.1						Brown poorly graded sand
TTS-1-TP		10-15	17-S-573				0.1	94.1	5.8						Red-Brown poorly graded sand with silt
TTS-1		45-46.5	17-S-574				0.0	53.0	47.0						Brown silty sand
TTS-2-TP		10-15	17-S-575				14.1	81.8	4.1						Light Brown poorly graded sand
TTS-2		21-21.5	17-S-576				0.0	66.9	33.1						Brown silty sand
TTS-3		15-16.5	17-S-577				0.0	2.5	97.5						Brown silt
TTS-4		15.5-16.5	17-S-578				0.0	51.2	48.8						Brown silty sand

THIELSCH ENGINEERING
195 Frances Avenue
Cranston, RI 02910 401-467-6454

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.1	0.1	21.2	76.7	1.9	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
.375	100.0		
#4	99.9		
#10	99.8		
#20	97.6		
#40	78.6		
#60	45.2		
#100	11.4		
#200	1.9		

* (no specification provided)

Material Description

Light Brown-White poorly graded sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** A-3

Coefficients

D_{90}= 0.5736 D_{85}= 0.4934 D_{60}= 0.3084
D_{50}= 0.2670 D_{30}= 0.2035 D_{15}= 0.1612
D_{10}= 0.1351 C_u= 2.28 C_c= 0.99

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 70-72' **Date Sampled:**

Sample Number: CLS-1

Thielsch Engineering Inc.

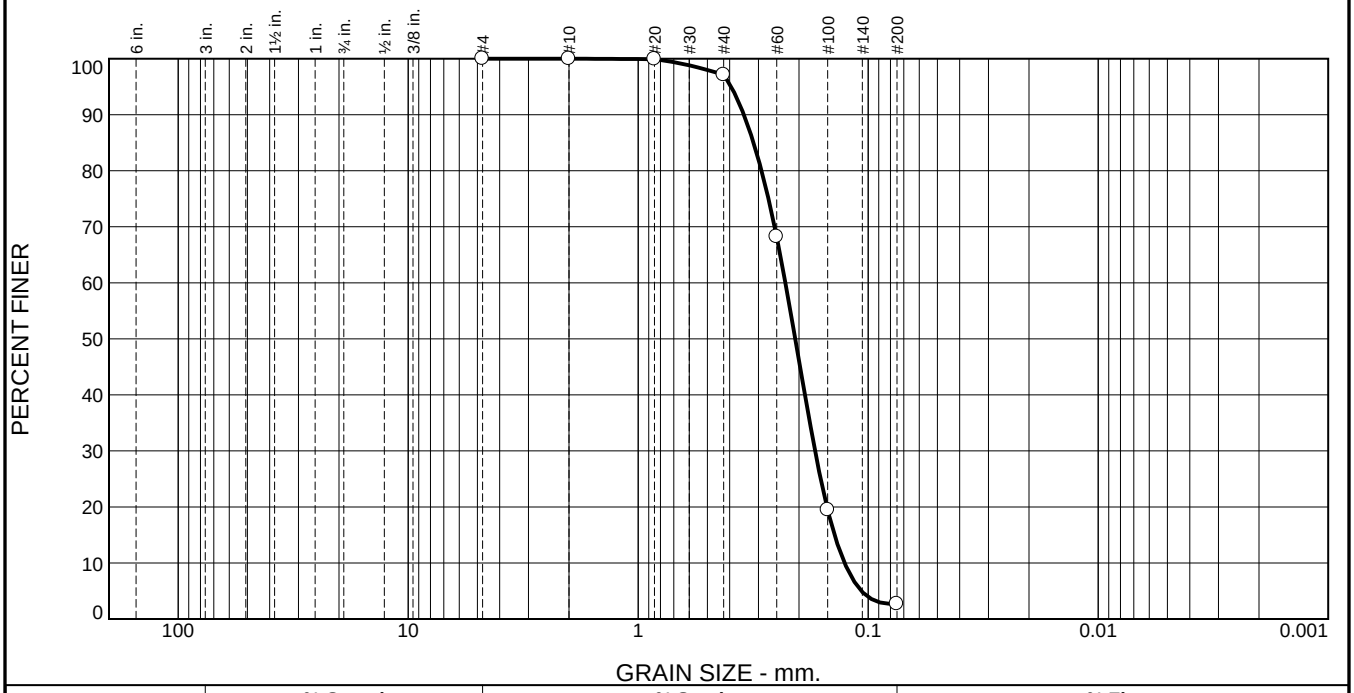
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-560

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	2.9	94.4	2.7	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	100.0		
#20	99.9		
#40	97.1		
#60	68.2		
#100	19.5		
#200	2.7		

* (no specification provided)

Material Description

Brown poorly graded sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** A-3

Coefficients

D_{90}= 0.3470 D_{85}= 0.3150 D_{60}= 0.2291
D_{50}= 0.2076 D_{30}= 0.1701 D_{15}= 0.1401
D_{10}= 0.1267 C_u= 1.81 C_c= 1.00

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 86-88' **Date Sampled:**

Sample Number: CLS-1

Thielsch Engineering Inc.

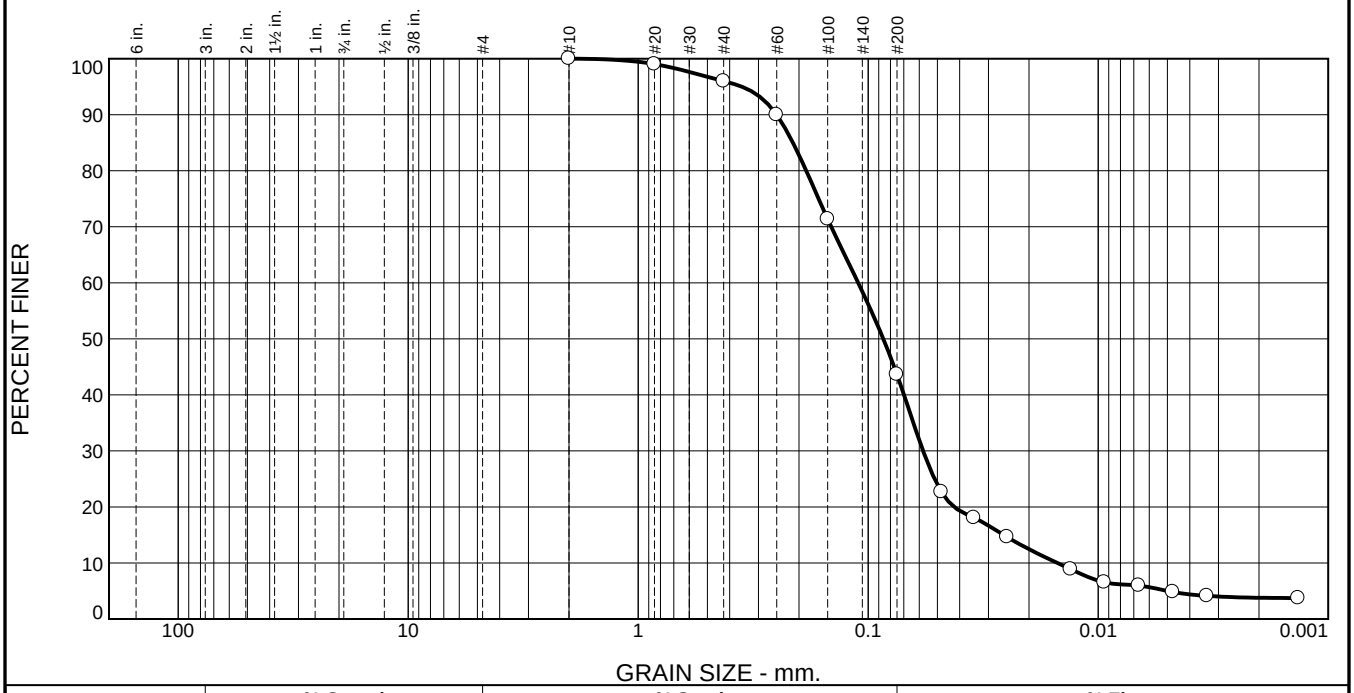
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-561

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	4.0	52.4	39.8	3.8

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#10	100.0		
#20	99.0		
#40	96.0		
#60	90.0		
#100	71.4		
#200	43.6		
0.0481 mm.	22.7		
0.0347 mm.	18.1		
0.0249 mm.	14.6		
0.0132 mm.	8.9		
0.0094 mm.	6.5		
0.0067 mm.	6.0		
0.0047 mm.	4.8		
0.0034 mm.	4.1		
0.0013 mm.	3.7		

* (no specification provided)

Material Description

Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.2502 D_{85}= 0.2124 D_{60}= 0.1106
D_{50}= 0.0860 D_{30}= 0.0577 D_{15}= 0.0257
D_{10}= 0.0150 C_u= 7.35 C_c= 2.00

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 95.5-96' **Date Sampled:**

Sample Number: CLS-1

Thielsch Engineering Inc.

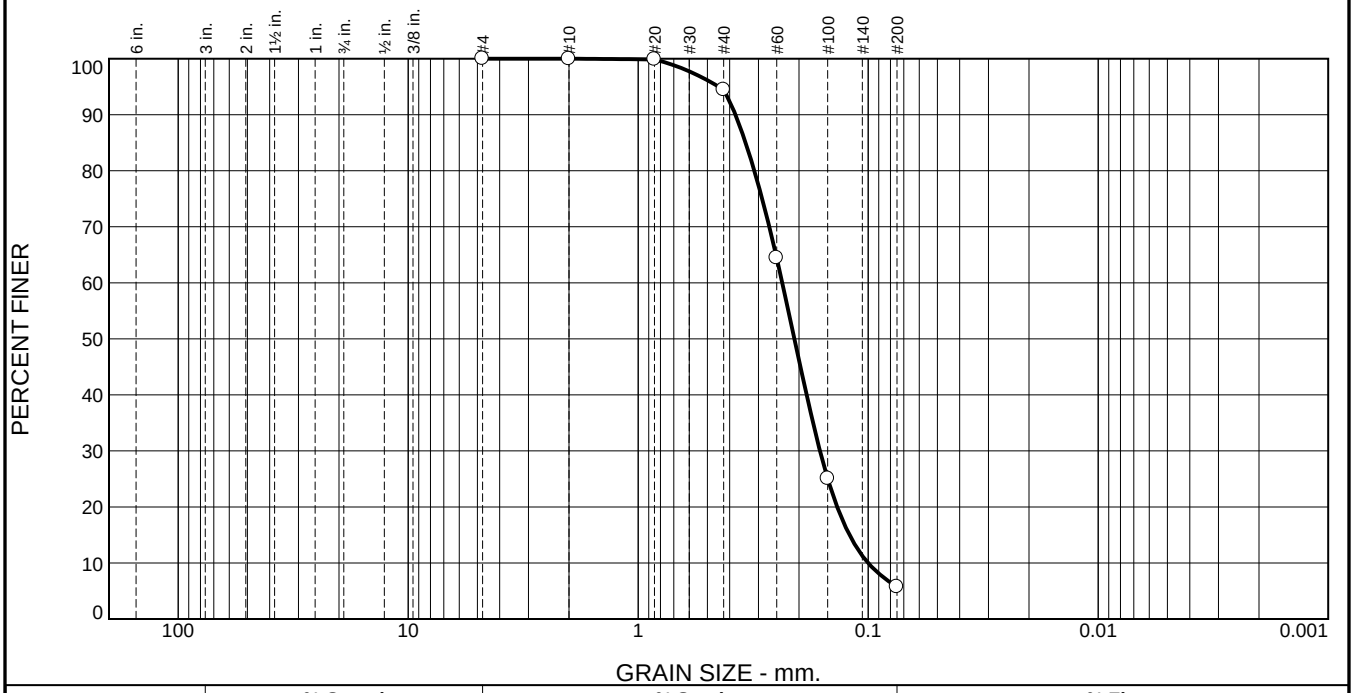
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-562

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	5.5	88.8	5.7	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	100.0		
#20	99.9		
#40	94.5		
#60	64.4		
#100	25.0		
#200	5.7		

* (no specification provided)

Material Description

Brown poorly graded sand with silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP-SM **AASHTO (M 145)=** A-3

Coefficients

D_{90}= 0.3778 D_{85}= 0.3410 D_{60}= 0.2364
D_{50}= 0.2093 D_{30}= 0.1620 D_{15}= 0.1206
D_{10}= 0.1001 C_u= 2.36 C_c= 1.11

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 108-110' **Date Sampled:**

Sample Number: CLS-1

Thielsch Engineering Inc.

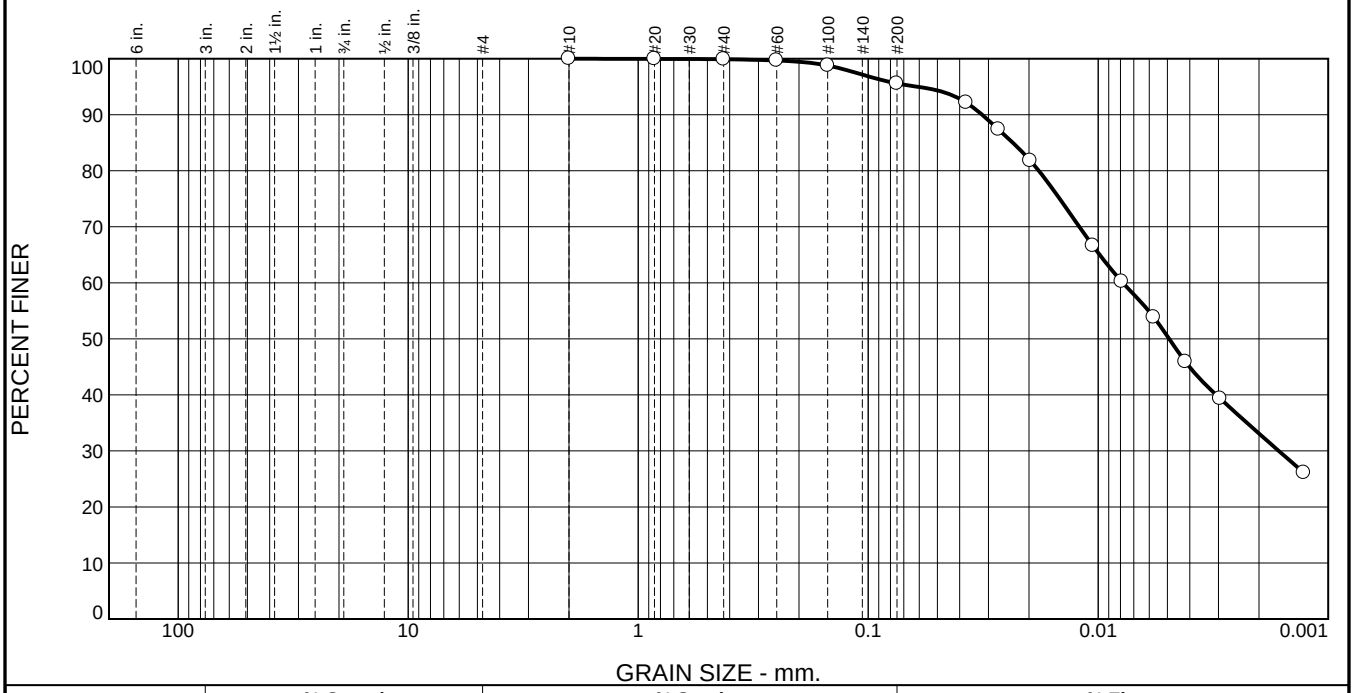
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-563

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.1	4.3	62.5	33.1

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#10	100.0		
#20	100.0		
#40	99.9		
#60	99.7		
#100	98.8		
#200	95.6		
0.0375 mm.	92.2		
0.0272 mm.	87.4		
0.0197 mm.	81.8		
0.0106 mm.	66.6		
0.0079 mm.	60.3		
0.0057 mm.	53.9		
0.0042 mm.	45.9		
0.0030 mm.	39.4		
0.0013 mm.	26.1		

* (no specification provided)

Material Description

Light Brown silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= ML **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.0320 D_{85}= 0.0235 D_{60}= 0.0078
D_{50}= 0.0049 D_{30}= 0.0016 D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 21-24' **Date Sampled:**

Sample Number: CLS-2

Thielsch Engineering Inc.

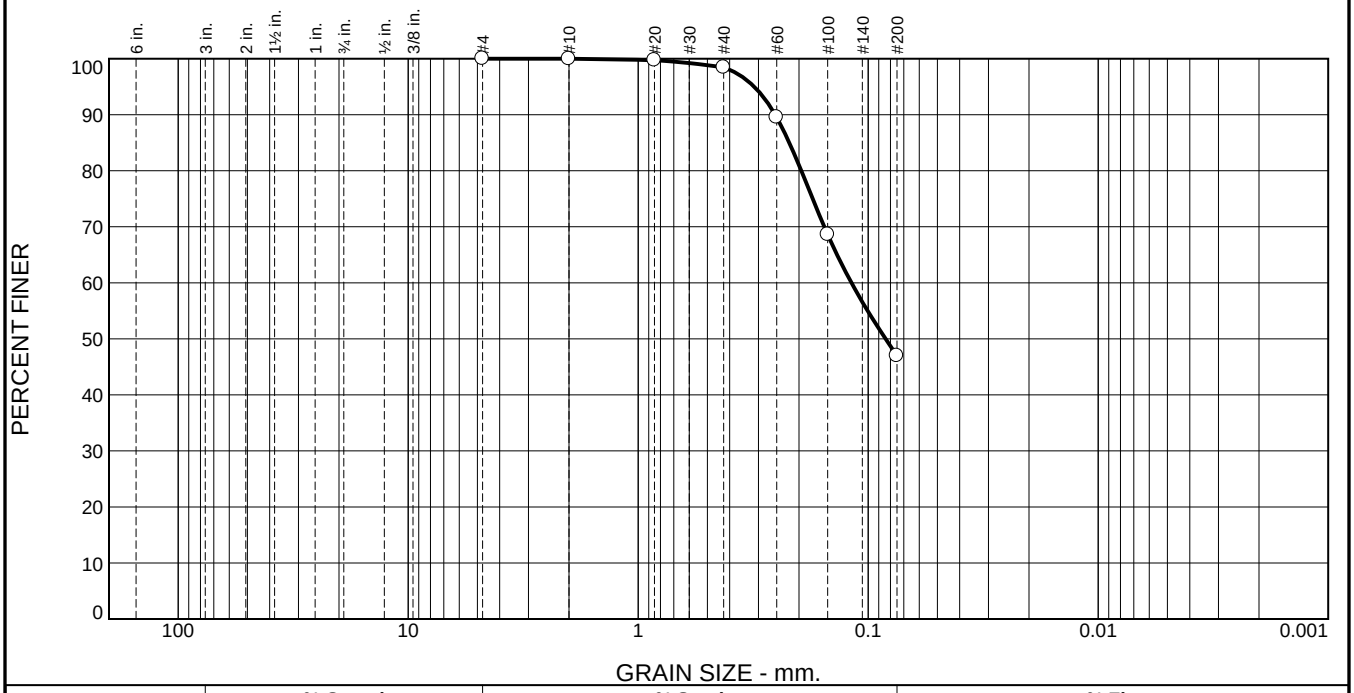
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-564

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	1.5	51.5	47.0	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	100.0		
#20	99.7		
#40	98.5		
#60	89.5		
#100	68.6		
#200	47.0		

* (no specification provided)

Material Description

Light White-Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.2537 D_{85}= 0.2203 D_{60}= 0.1183
D_{50}= 0.0840 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 64-66' **Date Sampled:**

Sample Number: CLS-2

Thielsch Engineering Inc.

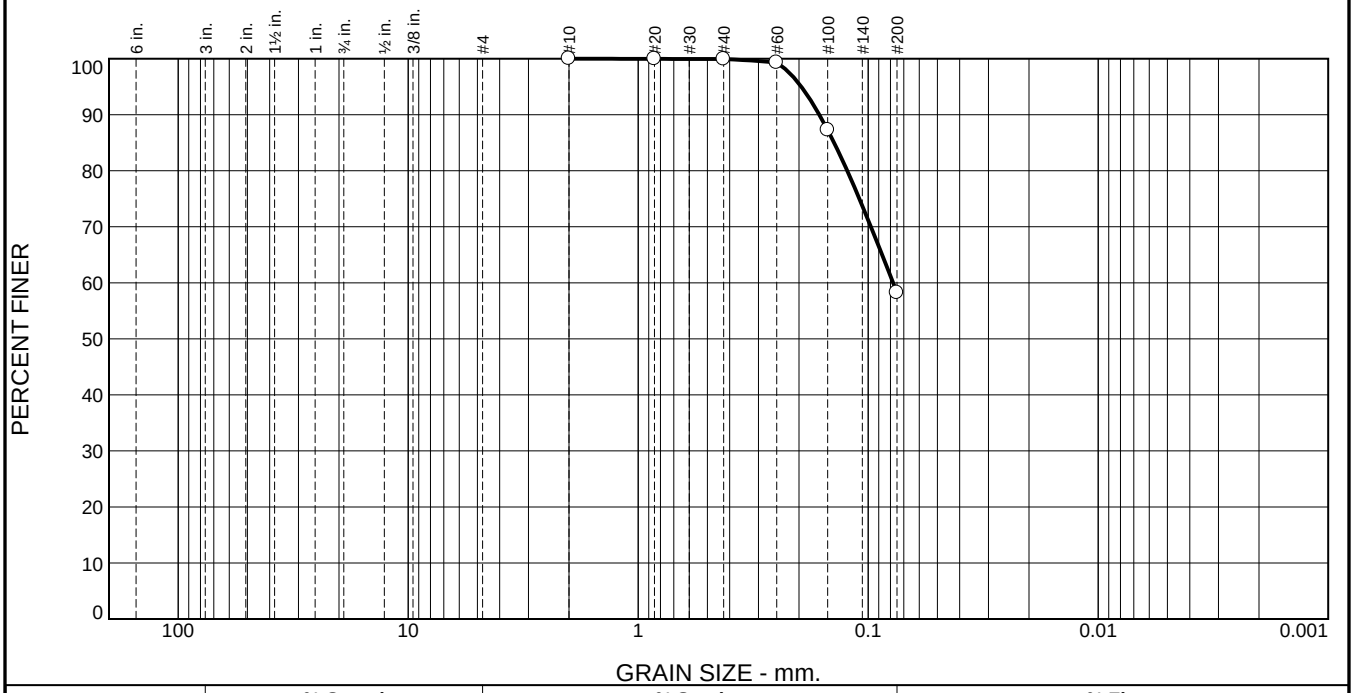
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-565

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.1	41.7	58.2	

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#10	100.0		
#20	100.0		
#40	99.9		
#60	99.3		
#100	87.3		
#200	58.2		

* (no specification provided)

Material Description

Light Brown sandy silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= ML **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.1630 D_{85}= 0.1407 D_{60}= 0.0779
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 74-76' **Date Sampled:**

Sample Number: CLS-2

Thielsch Engineering Inc.

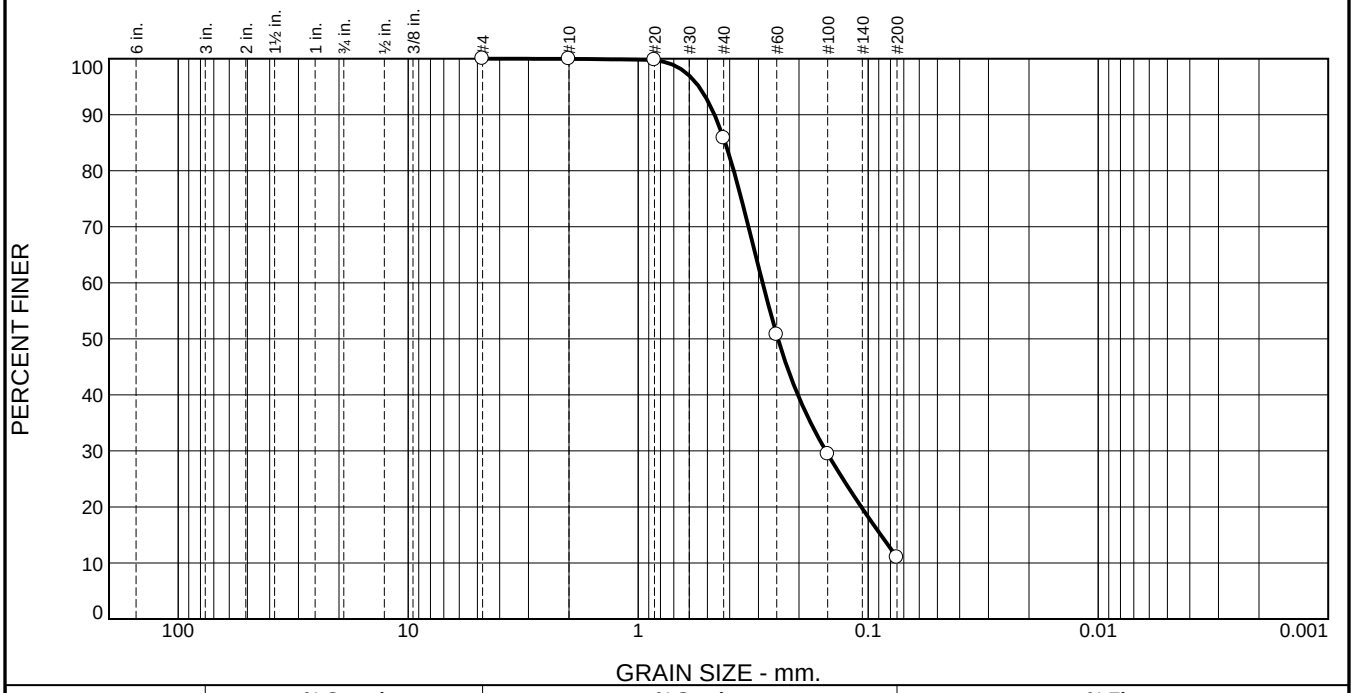
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-566

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	14.2	74.8	11.0	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	100.0		
#20	99.8		
#40	85.8		
#60	50.7		
#100	29.5		
#200	11.0		

* (no specification provided)

Material Description

Light Brown poorly graded sand with silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP-SM **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 0.4656 D_{85}= 0.4184 D_{60}= 0.2878
D_{50}= 0.2469 D_{30}= 0.1527 D_{15}= 0.0881
D_{10}= C_u= C_c=

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 80-82' **Date Sampled:**

Sample Number: CLS-2

Thielsch Engineering Inc.

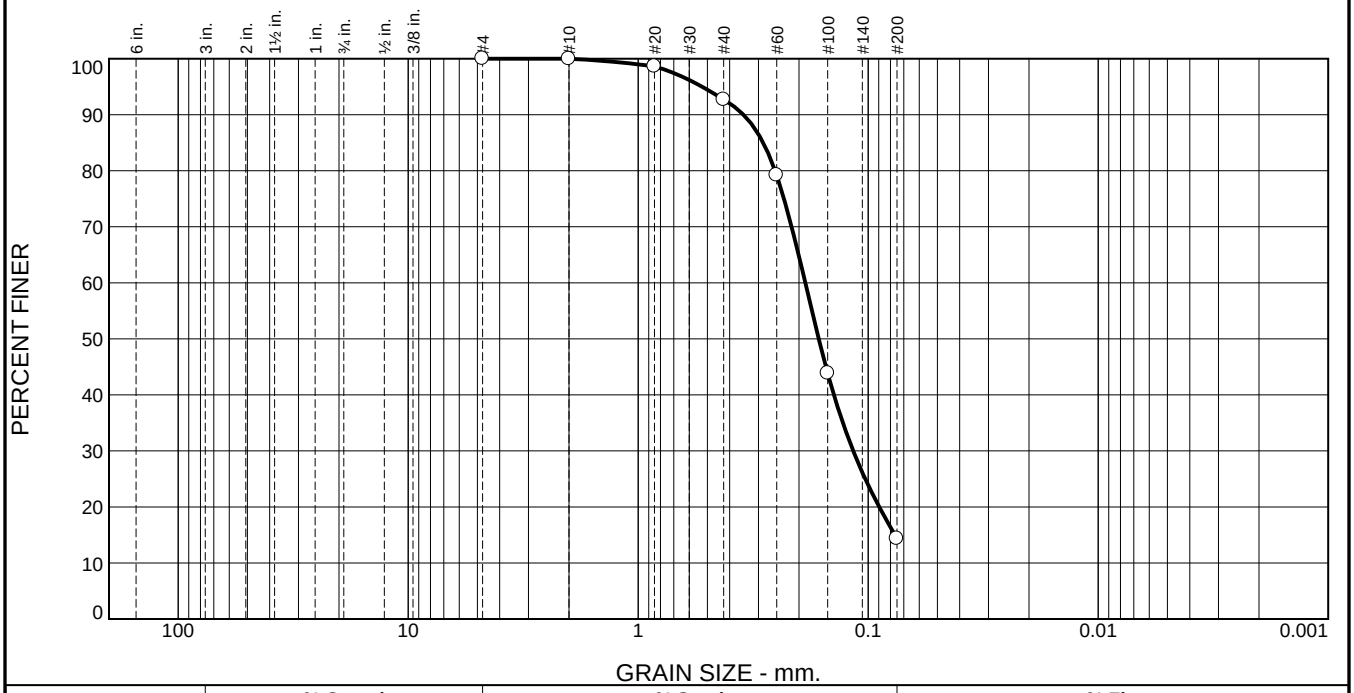
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-567

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	7.3	78.3	14.4	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	100.0		
#20	98.6		
#40	92.7		
#60	79.2		
#100	43.9		
#200	14.4		

* (no specification provided)

Material Description

Strong Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 0.3484 D_{85}= 0.2860 D_{60}= 0.1876
D_{50}= 0.1640 D_{30}= 0.1162 D_{15}= 0.0766
D_{10}= C_u= C_c=

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 65-69' **Date Sampled:**

Sample Number: CLS-3

Thielsch Engineering Inc.

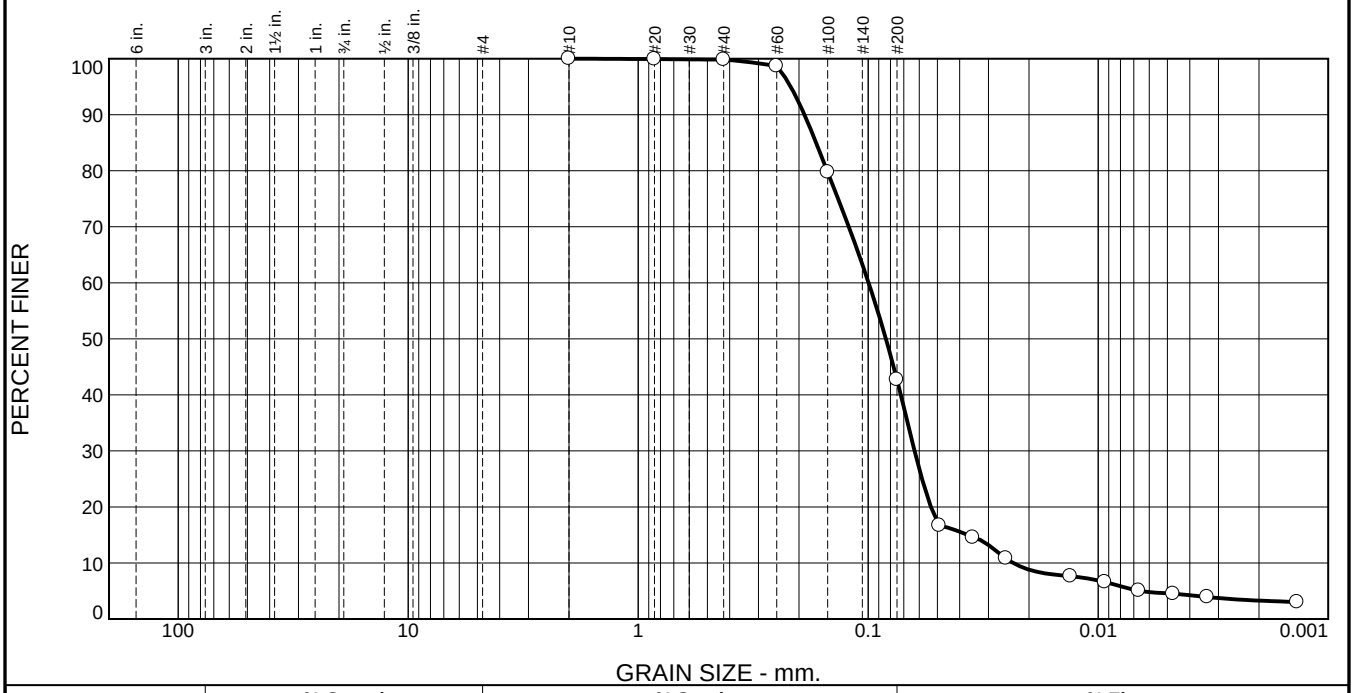
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-568

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.2	57.1	39.4	3.3

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#10	100.0		
#20	99.9		
#40	99.8		
#60	98.7		
#100	79.7		
#200	42.7		
0.0491 mm.	16.7		
0.0351 mm.	14.6		
0.0252 mm.	10.8		
0.0132 mm.	7.6		
0.0094 mm.	6.6		
0.0067 mm.	5.1		
0.0047 mm.	4.5		
0.0034 mm.	3.9		
0.0014 mm.	3.0		

* (no specification provided)

Material Description

Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.1894 D_{85}= 0.1685 D_{60}= 0.0996
D_{50}= 0.0837 D_{30}= 0.0628 D_{15}= 0.0370
D_{10}= 0.0234 C_u= 4.25 C_c= 1.69

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 73-77' **Date Sampled:**

Sample Number: CLS-3

Thielsch Engineering Inc.

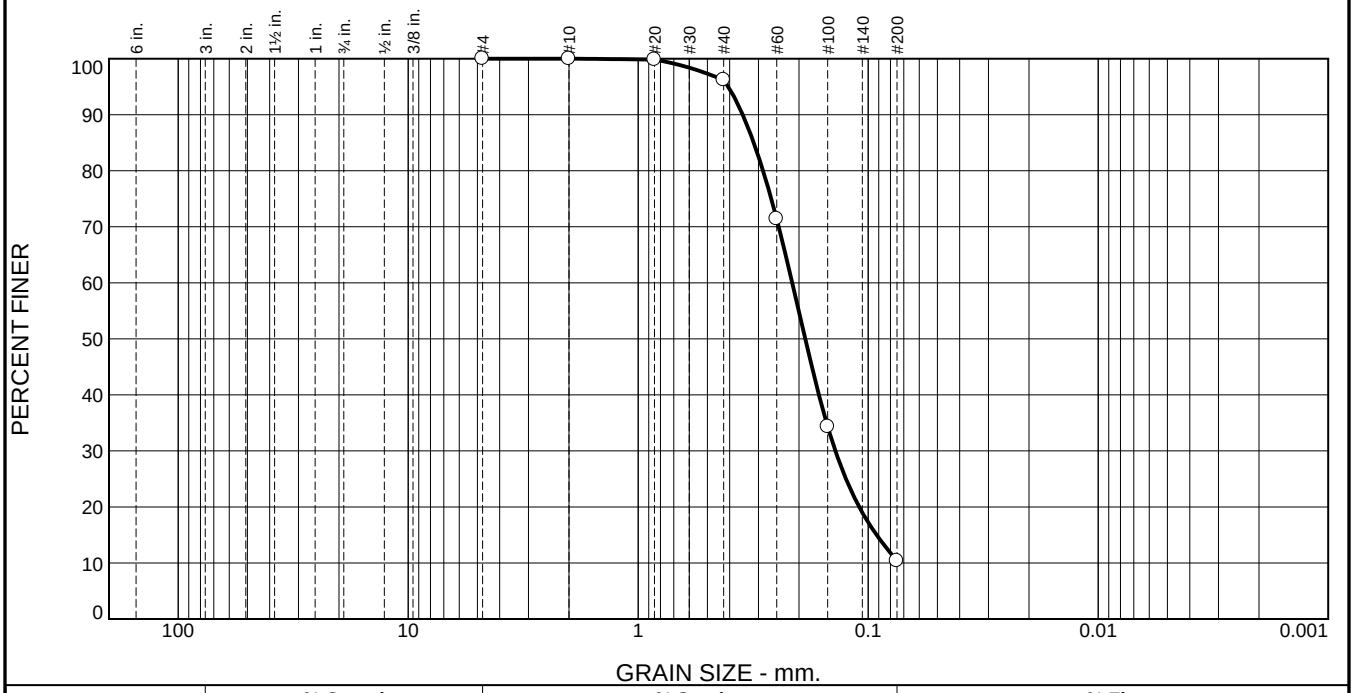
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-569

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	3.8	85.8	10.4	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	100.0		
#20	99.8		
#40	96.2		
#60	71.4		
#100	34.3		
#200	10.4		

* (no specification provided)

Material Description

Brown poorly graded sand with silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP-SM **AASHTO (M 145)=** A-3

Coefficients

D_{90}= 0.3511 D_{85}= 0.3144 D_{60}= 0.2139
D_{50}= 0.1878 D_{30}= 0.1389 D_{15}= 0.0919
D_{10}= C_u= C_c=

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 87-95' **Date Sampled:**

Sample Number: CLS-3

Thielsch Engineering Inc.

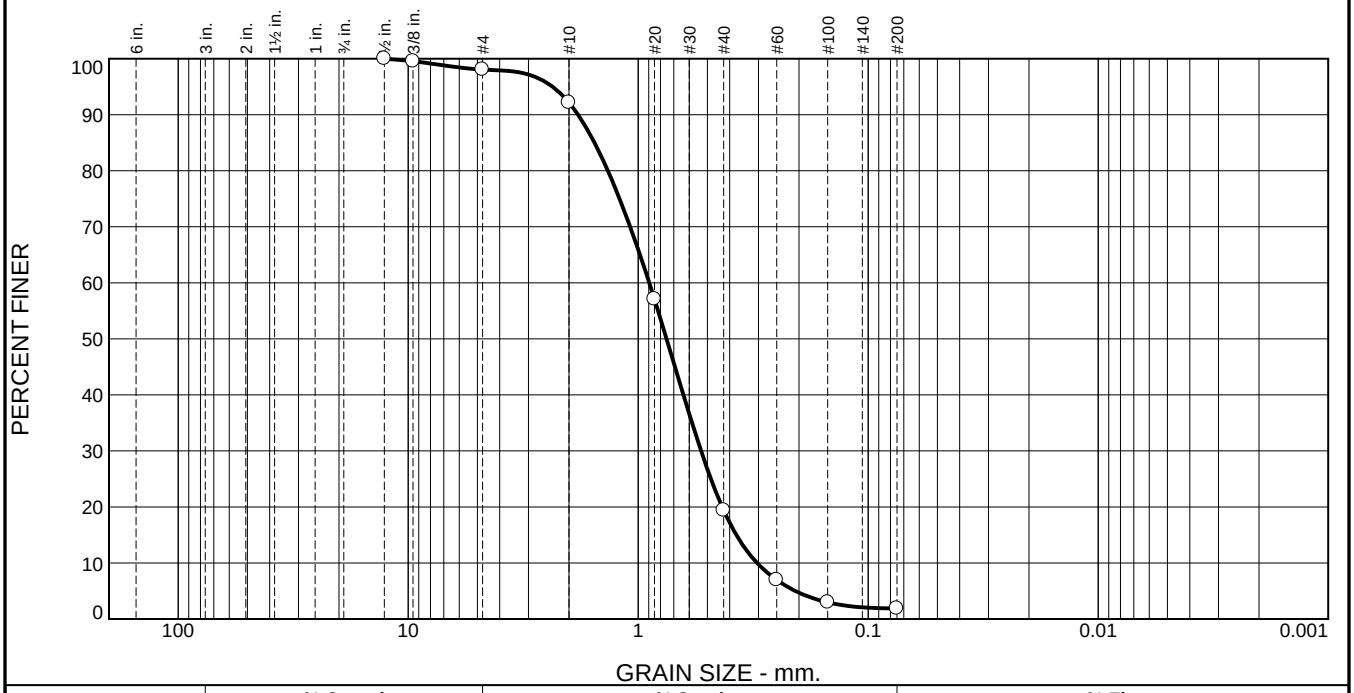
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-570

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	2.0	5.8	72.8	17.5	1.9	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
0.5	100.0		
0.375	99.5		
#4	98.0		
#10	92.2		
#20	57.1		
#40	19.4		
#60	7.0		
#100	3.0		
#200	1.9		

* (no specification provided)

Material Description

Red-Brown poorly graded sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= 1.8256 D_{85}= 1.5482 D_{60}= 0.8950
D_{50}= 0.7526 D_{30}= 0.5327 D_{15}= 0.3744
D_{10}= 0.3043 C_u= 2.94 C_c= 1.04

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 15-15' **Date Sampled:**

Sample Number: CLS-TP-3

Thielsch Engineering Inc.

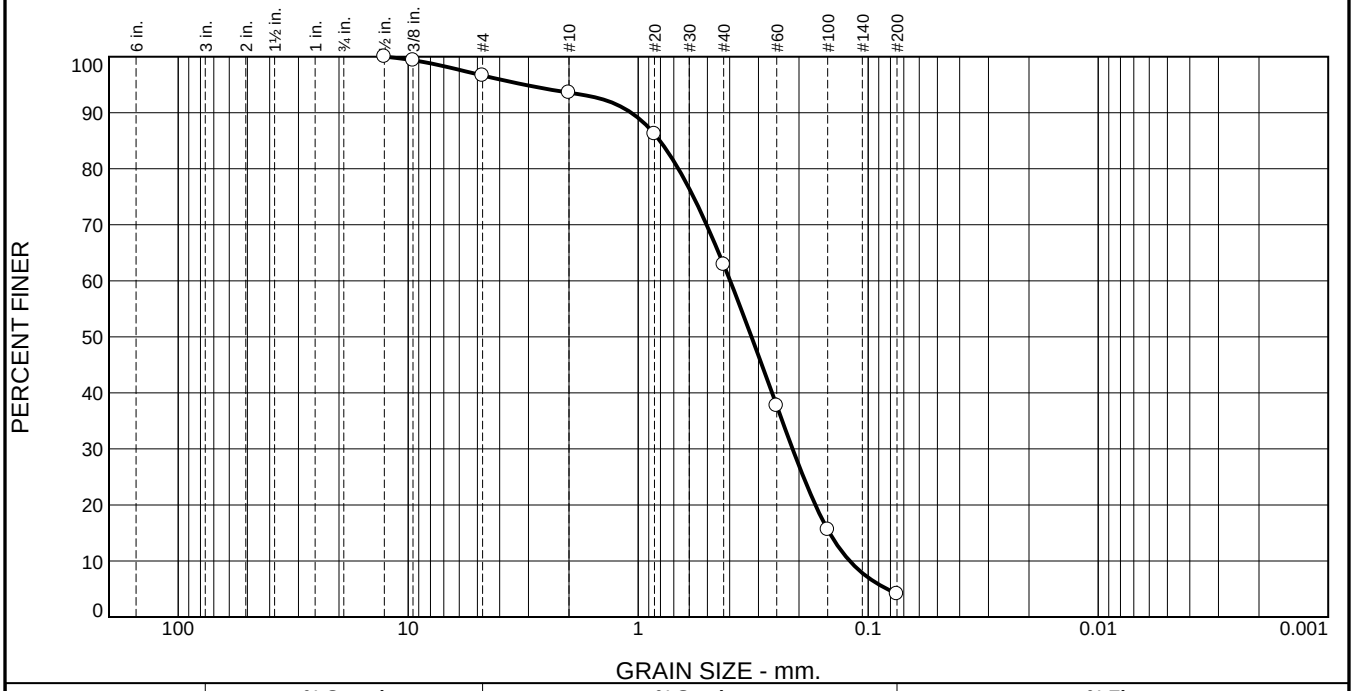
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-571

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	3.3	3.1	30.7	58.8	4.1	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
0.5	100.0		
0.375	99.4		
#4	96.7		
#10	93.6		
#20	86.2		
#40	62.9		
#60	37.7		
#100	15.6		
#200	4.1		

* (no specification provided)

Material Description

Brown poorly graded sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** A-3

Coefficients

D_{90}= 1.0713 D_{85}= 0.8044 D_{60}= 0.3983
D_{50}= 0.3214 D_{30}= 0.2132 D_{15}= 0.1472
D_{10}= 0.1203 C_u= 3.31 C_c= 0.95

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 10-15' **Date Sampled:**

Sample Number: CLS-TP-7

Thielsch Engineering Inc.

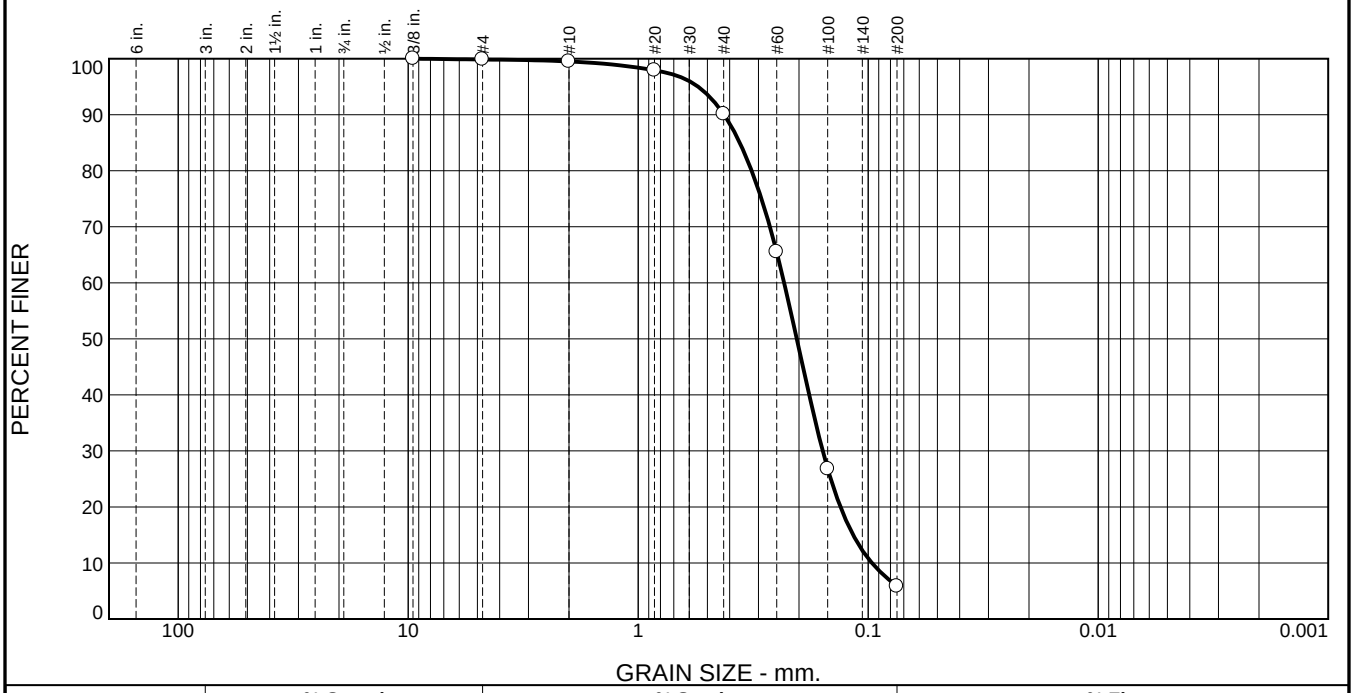
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-572

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.1	0.4	9.4	84.3	5.8	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
0.375	100.0		
#4	99.9		
#10	99.5		
#20	97.9		
#40	90.1		
#60	65.5		
#100	26.8		
#200	5.8		

* (no specification provided)

Material Description

Red-Brown poorly graded sand with silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP-SM **AASHTO (M 145)=** A-3

Coefficients

D_{90}= 0.4233 D_{85}= 0.3617 D_{60}= 0.2319
D_{50}= 0.2044 D_{30}= 0.1576 D_{15}= 0.1163
D_{10}= 0.0963 C_u= 2.41 C_c= 1.11

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 10-15' **Date Sampled:**

Sample Number: TTS-1-TP

Thielsch Engineering Inc.

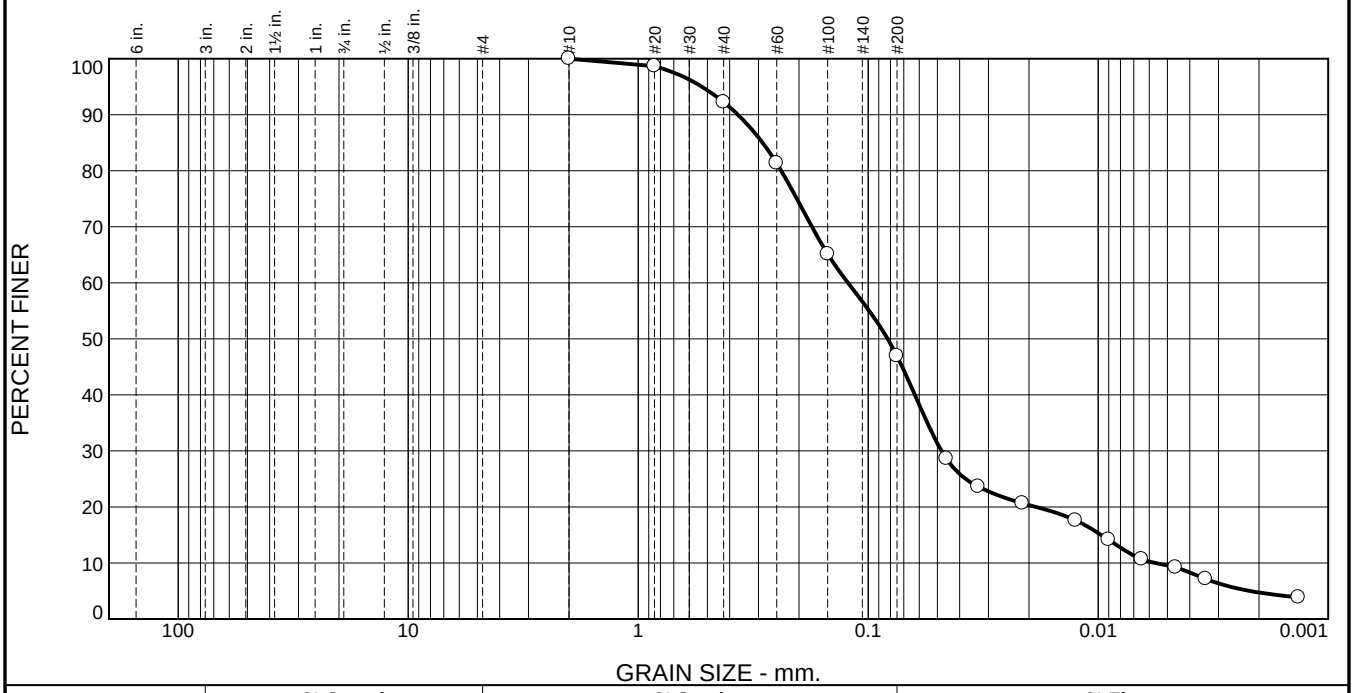
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-573

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	7.8	45.2	42.3	4.7

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#10	100.0		
#20	98.7		
#40	92.2		
#60	81.3		
#100	65.1		
#200	47.0		
0.0457 mm.	28.6		
0.0332 mm.	23.6		
0.0214 mm.	20.7		
0.0126 mm.	17.6		
0.0090 mm.	14.2		
0.0065 mm.	10.7		
0.0046 mm.	9.2		
0.0034 mm.	7.2		
0.0013 mm.	3.9		

* (no specification provided)

Material Description

Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.3684 D_{85}= 0.2876 D_{60}= 0.1225
D_{50}= 0.0823 D_{30}= 0.0480 D_{15}= 0.0097
D_{10}= 0.0056 C_u= 21.70 C_c= 3.33

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 45.46.5' **Date Sampled:**

Sample Number: TTS-1

Thielsch Engineering Inc.

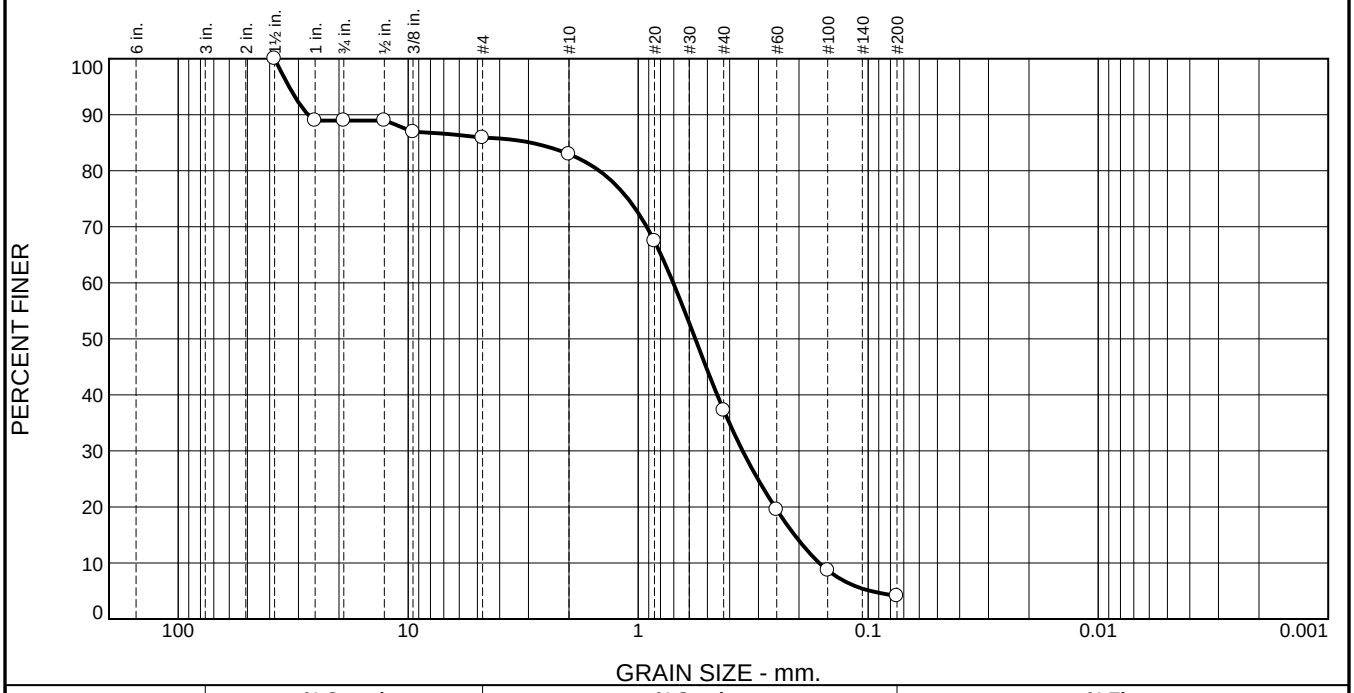
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-574

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	11.0	3.1	2.9	45.7	33.2	4.1	

TEST RESULTS (D6913)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1.5	100.0		
1	89.0		
.75	89.0		
0.5	89.0		
.375	86.9		
#4	85.9		
#10	83.0		
#20	67.5		
#40	37.3		
#60	19.5		
#100	8.7		
#200	4.1		

* (no specification provided)

Material Description

Light Brown poorly graded sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= 27.2477 D_{85}= 2.9193 D_{60}= 0.7039
D_{50}= 0.5646 D_{30}= 0.3514 D_{15}= 0.2091
D_{10}= 0.1632 C_u= 4.31 C_c= 1.07

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: JL

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 10-15' **Date Sampled:**

Sample Number: TTS-2-TP

Thielsch Engineering Inc.

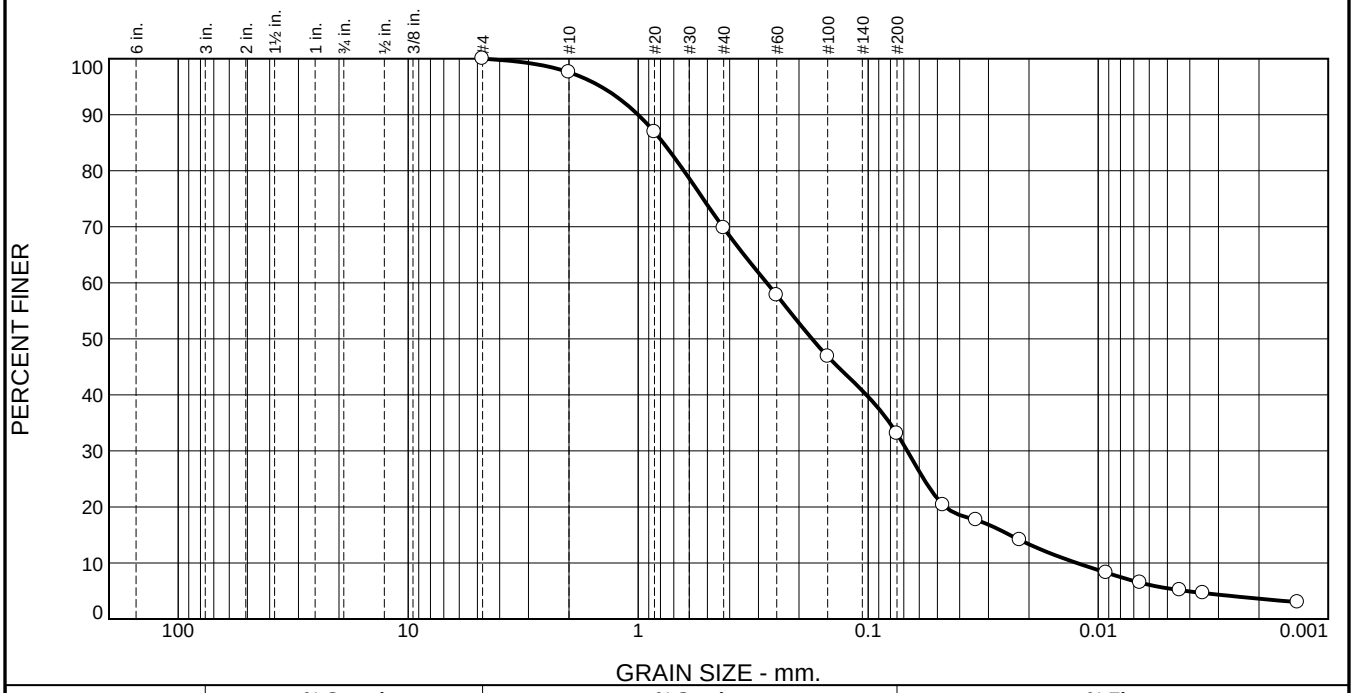
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-575

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	2.4	27.8	36.7	29.5	3.6

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	97.6		
#20	86.9		
#40	69.8		
#60	57.8		
#100	46.9		
#200	33.1		
0.0473 mm.	20.4		
0.0339 mm.	17.7		
0.0219 mm.	14.1		
0.0092 mm.	8.3		
0.0066 mm.	6.5		
0.0044 mm.	5.2		
0.0035 mm.	4.6		
0.0014 mm.	3.0		

* (no specification provided)

Material Description

Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 1.0006 D_{85}= 0.7782 D_{60}= 0.2763
D_{50}= 0.1754 D_{30}= 0.0676 D_{15}= 0.0242
D_{10}= 0.0124 C_u= 22.32 C_c= 1.33

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 21-21.5' **Date Sampled:**

Sample Number: TTS-2

Thielsch Engineering Inc.

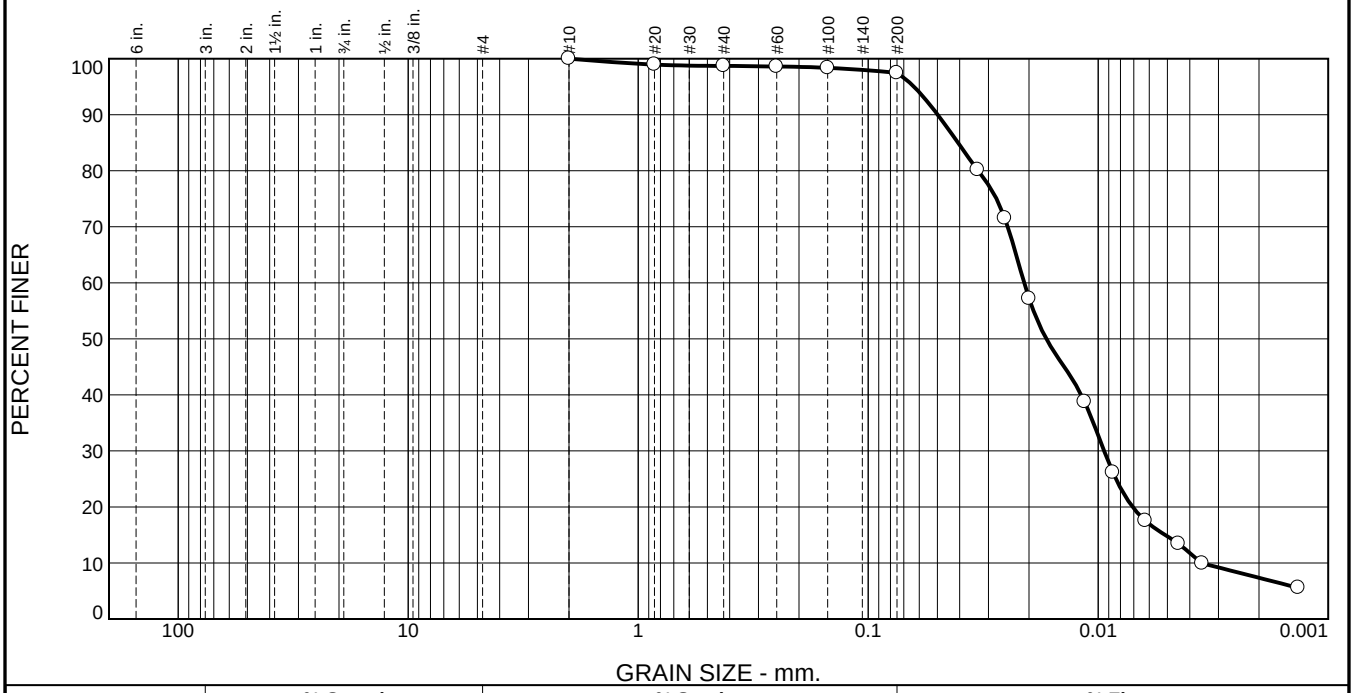
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-576

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	1.3	1.2	90.1	7.4

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#10	100.0		
#20	99.0		
#40	98.7		
#60	98.6		
#100	98.4		
#200	97.5		
0.0335 mm.	80.2		
0.0255 mm.	71.5		
0.0200 mm.	57.2		
0.0115 mm.	38.8		
0.0086 mm.	26.1		
0.0062 mm.	17.5		
0.0045 mm.	13.4		
0.0035 mm.	9.9		
0.0014 mm.	5.6		

* (no specification provided)

Material Description

Brown silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= ML **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.0499 D_{85}= 0.0407 D_{60}= 0.0210
D_{50}= 0.0168 D_{30}= 0.0094 D_{15}= 0.0051
D_{10}= 0.0035 C_u= 5.91 C_c= 1.19

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 15-16.5' **Date Sampled:**

Sample Number: TTS-3

Thielsch Engineering Inc.

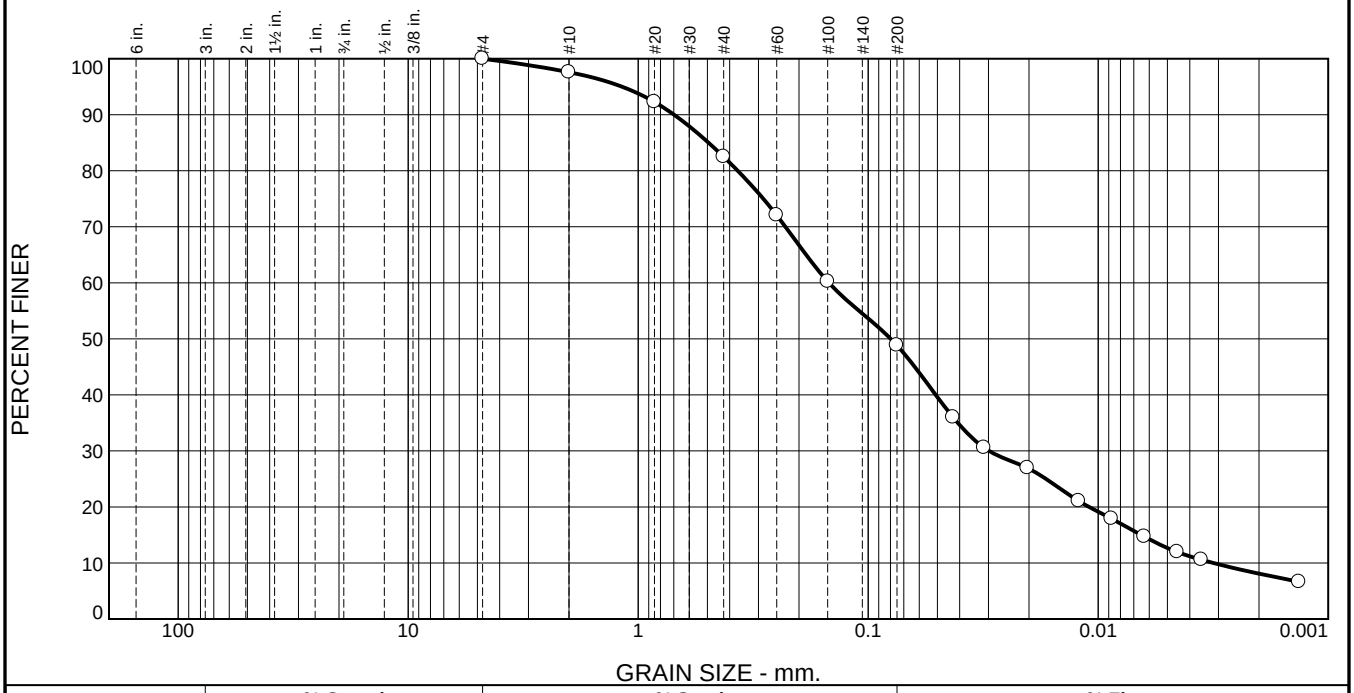
Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-577

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	2.4	15.1	33.7	40.7	8.1

TEST RESULTS (D7928)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
#4	100.0		
#10	97.6		
#20	92.3		
#40	82.5		
#60	72.1		
#100	60.2		
#200	48.8		
0.0427 mm.	36.0		
0.0314 mm.	30.6		
0.0203 mm.	27.0		
0.0122 mm.	21.1		
0.0088 mm.	17.9		
0.0063 mm.	14.7		
0.0045 mm.	12.0		
0.0036 mm.	10.6		
0.0013 mm.	6.7		

* (no specification provided)

Material Description

Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.6980 D_{85}= 0.4944 D_{60}= 0.1482
D_{50}= 0.0798 D_{30}= 0.0298 D_{15}= 0.0065
D_{10}= 0.0032 C_u= 46.95 C_c= 1.90

Remarks

Date Received: 05.01.17 **Date Tested:** 05.02.17

Tested By: IA

Checked By: Matthew Colman, P.E.

Title: Laboratory Manager

Source of Sample: Composite **Depth:** 15.5-16.5' **Date Sampled:**

Sample Number: TTS-4

Thielsch Engineering Inc.

Cranston, RI

Client: ESS/Town of Orleans

Project: Orleans - GWDP
Overland Way, MA

Project No: 1704795 **Figure** 17-S-578

1704794 4/28/17

SOILS LABORATORY TESTING ASSIGNMENT SHEET

THIELSCH ENGINEERING 401-467-6454 195 Frances Ave., Cranston, RI 02910

1704795

Project Name **Orleans - GWDP** Client **Town of Orleans** Assigned By **Mark Owen**

CTS Project No. **60476644.10.1.A** Site Location **Overland Way** Collected By **Mark Owen**

ESS Project No. _____ Date Assigned _____ Received By _____

Project Manager **T. Parece** Date Received _____ Date Required **Norman**

	Sample Information					Lab No.	Identification Tests							Permeability		Compaction			Strength		Consol.	Notes
	Boring/ Test Pit No.	Sample No.	Depth Ft.	Sample Date	ESS SAMPLE ID		Water Cont. %	LL & PL %	Org. %	Sieve -200 %	Hyd -2μ %	G_s	γ_t pcf	Sand	Clay	Mod.	Std.	CBR	Tor-vane	Type Test $\bar{\sigma}_c$ or σ_c	Cc/ 1+eo	
							D2216	D4318	D2974	D422		D854		D2434	D5084	D1557	D698	D1883		D2166/ D4767/ D2850	D2435	#
1	CLS - 1	70-72								X												
2	CLS - 1	86-88								X												
3	CLS - 1	95.5-96								X	X											
4	CLS - 1	108-110								X												
5	CLS - 2	21-24								X	X											
6	CLS - 2	64-66								X												
7	CLS - 2	74-76								X	X											
8	CLS - 2	80-82								X												
9	CLS-3	65-69								X												
10	CLS-3	73-77								X	X											
11	CLS-3	87-95								X												
12	CLS TP-3	15-Gst 15	MH							X												
13	CLS-TP-7	10-15	MH							X												

Notes: MH 2 4-28-17 @ 12:55 TCP 4/28/17 12:55 NOICE 22.1

TCP 2 4/28/17 @ 11:20 4/28/17 1659

1704795

SOILS LABORATORY TESTING ASSIGNMENT SHEET

THIELSCH ENGINEERING 401-467-6454 195 Frances Ave., Cranston, RI 02910

Project Name **Orleans - GWDP** Client **Town of Orleans** Assigned By **Mark Owen**

CTS Project No. **60476644.10.1.A** Site Location **Overland Way** Collected By **Mark Owen**

ESS Project No. _____ Date Assigned _____ Received By _____

Project Manager **T. Parece** Date Received _____ Date Required **Norman**

	Sample Information						Identification Tests							Permeability		Compaction			Strength		Consol.	Notes
	Boring/ Test Pit No.	Sample No.	Depth Ft.	Sample Date	ESS SAMPLE ID	Lab No.	Water Cont. %	LL & PL %	Org. %	Sieve -200 %	Hyd -2μ %	G_s	γ_t pcf	Sand	Clay	Mod.	Std.	CBR	Tor-vane	Type Test $\bar{\sigma}_c$ or σ_c	Cc/ 1+eo	#
							D2216	D4318	D2974	D422		D854		D2434	D5084	D1557	D698	D1883		D2166/ D4767/ D2850	D2435	#
14	TTS - 1	TP	10 - 15							X												
15	TTS - 1		45-46.5							X	X											
16	TTS-2	TP	10 - 15							X												
17	TTS-2		21-21.5							X	X											
18	TTS-3		15-16.5							X	X											
19	TTS-4		15.5-16.5							X	X											

Notes: 4-28-17 @ 12:55 4/25/17 12:55 No 22.1

4/25/17 @ 1420 4/28/17 1659

1704794 4/28/17

SOILS LABORATORY TESTING ASSIGNMENT SHEET

THIELSCH ENGINEERING

401-467-6454

195 Frances Ave., Cranston, RI 02910

1704795

Project Name **Orleans - GWDP** | Client **Town of Orleans** | Assigned By **Mark Owen**

CTS Project No. **60476644.10.1.A** | Site Location **Overland Way** | Collected By **Mark Owen**

ESS Project No. | Date Assigned | Received By

Project Manager **T. Parece** | Date Received | Date Required **Norman**

	Sample Information						Identification Tests							Permeability		Compaction			Strength		Consol.	Notes
	Boring/ Test Pit No.	Sample No.	Depth Ft.	Sample Date	ESS SAMPLE ID	Lab No.	Water Cont. %	LL & PL %	Org. %	Sieve -200 %	Hyd -2μ %	G_s	γ_t pcf	Sand	Clay	Mod.	Std.	CBR	Tor-vane	Type Test $\bar{\sigma}_c$ or σ_c	Cc/ 1+eo	#
							D2216	D4318	D2974	D422		D854		D2434	D5084	D1557	D698	D1883		D2166/ D4767/ D2850	D2435	#
1	CLS - 1	70-72								X												
2	CLS - 1	86-88								X												
3	CLS - 1	95.5-96								X	X											
4	CLS - 1	108-110								X												
5	CLS - 2	21-24								X	X											
6	CLS - 2	64-66								X												
7	CLS - 2	74-76								X	X											
8	CLS - 2	80-82								X												
9	CLS-3	65-69								X												
10	CLS-3	73-77								X	X											
11	CLS-3	87-95								X												
12	CLS TP-3	15-~~Oct~~ 15	MA							X												
13	CLS-TP-7	10-15	MA							X												

Notes: 4-28-17 @ 12:55 4/25/17 12:55 No ICE 22.1

4/25/17 @ 1420 4/28/17 1659

1704795

SOILS LABORATORY TESTING ASSIGNMENT SHEET

THIELSCH ENGINEERING 401-467-6454 195 Frances Ave., Cranston, RI 02910

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							D2216	D4318	D2974	D422		D854		D2434	D5084	D1557	D698	D1883		D2166/ D4767/ D2850	D2435	#
14	TTS - 1	TP	10 - 15							X												
15	TTS - 1		45-46.5							X	X											
16	TTS-2	TP	10 - 15							X												
17	TTS-2		21-21.5							X	X											
18	TTS-3		15-16.5							X	X											
19	TTS-4		15.5-16.5							X	X											

Notes: 4-28-17 @ 12:55 4/25/17 12:55 No 22.1 ICS

4/25/17 @ 1420 4/28/17 1659

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Appendix G

Nutrient Loading Results

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Estimate of Watershed Load with WWTF
Town of Orleans
Water Quality and Wastewater Planning

Discharge Rate - 100,000 gpd

Marsh	Present Nitrate Load[1]	Present Nitrate Threshold Load[1]	Watershed Load[2]	Estimated WWTF Nitrate Load	Watershed with WWTF with Load[3]	Present Nitrate Load[1]	Present Nitrate Threshold Load[1]	Watershed Load[2]	Estimated WWTF Nitrate Load	Watershed with WWTF with Load[3]
	(kg/day)					(kg/yr)				
Namskaket Marsk	9.441	45.89	36.449	0.460	35.989	3,446	16,750	13,304	168	13,136
Little Namskaket Marsh	7.663	12.74	5.077	0.674	4.403	2,797	4,650	1,853	246	1,607
Rock Harbor	ND	ND	ND	0.000	ND	ND	ND	ND	0	ND
Cape Cod Bay	ND	ND	ND	2.652	ND	ND	ND	ND	968 1,382	ND

Discharge Rate - 150,000 gpd

Marsh	Present Nitrate Load[1]	Present Nitrate Threshold Load[1]	Watershed Load[2]	Estimated WWTF Nitrate Load	Watershed with WWTF with Load[3]	Present Nitrate Load[1]	Present Nitrate Threshold Load[1]	Watershed Load[2]	Estimated WWTF Nitrate Load	Watershed with WWTF with Load[3]
	(kg/day)					(kg/yr)				
Namskaket Marsk	9.441	45.89	36.449	0.866	35.583	3,446	16,750	13,304	316	12,988
Little Namskaket Marsh	7.663	12.74	5.077	1.155	3.922	2,797	4,650	1,853	421	1,432
Rock Harbor	ND	ND	ND	0.000	ND	ND	ND	ND	0	ND
Cape Cod Bay	ND	None	ND	3.657	ND	ND	ND	ND	1,335	ND

Discharge Rate - 200,000 gpd

Marsh	Present Nitrate Load[1]	Present Nitrate Threshold Load[1]	Watershed Load[2]	Estimated WWTF Nitrate Load	Watershed with WWTF with Load[3]	Present Nitrate Load[1]	Present Nitrate Threshold Load[1]	Watershed Load[2]	Estimated WWTF Nitrate Load	Watershed with WWTF with Load[3]
	(kg/day)					(kg/yr)				
Namskaket Marsk	9.441	45.89	36.449	1.389	35.060	3,446	16,750	13,304	507	12,797
Little Namskaket Marsh	7.663	12.74	5.077	1.732	3.345	2,797	4,650	1,853	632	1,221
Rock Harbor	ND	ND	ND	0.000	ND	ND	ND	ND	0	ND
Cape Cod Bay	ND	None	ND	4.449	ND	ND	ND	ND	1,624 2,763	ND

Discharge Rate - 250,000 gpd

Marsh	Present Nitrate Load[1]	Present Nitrate Threshold Load[1]	Watershed Load[2]	Estimated WWTF Nitrate Load	Watershed with WWTF with Load[3]	Present Nitrate Load[1]	Present Nitrate Threshold Load[1]	Watershed Load[2]	Estimated WWTF Nitrate Load	Watershed with WWTF with Load[3]
	(kg/day)					(kg/yr)				
Namskaket Marsk	9.441	45.89	36.449	1.912	34.537	3,446	16,750	13,304	698	12,606
Little Namskaket Marsh	7.663	12.74	5.077	2.308	2.769	2,797	4,650	1,853	843	1,011
Rock Harbor	9.066	3.72	-5.346	0.000	-5.346	3,309	1,358	-1,951	0	-1,951
Cape Cod Bay	ND	None	ND	5.241	ND	ND	ND	ND	1,913	ND

Discharge Rate - 400,000 gpd

Marsh	Present Nitrate Load[1]	Present Nitrate Threshold Load[1]	Watershed Load[2]	Estimated WWTF Nitrate Load	Watershed with WWTF with Load[3]	Present Nitrate Load[1]	Present Nitrate Threshold Load[1]	Watershed Load[2]	Estimated WWTF Nitrate Load	Watershed with WWTF with Load[3]
	(kg/day)					(kg/yr)				
Namskaket Marsk	9.441	45.89	36.449	3.844	32.605	3,446	16,750	13,304	1,403	11,901
Little Namskaket Marsh	7.663	12.74	5.077	4.140	0.937	2,797	4,650	1,853	1,511	342
Rock Harbor	9.066	3.72	-5.346	0.000	-5.346	3,309	1,358	-1,951	0	-1,951
Cape Cod Bay	ND	None	ND	7.156	ND	ND	ND	ND	2,612	ND

Notes:

[1] Present and Threshold Loads from Draft and Final MEP Reports for Namskaket Marsh, Little Namskaket Marsh, and Rock Harbor. Tritown WWTF Loads Removed.
[2] Watershed Load = Threshold Load - Present Load
[3] Estimated Watershed Load with WWTF = Threshold Load -(Present Load + Estimated WWTF Load)
gpd = gallons per day
kg/day = kilograms per day
kg/yr = kiligrams per year
ND = No Data

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Appendix H

Properties with Potential Private Wells

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Potental Parcels with Private Wells
Overland Way Site
Water Quality and Wastewater Planning

	Street Address	MAP	PARCEL	EXTENSION	GIS Number
95	SKAKET BEACH RD	24	2	0	1844
99	WEST RD	32	58	0	1971

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