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Memorandum

To	George Meservey, Director of Planning & Community Development Michael Domenica, PE, Program Manager
CC	Betsy Shreve, AICP, AECOM Project Director Mark Owen, PG, AECOM
Subject	**Town of Orleans, MA** **Water Quality and Wastewater Planning** **Task Number 8.1 – Preplanning - Treatment and Disposal Site Investigations** **Deliverable 8.1.1.B – Technical Memorandum - Parcels 1/1A Environmental Screening - Final**
Project Number	60476644
From	Thomas Parece, P.E., AECOM Project Manager
Date	02/14/17

Approvals	Date	Signature / Initials
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Michael Domenica, PE, Water Resources Associates, Program Manager		

1. Background

This Technical Memorandum summarizes preliminary groundwater modeling results and screening for potential environmental impacts from Parcels 1/1A, a potential groundwater discharge location for the proposed Downtown Area Wastewater Treatment Facility (WWTF). An objective of the assessment is to identify potential environmental concerns requiring further study should the site be selected for a groundwater discharge.

2. Introduction

Groundwater modeling was proposed as a part of the environmental screening as the modeling can provide feedback on changes in groundwater flow directions based on the location and volume of the groundwater discharge. Through a series of model scenario's simulating a wastewater treatment facility effluent discharge at Parcels 1/1A, the path of the effluent through the aquifer can be estimated. The results of the preliminary modeling are provided in Technical Memorandum 8.1.1.a dated October 25, 2016. Some of the background information related to modeling is also provided in this memorandum to facilitate understanding of potential environmental impacts. The objective of the groundwater modeling is to screen for potential sensitive environmental receptors that may be impacted by a discharge at Parcels 1/1A. Impacts to potential sensitive environmental receptors will be addressed during the Groundwater Discharge Permitting (GWDP) process should a discharge at Parcels 1/1A be proposed.

The Overland Way (former Tri Town Septage Treatment Facility) Site 1/1A Parcels are located on a 26-acre site on Overland Road, in the Town of Orleans (Figure 1). Parcels 1/1A are located in the northeast corner of the site.

The geology and hydrogeology of the Overland Way site is well known and documented through several studies including several US Geological Survey (USGS) reports. The soils underlying Site 1/1A have not been evaluated and documented as part of a MassDEP required hydrogeologic evaluation the soils and hydrogeology would have to be confirmed and evaluated. It is expected however, that the soils would be similar to those documented across much of the site.

Parcels 1/1A are large enough to discharge the projected flow from the Downtown Area Wastewater Treatment Facility. The maximum flow is estimated at 250,000 gpd.

A disposal facility on this site would consist of subsurface leaching trenches, sand beds, or wicks. The discharge method selected would be based on the results of the hydrogeologic evaluation.

3. Groundwater Modeling Evaluation

Following is brief summary of the modeling techniques used. Parcels 1/1A are shown in Figure 1.

A. Modeling Method

A regional three-dimensional groundwater flow model of the Monomoy Lens was developed by the US Geological Survey as a tool for understanding the groundwater flow system and water budget (USGS, 2004). This regional model formed the basis of a groundwater flow model of the Town of Orleans.

MODFLOW was used 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.

B. Conceptual Model of the Aquifer System

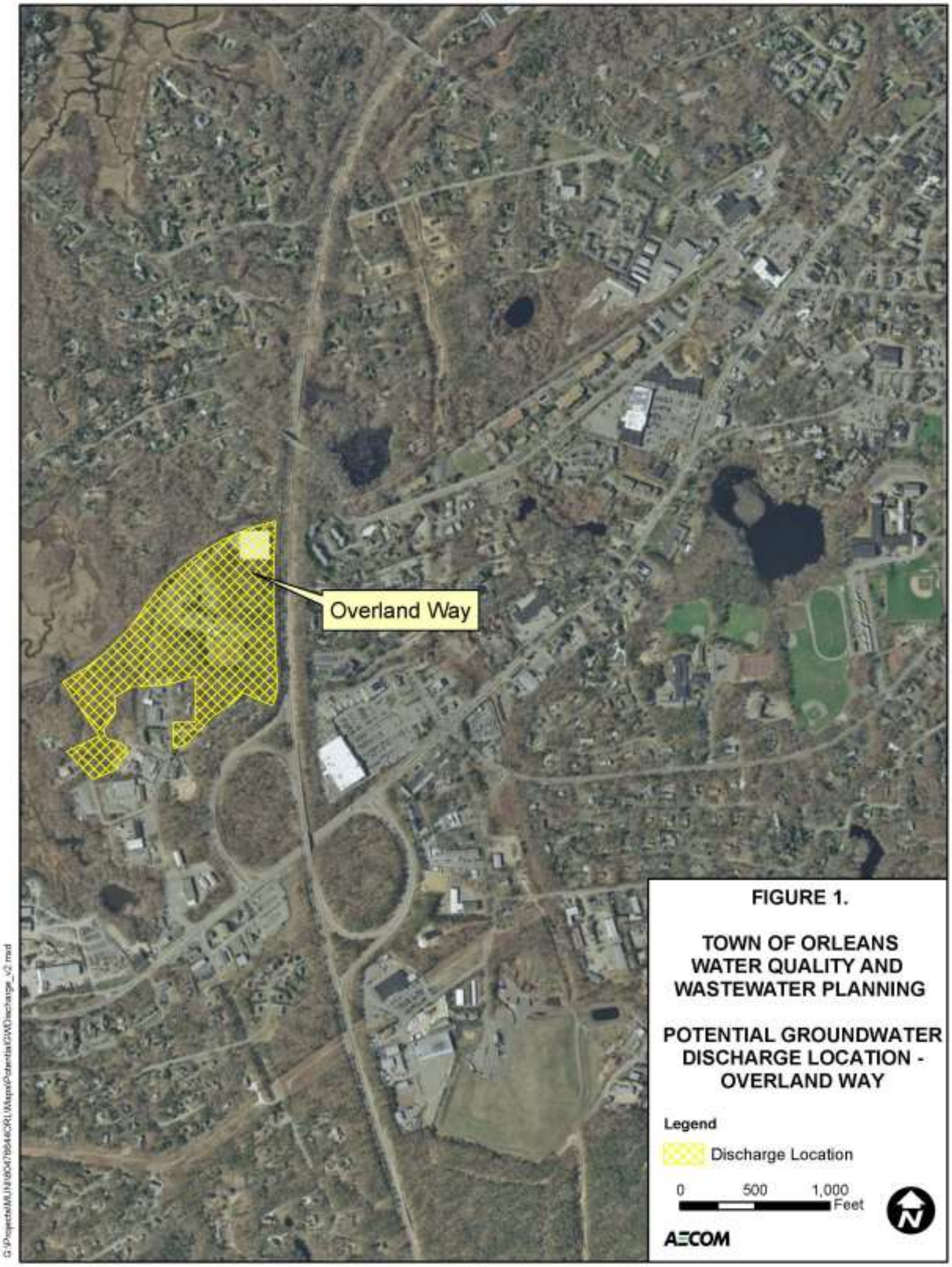
A conceptual model of a groundwater flow system is a representation of how an aquifer functions based on available data. Geologic maps and cross-sections, groundwater flow maps, and the generalized water balance (the volume of water entering and leaving the aquifer) are common elements of a conceptual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

The conceptual site model for hydrogeology and groundwater flow in the Monomoy Lens is well documented in the USGS, 2004 report. Overall, the conceptual site model documented in the US Geological Survey (2004) report is the same as is used for this modeling effort.

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.

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 leaves the aquifer system through surface water features, such as lakes, streams, wetlands, marshes, and the ocean.


Overland Way
FIGURE 1.
TOWN OF ORLEANS
WATER QUALITY AND
WASTEWATER PLANNING
POTENTIAL GROUNDWATER
DISCHARGE LOCATION -
OVERLAND WAY
Legend
Discharge Location
0
500
1,000
Feet
AECOM

C. Model Design and Updates

The numerical groundwater flow modeling was completed using the US Geological Survey 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 US Geological Survey 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.

The model design prepared by the US Geological Survey is structured as follows:

- The model was run as a steady-state model. This run incorporates long-term average conditions and does not include short-term (i.e., transient) changes in storage;
- The original model domain included the entire Monomoy Lens; a map of this domain is included in Figure 1-1A, Appendix 1 of the US Geological Survey report (USGS, 2004). The updated model domain 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 and current models are 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 fully wet layer 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 Figure 1-1B, Appendix 1 (USGS, 2004);
- Rainfall recharge was assigned using a variable array for the model domain. The rainfall recharge rate ranges from 0 feet per day to 0.00723 feet per day (0 to 31.67 inches per year). Most of the model area includes rainfall recharge around 29 inches per year. Lesser rates or zero rainfall recharge rates were assigned to wetlands, open water, and/or oceans;
- Surface water features were simulated 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.
- Hydraulic conductivity values used in the original groundwater model ranged from 10 feet per day for sandy silts to 300 feet per day for sand and gravel deposits. The hydraulic conductivity values for layers 7 and 8 are identical in the area of the proposed discharge. Layer represents the water table aquifer. High hydraulic conductivities (50,000 feet per day) were used for lakes; and
- The original US Geological Survey model included groundwater extraction consistent with water usage using the well (WEL) package. The updated model made no changes to the well rates for the updated model domain. The WEL package was used to simulate the groundwater discharge at Parcels 1/1A. This is discussed in the Simulations section, below.

A number of updates were made to the original model 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 US Geological Survey in the model documentation that accompanied the model files ("…due to licensing restrictions, the US Geological Survey 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 the US Geological Survey, 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 some of the discharge site. The US Geological Survey model used a grid size of 400 feet by 400 feet over the entire model domain. AECOM adjusted the grid to range from 50 feet by 50 feet to 400 feet by 400 feet, with the most refined portions of the model grid located in the areas of interest. This was completed to provide better resolution on the model inputs (i.e., discharge areas) and outputs;
- In refining the grid, some model features were updated:
  - Drain cell conductances were adjusted to reflect the geometry of the grid cells;
  - General head boundary conductances were adjusted to reflect the geometry of the grid cells; and
  - Horizontal flow barrier segments were added as needed to encompass the ponds/lakes in the model domain.

After the changes above were made, the model was verified to be an adequate representation of the original US Geological Survey model in the following ways:

- A comparison of predicted groundwater elevations were made in select cells/areas to demonstrate that the new version of the model predicted groundwater elevations similar to that predicted by the US Geological Survey model. Generally, the differences were less than 0.5 feet and lower in many instances. There are a handful of cells where the 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 US Geological Survey (specific reference). Generally speaking the new version of the model was the same or similar to the particle tracking under ambient conditions from the US Geological Survey version of the model;
- A comparison of mass balance generated by the model was completed. 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 US Geological Survey model. 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;
- The grid refinement, which doesn't allow a direct comparison of groundwater elevations in places where the grid has been changed significantly, the changes in conductance (in the drain and general head boundary packages) where the grid is refined and groundwater flows into and out of the model differently between the models and therefore results in slightly different elevations; and
- The change in model solver (from LMG to PCG2), which results in a slightly different solution.

In summary, a number of changes to the original US Geological Survey model domain and structure were completed to better meet the project objectives. Despite the changes, the model replicated the US Geological Survey 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.

D. Changes to Model Input Parameters

There were no changed made to model input parameters such as hydraulic conductivity, effective porosity, and other aquifer parameters.

E. Model Calibration

The full Monomoy Lens model was calibrated and this process is described in Appendix 1 of the US Geological Survey 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 original model compared favorably to the simulated groundwater elevations generated in the updated model;
- Simulated groundwater flow paths from the original model compared favorably to the simulated groundwater flow paths generated in the updated model;
- The water budget of the original model (for the area of interest) compared favorably with the water budget for the updated model; and
- Simulated groundwater elevations compared favorably to estimates for high groundwater elevation conditions.

Overall the updated model was able to reproduce the results from the original model very closely. Therefore model was considered a good tool for conducting simulations.

F. Predictive Simulations

The calibrated groundwater flow model was used to simulate several groundwater discharge scenarios in order to estimate groundwater flow from Parcels 1/1A on Overland Way.

Six separate discharge scenarios were simulated using the groundwater flow model. The six scenarios run simulated discharge rates ranging between 25,000 and 200,000 gpd. All scenarios simulated a groundwater discharge from Parcels 1/1A. Each scenario simulated the discharge under the average ambient water table conditions described above. The six scenarios were performed to preliminarily evaluate groundwater flow changes with increasing discharge rates.

The model's particle tracking module was used to estimate the path that the effluent would flow through the groundwater. The downgradient extent of the particle traces (where they terminate) indicates the general area where the effluent discharges to a surface water.

The particle traces are only estimates of groundwater flow and do not indicate either the quantity, quality or exact location of effluent flow. However, the number of particle traces terminating in an area, such as a watershed, can be a general indicator of the overall discharge amount. The simulation results with particle traces are provided in Attachment A.

The paths of the particle traces may change once additional site and regional data is incorporated in the model. These changes will be addressed as part of the groundwater discharge permitting process for the site should a discharge be proposed.

The model scenarios simulated are summarized below:

- **Simulation A (25,000 gpd)** – Model simulation A was performed at a discharge rate of 25,000 gpd. Through particle traces, the model simulation indicates that groundwater flows from Parcel 1/1A to the northwest below the Namskaket and Little Namskaket Creek watersheds terminating in the Cape Cod Bay area. A few particle traces terminate in the creeks and marshes of the Namskaket Creek Watersheds relatively close to where the Namskaket Creeks discharge to Cape Cod Bay.
- **Simulation B (50,000 gpd)** – Simulation B has a discharge scenario of 50,000 gpd. As with Simulation A, the model indicates that the discharge flows to the northwest of the site. As with Simulation A, a majority of the particle traces flows under the Namskaket and Little Namskaket Creek marshes directly to the Cape Cod Bay area. The particle traces widen (to the north and south) with the increased flow.
- **Simulation C (100,000 gpd)** – At a discharge rate of 100,000 gpd, the width of the particle traces continue to widen. The majority of the particle traces continue to terminate in Cape Cod Bay.
- **Simulation D (150,000 gpd)** – The width of the discharge continues to widen with the increased discharge rate of 150,000 gpd. As with the previous model simulations, the majority of the particle traces terminate in Cape Cod Bay.
- **Simulation E (200,000 gpd)** – With a discharge rate of 200,000 gallons per day, the overall spread of the particle traces continues to widen. The primary watershed where the particle traces terminate is Cape Cod Bay. As with Simulations A through D only small number of the particle traces terminate in the Marshes and Creeks of the Namskaket and Little Namskaket Creek Watersheds.

4. Potential Impacts

Potential impacts resulting from the proposed groundwater discharge can result from: (a) the additional nitrate load to the tidal creeks and marshes of the Namskaket and Little Namskaket Creek Watersheds; (b) increased freshwater flow to brackish tidal areas; (c) water quality impacts to public and private water supply wells; and (d) increases in water table elevations impacting existing structures.

A. Potential Nitrate Impacts to Namskaket and Little Namskaket Creeks and Cape Cod Bay

Discharge from the wastewater treatment facility is expected to be within water quality standards set by the state. However, the total nitrate load to these watersheds may increase. Based on the model simulations described in Chapter 3, discharges from the wastewater treatment facility will likely flow northwest discharging directly to Cape Cod Bay. Cape Cod Bay does not have a total maximum daily load (TMDL) for Nitrate. The additional load would not be expected to impact Cape Cod Bay’s water quality.

The model’s particle traces also indicate that a portion of the discharge may flow into the Namskaket or Little Namskaket Creek watersheds. The Namskaket and Little Namskaket Creek watersheds are presently below the nitrate total maximum daily load.

The areas into which discharge occurs are part of the Inner Cape Cod Bay ACEC. A more detailed environmental impact of each watershed and the ACEC would be part of the detailed hydrogeologic evaluation that would be required by MassDEP if a groundwater discharge is proposed at Parcels 1/1A.

B. Potential Freshwater Impacts to Namskaket and Little Namskaket Creeks

Additional freshwater from the wastewater treatment facility discharge entering Namskaket or Little Namskaket Creek tidal estuaries could potentially impact portions of the estuary. As discussed previously, the particle traces indicate that a majority of the wastewater treatment facility discharge appears to enter the aquifer, flow below the tidal influence of the streams and marshes of the Namskaket and Little Namskaket Creek Watersheds, and discharge directly to Cape Cod Bay. A freshwater discharge to this area would not impact Cape Cod Bay.

A portion of the flow may also discharge to the Namskaket and Little Namskaket Creek Watersheds. Based on the relatively few particle traces terminating in the Namskaket or Little Namskaket Creeks area, the flow to these areas may be relatively small. The particle traces indicate that the discharge to the estuaries would be near the mouth of the estuary where the tidal flux is greatest. A more detailed study of the potential environmental impacts from freshwater will be undertaken if a groundwater discharge is proposed at the site.

C. Potential Impacts to Private Drinking Water Supplies

According to Town records, the property at 40 and 95 Skaket Beach Road may have a private well. If the well is a 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.

D. Potential Groundwater Mounding Impacts

At this time, potential impacts from groundwater mounding cannot be conducted. The elevation of surrounding buildings as well as the groundwater discharge rate are not known. Most of the groundwater mounding occurs directly below the discharge. The depth to the water table below Parcels 1/1A is expected to be 40 feet or greater. Mounding at the Overland Way site is not expected to be a concern. Mounding at existing structures outside of the site, as well as surrounding ground elevations, would be considered as part a groundwater discharge permitting process.

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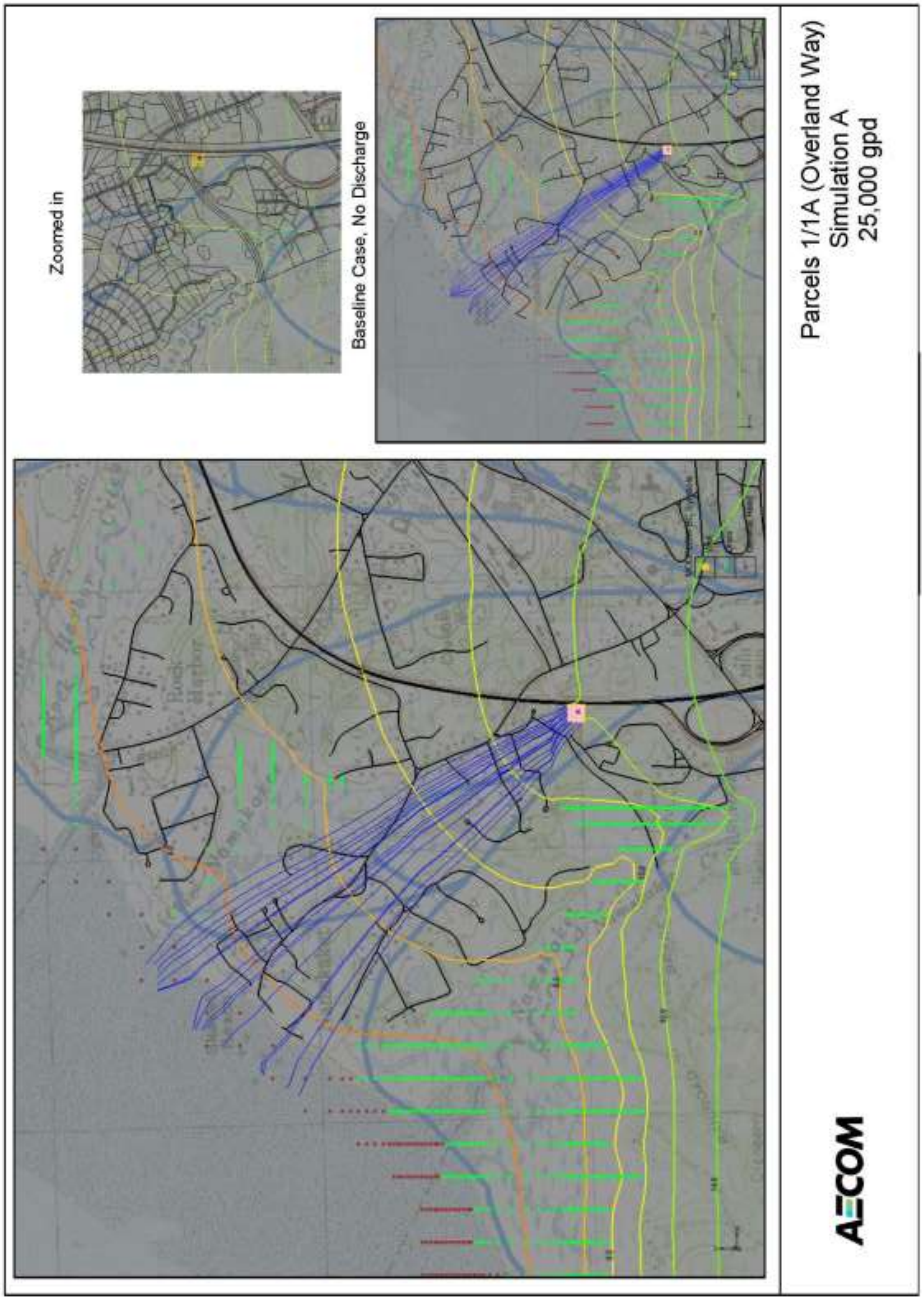
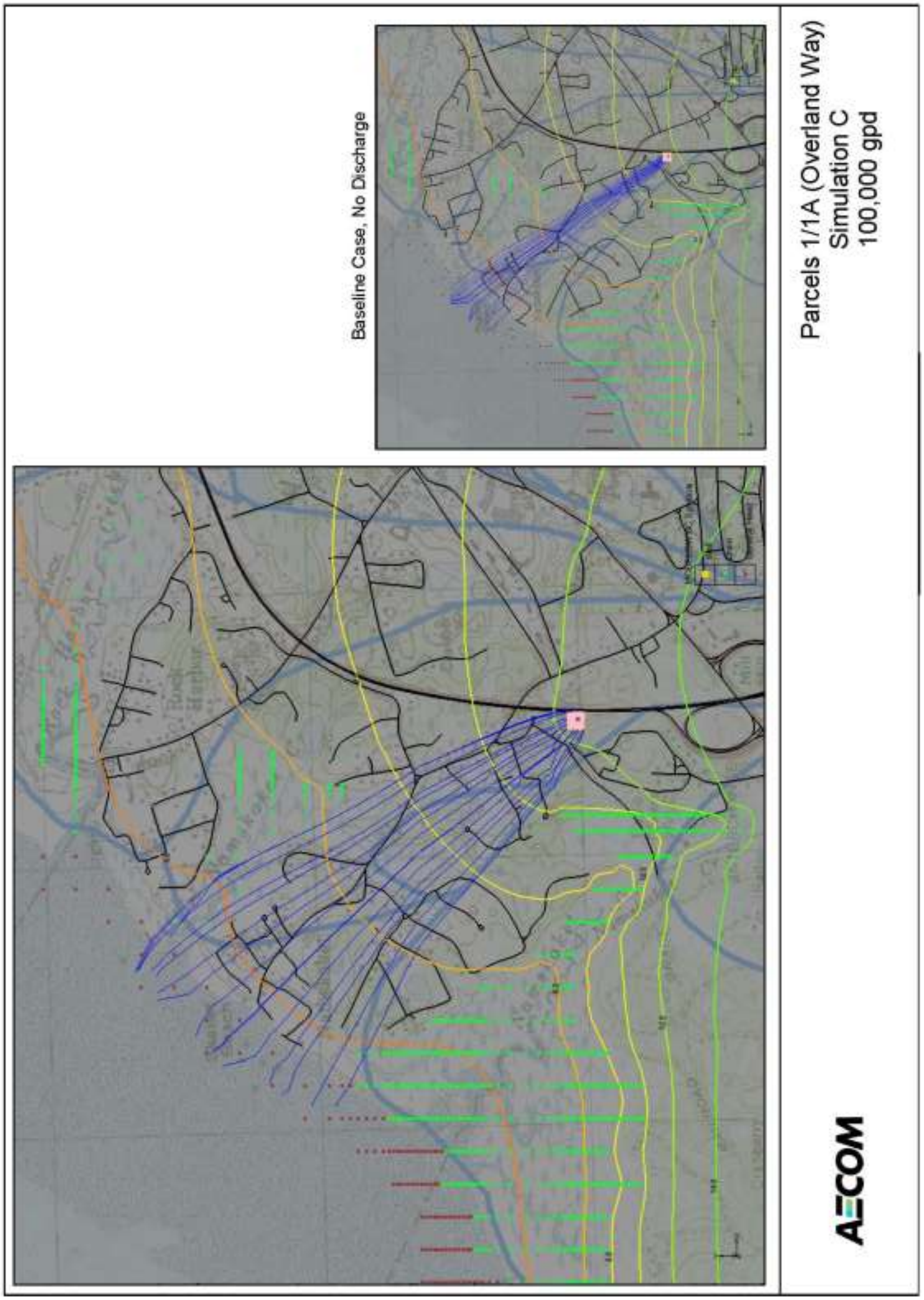
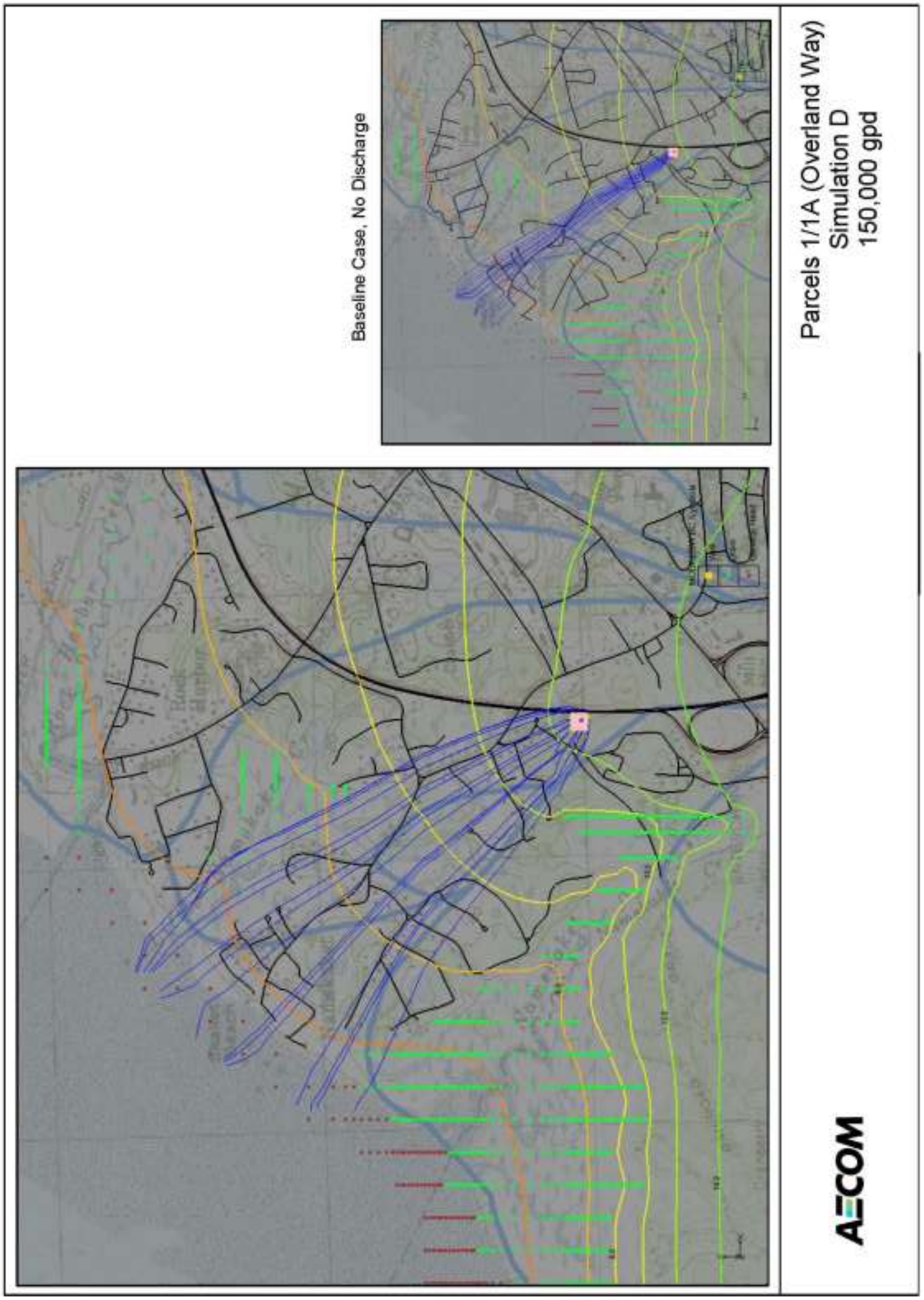
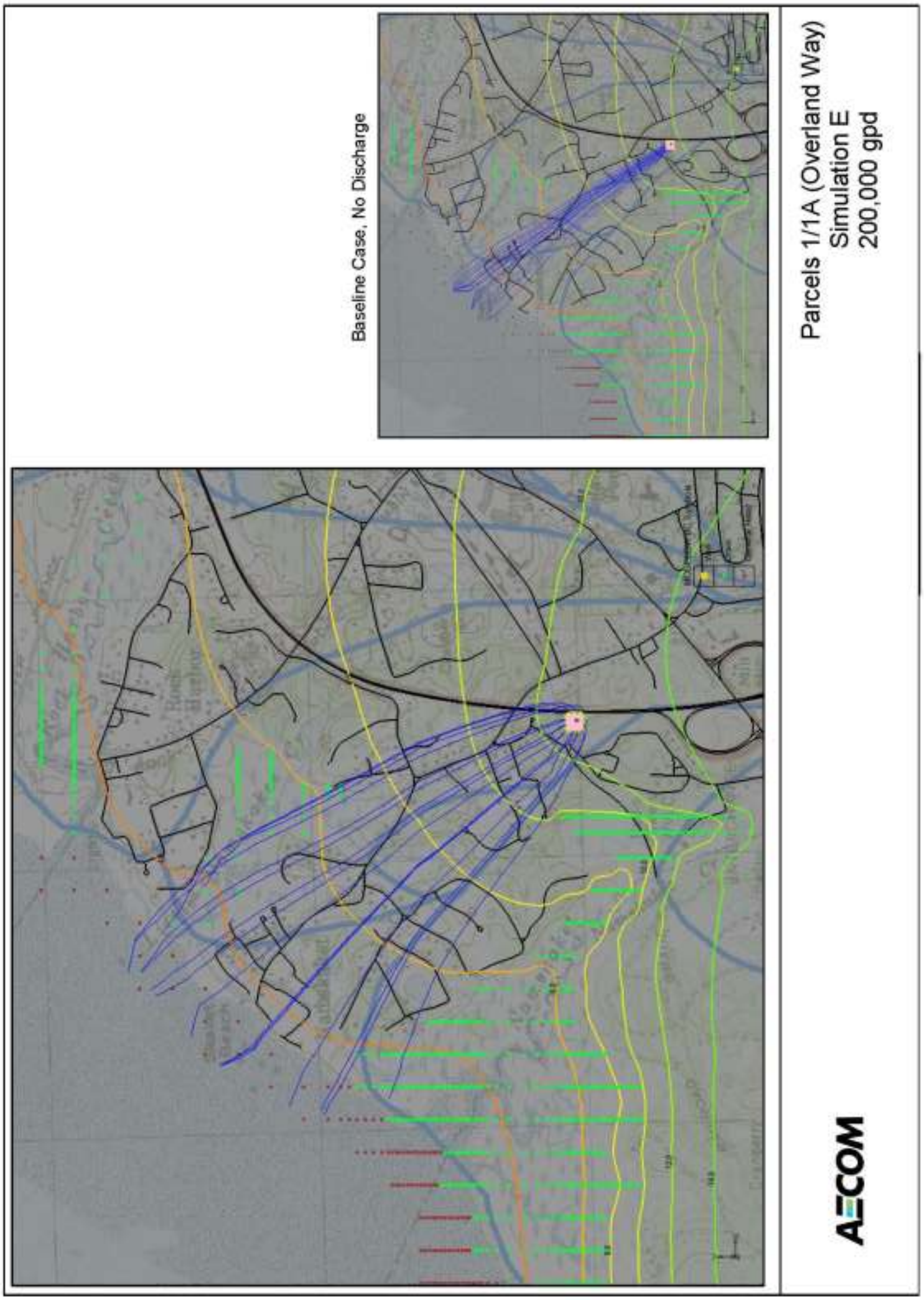
ATTACHMENT A


Zoomed in
Baseline Case, No Discharge
Parcels 1/1A (Overland Way)
Simulation A
25,000 gpd


Baseline Case, No Discharge
Parcels 1/1A (Overland Way)
Simulation B
50,000 gpd
AECOM


Baseline Case, No Discharge
Parcels 1/1A (Overland Way)
Simulation C
100,000 gpd


Baseline Case, No Discharge
Parcels 1/1A (Overland Way)
Simulation D
150,000 gpd


Baseline Case, No Discharge
Parcels 1/1A (Overland Way)
Simulation E
200,000 gpd
AECOM

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