STATE OF MAINE
BOARD OF ENVIRONMENTAL PROTECTION

IN THE MATTER OF

NORDIC AQUAFARMS, INC		
Belfast and Northport	)	APPLICATION FOR AIR EMISSION, SITE
Waldo County, Maine	)	LOCATION OF DEVELOPMENT,
	)	NATURAL RESOURCES PROTECTION
A-1146-71-A-N	)	ACT, and MAINE POLLUTANT
L-28319-26-A-N	)	DISCHARGE ELIMINATION
L-28319-TG-B-N	)	SYSTEM/WASTE DISCHARGE LICENSES
L-28319-4E-C-N	)	
L-28319-L6-D-N	)	
L-28319-TW-E-N	)	
W-009200-6F-A-N	)	

PRE-FILED DIRECT TESTIMONY OF MICHAEL MOBILE, PH.D.
MCDONALD MORRISSEY ASSOCIATES, LLC

1. My name is Michael Mobile. I work as a Managing Partner with McDonald Morrissey Associates, LLC (MMA). I hold a Bachelor of Science degree in hydrology from the University of New Hampshire, a Master of Science degree in environmental engineering from Virginia Tech, and a Doctoral degree in civil engineering from Virginia Tech. My technical experience is focused in the areas of groundwater hydrology and numerical groundwater modeling. I have more than 15 years of experience in these areas, including development and application of several models to assess large groundwater withdrawals in the state of Maine. I have led professional seminars and assisted in teaching undergraduate and graduate level courses in groundwater hydrology and modeling techniques. My professional experience and qualifications are further detailed by my curriculum vitae, which is included as Addendum A.

2. During September of 2018, MMA was asked to support an assessment of the local groundwater system in the vicinity of the proposed Nordic Aquafarms, Inc. (Nordic) facility in Belfast, Maine. As part of this assessment, a pumping configuration (i.e., number, locations, and typical withdrawal rates of supply wells) was identified that could provide groundwater to the proposed facility while also meeting applicable Site Location of Development Act permit requirements, including avoiding interference with current use of private supply wells on neighboring properties. MMA's technical memorandum describing the numerical modeling component of this assessment, which I authored, is dated April 10, 2019 and provided as Nordic Exhibit 3. This model provided a testing ground for predictive scenarios representing different potential groundwater supply configurations, including well locations and associated withdrawal rates. I led this effort, with technical support being provided by MMA personnel under my direction.

3. The objectives of the modeling work are identified within the aforementioned memorandum as follows:

1. *“construct a numerical groundwater flow model for the bedrock aquifer occurring in the Site vicinity based on available data and information;*

2. *with support from the model, assess primary source(s) of recharge to the local bedrock aquifer and proposed supply well network; and*

3. *with support from the model, assess potential long-term viability of proposed withdrawal rates based on drawdown effects occurring away from the proposed well network.”*

4. To address these objectives, we developed numerical groundwater flow model using available information and data obtained from a variety of sources, including the hydrogeologic investigation led by Ransom Consulting, Inc. (Ransom). That investigation included four (4) hydraulic aquifer tests conducted between March 2018 and January 2019. These tests, which were designed with different combinations of cumulative withdrawal rates and pumping locations, provided extensive data representative of on- and off-site hydraulic responses to withdrawal from the local fractured bedrock aquifer.

5. The modeling process included certain assumptions and generalizations that are common and necessary to standard numerical modeling practice. The assumptions and generalizations made in creating this model are reasonable in consideration of available information, professional experience, and as influenced by modeling objectives.

6. We followed a common, stepwise modeling approach that included calibration and verification steps. Calibration is a process through which model inputs are adjusted in order to develop consistency between measured and modeled aquifer conditions and/or responses to stresses (e.g., pumping groundwater from wells). We used data collected during the first three aquifer tests to support calibration. Verification involves comparing modeled results to an independent data set to ensure consistency (i.e., actual and modeled aquifer conditions) is maintained. We used data collected during the fourth and most complex aquifer test to support verification.

7. The result of successful calibration and verification steps was a numerical model that generally demonstrates consistency with available data representative of actual aquifer responses under active pumping conditions. This result addresses the first modeling objective and supports use of the model as a reasonable and appropriate basis for performing predictive simulations to address the second and third modeling objectives.

8. Model application included performing several forward-looking (i.e., projection) simulations. The three pumping scenarios assessed during model application represent different combinations of five potential supply well locations, with cumulative pumping rates ranging from a minimum of approximately 228 gallons per minute (gpm) to a maximum of 515 gpm. Each scenario was designed based on a specific stage of aquifer testing for which aquifer response data were available. Our technical memorandum describes this work as follows:

"simulations were performed to estimate system responses under different pumping scenarios where locations and rates of withdrawal were varied. The objectives of these projection simulations were the following:

1. *for a given pumping rate scenario, estimate the maximum amount of drawdown that may develop under long-term, average conditions; and*

2. *for a given pumping rate scenario, estimate the time required for drawdown to stabilize.*

Relative to objective 1, above, estimates were generated using steady-state model simulations. First, a non-pumping (i.e., no active wells) simulation…. was performed to create a baseline condition. Additional steady-state simulations were then performed for three pumping scenarios."

9. Maximum drawdown estimates were created for all locations within the model domain by calculating differences between the pumping rate scenario results and the non-pumping result. In general, these estimates reflect drawdown ranging from generally minor in areas located away from the simulated well locations (e.g., west of the proposed facility where several private supply wells are located) to greater at locations where facility wells are simulated. As expected, maximum drawdown estimates were generally greater for scenarios in which total pumping rates were higher.

10. In addition to the steady-state simulations described above, transient pumping scenario simulations were performed to provide an estimate of the time required for drawdowns to stabilize under average conditions. These simulations are described within our technical memorandum as follows:

"To address objective 2, above [reproduced in Item 8 of this testimony], the steady-state baseline simulation was extended by adding a second transient stress period with a duration of approximately 10 years. Simulations were performed with this version of the model with an initial, steady-state, non-pumping period followed by a transient period representative of each pumping scenario."

11. The results of the transient simulations suggest drawdown rates will be spatially variable, and stabilization will require a significant period of time. The latter result is particularly meaningful relative to providing time to monitor aquifer condition changes, as discussed within Items 16 and 17 herein below. Our technical memorandum provides greater detail on these results as follows:

"drawdown effects may develop more rapidly in areas located west-northwest of the Site (i.e., as indicated by the estimated responses at the WSW-01, WSW-03, and WSW-05 locations) compared to areas due west (i.e., as indicated by the estimated response at the WSW-02 location) and south (i.e., as indicated by the WSW-04 response) of the Site. Stabilization times, however, are estimated to be many years to more than a decade for all locations under all simulated scenarios."

12. In reference to assessing the primary source(s) of recharge to the local bedrock aquifer and proposed supply well network, our technical memorandum provides the following commentary:

> *"recharge from precipitation represents the major source of water to the modeled groundwater system, with supplemental volume being provided from reservoir/pond leakage. These sources are mostly offset…. by groundwater discharge to streams and the coastal boundary. With pumping active (Scenario 1 case), the withdrawal demand appears to be partly satisfied by interception of groundwater that was previously discharging to streams, reservoirs/ponds, and the coastal boundary; though, some inflow from the coastal boundary is predicted."*

13. Ultimately, the results of the modeling effort are summarized within our technical memorandum as follows:

> *"The numerical modeling described herein generally supports a proposed withdrawal plan similar to the Scenario 1 condition (a total of 455 gpm from wells PW-1, GWW-103, and DRX-102).*

14. While the model suggests the local groundwater system may support higher cumulative withdrawal rates under certain conditions, the 455 gpm pumping rate scenario avoids reliance upon supply wells that, when pumped during aquifer testing conducted during the hydrogeologic investigation, appeared to produce hydraulic responses in certain private water supply wells located west of the proposed facility.

15. As is the case in any similar modeling assessment, the results are subject to predictive uncertainty and certain limitations, including system characteristics that were not directly represented by the model. Relative to the former, one source of uncertainty is the assumption that the fractured bedrock aquifer can be represented as an equivalent porous medium. Relative to the latter, given data availability and aquifer complexity, it was technically infeasible to simulate groundwater chemistry (i.e., behavior of solutes occurring within groundwater) with reasonable accuracy. In both cases, it is common practice to complement a modeling assessment with data collection as an empirical check, and to plan for unlikely situations where actual conditions deviate from model predictions. Our memorandum presented the following recommendations in consideration of these factors:

- "*Conduct further assessment of residential supply wells located in the Site vicinity to better understand typical conditions (e.g., range of head fluctuations occurring under normal use) and physical characteristics (e.g., pump depth).*
- *Develop a plan for monitoring:*
    - *drawdown in bedrock supply wells located on- and off-Site;*
    - *drawdown of the water table near surface water features in the Site vicinity; and*

- *in certain locations, water quality (e.g., total dissolved solids or TDS).*

- *Develop contingencies to address cases where current use changes (e.g., reduced well yield) can be attributed to effects caused by Site-related pumping."*

16. Nordic's State and local (i.e., City of Belfast) permit applications include a Water Resource Monitoring Plan (WRMP) that addresses our recommendations. Comments presented to Nordic by State application reviewer John Hopeck, Ph.D. (Nordic Exhibit 4), resulted in proposed refinements to the WRMP that are detailed within the response letter provided as Nordic Exhibit 5.

17. Inclusive of the proposed refinements, the WRMP represents a thorough and adaptable program for establishing baseline (i.e., pre-pumping) conditions and monitoring for potential post-development changes. The WRMP also describes indicators and presents actions that would be taken in cases where unforeseen adverse effects occur as a result of Nordic's freshwater withdrawals. These actions range from addressing isolated issues (e.g., alteration of an existing private supply well and/or the associated well pump) to implementation of broader operational shifts, including reproportioning amongst the three proposed freshwater sources (i.e., groundwater from facility supply wells, diverted surface water from the Lower Reservoir, and water supplied to the facility by the Belfast Water District), as necessary.

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Dated December 3, 2019

by: ______________________

Michael Mobile, Ph.D., Managing Partner
McDonald Morrissey Associates, LLC

State of NEW HAMPSHIRE
County of MERRIMACK, ss.

December 3, 2019

Personally appeared the above-named Michael Mobile and made oath as to the truth of the foregoing pre-filed testimony.

Before me,

____
Notary Public / Attorney at law

DAWN E. FLANDERS
Notary Public - New Hampshire
My Commission Expires August 14, 2024

McDonald Morrissey ASSOCIATES, LLC
GROUND WATER HYDROLOGISTS

Michael A. Mobile, Ph.D.

Summary

Dr. Mobile focuses in the areas of quantitative hydrogeology and hydrology, solute fate-and-transport, and water resources management. He has worked as a researcher and consultant specializing in numerical groundwater flow and reactive fate-and-transport modeling for more than 15 years. Project experience has included model development in support of several large-scale, high-profile construction activities; natural resource management projects; and litigation/conflict resolution assignments. The challenging nature of much of this work has allowed Dr. Mobile to explore a wide variety of innovative and interdisciplinary approaches to addressing site-specific challenges.

Professional Experience

McDonald Morrissey Associates, LLC, Managing Partner (2018-current)

Directs and provides technical contributions to projects dealing with a wide variety of water resource issues. Leads design, development, calibration and sensitivity testing of numerical groundwater flow and solute fate-and-transport models. Oversees geospatial data management and geostatistical evaluations. Acts as lead expert on projects involving assessments of PFAS occurrence and fate-and-transport in groundwater. Provides technical support to colleagues serving as experts on a range of other water resource issues, including solute fate-and-transport assessment, water rights, and interaction between groundwater and surface water.

GZA GeoEnvironmental, Inc., Senior Technical Specialist (2012-2018)

Served as a technical resource and project manager for a variety of projects spanning multiple disciplines. Served as in-house technical lead on quantitative groundwater modeling, per- and polyfluoroalkyl substance (PFAS) contamination, and three-dimensional data analysis and geostatistics.

Independent Consulting with Dr. M. Widdowson, Technical Specialist (2007-2012)

Provided numerical modeling support to environmental and geotechnical engineering projects. Modified and implemented advanced reactive transport codes to simulate non-aqueous phase liquid (NAPL) source behavior.

McDonald Morrissey Associates, Inc., Hydrogeologist (1999-2006)

Supported a variety of numerical modeling projects. Assisted with geographical information system (GIS) data analysis and model integration.

Representative Major Projects

Confidential Project, Long Island, New York, 2018 – current – Primarily responsible for reviewing MODPATH advective transport and MT3DMS reactive transport simulations. Supported condition evaluations by team members using analytical modeling, data assessment, and independent modeling techniques.

Confidential Modeling Assessment, Southern Vermont, 2018 – current – Served as project director and technical lead overseeing the development of groundwater flow and advective transport simulations using MODFLOW-NWT and MODPATH, respectively. Led advanced calibration efforts using PEST_HP and local high-performance computing cluster.

Municipal Water Supply Expansion Assessment, Bethel, Connecticut, 2018 - 2019 – Served as project director and technical lead responsible for overseeing data assessment and assimilation into numerical model dedicated to assessing potential yield of proposed municipal supply well. Utilized unstructured grid modeling code (MODFLOW-USG) and applied advanced techniques (PEST_HP) to support extensive calibration effort.

Representative Major Projects Completed Prior to Rejoining MMA

Confidential Contaminated Site, Michigan, 2017 – 2018 – Primarily responsible for reviewing analytical data associated with sampling and analysis of soil, groundwater, and drinking water from sites potentially impacted by PFAS use at former tannery. Additional responsibilities included preparation and implementation of site investigation work plans and conceptual model development.

Investigation of Perfluorooctanoic Acid (PFOA) Contamination, Amherst, New Hampshire, 2016 - 2018 – Responsible for preparation and implementation of soil sampling and site investigation work plans associated with assessing PFOA contamination linked to a former textile coating operation in Amherst, New Hampshire. Additional responsibilities included serving as point-of-contact with the State regulatory agency, coordination and management of specialized analytical laboratory services, and coordination of performance sampling related to temporary point-of-entry treatment (POET) systems.

Brentwood Drill Yard Site Investigation, Brentwood, New Hampshire, 2017 – 2018 – Responsible for preparation and implementation of site investigation work plan associated with assessing PFAS contamination linked to historical fire training practices. Additional responsibilities included serving as point-of-contact with the State regulatory agency, coordination and management of specialized analytical laboratory services, data analysis, and report preparation.

Representative Major Projects Completed Prior to Rejoining MMA (cont.)

Third-Party Review of Supplemental Remedial Investigation of the Former Chlor-Alkali Plant Property, Berlin, New Hampshire, 2017 – 2018 – Provided third-party reviews of documents submitted by the responsible party's consultant pertaining to assessing and proposing potential remedial options for various site contaminants, including mercury in soil, groundwater, and occurring in liquid elemental form within the Androscoggin River. Acted as technical lead in communications with EPA, the responsible party, and their consultants.

Expert Support for the Independent Oil and Gas Association of West Virginia, 2016 – 2017 – Provided expert review services related to a geospatial analysis and empirical modeling technique being used to determine zones of critical concern (ZCCs) and zones of peripheral concern (ZPCs) above surface water intakes. Presented expert opinion during appeal heard by the West Virginia Environmental Quality Board.

Remedial Performance Assessment for Confidential Industrial Client, Massachusetts, 2014 – 2016 – Served as technical lead responsible for evaluating state of capture associated with existing groundwater "pump-and-treat" remediation system at a site contaminated with chlorinated solvents. Developed three-dimensional numerical groundwater flow model (MODFLOW-2005) for the site and calibrated the model to observed hydraulic head and pumping test data using a model-independent parameter estimation technique (PEST). Recommendations were made to the client regarding locations and target pumping rates for recovery system expansions and replacements.

Remedial Investigation Support, Town of Salem, New Hampshire, 2016 – 2018 – Served as technical lead responsible for evaluating plume extent and degradation rates at a site contaminated with chlorinated solvents. Developed three-dimensional numerical groundwater flow (MODFLOW-2005) and reactive-solute transport model (MT3DMS) for the site. Reactivity with a remedial additive was simulated to determine zone-of-influence dimensions and to evaluate potential for interaction with down-gradient groundwater sink.

Education

2003 – B.S. Hydrology, University of New Hampshire

2008 – M.S. Environmental Engineering, Virginia Polytechnic Institute and State University (Virginia Tech)

2012 – Ph.D. Civil Engineering, Virginia Polytechnic Institute and State University (Virginia Tech)

Publications and Presentations Within the Last 10 Years

Mobile, M. A., Widdowson, M., Stewart, L., Nyman, J., Deeb, R., Kavanaugh, M., Mercer, J., Gallagher, D., In-situ Determination of Field-Scale NAPL Mass Transfer Coefficients: Performance, Simulation, and Analysis, Journal of Contaminant Hydrology 187:31-46, 2016.

Mobile, M. A., Widdowson, M., Gallagher, D., Multicomponent NAPL Source Dissolution: Evaluation of Mass-Transfer Coefficients, Environmental Science & Technology 46(18): 10047-54, 2012.

Mobile, M. A., Stapleton, D., Stewart, D, Branscome, L. Assessing Extreme Coastal Storm Climatology and Associated Flooding Potential for Coastal New England, (Platform) Coasts, Oceans, Ports, and Rivers Institute (COPRI) Coastal Structures and Solutions to Coastal Disasters Joint Conference 2015, September 11, 2015.

Wang, B., Liu, T., Stapleton, D., Mobile, M. Coastal Data Application: Projecting Future Coastal Flood Risk for Massachusetts Bay, (Platform) Coastal GeoTools Conference, April 2, 2015.

Wang, B., Mobile, M., Stapleton, D., Leone, D. Low-Probability Storm Surge Analysis, (Platform) American Shore and Beach Preservation Association (ASBPA) 2014 - Virginia Beach, October 14, 2014.

Kinsella, K., Mobile, M. Phytoremediation for Tritiated Groundwater Management, (Platform) Electric Power Research Institute (EPRI) Nuclear Energy Institute (NEI) Groundwater Protection Workshop, June 27, 2014.

Mobile, M. A., Barvenik, M., Hunu, K. Impacts of Flooding on Groundwater at Nuclear Power Plants, (Platform) EPRI NEI Groundwater Protection Workshop, June 27, 2013.

Mobile, M. A. Using Models to Evaluate Remedial Options, (Platform) Joint American Council of Engineering Companies (ACEC) and Maine Department of Environmental Protection (MEDEP) Technical Seminar – Key Challenges Affecting Development and Engineering Work in Maine, 2013.

Mobile, M. A., Widdowson, M., Gallagher, D., Multicomponent Non-Aqueous Phase Liquid (NAPL) source dissolution: evaluation of mass transfer coefficients, (Platform) Remediation of Chlorinated and Recalcitrant Compounds Conference, May 22, 2012.

Mobile, M. A., Widdowson, M., Deeb, R., Kavanaugh, M., Nyman, J., Mercer, J., Stewart, L. Inverse model-based evaluation of parameters controlling field-scale mass transfer from

Professional Affiliations

Geological Society of America (GSA)
National Groundwater Association (NGWA)
Interstate Technology and Regulatory Council (ITRC), PFAS technical team (former)

Honors/Relevant Training

OSHA HAZWOPER 40 Hour Training Certificate
Edna Bailey Sussman Research Fellowship
NEWMOA Monitored Natural Attenuation (MNA) for Site Cleanup Short Course
IGWMC Certificate, Introduction to Numerical Modeling
Best Student Research Poster, 2011 REMTEC Summit

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FROM: Michael A. Mobile, Ph.D., McDonald Morrissey Associates, LLC

TO: Elizabeth M. Ransom, P.G., Ransom Consulting, Inc.

DATE: April 10, 2019

SUBJECT: **Summary of Groundwater Modeling to Support Significant Groundwater Well Permit Application, Proposed Nordic Aquafarms Facility, Belfast, Maine**

Background

This technical memorandum summarizes a groundwater modeling assessment performed by McDonald Morrissey Associates, LLC (MMA) to support the Significant Groundwater Well permit application associated with the proposed Nordic Aquafarms facility located in Belfast, Maine. The wells associated with this proposed facility are located on property situated immediately north of the Lower Reservoir (an area generally referred to herein as the Site). A map showing the Site location and associated key features is included as **Figure 1**.

The objectives of the modeling effort summarized herein are as follows:

1. Construct a numerical groundwater flow model for the bedrock aquifer occurring in the Site vicinity based on available data and information;

2. With support from the model, assess primary source(s) of recharge to the local bedrock aquifer and proposed supply well network; and

3. With support from the model, assess potential long-term viability of proposed withdrawal rates based on drawdown effects occurring away from the proposed well network.

The following sections summarize development of the above-referenced numerical model and results produced from its application. Additional background information pertaining to the Site, including summaries of the hydrogeologic setting, the conceptual hydrogeologic model, and data collection activities, is presented in the Site's Hydrogeologic Investigation Report.

Code Selection and Model Construction

A three-dimensional numerical model of the Site vicinity was prepared using the MODFLOW-USG (Un-Structured Grid) numerical modeling code (Panday et al., 2017). MODFLOW-USG was developed by the U. S. Geological Survey (USGS) to support a variety of structured and unstructured grid types, including nested grids and grids based on prismatic triangles, rectangles, hexagons, and other cell shapes. The flexibility in grid design afforded by MODFLOW-USG was used in this project to focus resolution along certain boundary conditions and in the vicinity of active groundwater withdrawals where hydraulic gradient magnitudes were anticipated to be greatest. Model pre- and post-processing steps were completed using the Groundwater Modeling System (GMS) software package[1].

The following information was used to support construction of the numerical model:

- Publicly-available information from the Maine Office of GIS Data Catalog[2], including surficial geology mapping; LiDAR elevation data; and hydrography coverages.

- Publicly-available information on private wells in the Site vicinity obtained from the Maine Geological Survey's Water Well Database[3].

- Publicly-available predicted tide data obtained from the National Oceanographic and Atmospheric Administration (NOAA) Tides & Currents database[4].

- Data collected during investigations conducted within the study area vicinity, including geophysical survey results; boring logs; measured groundwater elevations; and streamflow measurements. Locations associated with these measurements are illustrated as **Figure 2**.

- Reports describing local and regional hydrology and hydrogeology, including reports prepared by the United States Geological Survey (USGS).

- Input and output files associated with a preliminary numerical groundwater flow model for the Site vicinity developed by Ransom.

Model Domain and Spatial Discretization

MODFLOW-USG provides flexibility to efficiently focus finite-difference grid resolution in areas of interest. This functionality was used, as illustrated by **Figure 3**, to focus grid resolution near pumping wells to model cell dimensions of approximately 9 inches by 9 inches relative to row and column orientation, respectively. At the perimeter

[1] Groundwater Modeling System (GMS) – a software package developed by Aquaveo, LLC of Provo, UT. https://www.aquaveo.com/software/gms-groundwater-modeling-system-introduction
[2] Maine Office of GIS Data Catalog: https://www1.maine.gov/geolib/catalog/index.shtml
[3] Maine Geological Survey Water Well Database: https://www.maine.gov/dacf/mgs/pubs/digital/well.htm
[4] NOAA Tides & Currents Database: https://tidesandcurrents.noaa.gov/

of the model where grid resolution becomes coarse, model cell dimensions approach approximately 800 feet by 800 feet.

Vertically, the model domain was discretized using the following steps:

1. A generic model domain was developed and vertically divided into three (3) model layers[5]. Conceptually, layers 1 through 3 were created to approximately coincide with unconsolidated overburden materials (e.g., Presumpscot Formation, glacial till), the interfacial region between the unconsolidated overburden and competent bedrock (e.g., weathered bedrock zone), and the productive portion of the more-competent fractured bedrock aquifer, respectively.

2. The top of the model was designed based on LiDAR data available for the study area. LiDAR data were converted to a Triangulated Irregular Network (TIN), which was then converted to model layer 1 top elevation assignments within GMS using linear interpolation, as illustrated by **Figure 4**.

3. Bottom of layer 1 / top of layer 2 elevation assignments were supported by developing a data set containing reported bedrock depths from Site wells and the MGS private well database. **Figure 5** shows the locations associated with this data set. Where surveyed reference elevations were not available (e.g., private wells), bedrock elevations were estimated by offsetting reported bedrock depths using available LiDAR elevation data. The resultant data set was then converted to model input using linear interpolation.

4. Similar to step 3, bottom of layer 2 / top of layer 3 elevation assignments were supported by developing a data set containing reported casing depths from Site wells and the MGS private well database.

5. Finally, layer 3 bottom elevation assignments were developed based on a constant thickness approach, where thickness was determined based on the difference between the casing bottom elevation and elevation at the depth-of-penetration at PW-1.

Cross-sections illustrating the extent of the model domain and vertical grid discretization, or model layering, are included as **Figures 6a and 6b**.

Temporal Discretization

Individual simulations were performed to support calibration (and sensitivity testing), verification, and application of the numerical model. The following table summarizes periods of coverage and the general manner in which time is discretized within each simulation:

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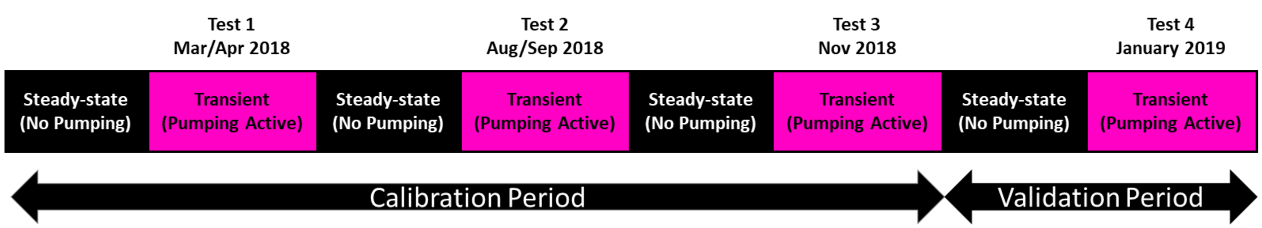
[5] Spatial discretization tasks were performed based on information projected using the Maine State Plane Coordinate System (East Zone) referenced horizontally to the North American Datum of 1983 (NAD83) and vertically to the North American Vertical Datum of 1988 (NAVD88), units of U.S. survey feet.

Simulation Type	Starting Date	Ending Date	Number of Stress Periods	Additional Notes
Calibration and Sensitivity Testing	3/30/2018	11/29/2018	133	Steady-state periods initialize transient periods spanning three pumping tests (1 through 3). Stress periods designed to represent variations in supply well pumping rates and predicted high and low tide conditions.
Verification	1/8/2019	1/18/2018	8	Single steady-state period initializing a transient period associated with pumping test 4. Stress periods designed to coincide with timing of well additions and rate increases.
Application	Not applicable		1	Steady-state projection runs performed with and without pumping to estimate maximum stabilized drawdown. Transient simulations used to estimate the time required for drawdowns to stabilize.

The simulation period associated with model calibration and verification can be schematically depicted relative to the pumping tests conducted at the Site as follows:



Boundary Conditions

A map showing the locations and types of boundary conditions represented within the model is included as **Figure 7**. These boundary types are described below by category:

No-Flow Boundaries

No-flow boundaries were used to limit the active portion of the model domain to an area coinciding with the approximate extent of the Little River watershed. These boundaries were assigned consistently in all model layers under the assumption that groundwater flow to-and-from the delineated drainage basin is small relative to flow within the active model area. A no-flow boundary was also assigned at the base of model layer 3, reflecting the assumption that deeper zones within the bedrock aquifer do not contribute significantly to wells drawing from shallower zones.

Specified Head Boundary

A combination of no-flow and constant head boundaries, the latter being assigned using the MODFLOW Time-Variant Specified Head or CHD package, was used to represent the freshwater/saltwater interface occurring along the coastline adjacent to Belfast Bay and within the tidal inlet below the Lower Reservoir.

Within model layer 1, these locations were treated as a specified head boundary. Tidal predictions at the NOAA subordinate station in Belfast (Station ID 8415191, refer to **Figure 8**) were used to support the development of CHD boundary head specifications. The approach used to convert this information to head specifications varied by simulation and stress period type. For transient stress periods associated with calibration simulations (i.e., where greater temporal definition was desired), head assignments were varied with time to account for the oscillating tidal condition. Head assignments pertaining to other simulations (i.e., verification and application) and all simulated steady-state stress periods are representative of a mean sea level condition[6], which is assumed to approximate the average hydraulic condition at this boundary. Prior to developing the boundary assignments, tidal predictions were adjusted based on Haitjema (2007) to appropriately estimate the so-called "freshwater head" condition influencing the simulated freshwater system[7].

Within model layers 2 and 3, the eastern limit of the active model domain was treated as no-flow boundary to reflect a steeply-dipping freshwater/saltwater interface. This approach is generally consistent with the Ghyben-Herzberg Relationship, which suggests that the depth to the position of the freshwater/saltwater interface can be estimated by multiplying the local freshwater hydraulic head by a factor of 40 (Masterson, 2004).

Head-Dependent Boundaries

The Little River and associated tributary network occurring above the Upper Reservoir and between the reservoirs were represented within the model using the MODFLOW Stream Flow Routing (SFR2) package. Stream top elevation inputs were estimated using available LiDAR data. Flow within the simulated streams was estimated using a wide channel approximation, as described by Niswonger and Prudic (2005).

The MODFLOW General Head Boundary (GHB) package was used to represent certain persistent water bodies, including the Upper Reservoir and the Lower Reservoir (refer to **Figure 7**). For the reservoirs, head assignments were developed by estimating an average representative stage based on available data collected from representative staff gages (SG-2 and SG-3). For smaller water bodies, representative heads were estimated using available LiDAR data.

The MODFLOW Drain (DRN) package was used to represent smaller streams and gullies occurring below the reservoirs. These features were assumed to represent limited sources of recharge to the local groundwater system. Drain bottom elevations were assigned based on available LiDAR data.

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[6] As reported as the Mean Sea Level (MSL) datum for NOAA subordinate station ID 8415191

[7] "Freshwater head" conditions were estimated via equation 3 from Haitjema (2007) under the assumption of a confined flow condition.

As required for head-dependent boundaries, cell-specific conductance parameters are specified in the GHB and DRN input files[8]. Similarly, the hydraulic conductivities of streambed sediments are specified in the SFR2 input file. These values were included as variable parameters in the calibration process, as discussed in the **Model Calibration** section below.

Hydraulic Properties

Hydraulic properties assigned to active model cells include horizontal hydraulic conductivity (K_h), horizontal anisotropy factor (HANI)[9], vertical anisotropy factor (VANI)[10], specific storage (S_s), and specific yield (S_y). Properties were either assigned as constant/uniform values for a given model layer or material type (i.e., based on surficial geology mapping) or as spatially-varying fields for given model layer or material type. The latter is an approach referred to as pilot-point parameter specification, which required an inverse-distance weighted (IDW) interpolation scheme to develop parameter value fields based on distributed point estimates.

The following table provides a summary of the techniques used to specify K_h, HANI, VANI, S_s, and S_y:

Model Layer	Horiz. Hyd. Conductivity (K_h)	Horiz. Aniso. (HANI)	Vert. Aniso. (VANI)	Storage Parameter(s) (S_s and/or S_y)
1	Constant value for areas generally mapped as glacial till; pilot point approach for Presumpscot Formation area	Constant value of 1.0	Variable for layer based on pilot point approach	Layer type set as convertible. S_y set to constant value of 0.1. S_s set to constant value of 3.4e-4 per foot (Anderson and Woessner, 1991).
2	Variable for layer based on pilot point approach	Constant value of 1.0	Variable for layer based on pilot point approach	Layer type set as convertible. S_y set to constant value of 0.1. S_s set to constant value of 3.4e-4 per foot (Anderson and Woessner, 1991).
3	Variable for layer based on pilot point approach	Constant value	Constant value	Layer type set as confined. S_s variable for layer based on pilot point approach.

[8] GHB conductance per unit area of coverage within a given model cell was assumed to be equal to swamp deposit hydraulic conductivity, as estimated via calibration, divided by a wetland bottom thickness of 1 foot.

[9] Horizonal anisotropy factors (HANI) represent the ratio of horizontal hydraulic conductivity along model columns to horizontal hydraulic conductivity along model rows.

[10] Vertical anisotropy factors (VANI) represent the ratio of horizontal hydraulic conductivity to vertical hydraulic conductivity.

Where specific values are indicated in the table above, property value assignments were held constant through the model calibration process. Examples include constant HANI values of 1.0 in model layers 1 and 2, which reflect the general assumption of horizontally-isotropic hydraulic conductivity in unconsolidated deposits and highly-weathered bedrock, and uses of representative (i.e., mean), literature-supported values of storage parameters for model layers 1 and 2.

Where specific values are not provided (e.g., "constant value") or where the pilot point approach is referenced, parameter values are ultimately determined via the model calibration process, which is further discussed below in the **Model Calibration** section.

Recharge/Discharge

Recharge from Precipitation

Rates of groundwater recharge assigned to the model domain were guided by several studies of hydrogeologic conditions occurring in the Site vicinity. These studies focused on areas with hydrogeologic characteristics like those of the Site vicinity, including significant presences of glacial till and the glaciomarine Presumpscot formation.

A summary of the above-referenced studies presented by Nielsen and Locke (2014) was used to estimate representative mean annual recharge rates as input to the MODFLOW Recharge (RCH) package. Areas within the active model domain mapped as glacial till were assigned a mean annual recharge rate equivalent to 5.25 inches per year (based on an average of the reported range of 2.5 to 8 inches per year). Similarly, areas mapped as Presumpscot formation were assigned a mean annual recharge rate equivalent to 1.2 inches pear year (based on an average of the reported range of 0.5 to 1.9 inches per year). These rates were applied to steady-state stress periods; recharge was conservatively assumed to be inactive during transient periods with the exception of transient application simulations performed to estimate the time required for stabilization of drawdown.

The recharge rates described above are assumed to represent net aquifer recharge inclusive of unsaturated zone and shallow saturated zone effects, including evapotranspiration (ET). For this reason, ET was not explicitly simulated as an active process in this modeling effort.

Supply Well Withdrawals

Information describing timing, rates, and locations of pumping withdrawals occurring during the four pumping tests conducted at the Site was provided to MMA by Ransom. This information was used as input to the MODFLOW Well (WEL) package, which was used to represent supply well withdrawals in the form of specified flux to or from a given model cell. **Figures 9a and 9b** summarize the planned pumping rates associated with the pumping tests 1 through 3, which coincide with the simulation periods used for model calibration, and pumping test 4, which coincides with the simulation period used for model verification.

In developing input for calibration simulations, WEL package inputs were refined based on daily and sub-daily withdrawal records provided to MMA by Ransom, which highlighted generally minor deviations from the planned rates presented in **Figures 9a and 9b**. Examples include rare cases of pump downtime (e.g., DRX-102 during 11/18/2018 due to generator failure) and decreasing well yield due to hydraulic head reduction (e.g., PW-1 rate decreased from 250 gallons per minute [gpm] during 11/18/2018 to 230 gpm by the conclusion of the third pumping test on 11/21/2018).

Verification simulations used the planned rates directly, as daily/sub-daily field records suggested deviations, in most cases, were minimal during the fourth pumping test. However, based on these records, the withdrawal rate at PW-1 did appear to decrease as the test progressed and head above the pump was reduced, as was the case during the third pumping test. This difference between verification model input specifications and field conditions is further discussed below in the **Model Verification** section.

Note that residential pumping was not represented within the model due to limited information availability (e.g., unavailable well construction information, limited information describing timing and rates of active pumping, etc.). Furthermore, it was assumed that residential pumping represents a negligible consumptive component of the simulated system's volumetric balance, as residential pumping rates are generally low, wells are generally distributed in terms of their locations, and some return flow from private septic infiltration would be anticipated.

Model Calibration

Model calibration was accomplished using trial-and-error and automated techniques, with the latter approach involving use of a model-independent parameter estimation utilities called PEST (Watermark Numerical Computing, 2016) and PEST_HP (Watermark Numerical Computing, 2017). In using this utility, batches of parallel calibration simulations reflecting parameter value perturbations were performed to minimize an aggregated difference of simulated and measured hydraulic heads, the latter of which is referred to herein as the calibration target data set.

The calibration target data set was created using head measurements provided to MMA by Ransom. These head measurements were collected using a network of pressure transducers placed in shallow piezometers, monitoring wells, pumping wells, residential wells, and staff gages located throughout the Site vicinity. In generating the calibration target data set, only pressure transducer data were used; manual measurements were not included.

To support and constrain the calibration process, initial values and upper and lower limits for adjustable parameters were estimated based on site-specific information, where available, and published ranges consistent with the general descriptions of the material/deposit types (e.g., Anderson and Woessner, 1992). In select cases, a combination of modeling experience and relatively broad parameter value ranges was used to provide flexibility to the calibration process.

Model calibration results are summarized by **Figures 10a through 10c**, which compare measured hydraulic heads from the calibration target data set to comparable (i.e., in space and time) simulated conditions. These plots suggest general consistency between measured and modeled conditions. This consistency is further evidenced through the following tabulated statistical summary, which is presented in terms of Residual Mean (RM) values, which are arithmetic averages of residuals calculated using the calibration target data set (measured groundwater elevation minus the comparable simulated groundwater elevation):

	Residual Mean (RM) Statistics		
Pumping Test / Simulated Period	**Mean**	**10th Percentile**	**90th Percentile**
1 – March/April 2018	1.0	-1.0	3.0
2 – August/September 2018	-1.6	-4.1	0.1
3 – November 2018	0.2	-1.7	2.1

Additionally, the calibration simulation produces a reasonable balance between volumetric inflows and outflows, as evidenced by the following summary:

	Volumetric Balance Percent Discrepancy
Minimum[1]	**-0.34%**
Maximum[1]	**+0.01%**
Cumulative	**-0.15%**

[1]Calculated from percent discrepancies reported for all calibration simulation time steps

Final hydraulic parameter values and ranges (i.e., for parameters estimated using pilot points) are presented in the following table:

Horizontal Hydraulic Conductivity (feet/day)			
Model Layer	Mapped Material Type	Parameter Bounds (lower – upper)	Calibrated Value/Range (value / lower – upper)
1	Presumpscot formation	5.0E-04 - 150.0	5.0E-04 - 127.9
1	Glacial till	0.045 - 4.0	0.045
2	Shallow bedrock	0.05 - 10.0	0.05 - 9.9
3	Bedrock	0.001 - 50.0	0.001 - 49.9
Horizontal Anisotropy (dimensionless)			
3	Bedrock	0.005 - 1.0	0.01
Vertical Anisotropy (dimensionless)			
1	Presumpscot formation & glacial till	1.0 - 100.0	1.0 - 98.7
2	Shallow bedrock	1.0 - 100.0	1.0 - 100.0
3	Bedrock	1.0 - 100.0	1.0
Specific Storage (1/foot)			
3	Bedrock	1.0E-10 - 2.1E-05	3.8E-09 - 2.1E-05

Notes:

1. Calibrated ranges indicate the range of values for pilot points produced via calibration.
2. Horizonal Anisotropy and Vertical Anisotropy refer to the HANI and VANI factors, respectively.

Where applicable, IDW interpolation was used to convert parameter values estimated at pilot point locations to parameter fields. An example is shown in **Figure 11**, which depicts the final calibrated hydraulic conductivity fields for models layers 1 through 3.

Final parameter values associated with head-dependent boundaries are presented in the following table:

Drain Bed Conductance (feet^2/day)		
Location	Parameter Bounds (lower – upper)	Calibrated Value/Range (value / lower – upper)
Periphery	0.001 - 15.0	0.30
Near proposed site	0.001 - 15.0	0.001
Reservoir Bed Conductance (feet^2/day)		
Upstream pond	1.0E-4 - 15.0	15.0
Upper reservoir	1.0E-4 - 15.0	15.0
Lower reservoir	1.0E-4 - 15.0	7.7
Stream Bed Hydraulic Conductivity (feet/day)		
Streams draining to the Upper Reservoir	0.1 - 50.0	27.2
Reach connecting reservoirs	0.1 - 50.0	3.7
Streams draining to the Lower Reservoir	0.1 - 50.0	0.1

Additional summaries of calibration simulation results are provided within the attached **Appendix**.

Sensitivity Testing

Following calibration, sensitivity testing was performed to assess the influence of parameters on the quality of model calibration. This assessment was performed using RM and two additional statistical performance metrics:

1. The Absolute Residual Mean (ARM), which is the arithmetic average of the absolute values of residuals calculated using the calibration target data set; and

2. The Residual Sum of Squares (RSOS), which is the sum of the squared values of residuals calculated using the calibration target data set.

In general, it is desirable from a calibration perspective to have RM approach a value of zero (0) while simultaneously minimizing the values of ARM and RSOS. It is important to note, however, that RSOS will typically be significantly greater in magnitude than ARM due to squaring and summing of residual values.

With the results of the calibration simulation as a starting point, sensitivity tests were performed by increasing and decreasing values for several parameter groups. Dedicated simulations were performed for adjustments to values of horizontal hydraulic conductivity, vertical anisotropy, horizontal anisotropy (model layer 3 only), specific storage, specific yield, recharge rate, GHB conductance, DRN conductance, and streambed (SFR2) hydraulic conductivity. The following table summarizes the sensitivity testing results:

Parameter Group	Change	RM (ft)	ARM (ft)	RSOS (ft^2)
Baseline (no change)	None	-0.1	1.5	4.6E+05
Horizontal Hydraulic Conductivity	+50%	-3.1	5.1	5.2E+06
Horizontal Hydraulic Conductivity	-50%	10.2	11.8	3.7E+07
Vertical Anisotropy	+50%	-2.0	2.7	9.9E+05
Vertical Anisotropy	-50%	2.3	3.5	1.5E+06
Horizontal Anisotropy (model layer 3 only)	+50%	-1.0	2.7	1.2E+06
Horizontal Anisotropy (model layer 3 only)	-50%	1.8	3.6	2.7E+06
Specific Storage	+50%	-0.4	1.8	5.9E+05
Specific Storage	-50%	0.4	2.1	7.1E+05
Specific Yield	+50%	-0.3	1.5	4.6E+05
Specific Yield	-50%	0.5	1.7	5.0E+05
Recharge Rate	+50%	-1.8	2.2	8.1E+05
Recharge Rate	-50%	3.6	3.9	1.7E+06
GHB Conductance	×10	-0.1	1.5	4.5E+05
GHB Conductance	÷10	-0.1	1.5	4.5E+05
DRN Conductance	×10	0.0	1.5	4.5E+05
DRN Conductance	÷10	-0.1	1.5	4.5E+05
Streambed (SFR2) Hydraulic Conductivity	×10	0.3	1.6	4.7E+05
Streambed (SFR2) Hydraulic Conductivity	÷10	-1.5	2.1	6.8E+05

As indicated by this table, RM, ARM, and RSOS are generally quite sensitive to hydraulic parameter values, with particularly sensitivity evident for the horizontal hydraulic conductivity parameter group. Conversely, the model generally demonstrates limited sensitivity to conductance and hydraulic conductivity values associated with head-dependent boundary types (GHB, DRN, and SFR2). This result appears to be consistent with conditions predicted by the model at these boundaries (i.e., generally low volumetric rates of groundwater discharge to the boundary).

Model Verification

Following calibration, a simulation of pumping test 4 was performed as an additional assessment of model performance (referred to generally herein as verification). The assessment was supported by developing a verification data set, which was composed in the same manner as the calibration target data set, as described previously.

Results produced by the verification simulation are summarized by **Figure 12**, which compares measured hydraulic heads from the verification target data set to comparable (i.e., in space and time) simulated conditions. As was the case for the calibration results, these plots suggest general consistency between measured and modeled conditions. This consistency is further evidenced through the following tabulated summary of RM values:

	Residual Mean (RM) Statistics		
Pumping Test / Simulated Period	**Mean**	**10th Percentile**	**90th Percentile**
4 – January 2019	0.9	-1.6	4.0

As previously noted, the verification simulation included WEL package inputs reflecting planned pumping rates; though, a relatively minor deviation from the planned rate evident at PW-1 based on daily/sub-daily field records. As illustrated by **Figure 13** this difference appears to result in a continued downward trend in simulated hydraulic head at PW-1 that deviates slightly from the observed conditions at this location; whereas, the deviation is not as pronounced for the other active wells where planned rates were generally maintained throughout the duration of the pumping test.

Additional summaries of measured and simulated water levels from the verification simulation are provided within the attached **Appendix**.

Model Application

Following the calibration and verification steps, projection simulations were performed to estimate system responses under different pumping scenarios where locations and rates of withdrawal were varied. The objectives of these projection simulations were the following:

1. For a given pumping rate scenario, estimate the maximum amount of drawdown that may develop under long-term, average conditions; and

2. For a given pumping rate scenario, estimate the time required for drawdown to stabilize.

Relative to objective 1, above, estimates were generated using steady-state model simulations. First, a non-pumping (i.e., no active wells) simulation with estimated average recharge rate specifications was performed to create a baseline condition. Additional steady-state simulations were then performed for three pumping scenarios. Each pumping scenario was simulated three times: once with estimated average recharge rate specifications consistent with the baseline simulation, once with the estimated average recharge rates halved to roughly approximate the lower bounds of the material-specific recharge rate ranges reported by Nielsen and Locke (2014)[11], and once reflecting a 2-foot reduction in the head assigned to the Lower Reservoir head-dependent boundary. The second set of simulations (i.e., halved recharge rates) was performed to support a general assessment of the sensitivity of drawdown estimates to long-duration, reduced recharge conditions.

The third set of simulations was performed to support a general assessment of the sensitivity of drawdown estimates to long-duration changes to the stage of the Lower Reservoir. Minor modifications to model layering were required to support these simulations (i.e., lowering layer 1 bottom elevation assignments in the vicinity of the Lower Reservoir). No additional calibration or recalibration was performed using the modified version of the model grid; therefore, the results of the Lower Reservoir stage sensitivity assessment are considered to be general and qualitative.

Estimates of maximum drawdown under each pumping scenario and recharge condition were then generated by subtracting simulated heads for each model run from comparable (i.e., in terms of location) simulated heads from the baseline condition. Estimated maximum drawdown changes pertaining to the Lower Reservoir stage sensitivity assessment were generated by comparing simulated heads under normal stage (i.e., Lower Reservoir stage used during calibration) and modified stage (i.e., 2-foot reduction) conditions.

To address objective 2, above, the steady-state baseline simulation was extended by adding a second transient stress period with a duration of approximately 10 years. Simulations were performed with this version of the model with an initial, steady-state, non-pumping period followed by a transient period representative of each pumping scenario. Estimated average recharge rate specifications were used during the transient period.

The three pumping scenarios assessed using these approaches are summarized as follows:

[11] For the glacial till material group, the specified recharge rate was 5.25 inches per year / 2 = 2.63 inches per year versus a lower bound of 2.5 inches per year per Nielsen and Locke (2014). For the Presumpscot formation material group, the specified recharge rate was 1.2 inches per year / 2 = 0.6 inches per year versus a lower bound of 0.5 inches per year per Nielsen and Locke (2014).

Scenario ID	PW-1 (gpm)	GWW-103 (gpm)	DRX-102 (gpm)	PSD-102 (gpm)	DRX-101 (gpm)	Total Pumping (gpm)
1	250	175	30	0	0	455
2	250	175	30	30	30	515
3	125	87.5	15	0	0	227.5

The bases for these pumping scenarios are summarized as follows:

- Scenario 1 was designed based on the locations and rates active during pumping test 4 prior to adding PSD-102, which appeared to be well connected with residential supply wells (e.g., WSW-03) located west of the Site based on monitoring data.

- Scenario 2 was designed to match the final design rates targeted during pumping test 4. Thus, this scenario was simulated in order to approximately extend the final stage of pumping test 4.

- Scenario 3 is based on Scenario 1, but all withdrawal rates were halved.

Figures 14a through 14c illustrate simulated maximum drawdown in model layer 3 (fractured bedrock aquifer) for each of the three pumping scenarios under estimated average recharge conditions. For Scenario 1, maximum drawdown estimates for an on-Site monitoring/supply well and an off-Site monitored residential well are approximately 200 feet (PW-1) and 15 feet (WSW-04), respectively. For Scenario 2, maximum drawdown estimates at these locations increase to approximately 220 feet and 18 feet, respectively. For Scenario 3, maximum drawdown estimates at these locations decrease to approximately 85 feet and 5 feet, respectively.

Results for shallow piezometer monitoring locations (i.e., model layer 1) are similar for all scenarios under estimated average recharge conditions, with the maximum simulated drawdown for each scenario slightly exceeding 5 feet (PZ-1S).

Under reduced recharge conditions (halved recharge rates), maximum drawdown estimates increase to slightly more than 20 feet at off-Site locations for Scenario 1 (WSW-04 and WSW-01). Similar proportional increases are noted relative to Scenarios 2 and 3 compared to results produced under estimated average recharge conditions.

Qualitatively, model simulations reflecting a 2-foot lowering of Lower Reservoir stage suggest limited sensitivity at off-Site locations. For all simulated pumping scenarios, increases in maximum estimated drawdown of several feet or more (i.e., compared to the normal stage condition) were generally limited to the Site vicinity. Overall, the largest estimated change in maximum drawdown associated with the 2-foot lowering of the

Lower Reservoir stage occurred in the vicinity of pumping well GWW-103 for all simulated pumping scenarios.

Additional summaries of simulated drawdown results are provided within the attached **Appendix**.

Figure 15 provides a comparison of the volumetric flow budgets for the baseline (no pumping) and Scenario 1 simulations, both under estimated average recharge conditions. In both cases, recharge from precipitation represents the major source of water to the modeled groundwater system, with supplemental volume being provided from reservoir/pond leakage. These sources are mostly offset, in both cases, by groundwater discharge to streams and the coastal boundary. With pumping active (Scenario 1 case), the withdrawal demand appears to be partly satisfied by interception of groundwater that was previously discharging to streams, reservoirs/ponds, and the coastal boundary; though, some inflow from the coastal boundary is predicted. Sensitivity testing performed during model application also suggests that the volumetric rate of inflow from the coastal boundary may increase under reduced recharge and reduced Lower Reservoir stage conditions.

Transient scenario simulation results are presented in **Figures 16a through 16c** for monitored residential wells in the Site vicinity. Based on these results, drawdown effects may develop more rapidly in areas located west-northwest of the Site (i.e., as indicated by the estimated responses at the WSW-01, WSW-03, and WSW-05 locations) compared to areas due west (i.e., as indicated by the estimated response at the WSW-02 location) and south (i.e., as indicated by the WSW-04 response) of the Site. Stabilization times, however, are estimated to be many years to more than a decade for all locations under all simulated scenarios.

Summary

The numerical modeling described herein generally supports a proposed withdrawal plan similar to the Scenario 1 condition (a total of 455 gpm from wells PW-1, GWW-103, and DRX-102). Because modeling suggests pumping of Site wells may result in condition changes under average conditions (e.g., drawdown and induced coastal boundary flow), and because deviations from average conditions, such as sustained drought conditions, may alter these estimates, the following is recommended:

- Conduct further assessment of residential supply wells located in the Site vicinity to better understand typical conditions (e.g., range of head fluctuations occurring under normal use) and physical characteristics (e.g., pump depth).

- Develop a plan for monitoring:
  - drawdown in bedrock supply wells located on- and off-Site;
  - drawdown of the water table near surface water features in the Site vicinity; and
  - in certain locations, water quality (e.g., total dissolved solids or TDS).

- Develop contingencies to address cases where current use changes (e.g., reduced well yield) can be attributed to effects caused by Site-related pumping.

Though calibration and verification simulations suggest good agreement between measured and simulated hydraulic conditions, it is important to note that model results are sensitive to key assumptions made in the modeling process that impact the availability of water within the simulated system. These assumptions include the conceptualization and representation (within the model) of system characteristics, including the key assumption that hydraulic properties controlling groundwater flow through porous media can be used to reasonably estimate bulk groundwater flow through the local fractured rock aquifer (generally referred to as the Equivalent Porous Medium or EPM assumption). Hydraulic controls that are not readily apparent from available data may alter model-based estimates, including point estimates of maximum anticipated drawdown and stabilization time for any pumping scenario, as well as the simulated extent of drawdown effects. Furthermore, scenario simulations (model application) were designed under the assumption that long-term conditions (e.g., estimated average and reduced annual recharge rates) reflect an appropriate basis for assessing drawdown effects in the Site vicinity. Shorter duration events, such as seasonal drought periods, were not assessed. Further discussion of limitations pertaining to the results presented herein is presented in the **Limitations** section.

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Attachments:

(1) Appendix A – Supplemental Tables and Figures

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Limitations

General

This technical memorandum was produced by McDonald Morrissey Associates, LLC (MMA) for exclusive use by our client and according to the purposes specifically described in the associated Scope of Work. MMA does not accept responsibility and/or liability for uses of the information contained within this memorandum by other parties and/or for other purposes without MMA's express written consent.

Additional Limitations

1. This technical memorandum summarizes a numerical model developed by MMA using data and information collected by and made available to MMA by other parties. The data and information represent discrete spatial and temporal measurements/interpretations of study area conditions, which may vary between points of measurement/information collection. No independent assessment of the quality of the data, including verification and/or validation, was performed by MMA.

2. In developing the numerical model described by this technical memorandum, simplifying assumptions and general simplifications pertaining to the simulated system were necessary and are inherent in any similar modeling assessment. Key assumptions and simplifications specific to the study area, which are summarized in the memorandum, were supported by MMA's professional judgement and were based on available information and data. Additional information and data collected and made available after the date of this memorandum may result in refinement or revision to the presented findings.

3. MMA performed the work described by this technical memorandum at a level of technical proficiency commensurate with that which would be anticipated from similar qualified professional practitioners provided with the same information, data, and objectives.

4. The work summarized by this technical memorandum is not subject to any form of warranty by MMA.

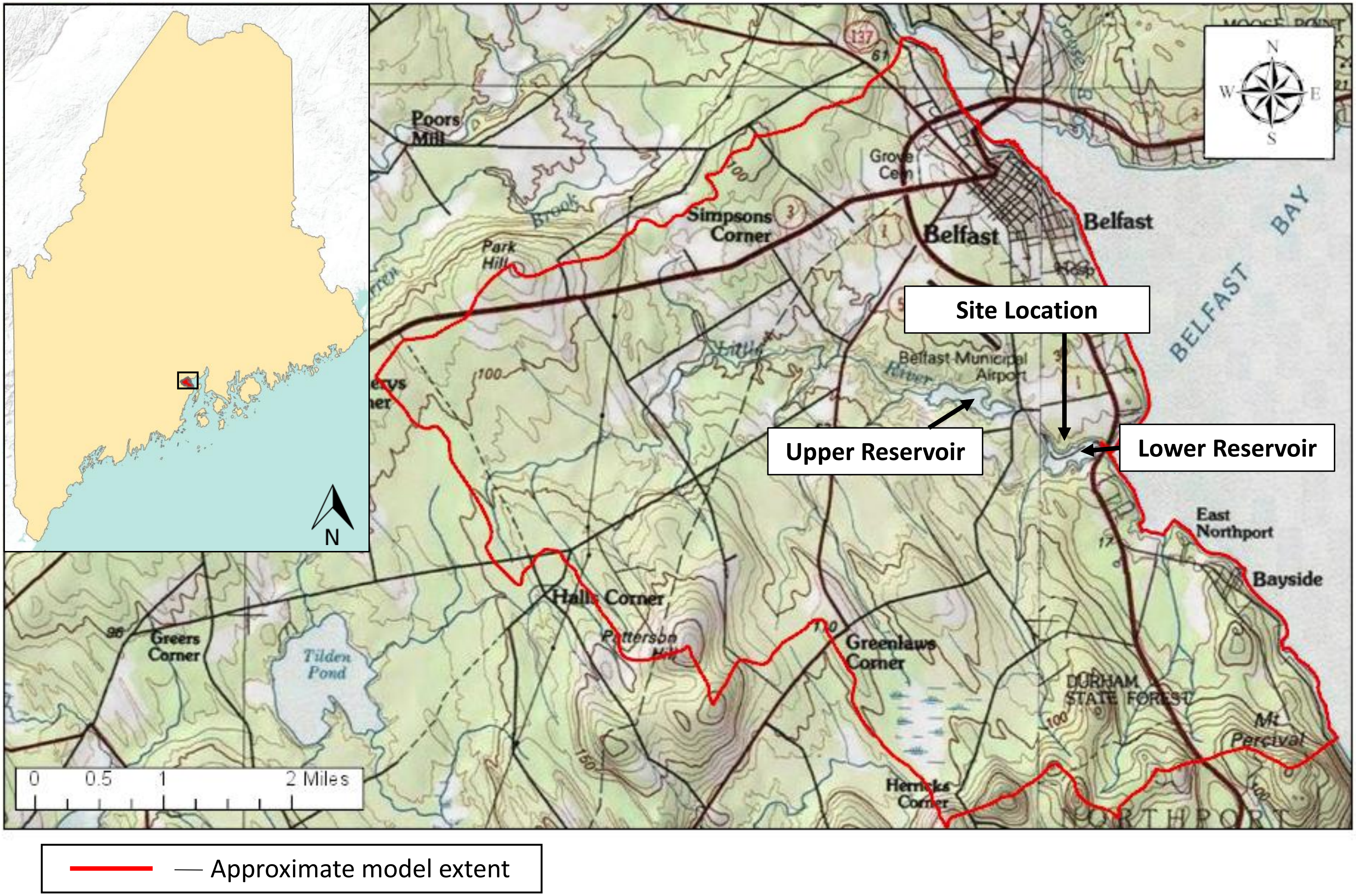

Figure 1 – Study area location.

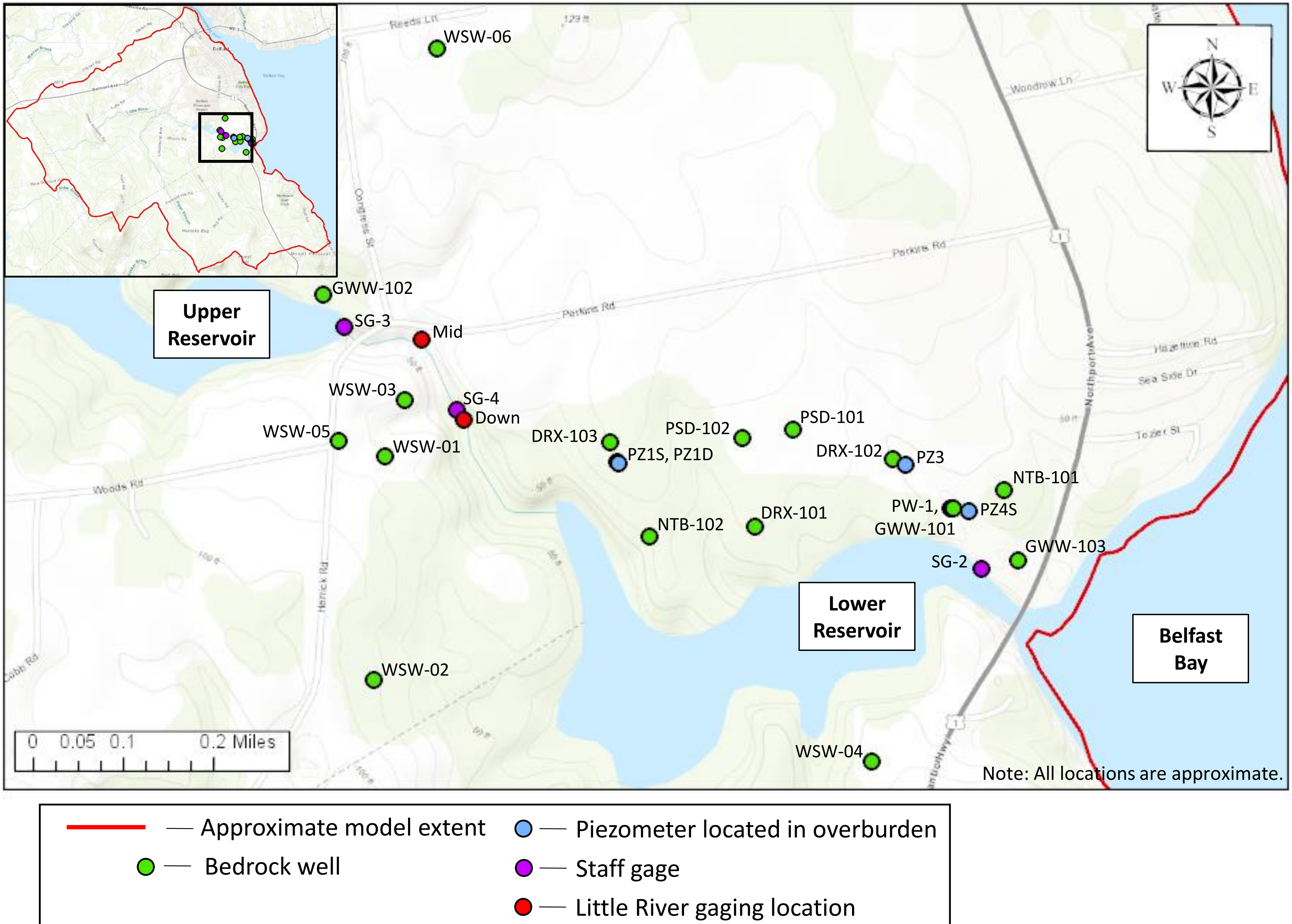

Figure 2 – Data collection locations.

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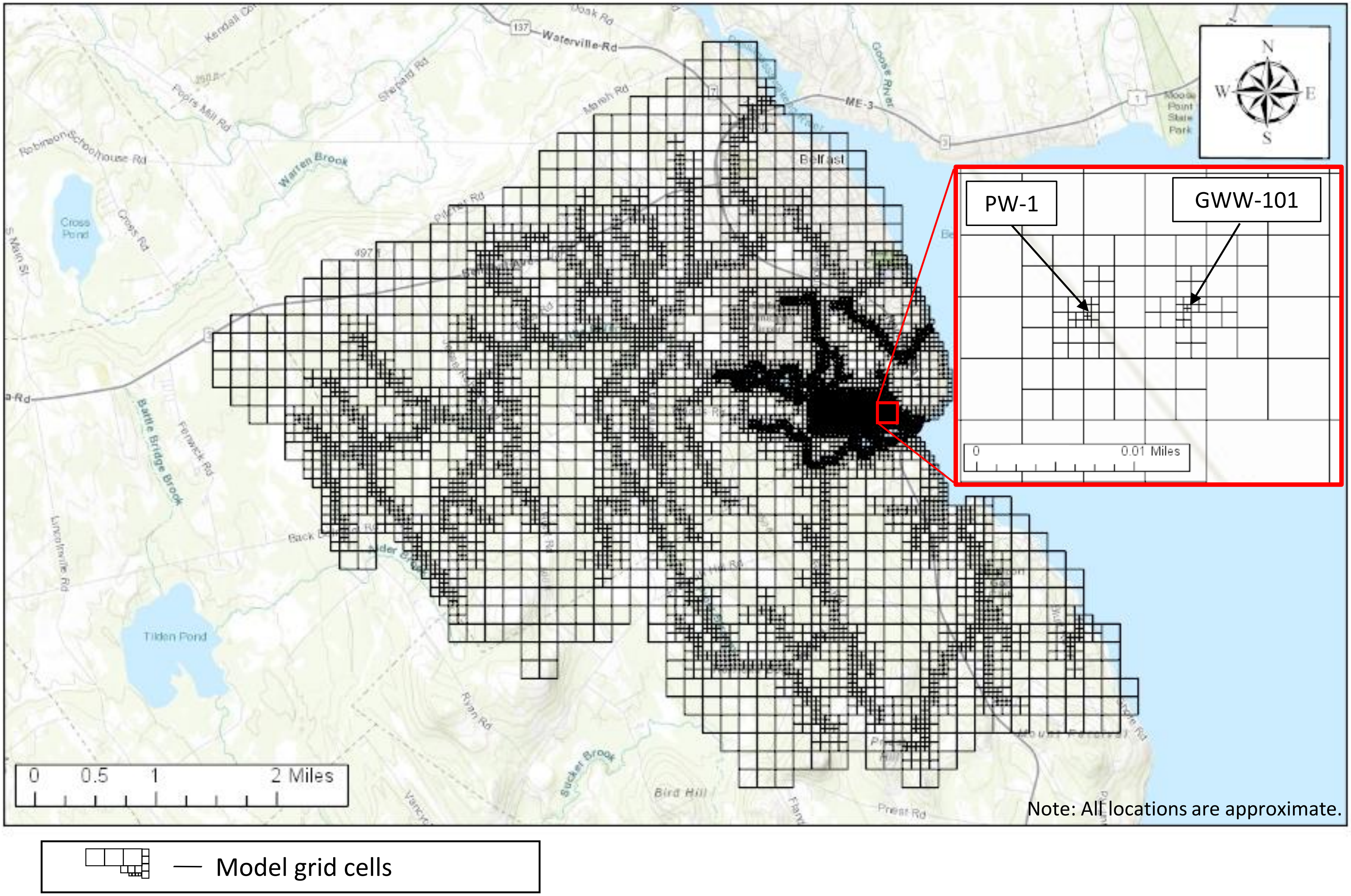

Figure 3 – Model domain and numerical grid discretization.

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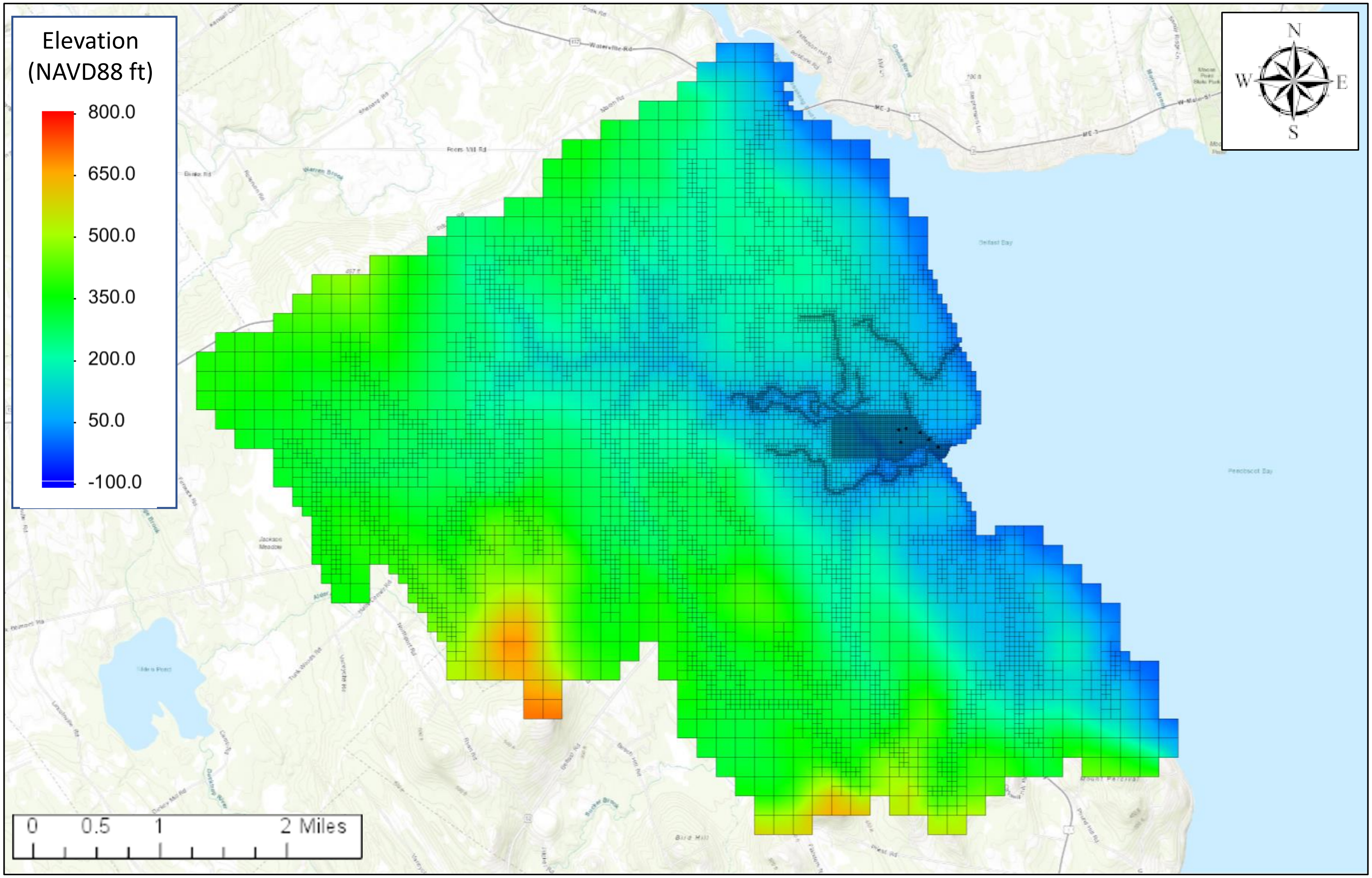

Figure 4 – Model top elevations.

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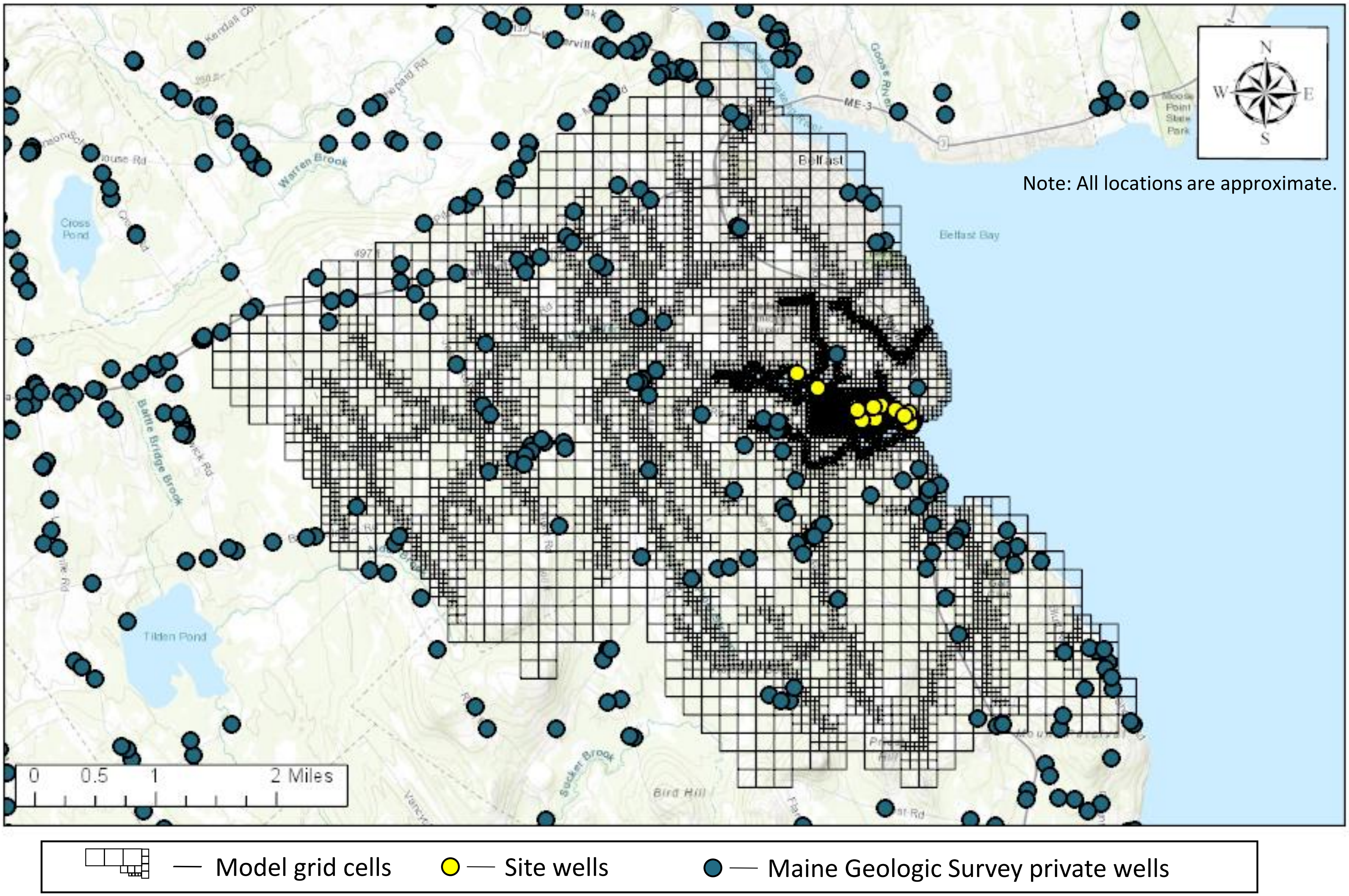

Figure 5 – Locations of wells records used to support model layering.

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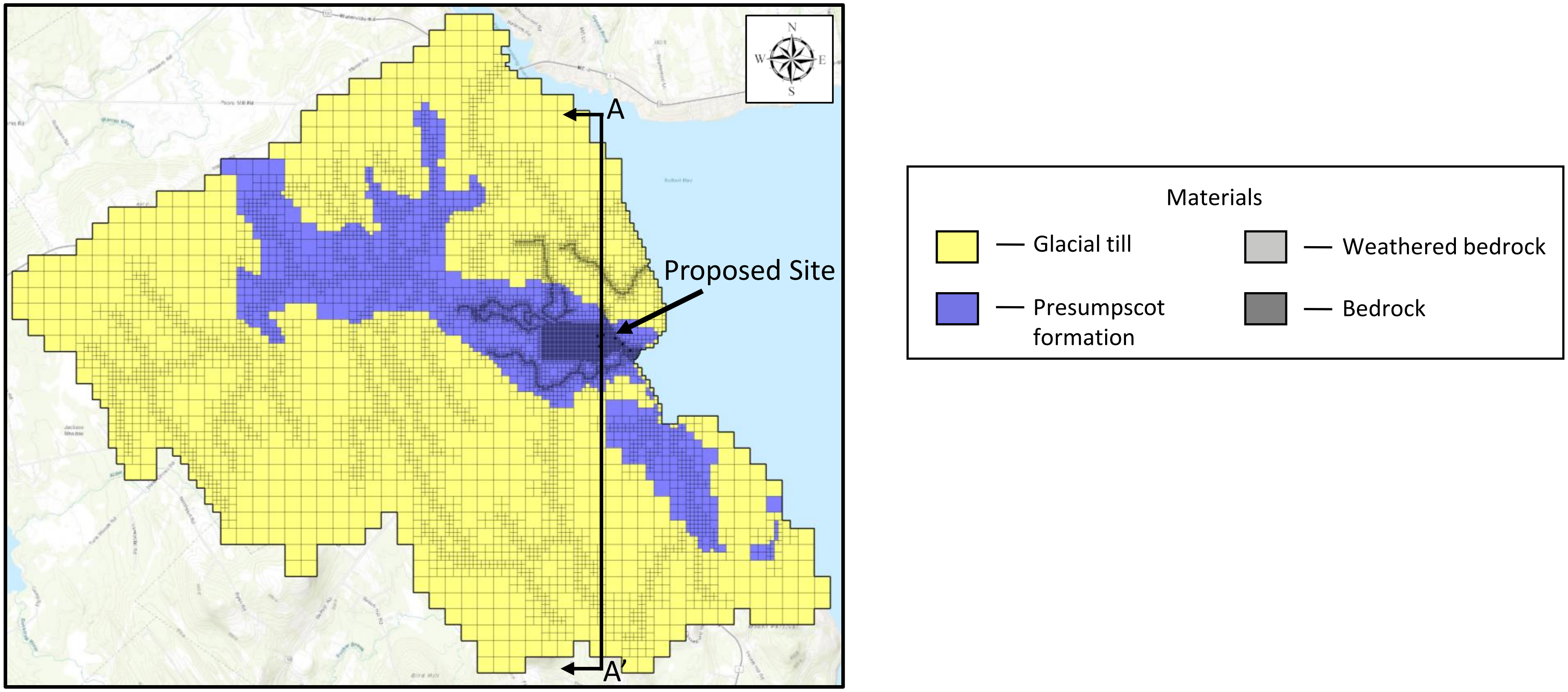

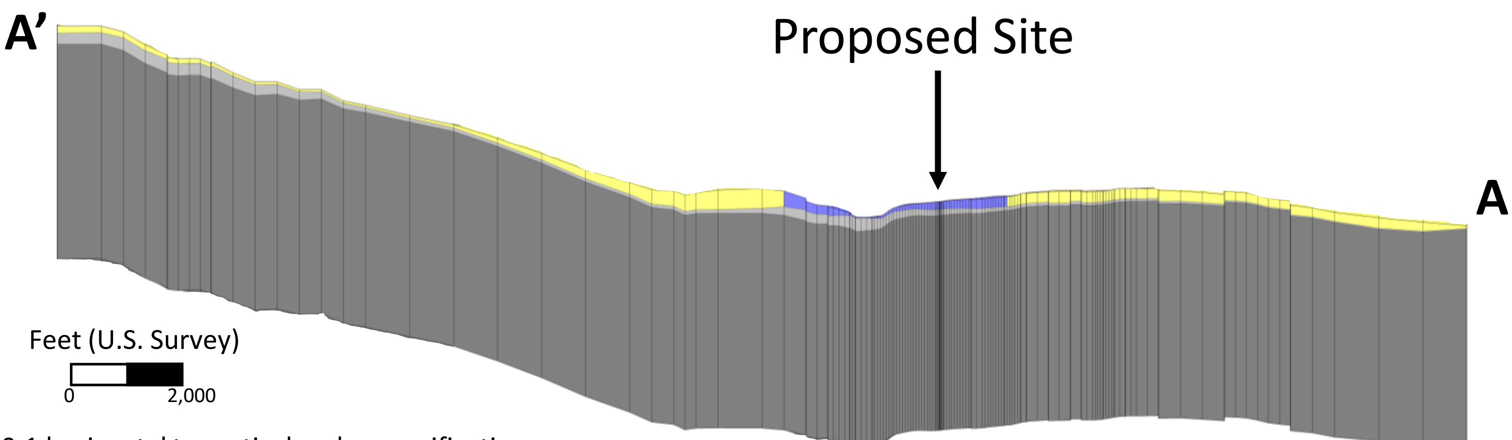

Note: 10:1 horizontal to vertical scale magnification.

Figure 6a – North/south cross-section illustrating model layering.

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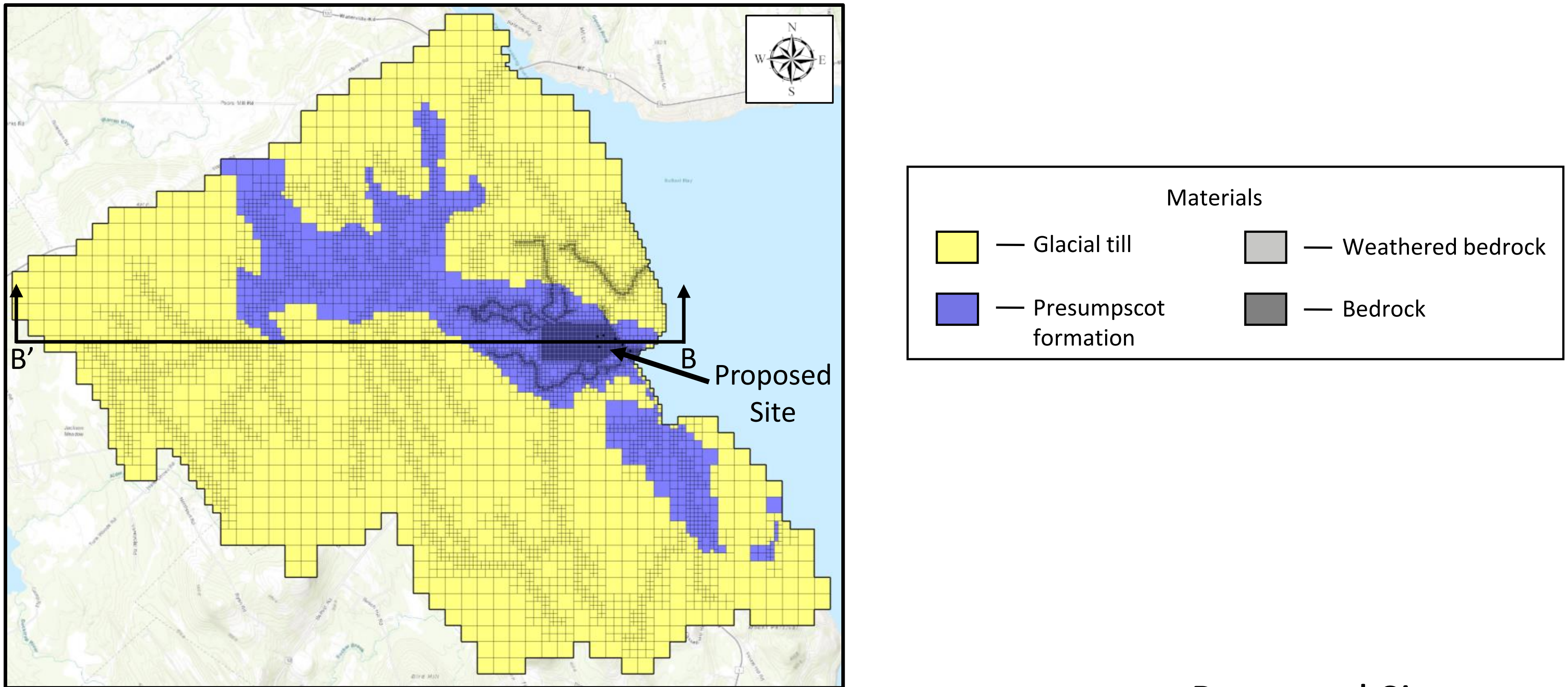

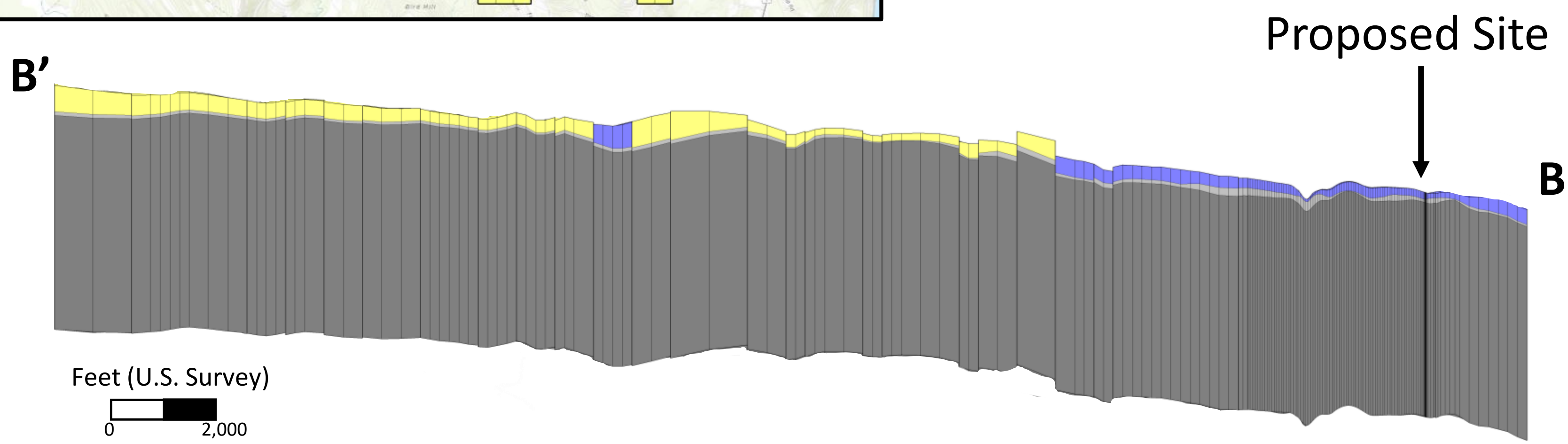

Note the 10:1 horizontal to vertical scale magnification.

Figure 6b – East-west cross-section illustrating model layering.

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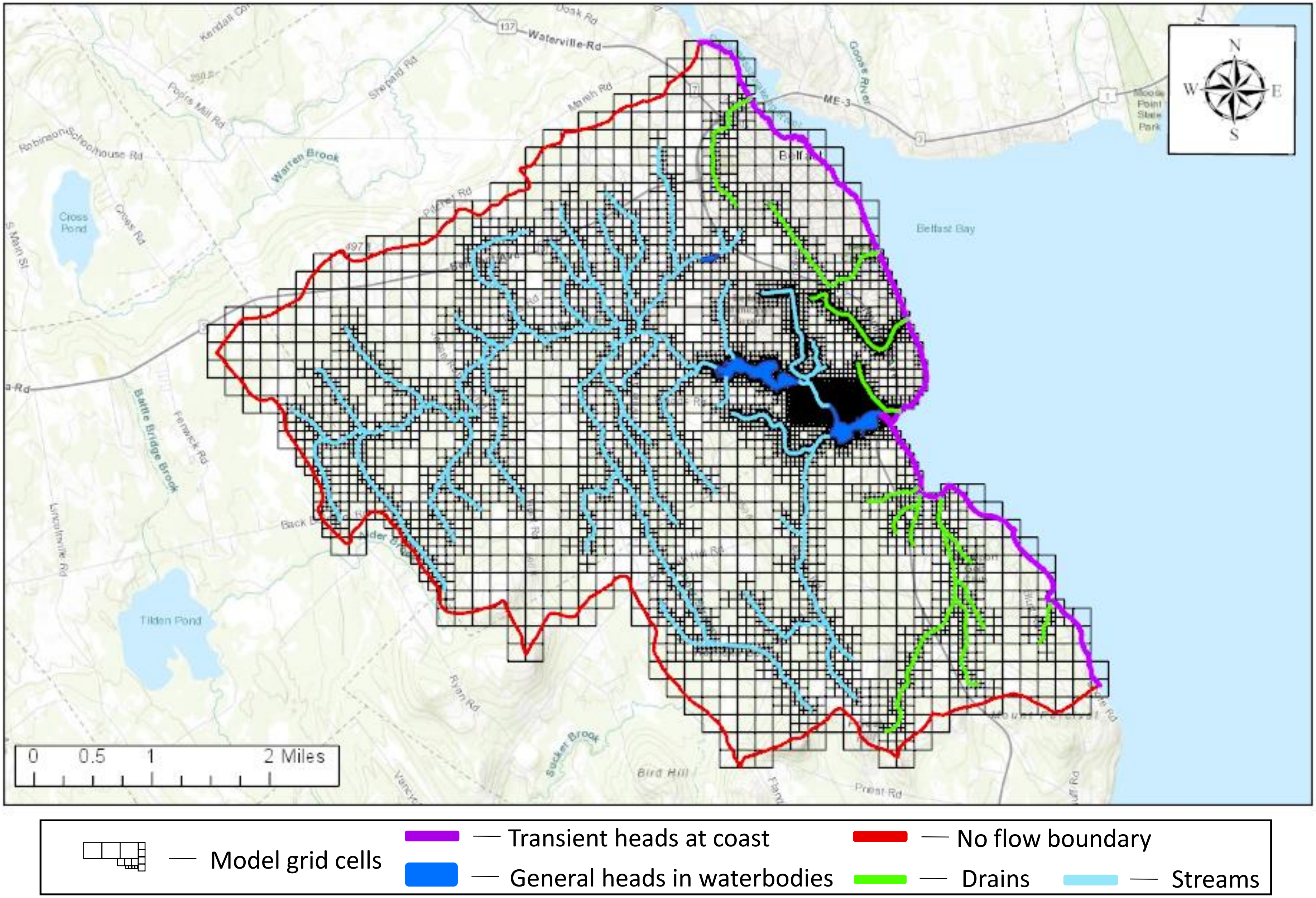

Figure 7 – Approximate locations of model boundary conditions in layer 1.

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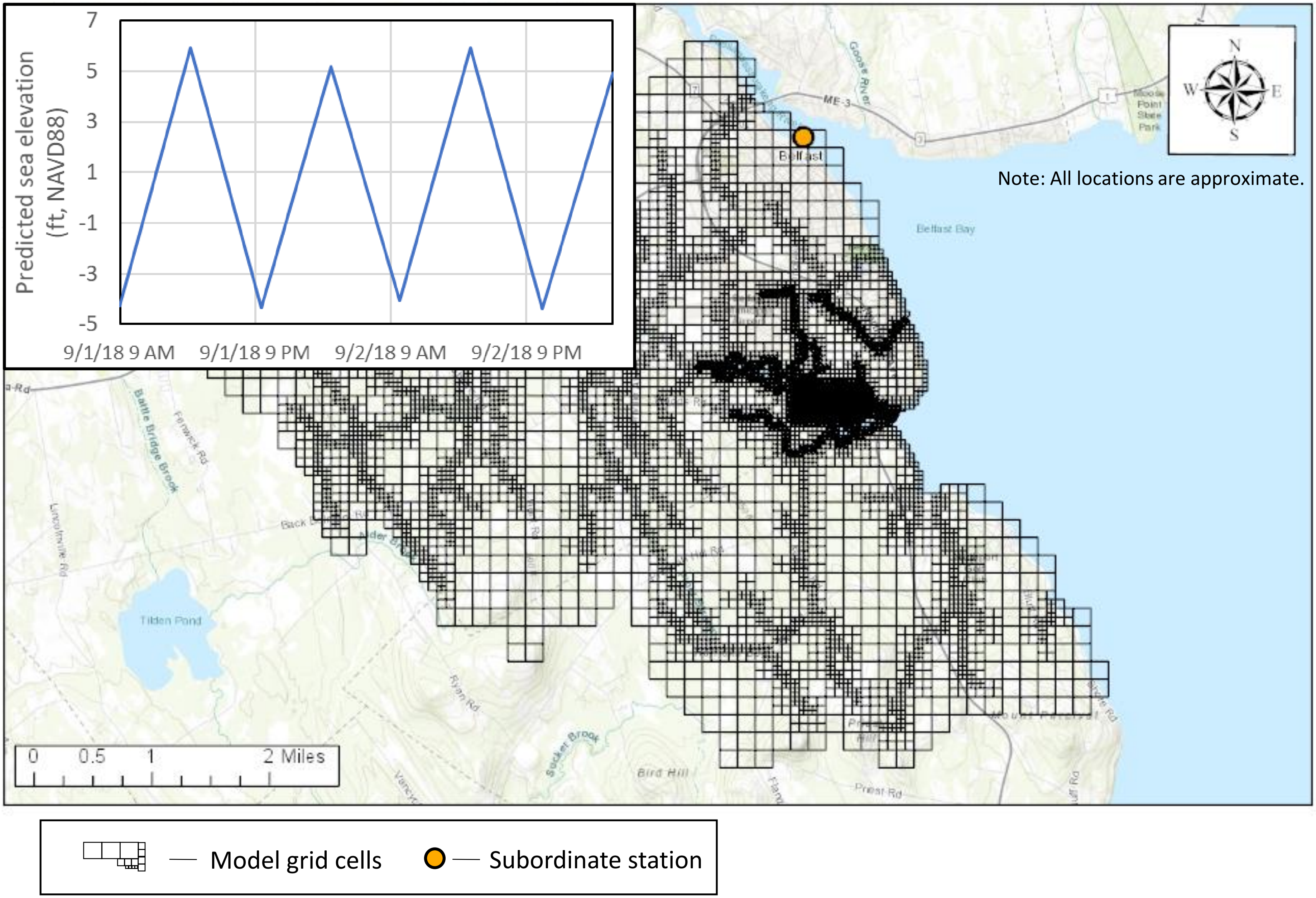

Figure 8 – Location of NOAA subordinate station ID 8415191.

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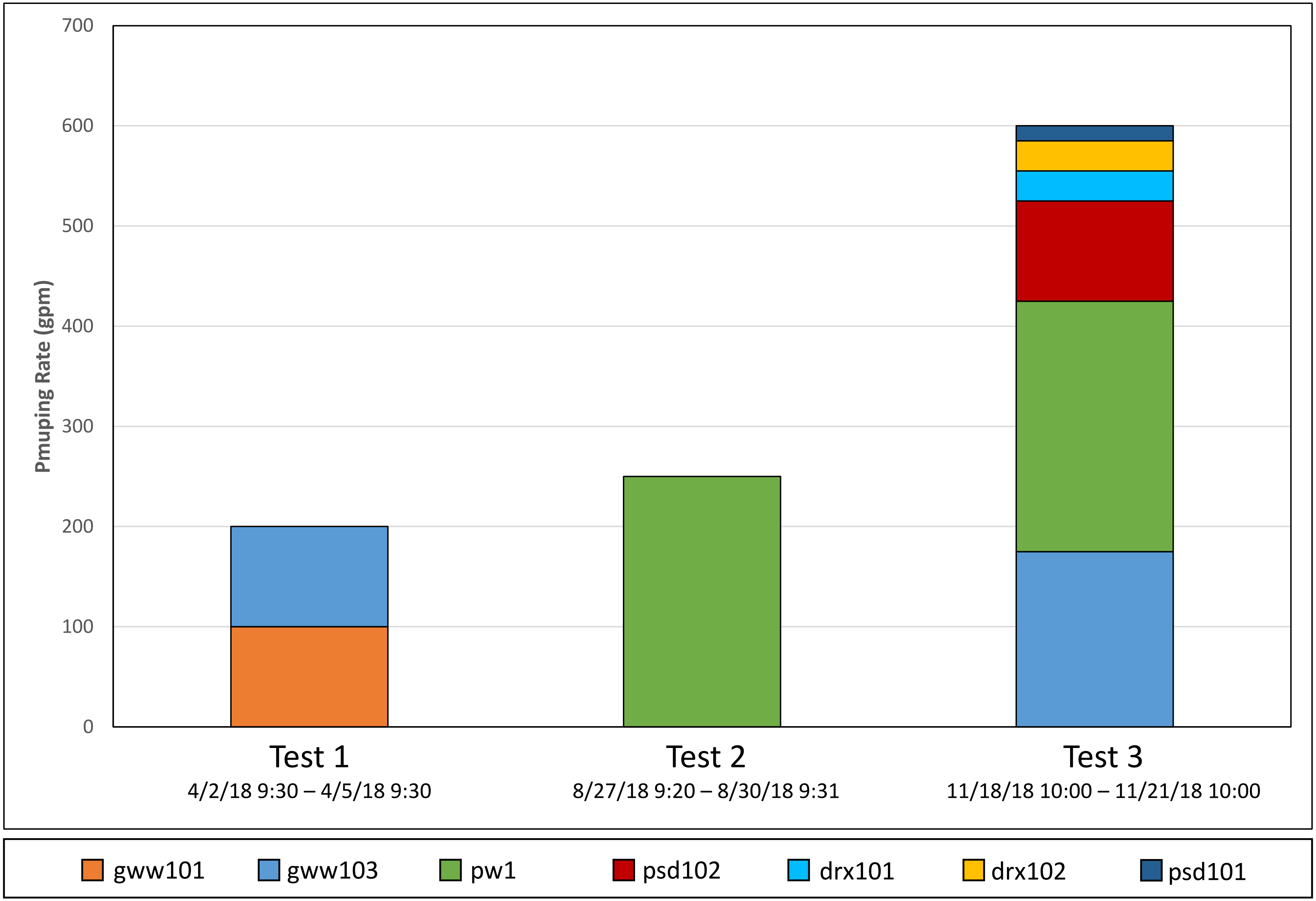

Figure 9a – Planned pumping rates during calibration stress periods.

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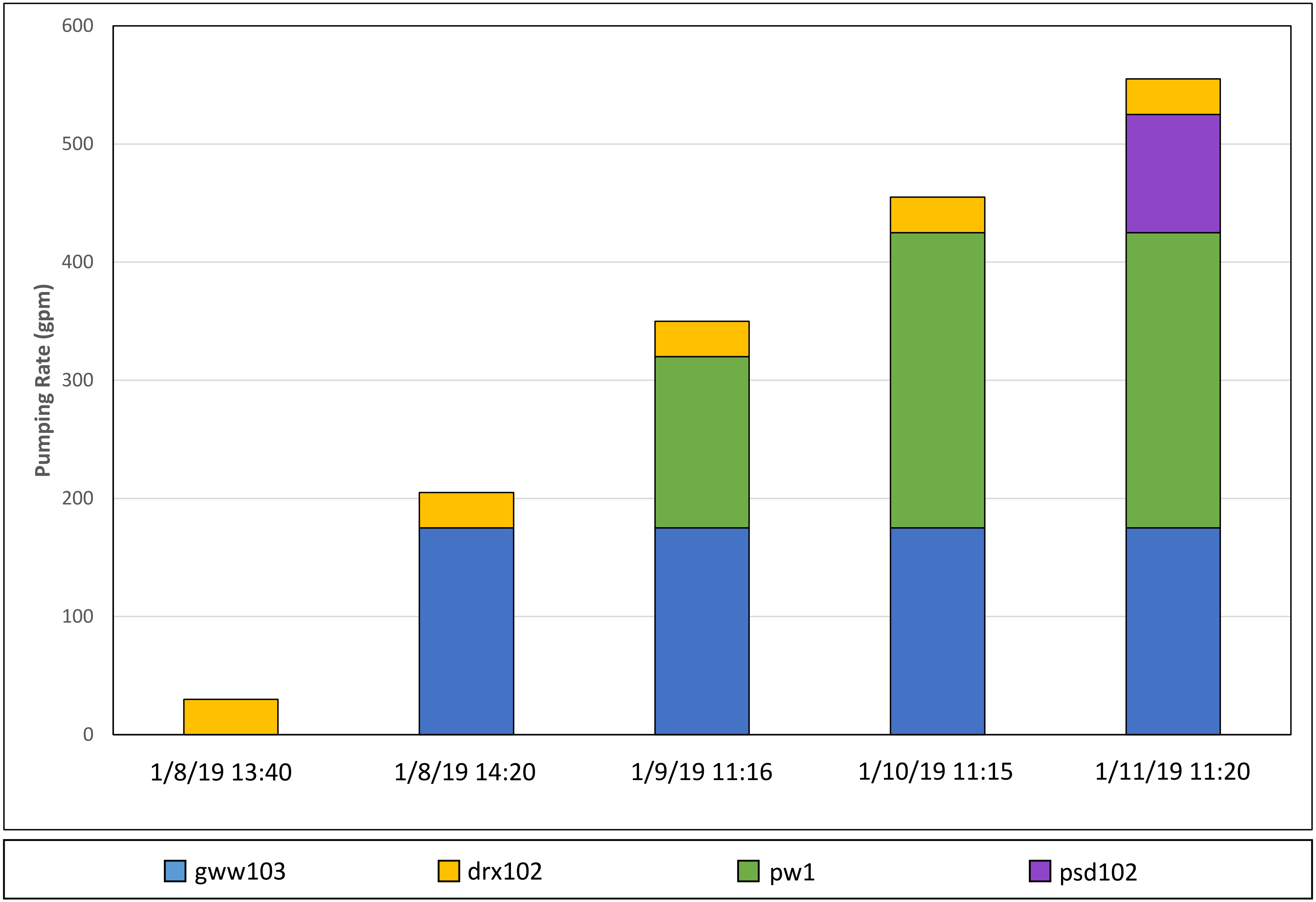

Figure 9b – Planned pumping rates during verification stress periods.

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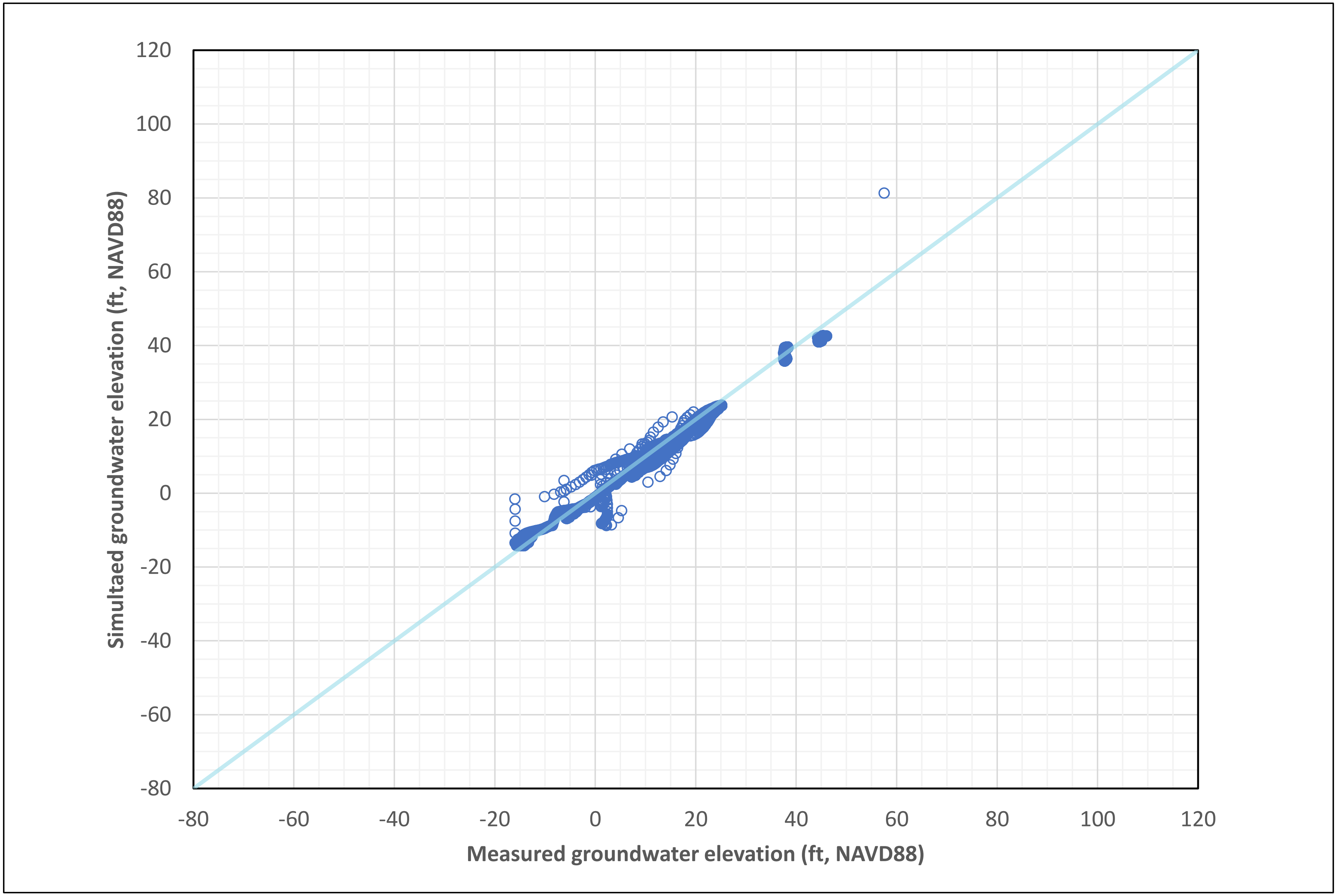

Figure 10a – Measured and simulated groundwater elevations at monitored wells for pumping test 1 (3/30/2018 - 4/9/2018).

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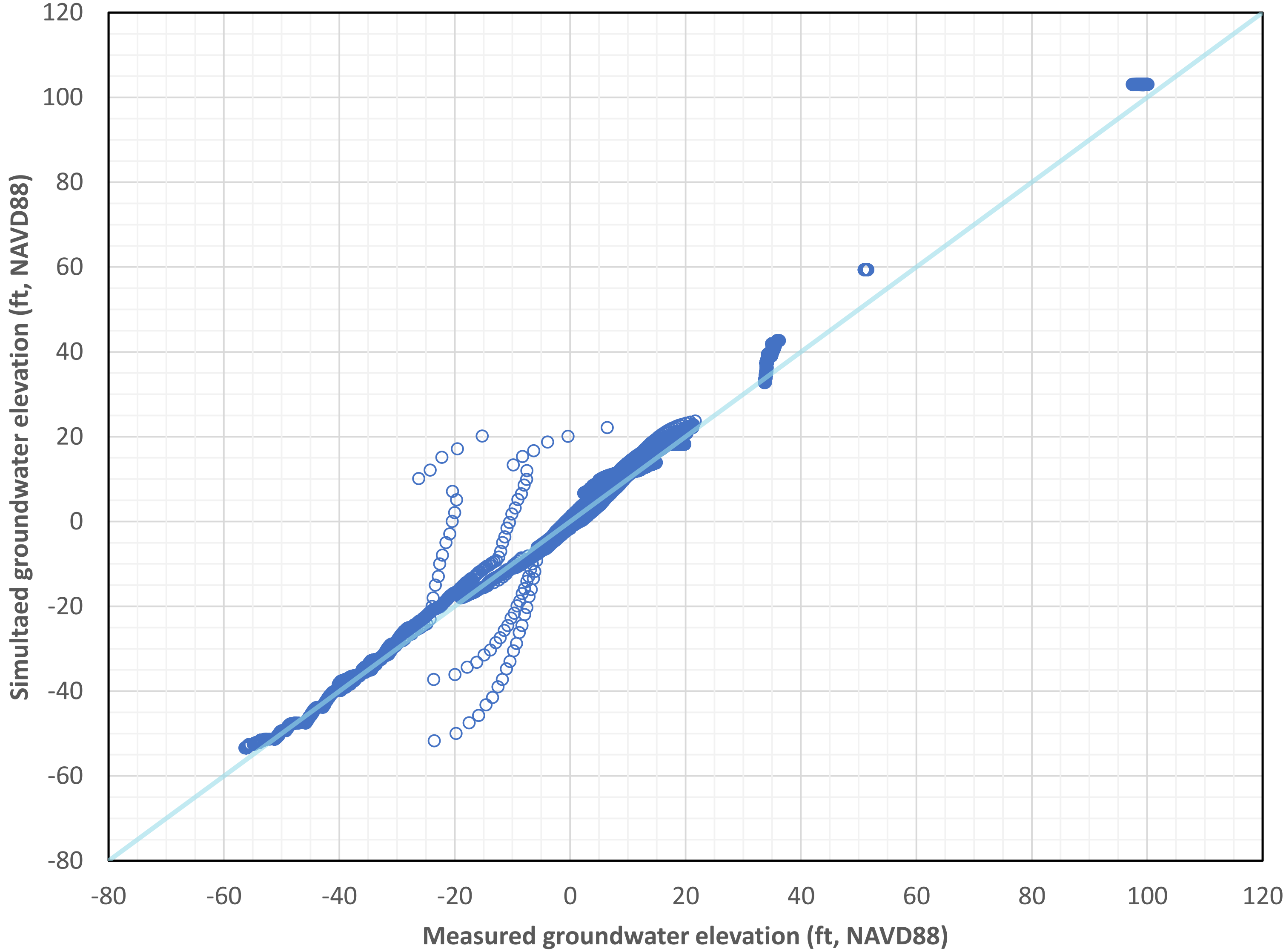

Figure 10b – Measured and simulated groundwater elevations at monitored wells for pumping test 2 (8/27/2018 - 9/5/2018).

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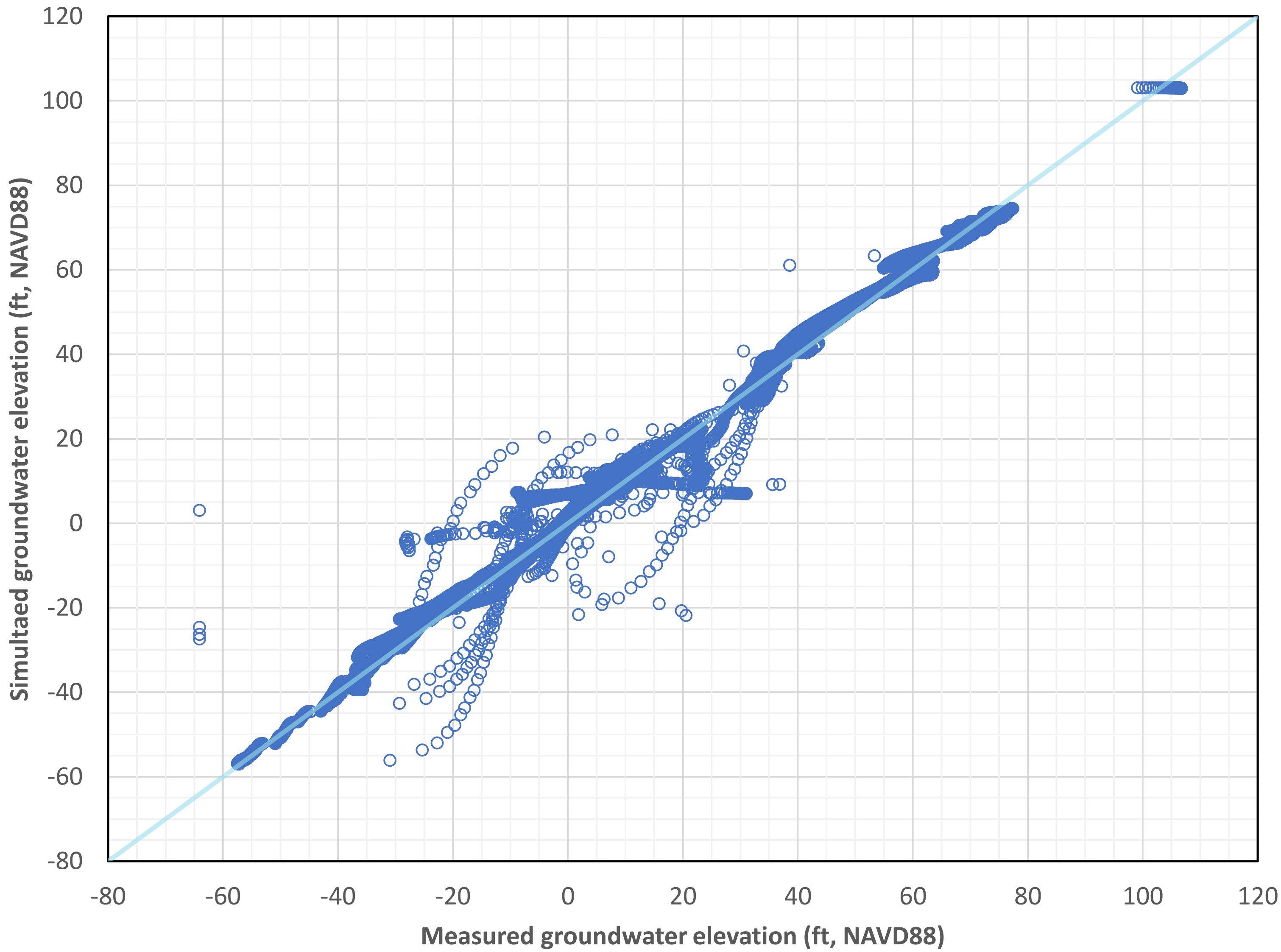

Figure 10c – Measured and simulated groundwater elevations at monitored wells for pumping test 3 (11/18/2018 – 11/29/2018).

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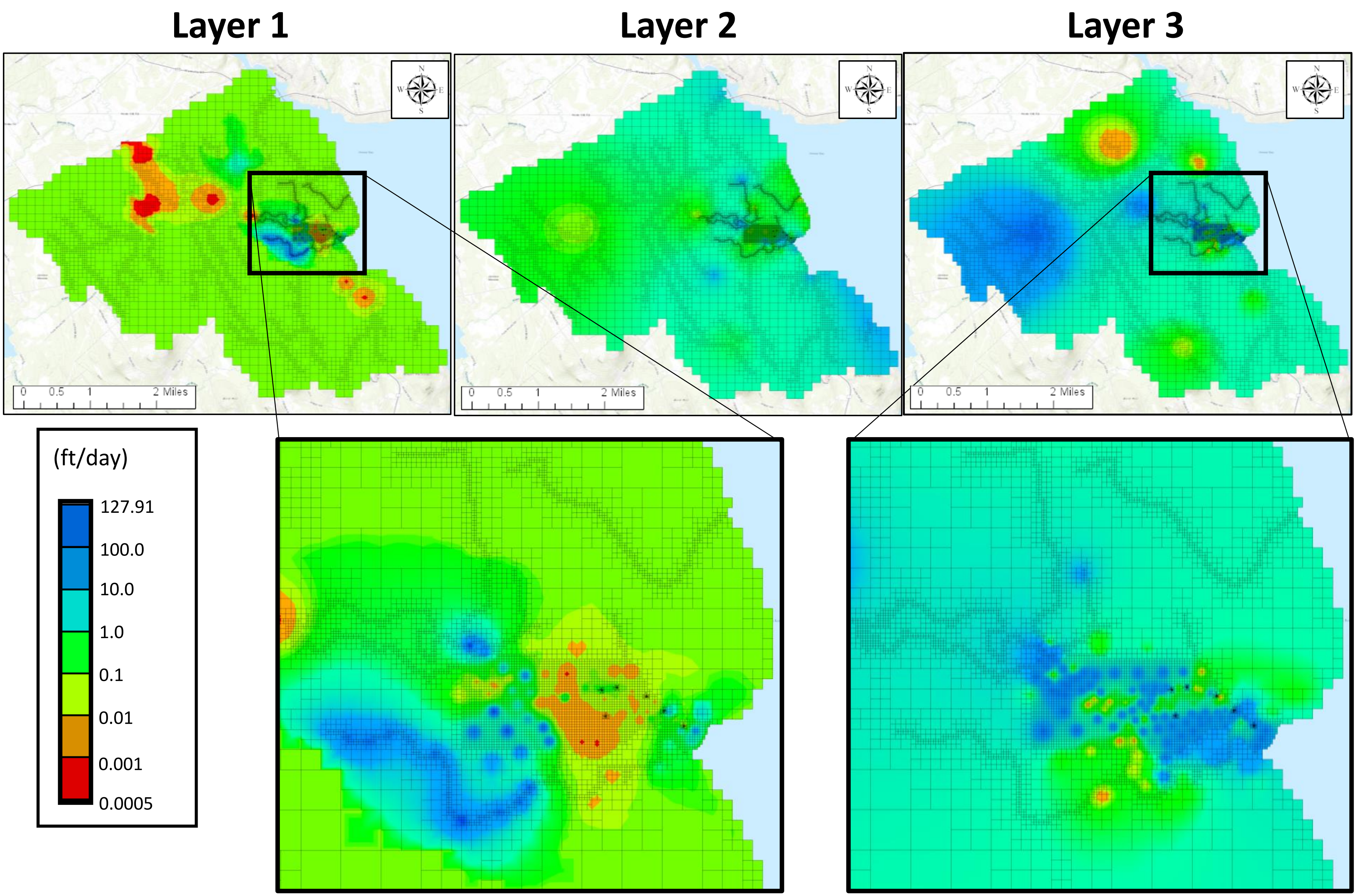

Figure 11 – Final calibrated hydraulic conductivity fields by model layer.

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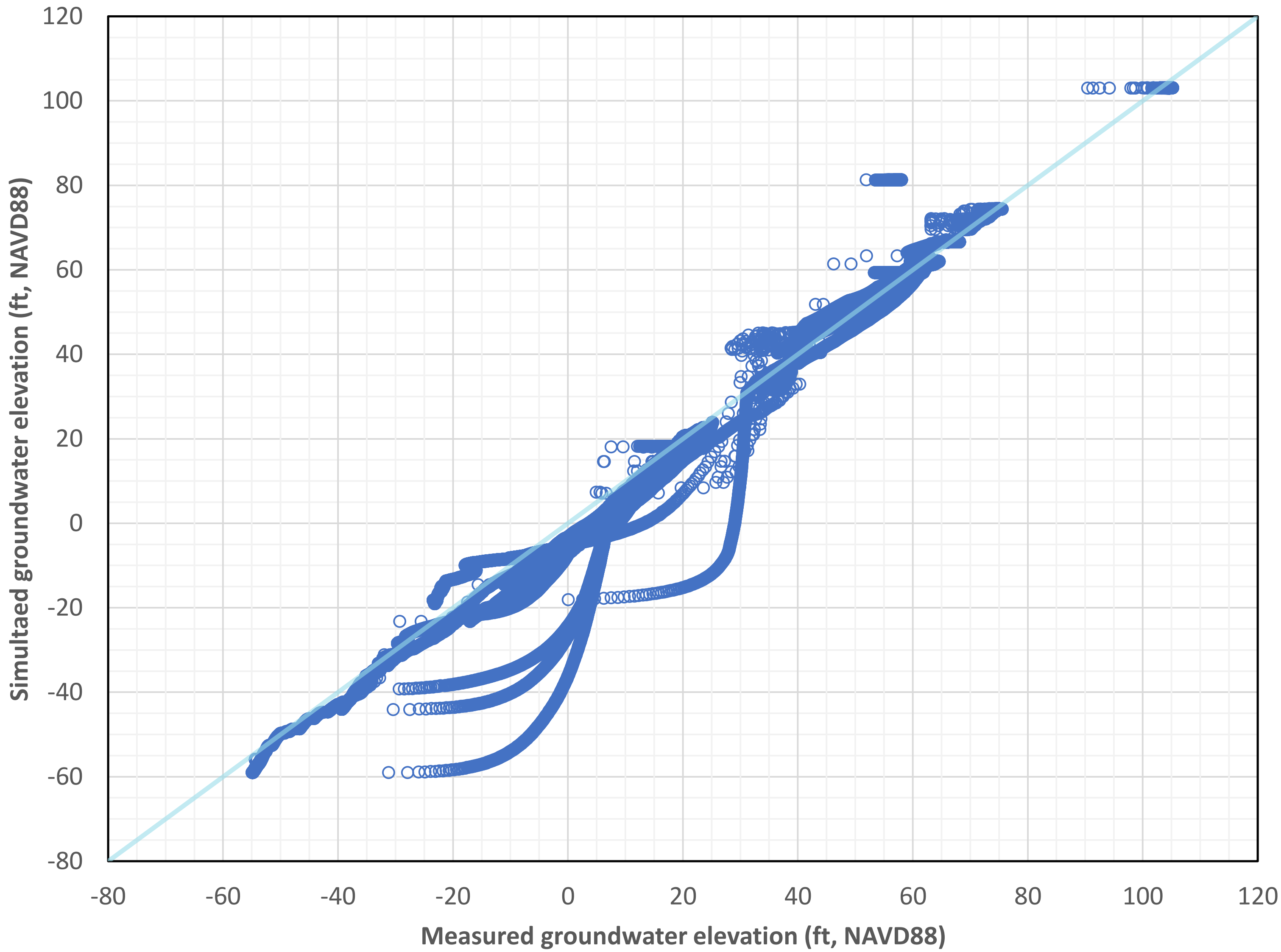

Figure 12 – Measured and simulated groundwater elevations at monitored wells for pumping test 4 (1/8/2019 – 1/18/2019).

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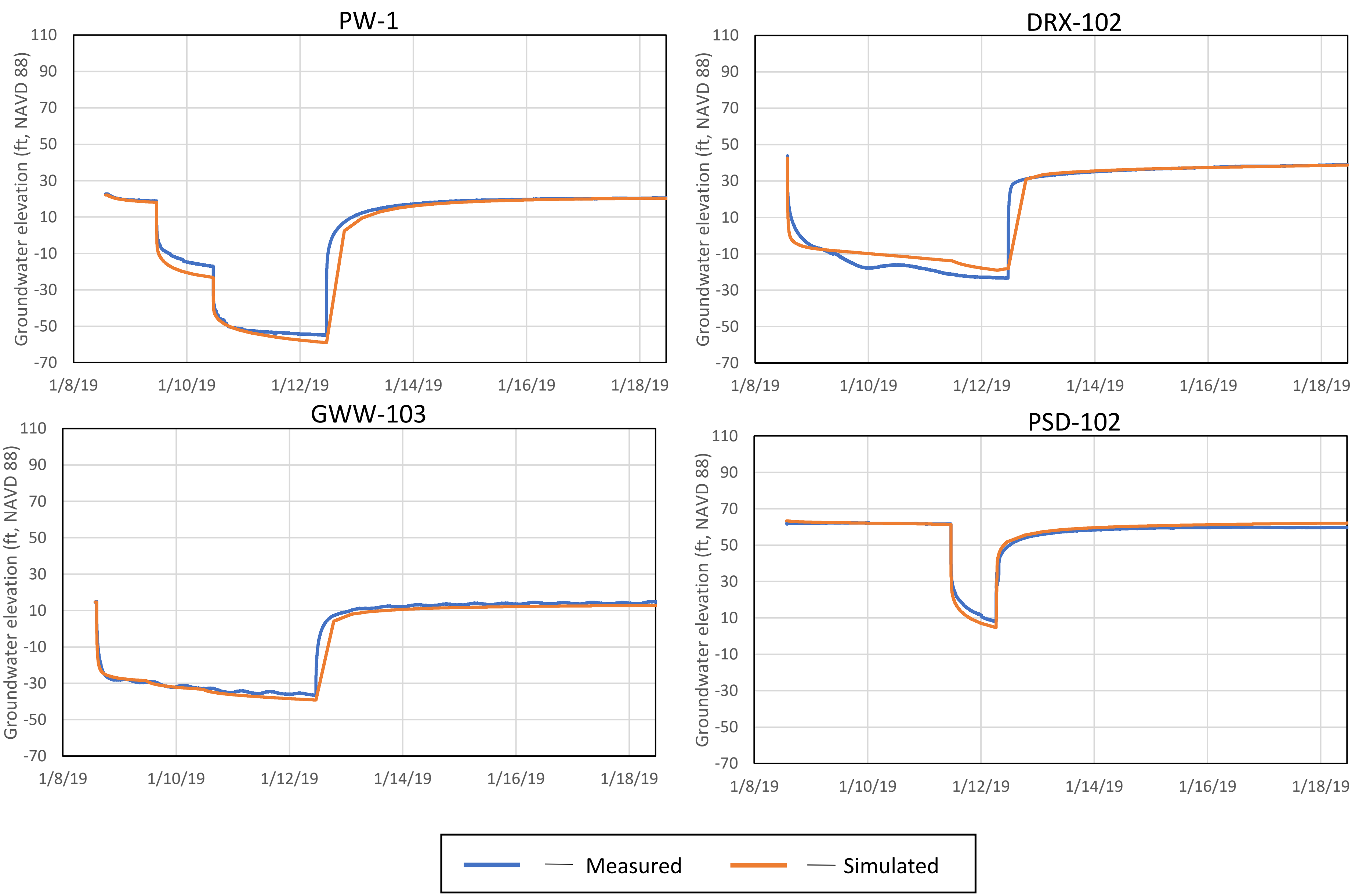

Figure 13 – Measured and simulated groundwater elevations at pumping wells PW-1, DRX-102, GWW-103, and PSD-102 for pumping test 4 (1/8/19 - 1/18/19).

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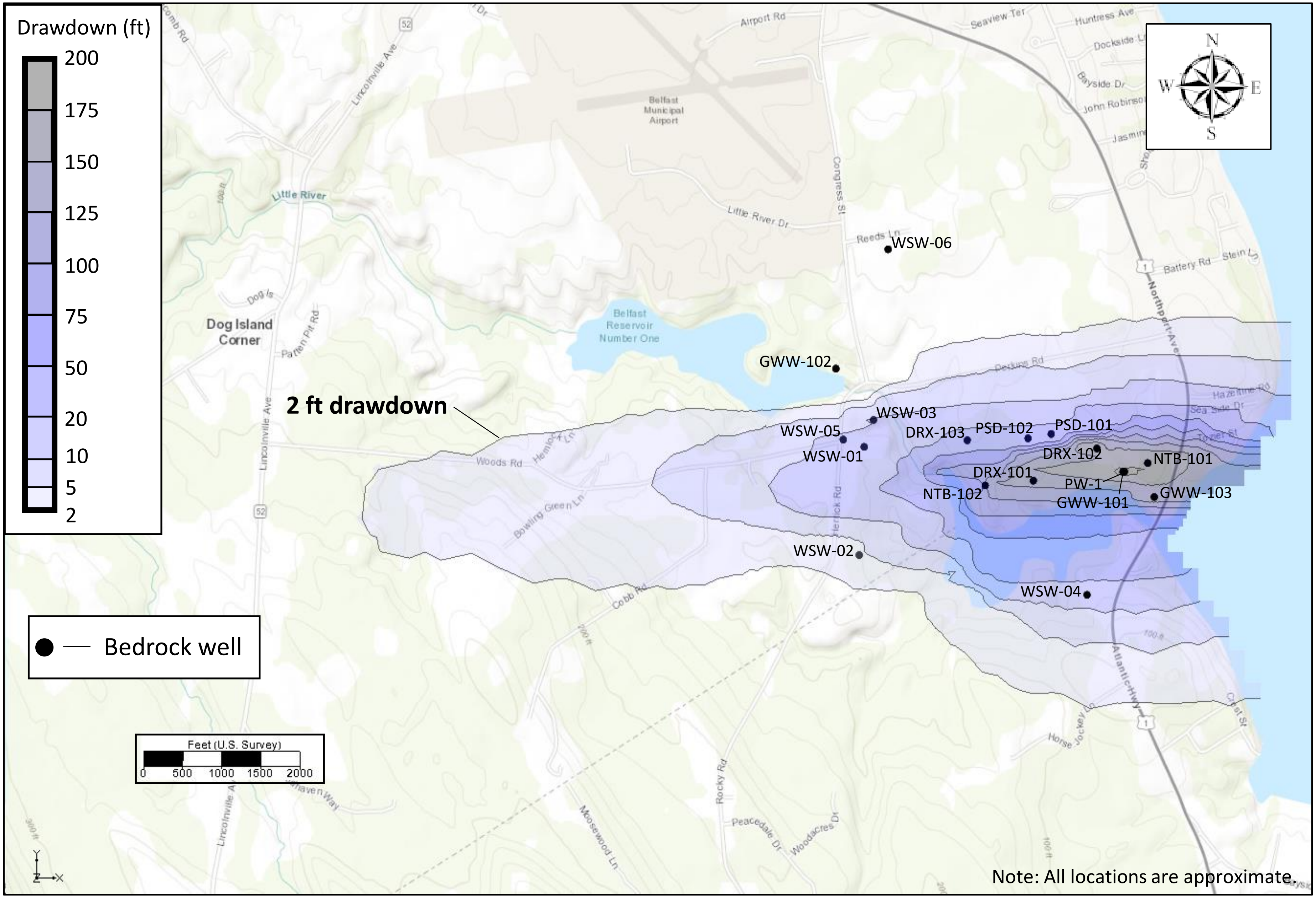

Figure 14a – Simulated maximum drawdown for scenario 1 within model layer 3.

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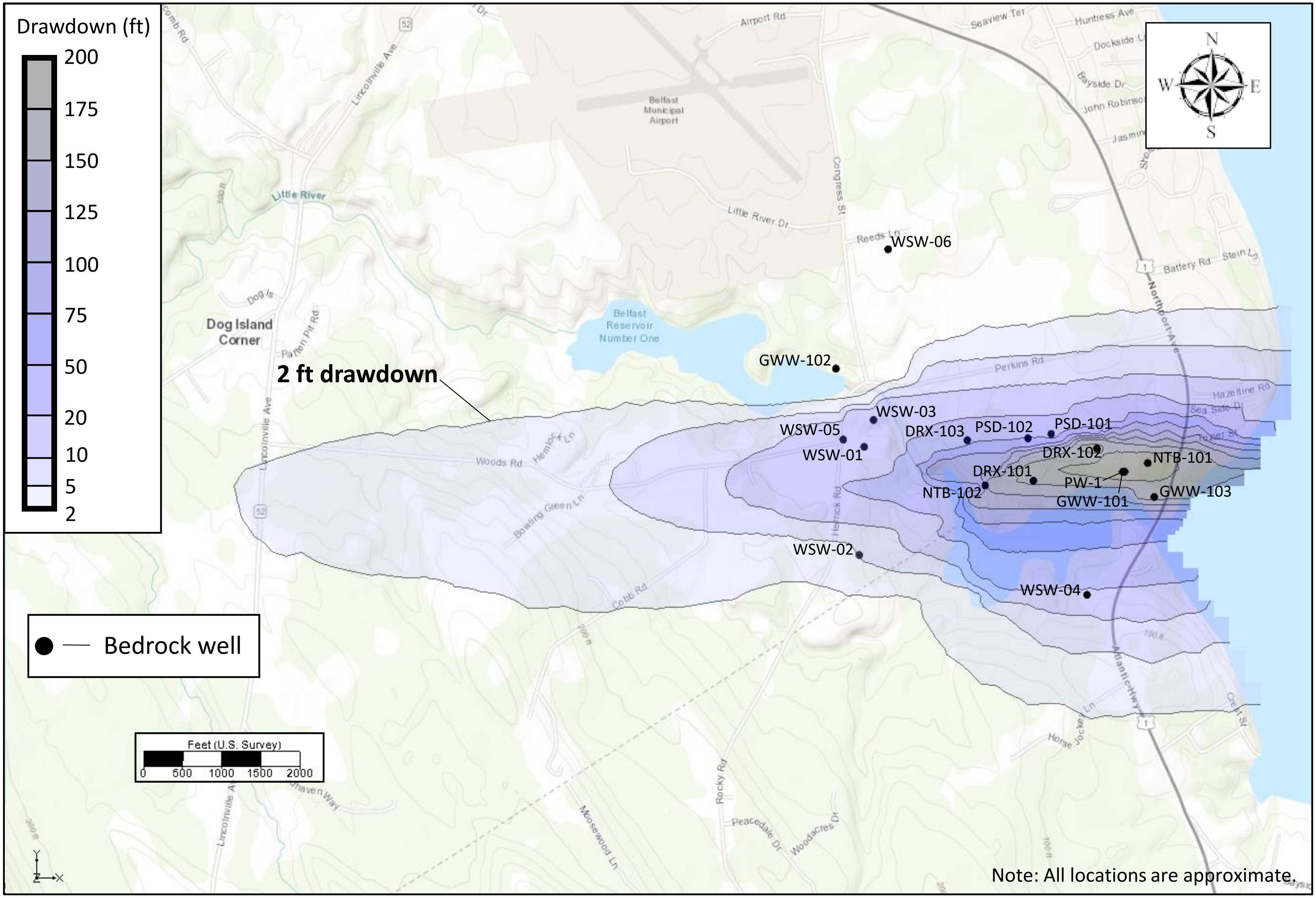

Figure 14b – Simulated maximum drawdown for scenario 2 within model layer 3.

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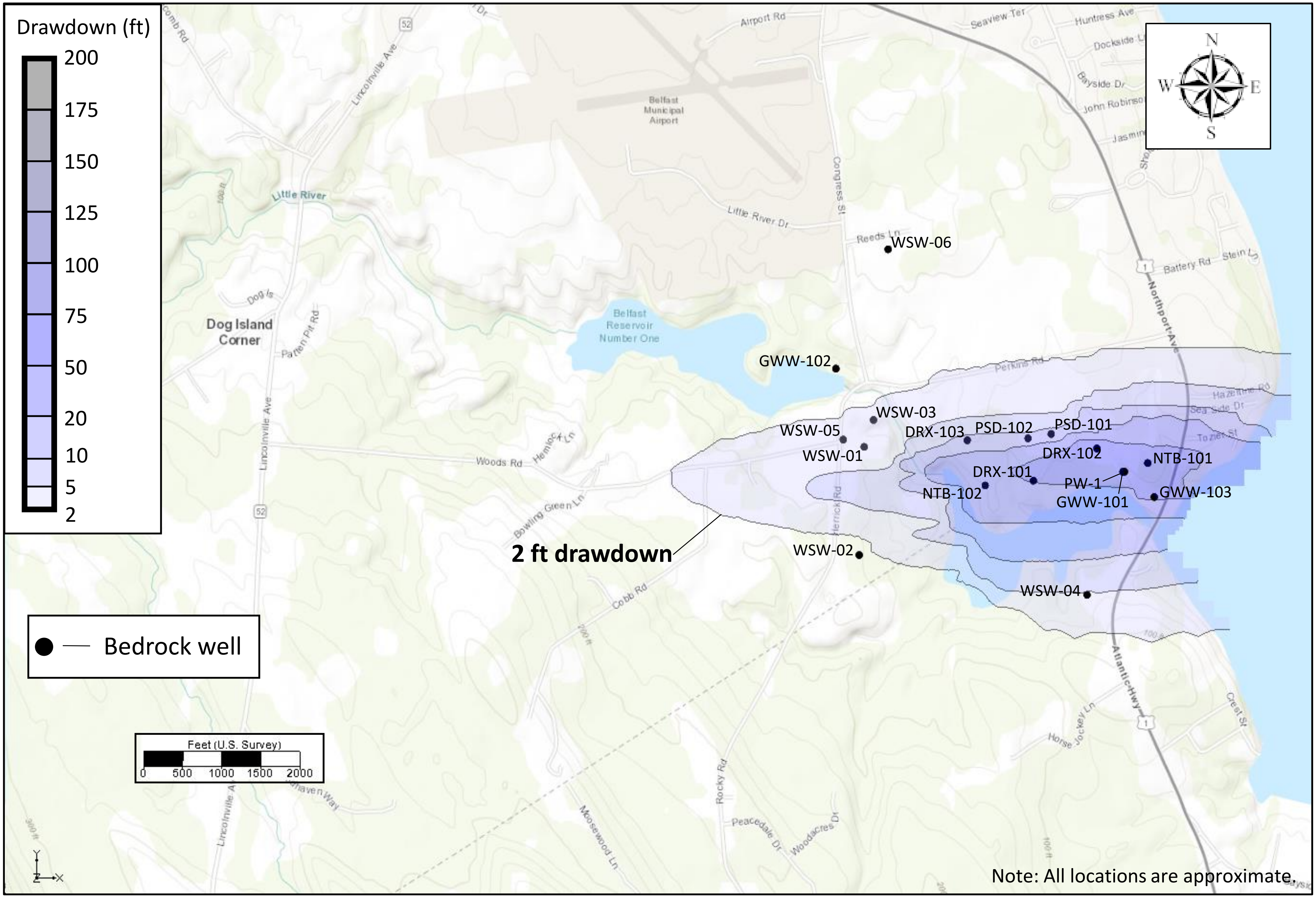

Figure 14c – Simulated maximum drawdown for scenario 3 within model layer 3.

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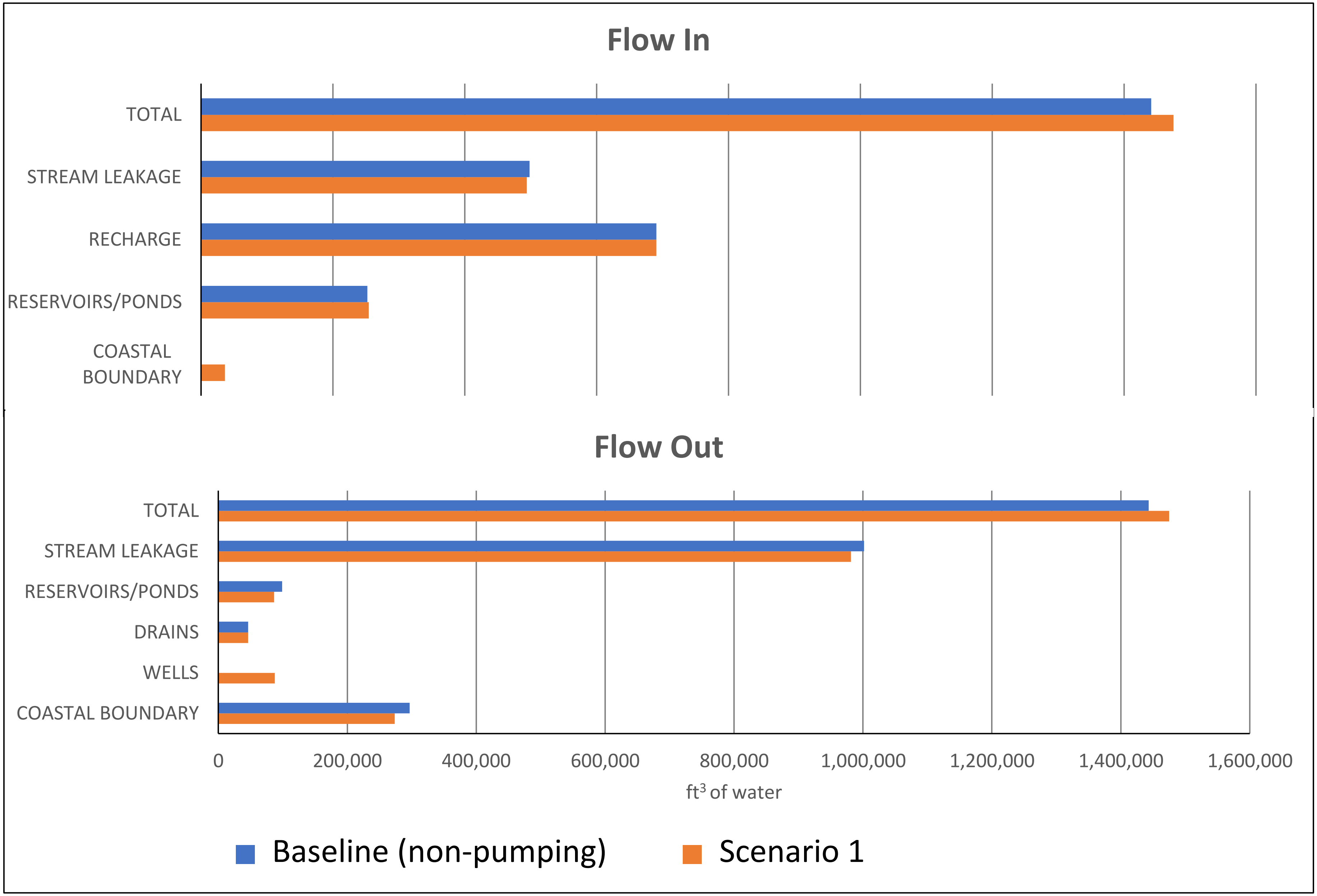

Figure 15 – Steady-state flow budget comparison.

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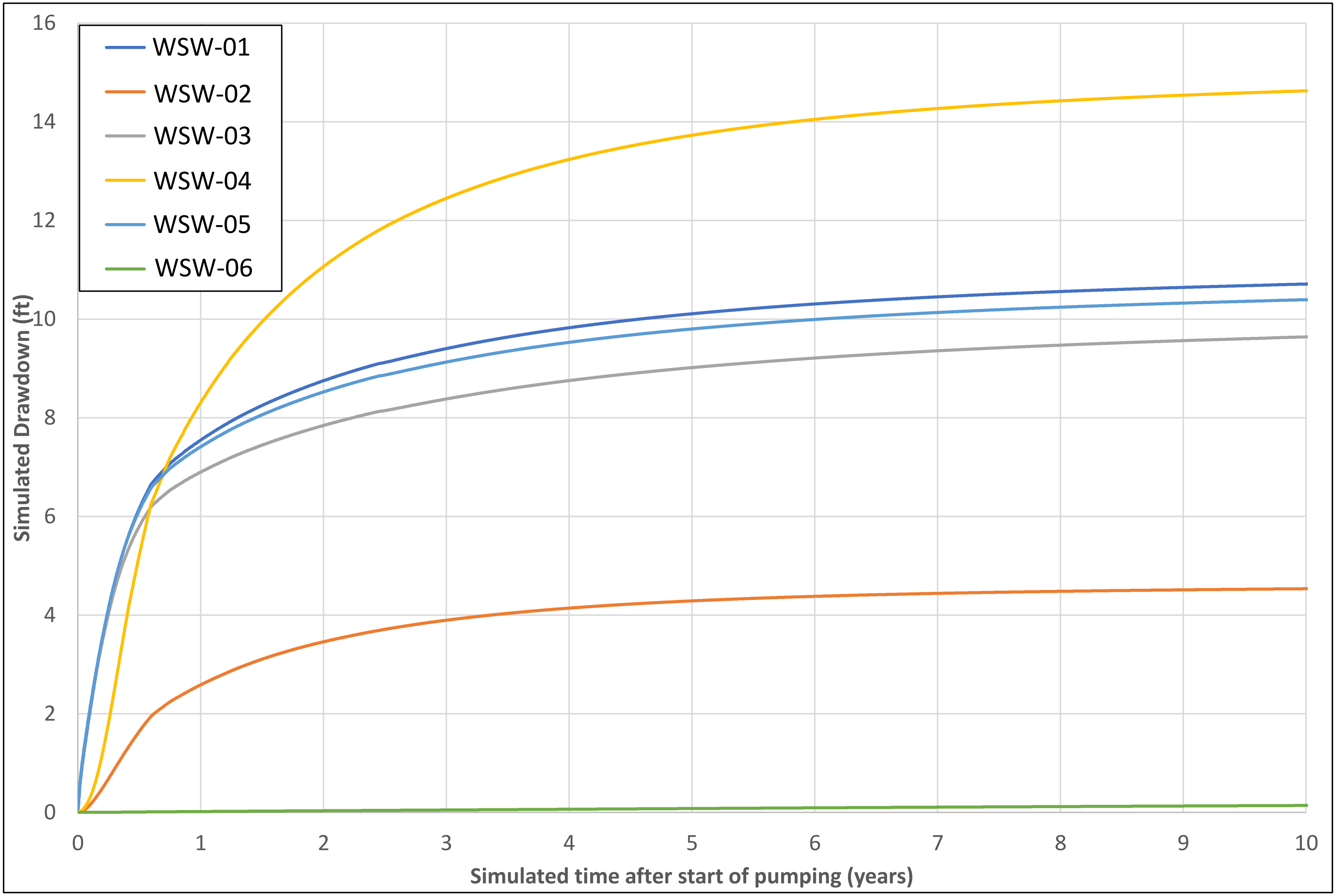

Figure 16a – Simulated drawdown at private bedrock wells for Scenario 1.

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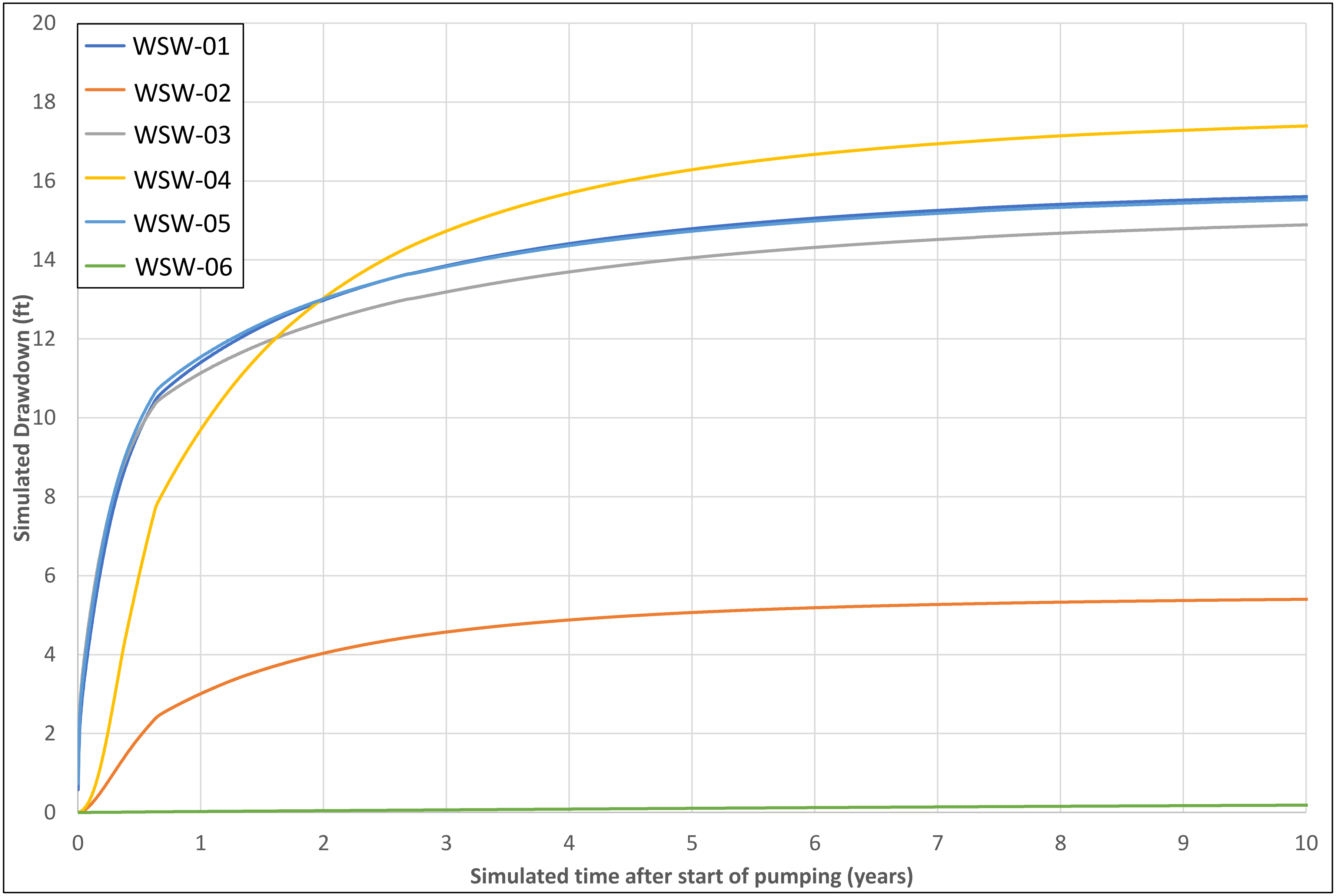

Figure 16b – Simulated drawdown at private bedrock wells for Scenario 2.

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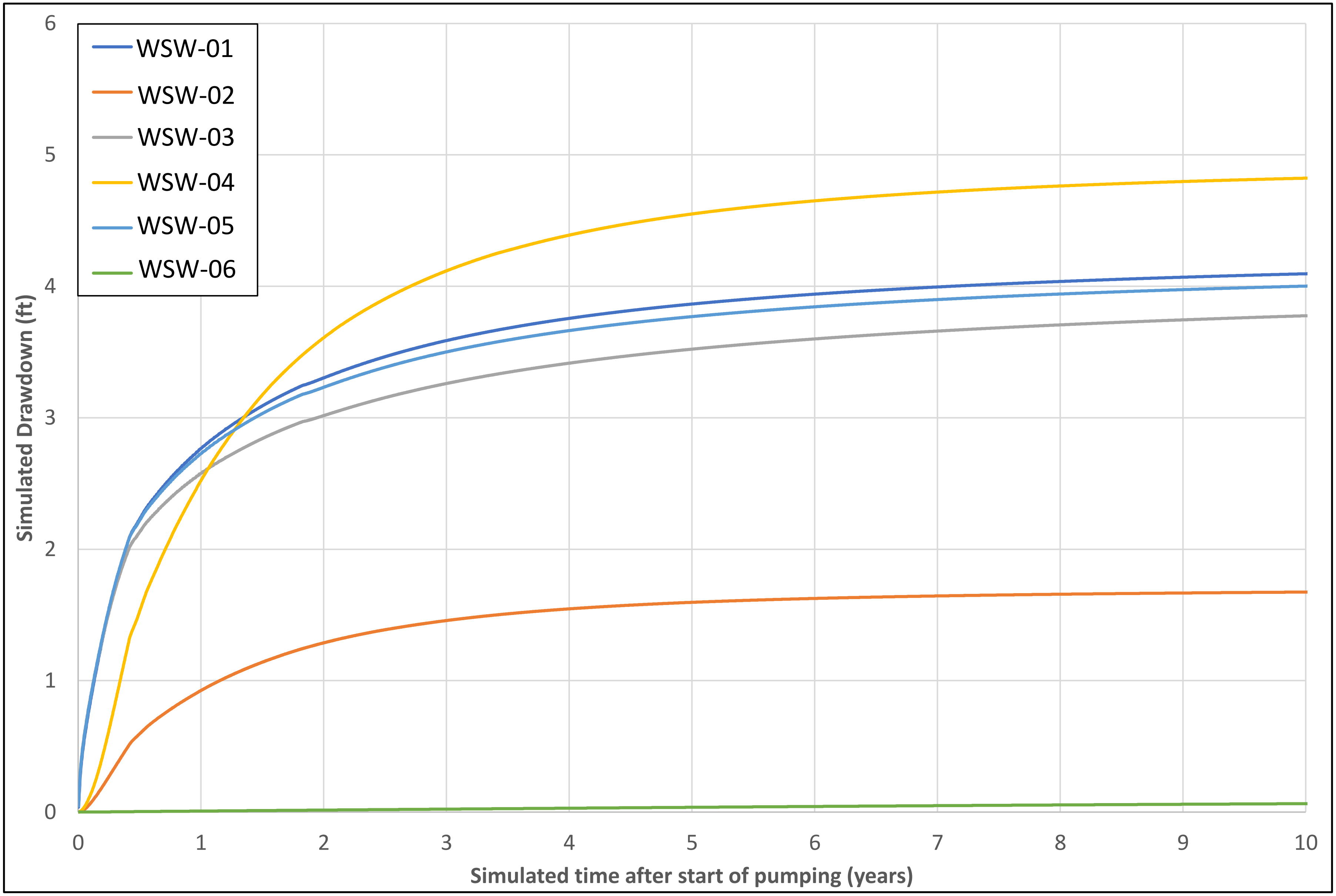

Figure 16c – Simulated drawdown at private bedrock wells for Scenario 3.

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Summary of Groundwater Modeling to Support Significant Groundwater Well Permit Application

Proposed Nordic Aquafarms Facility

Belfast, Maine

Appendix A

Supplemental Tables and Figures

Table A1. Target mean residuals and residual 10th and 90th percentiles during pumping test 1 (3/30/2018 – 4/9/2018).

	Residual Statistics (ft)		
Well ID	**Mean**	**10th Percentile**	**90th Percentile**
DRX-101	1.1	0.7	1.5
DRX-102	3.0	2.5	3.5
DRX-103	-	-	-
GWW-101	0.4	0.0	1.1
GWW-102	-	-	-
GWW-103	-0.2	-2.0	0.9
NTB-101	2.0	1.3	2.9
NTB-102	-0.1	-1.5	1.7
PSD-101	-	-	-
PSD-102	-	-	-
PW-1	-	-	-
PZ1D	-	-	-
PZ1S	-	-	-
PZ3	-	-	-
PZ4S	-	-	-
WSW-01	-	-	-
WSW-02	-	-	-
WSW-03	-	-	-
WSW-04	-	-	-
WSW-05	-	-	-
WSW-06	-	-	-

Note: Residual value calculated as [measured elevation – simulated elevation].

Table A2. Target mean residuals and residual 10th and 90th percentiles during pumping test 2 (8/27/2018 – 9/5/2018).

	Residual Statistics (ft)		
Well ID	**Mean**	**10th Percentile**	**90th Percentile**
DRX-101	-1.8	-3.1	-0.7
DRX-102	-5.8	-6.8	-4.6
DRX-103	-	-	-
GWW-101	-1.2	-1.9	-0.9
GWW-102	-8.1	-8.4	-7.9
GWW-103	-1.4	-4.2	0.6
NTB-101	-1.1	-2.3	0.9
NTB-102	-1.8	-3.7	0.5
PSD-101	-	-	-
PSD-102	-	-	-
PW-1	-0.9	-2.0	0.0
PZ1D	-	-	-
PZ1S	-	-	-
PZ3	-	-	-
PZ4S	-	-	-
WSW-01	-	-	-
WSW-02	-	-	-
WSW-03	-	-	-
WSW-04	-0.1	-1.7	1.5
WSW-05	-	-	-
WSW-06	-3.8	-4.4	-3.3

Note: Residual value calculated as [measured elevation – simulated elevation].

Table A3. Target mean residuals and residual 10th and 90th percentiles during pumping test 3 (11/18/2018 – 11/29/2018).

	Residual Statistics (ft)		
Well ID	**Mean**	**10th Percentile**	**90th Percentile**
DRX-101	0.0	-1.4	1.0
DRX-102	-0.2	-1.4	3.2
DRX-103	0.2	-1.6	1.8
GWW-101	0.5	0.0	1.0
GWW-102	-0.9	-2.0	0.2
GWW-103	0.9	-1.9	2.3
NTB-101	-1.1	-4.0	0.2
NTB-102	0.8	-2.2	4.0
PSD-101	0.2	-3.7	2.1
PSD-102	0.0	-1.8	1.8
PW-1	0.1	-0.7	0.9
PZ1D	1.7	-1.0	4.1
PZ1S	0.1	-0.6	0.7
PZ3	-0.3	-1.1	1.1
PZ4S	2.4	2.1	3.2
WSW-01	0.9	0.0	2.4
WSW-02	-	-	-
WSW-03	-2.0	-5.6	0.7
WSW-04	0.3	-1.1	1.4
WSW-05	0.3	-1.4	1.8
WSW-06	3.0	2.6	3.5

Note: Residual value calculated as [measured elevation – simulated elevation].

Table A4. Target mean residuals and residual 10th and 90th percentiles during pumping test 4 (1/8/2019 – 1/18/2019).

	Residual Statistics (ft)		
Well ID	**Mean**	**10th Percentile**	**90th Percentile**
DRX-101	3.3	0.9	7.8
DRX-102	-0.9	-6.3	0.4
DRX-103	-0.5	-1.8	0.2
GWW-101	2.1	0.0	4.1
GWW-102	-2.3	-5.1	-0.2
GWW-103	2.1	0.1	2.8
NTB-101	1.6	-0.4	5.6
NTB-102	2.8	0.2	5.2
PSD-101	-0.6	-1.8	1.0
PSD-102	-0.7	-2.3	0.1
PW-1	2.5	0.1	6.0
PZ1D	1.8	0.9	2.4
PZ1S	0.0	-0.9	1.1
PZ3	-0.9	-2.1	1.3
PZ4S	2.3	1.7	3.1
WSW-01	0.1	-0.6	0.8
WSW-02	-24.8	-25.7	-23.7
WSW-03	-2.1	-3.5	-0.7
WSW-04	0.1	-1.6	1.6
WSW-05	-0.7	-1.6	0.3
WSW-06	1.4	0.8	1.9

Note: Residual value calculated as [measured elevation – simulated elevation].

Table A5. Maximum simulated drawdowns under estimated average recharge conditions for scenarios 1 – 3.

	Drawdown (ft)		
Well ID	**Scenario 1**	**Scenario 2**	**Scenario 3**
DRX-101	133.2	158.2	50.9
DRX-102	180.4	198.1	75.7
DRX-103	28.8	46.3	11.3
GWW-101	187.2	206.3	76.3
GWW-102	0.2	0.2	0.1
GWW-103	153.6	169.0	58.9
NTB-101	172.6	191.6	68.4
NTB-102	90.8	106.1	33.9
PSD-101	29.7	45.4	11.7
PSD-102	29.6	56.8	11.6
PW-1	202.1	221.3	83.8
PZ1D	9.6	9.7	9.2
PZ1S	5.4	5.4	5.2
PZ3	4.2	4.2	4.1
PZ4S	0.1	0.1	0.1
WSW-01	11.1	16.1	4.3
WSW-02	4.6	5.6	1.7
WSW-03	10.1	15.4	4.0
WSW-04	15.0	17.9	4.9
WSW-05	10.8	16.0	4.2
WSW-06	0.2	0.3	0.1

Table A6. Maximum simulated drawdowns under estimated low recharge conditions for scenarios 1 – 3.

	Drawdown (ft)		
Well ID	Scenario 1	Scenario 2	Scenario 3
DRX-101	143.0	169.9	55.4
DRX-102	190.6	209.7	82.9
DRX-103	36.4	54.9	16.7
GWW-101	197.0	218.1	80.8
GWW-102	0.5	0.5	0.4
GWW-103	162.4	179.8	62.3
NTB-101	182.6	203.6	73.2
NTB-102	102.1	119.6	39.8
PSD-101	37.3	54.1	16.9
PSD-102	37.2	65.4	17.0
PW-1	211.9	233.1	88.3
PZ1D	9.8	9.8	9.6
PZ1S	8.1	8.1	8.0
PZ3	4.9	4.9	4.9
PZ4S	0.2	0.2	0.2
WSW-01	20.1	26.1	11.3
WSW-02	14.0	15.7	9.3
WSW-03	15.9	21.9	8.5
WSW-04	20.3	24.1	8.2
WSW-05	18.7	24.9	10.4
WSW-06	15.0	15.1	14.7

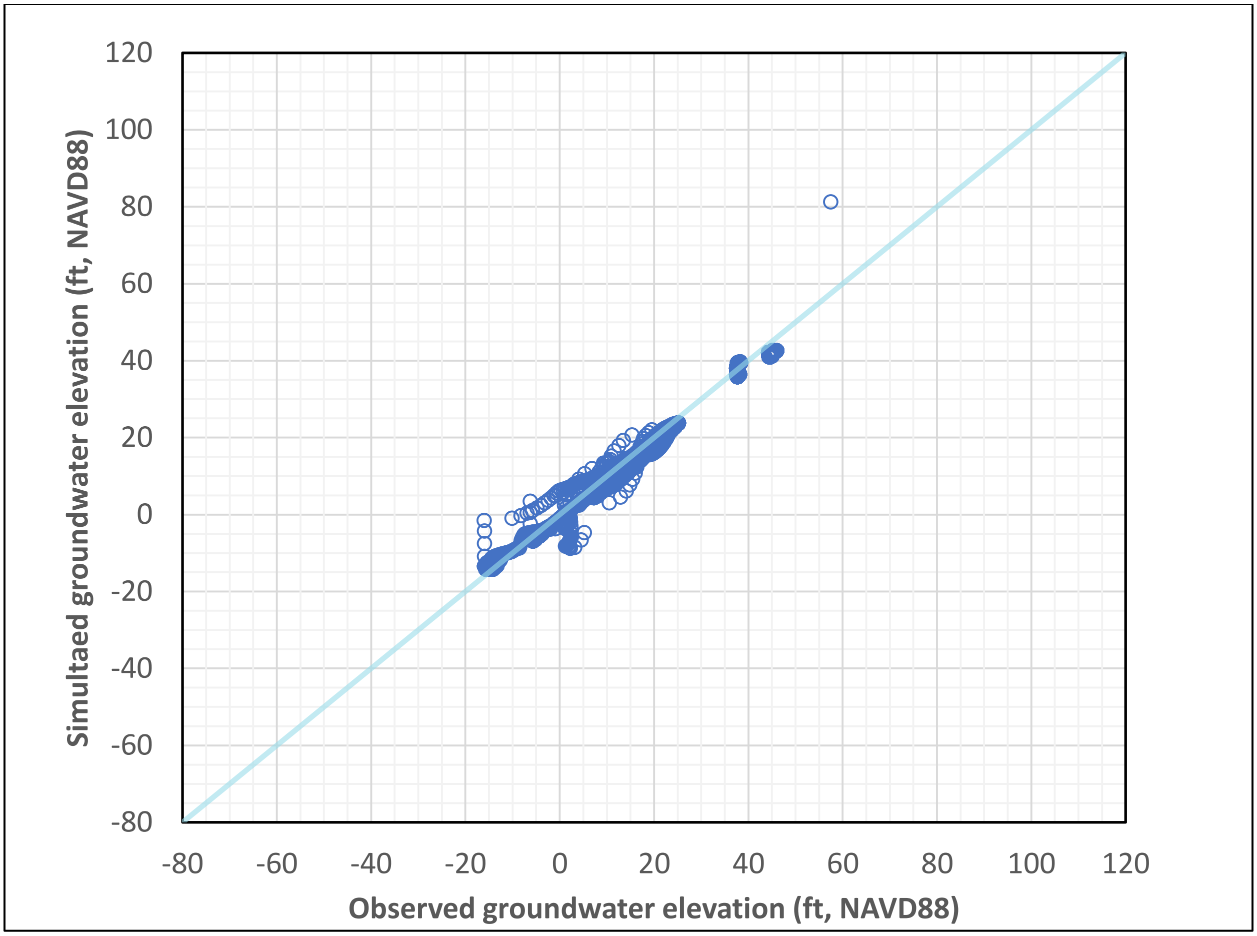

Figure A1. Observed and simulated groundwater elevations at bedrock wells for pumping test 1 (3/30/2018 - 4/9/2018).

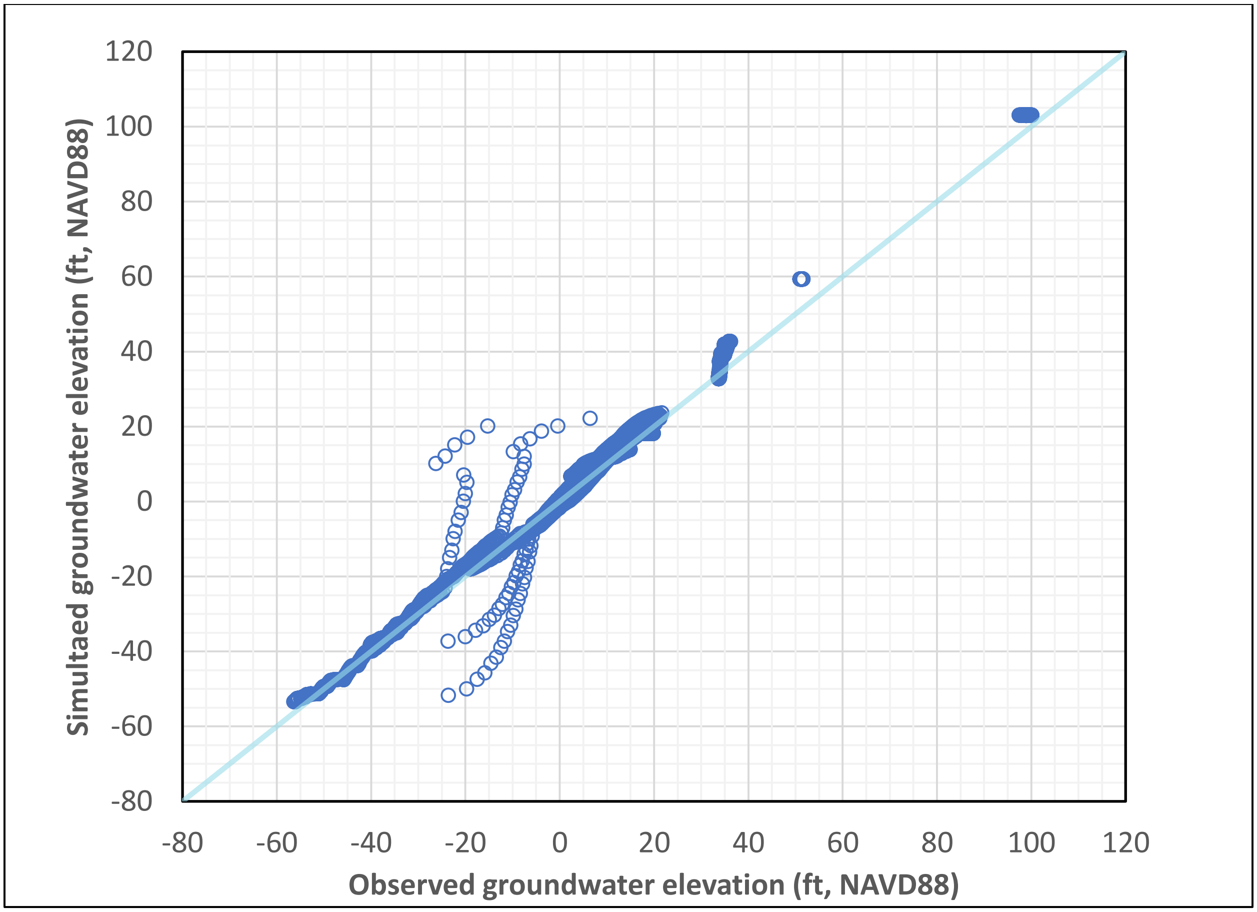

Figure A2. Observed and simulated groundwater elevations at bedrock wells for pumping test 2 (8/27/2018 - 9/5/2018).

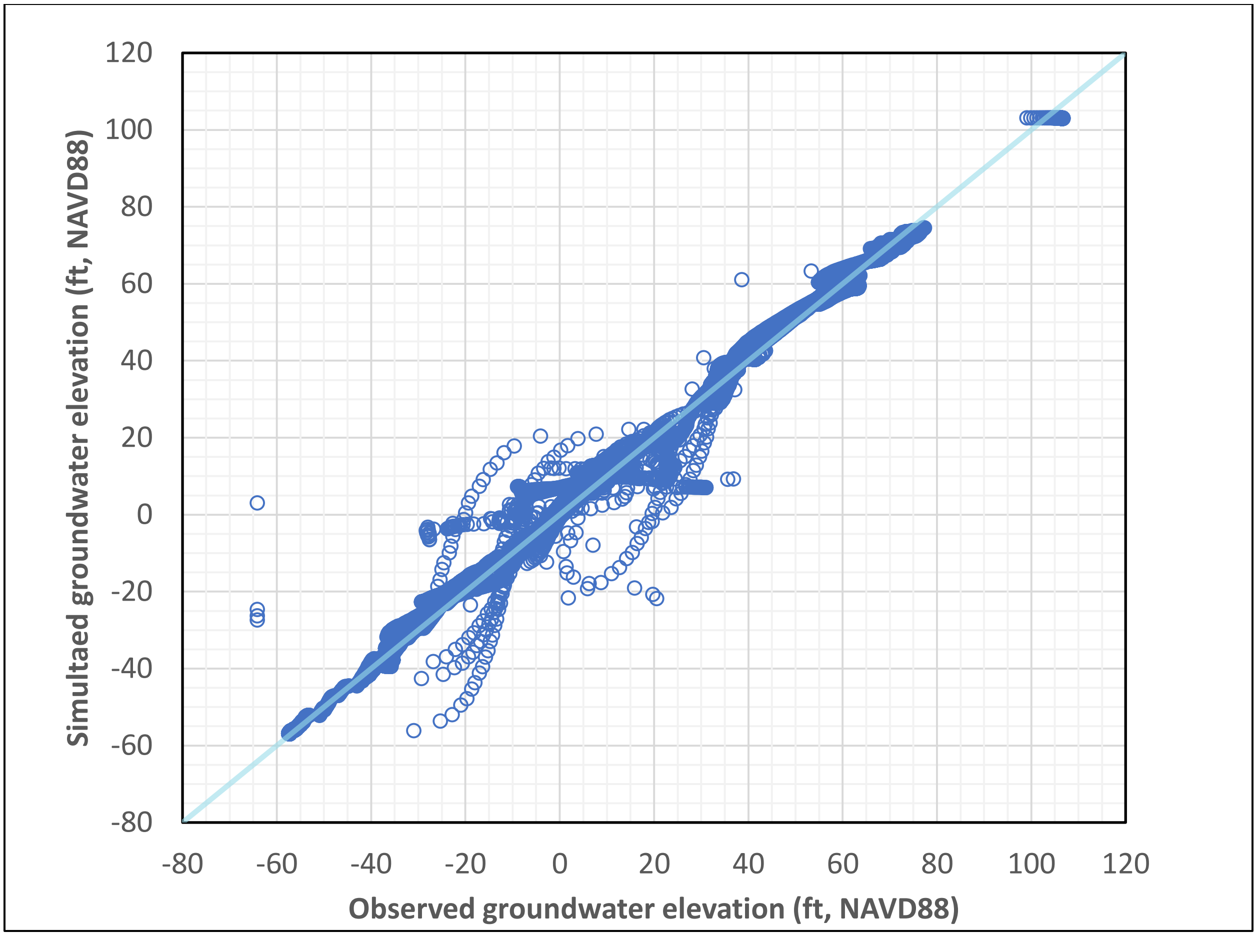

Figure A3. Observed and simulated groundwater elevations at bedrock wells and piezometers for pumping test 3 (11/18/2018 - 11/29/2018).

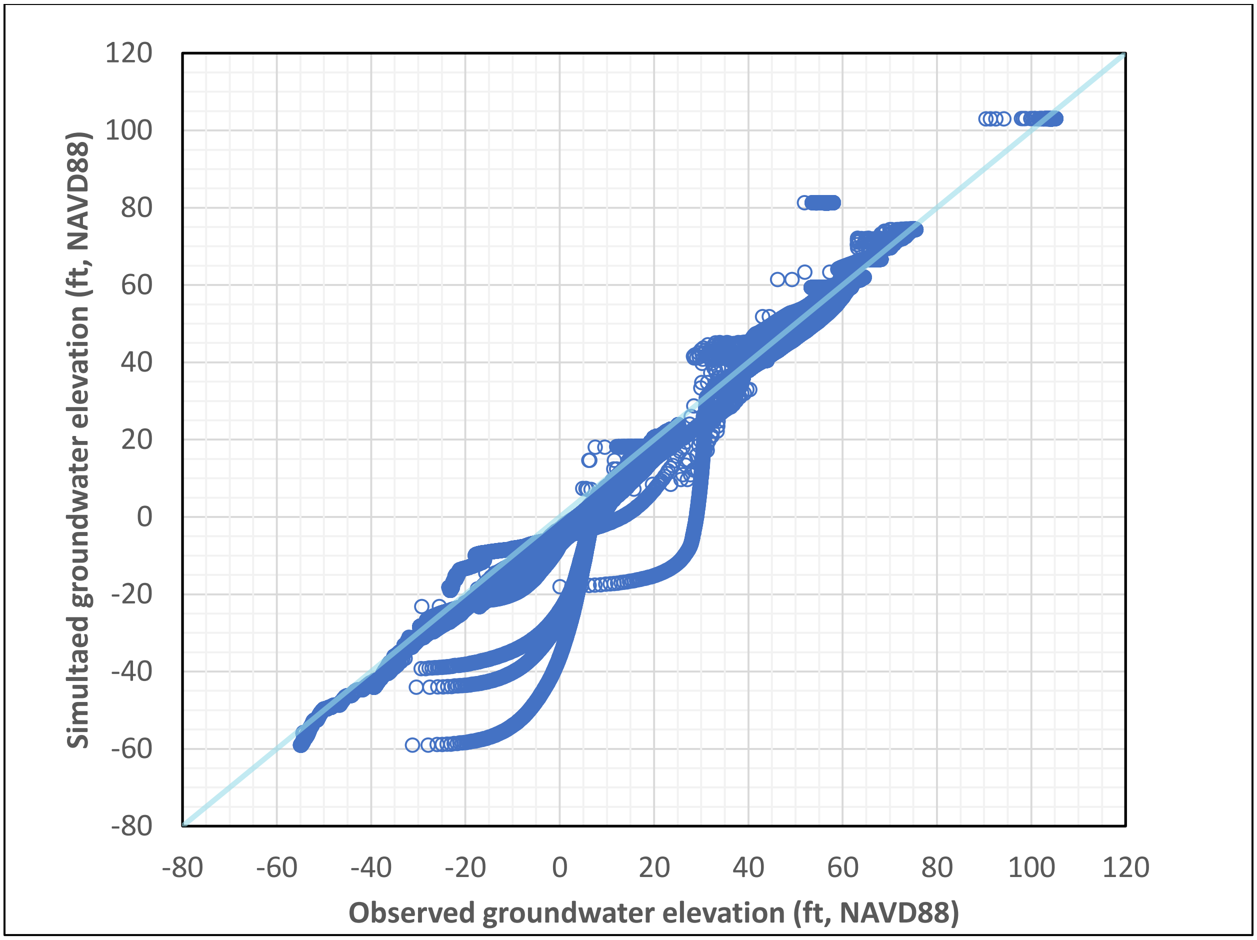

Figure A4. Observed and simulated groundwater elevations at bedrock wells and piezometers for pumping test 4 (1/8/2019 - 1/18/2019).

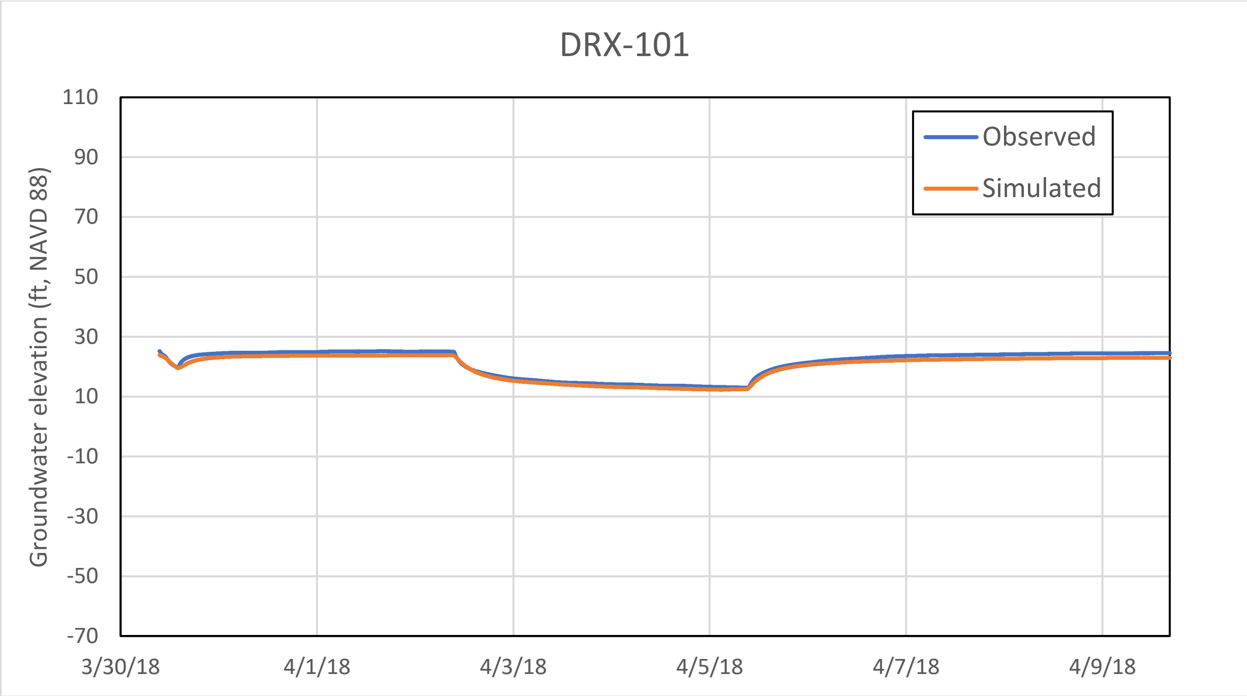

Figure A5. Observed and simulated groundwater elevations at pumping well DRX-101 during pump test 1 (3/30/2018 - 4/9/2018).

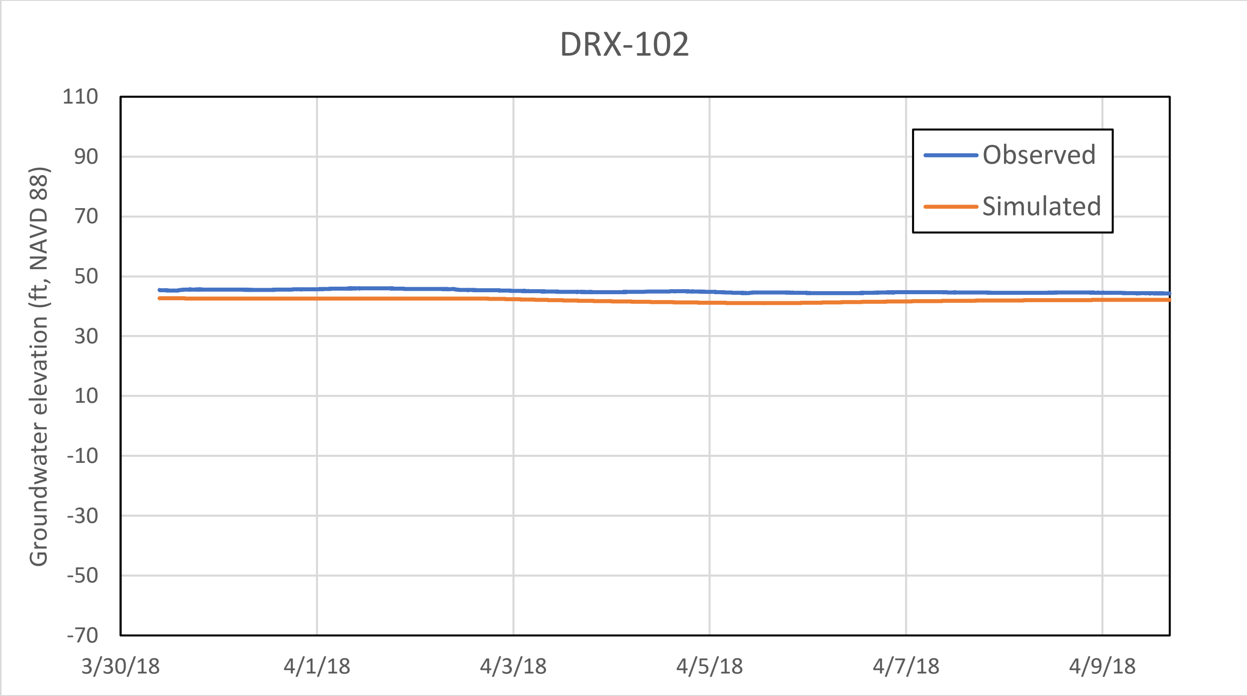

Figure A6. Observed and simulated groundwater elevations at pumping well DRX-102 during pump test 1 (3/30/2018 - 4/9/2018).

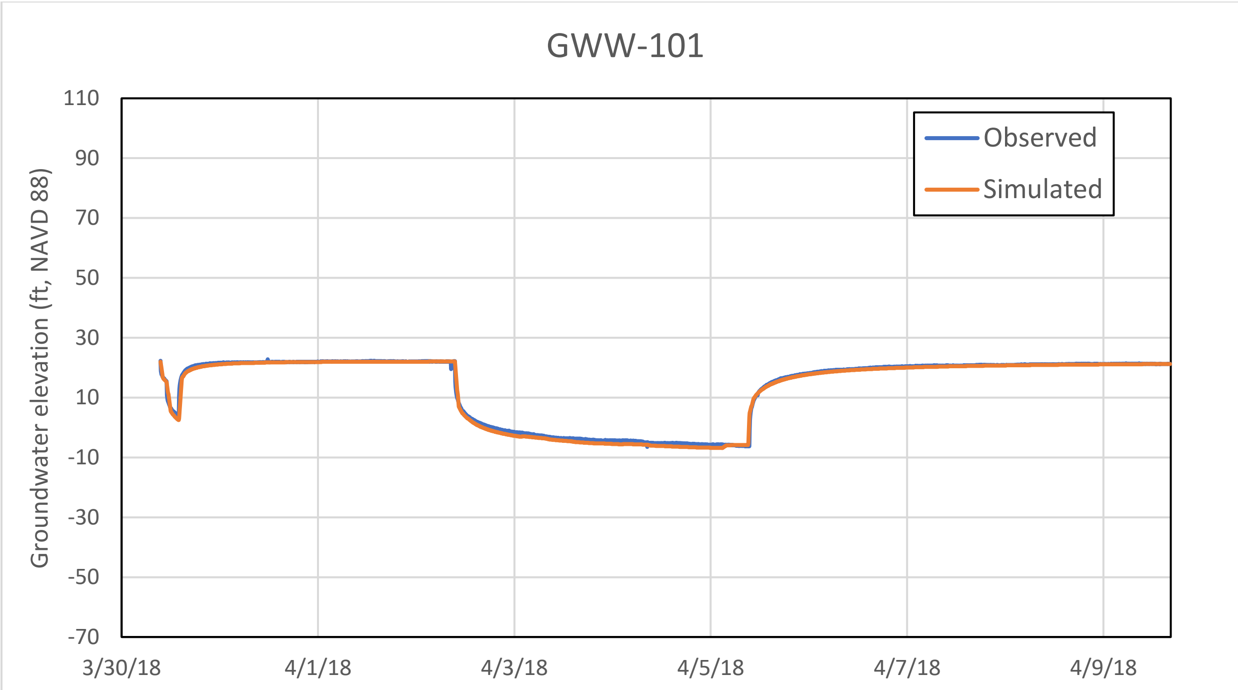

Figure A7. Observed and simulated groundwater elevations at pumping well GWW-101 during pump test 1 (3/30/2018 - 4/9/2018).

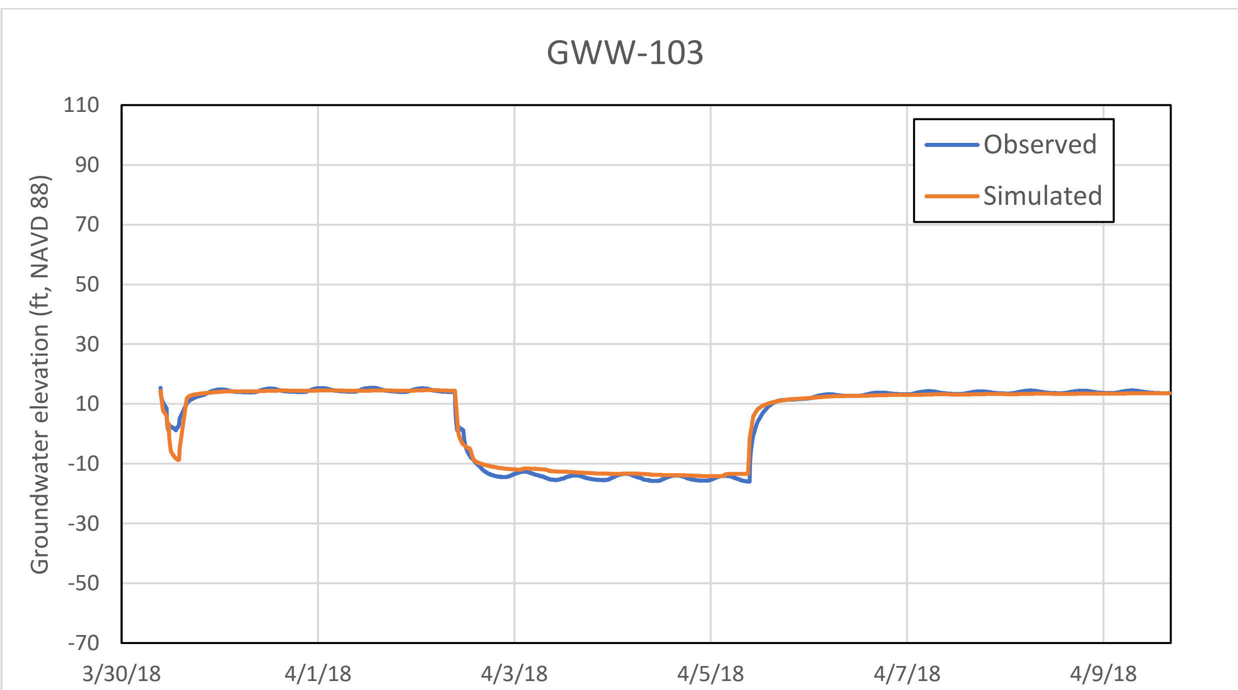

Figure A8. Observed and simulated groundwater elevations at pumping well GWW-103 during pump test 1 (3/30/2018 - 4/9/2018).

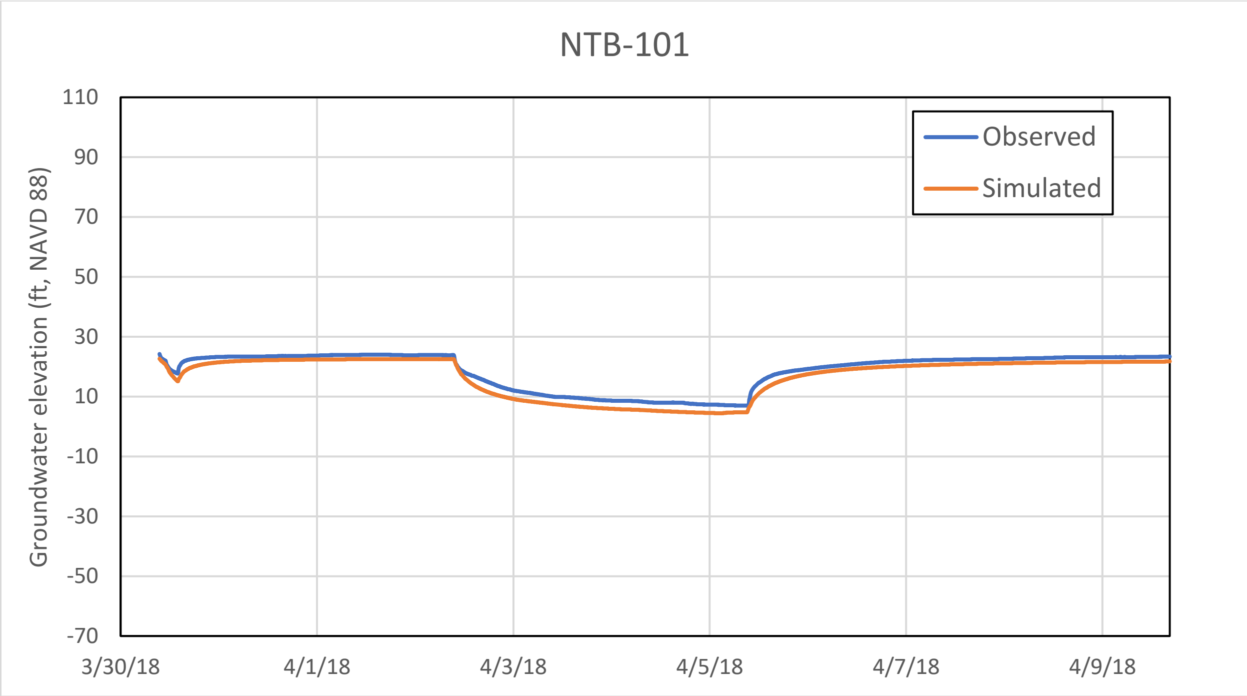

Figure A9. Observed and simulated groundwater elevations at bedrock well NTB-101 during pump test 1 (3/30/2018 - 4/9/2018).

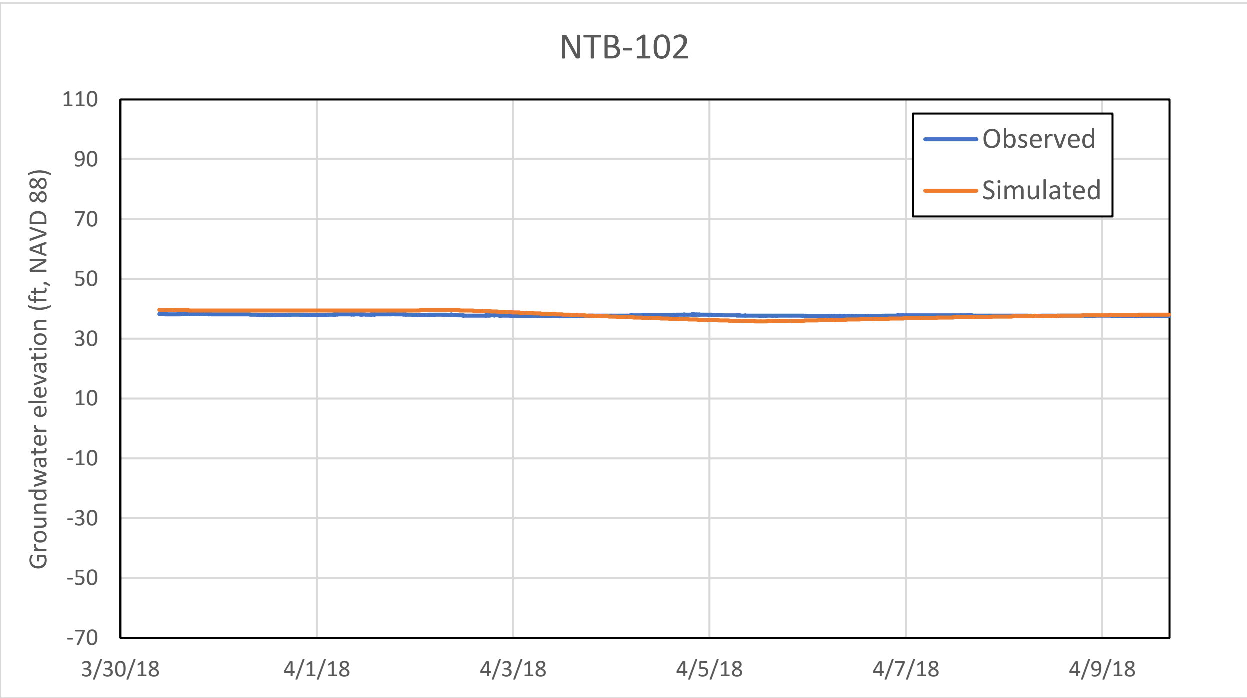

Figure A10. Observed and simulated groundwater elevations at bedrock well NTB-102 during pump test 1 (3/30/2018 - 4/9/2018).

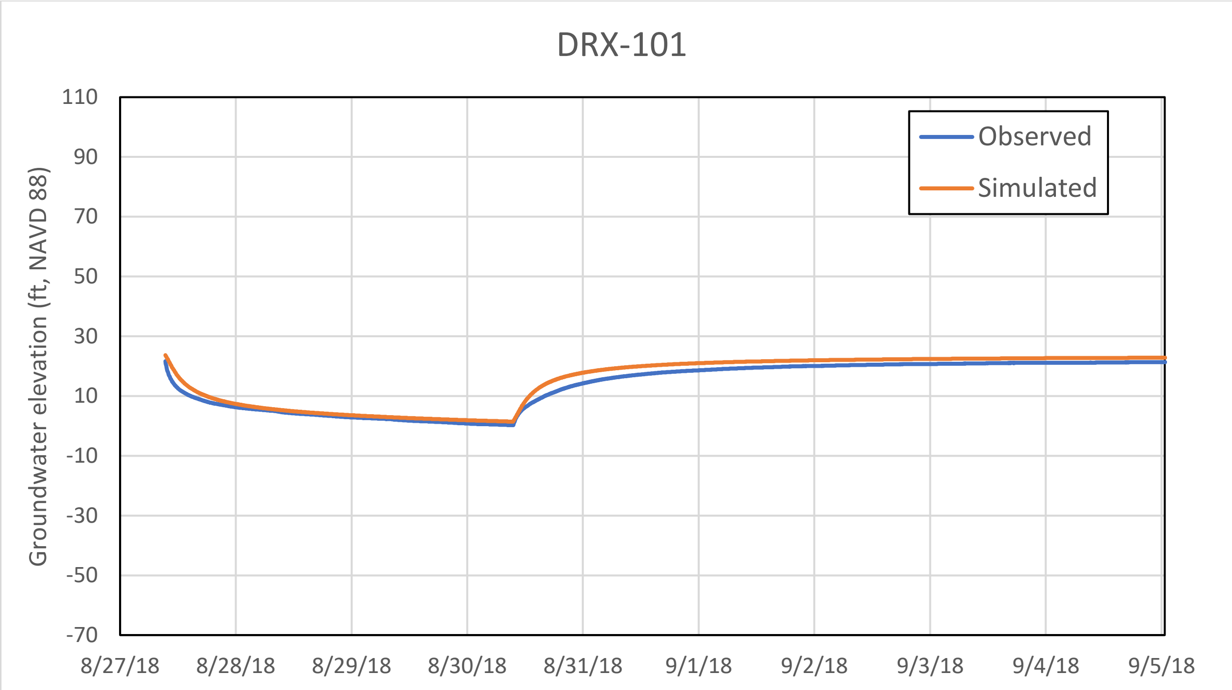

Figure A11. Observed and simulated groundwater elevations at pumping well DRX-101 during pump test 2 (8/27/2018 - 9/5/2018).

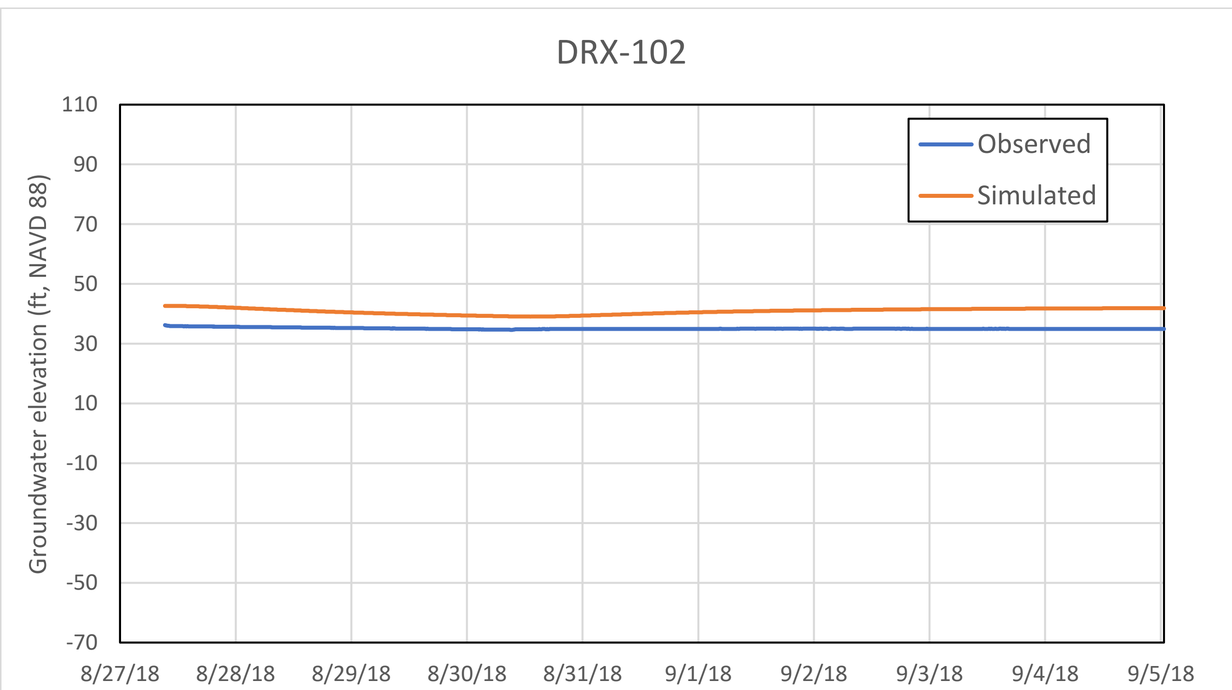

Figure A12. Observed and simulated groundwater elevations at pumping well DRX-102 during pump test 2 (8/27/2018 - 9/5/2018).

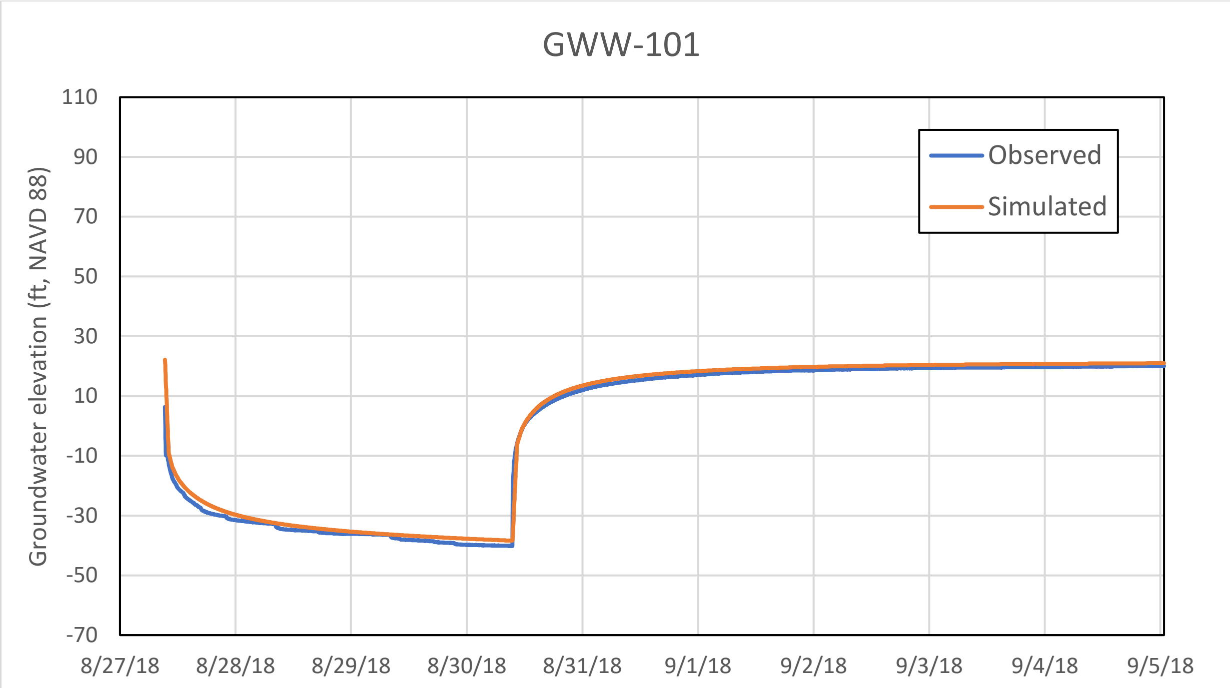

Figure A13. Observed and simulated groundwater elevations at pumping well GWW-101 during pump test 2 (8/27/2018 - 9/5/2018).

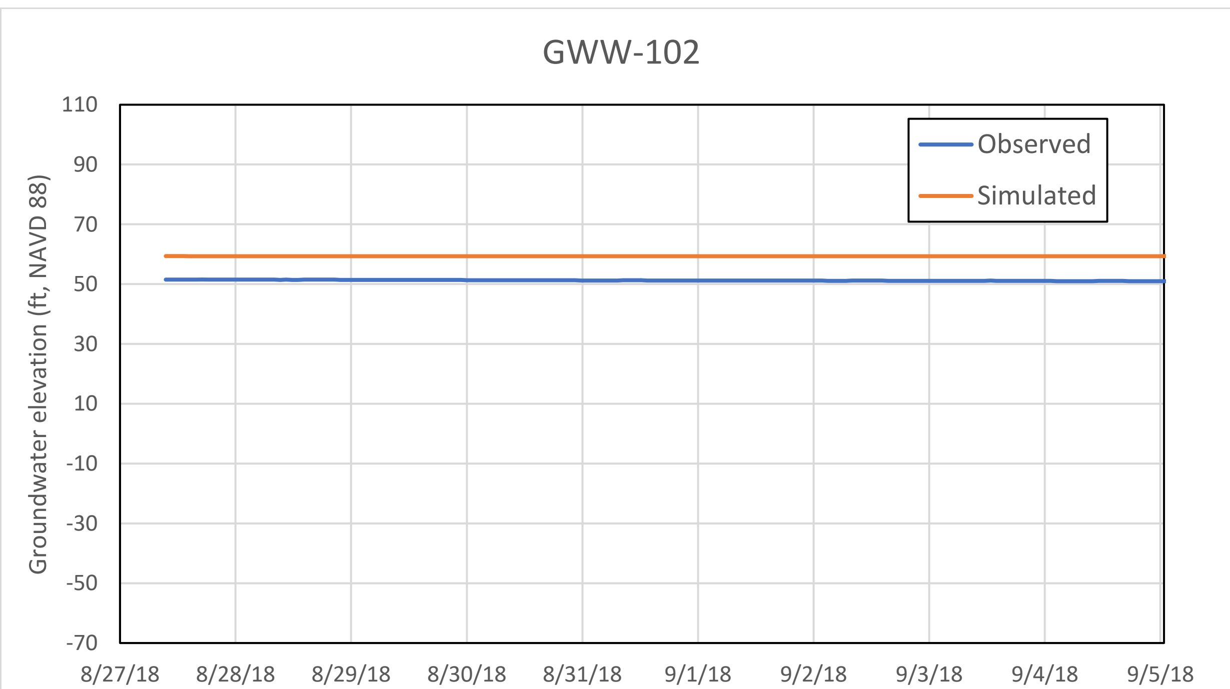

Figure A14. Observed and simulated groundwater elevations at bedrock well GWW-102 during pump test 2 (8/27/2018 - 9/5/2018).

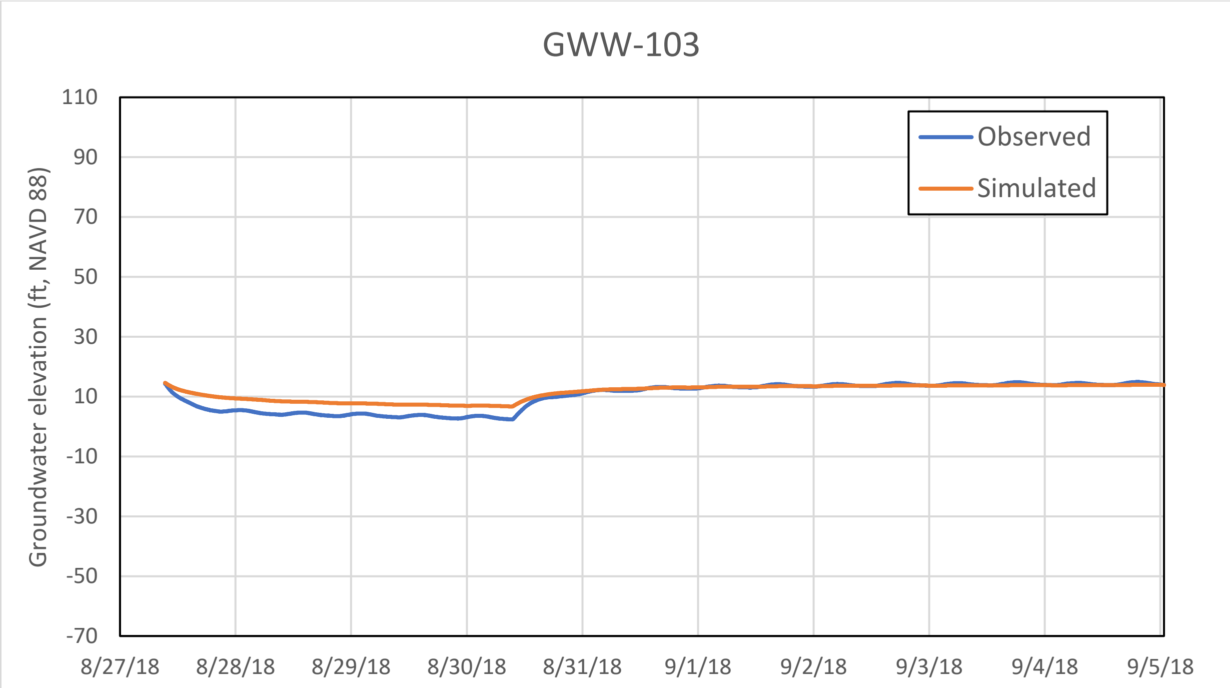

Figure A15. Observed and simulated groundwater elevations at pumping well GWW-103 during pump test 2 (8/27/2018 - 9/5/2018).

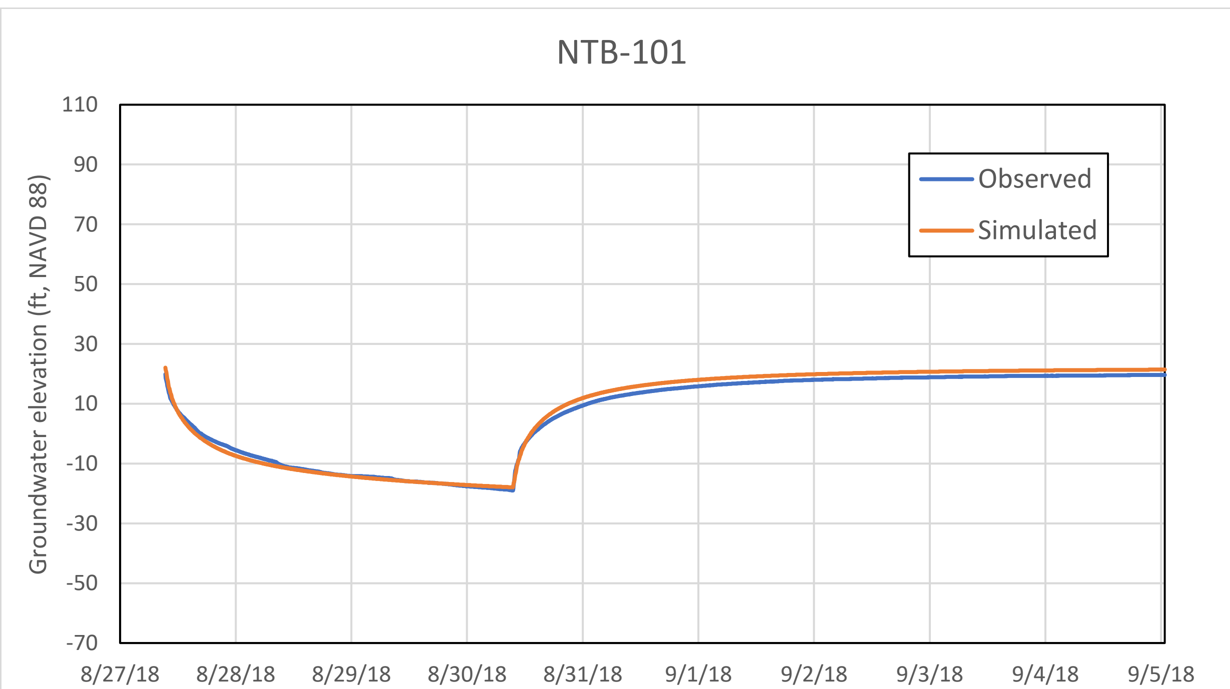

Figure A16. Observed and simulated groundwater elevations at bedrock well NTB-101 during pump test 2 (8/27/2018 - 9/5/2018).

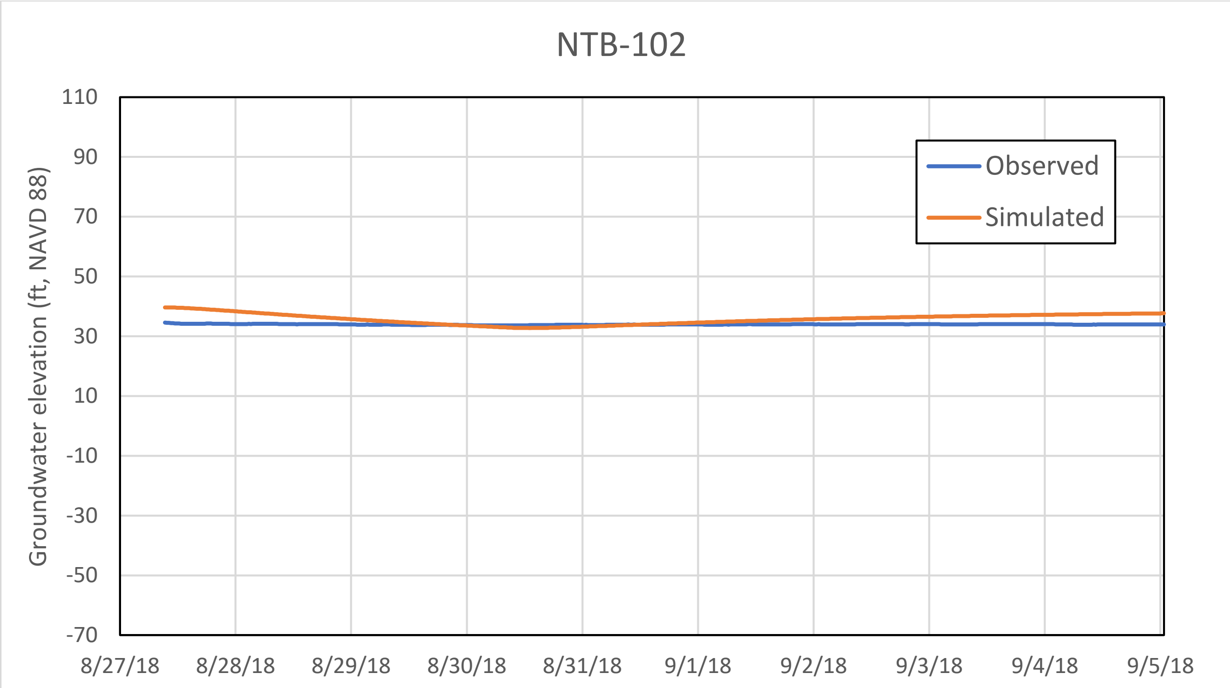

Figure A17. Observed and simulated groundwater elevations at bedrock well NTB-102 during pump test 2 (8/27/2018 - 9/5/2018).

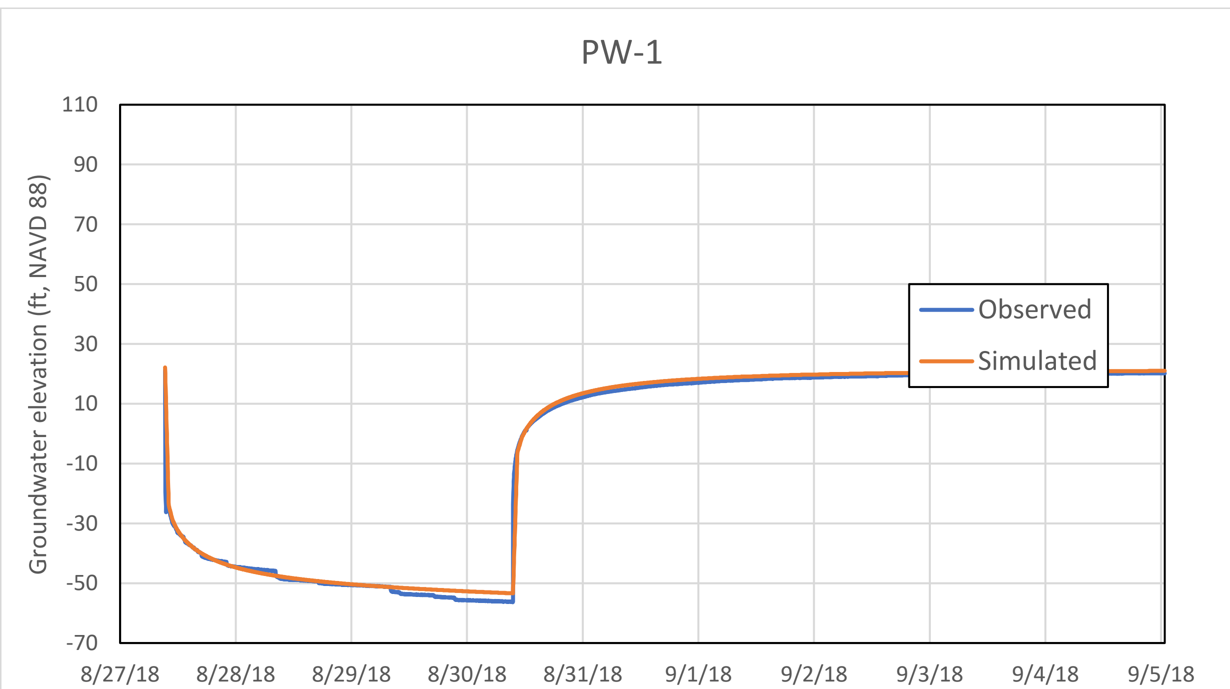

Figure A18. Observed and simulated groundwater elevations at pumping well PW-1 during pump test 2 (8/27/2018 - 9/5/2018).

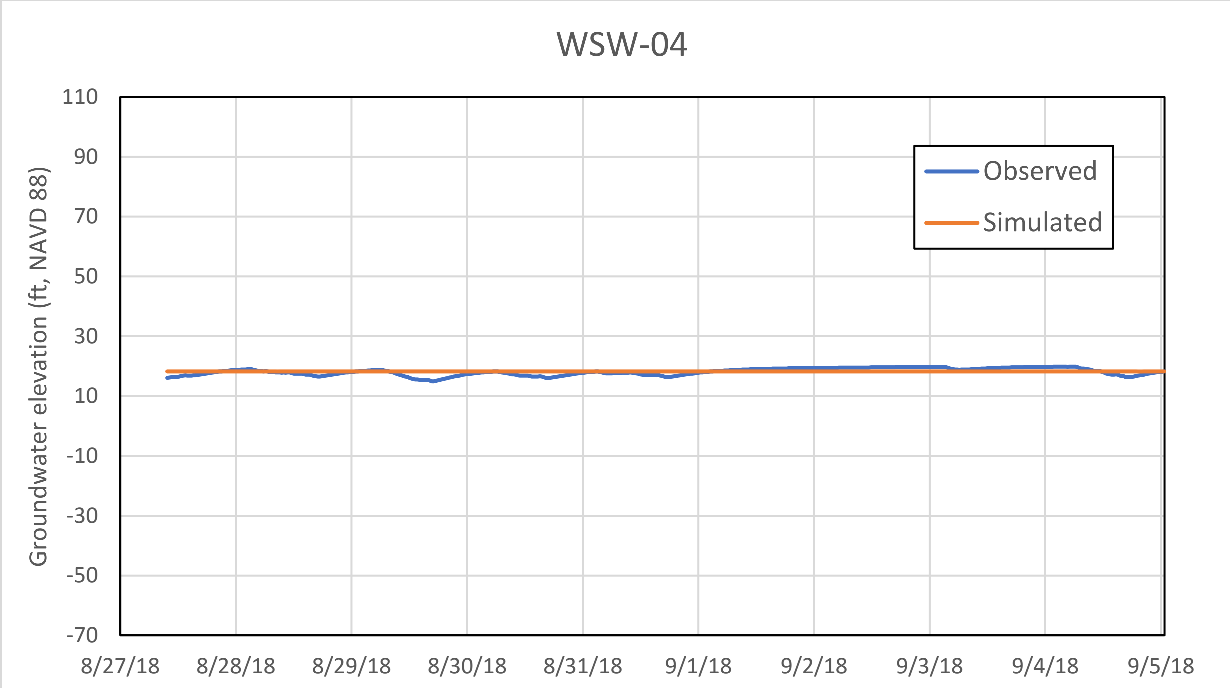

Figure A19. Observed and simulated groundwater elevations at bedrock well WSW-04 during pump test 2 (8/27/2018 - 9/5/2018).

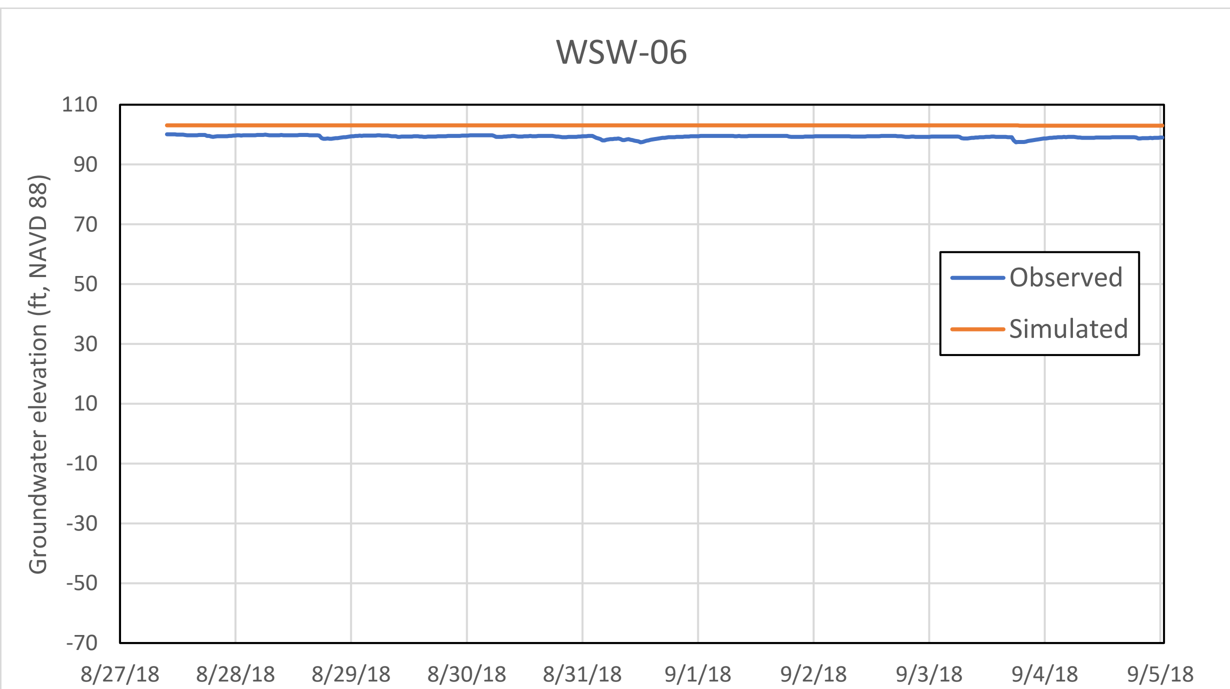

Figure A20. Observed and simulated groundwater elevations at bedrock well WSW-06 during pump test 2 (8/27/2018 - 9/5/2018).

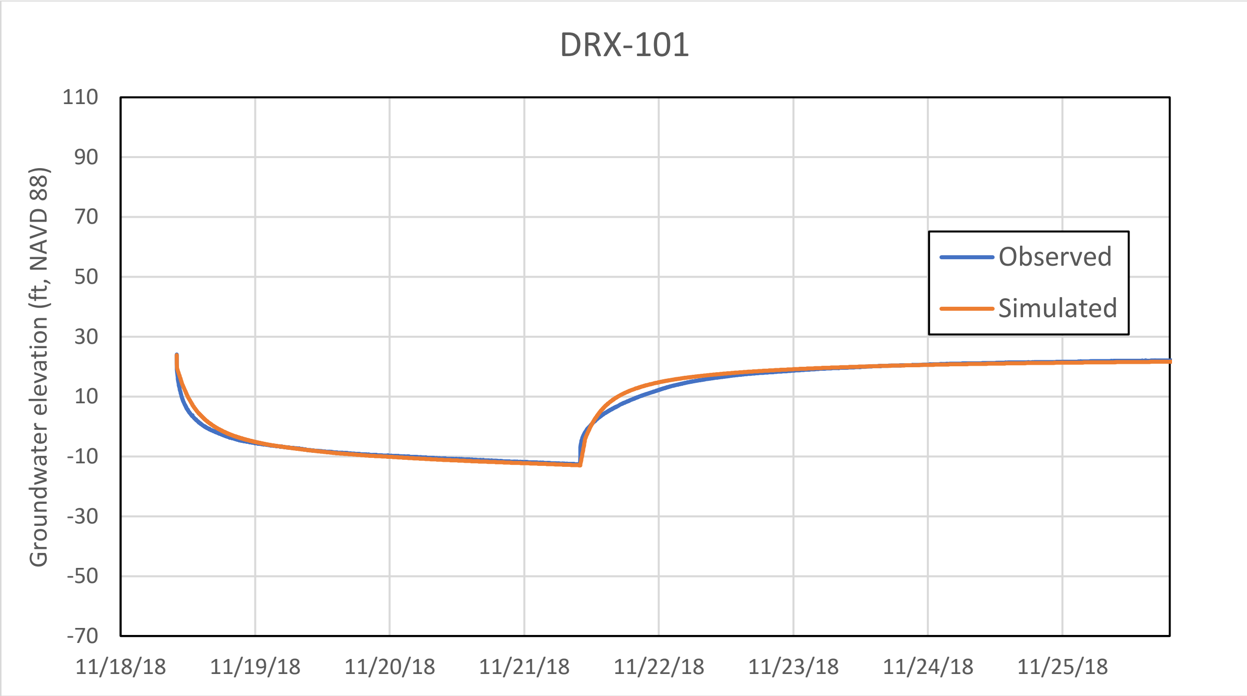

Figure A21. Observed and simulated groundwater elevation at pumping well DRX-101 during pump test 3 (11/18/2018 – 11/29/2018).

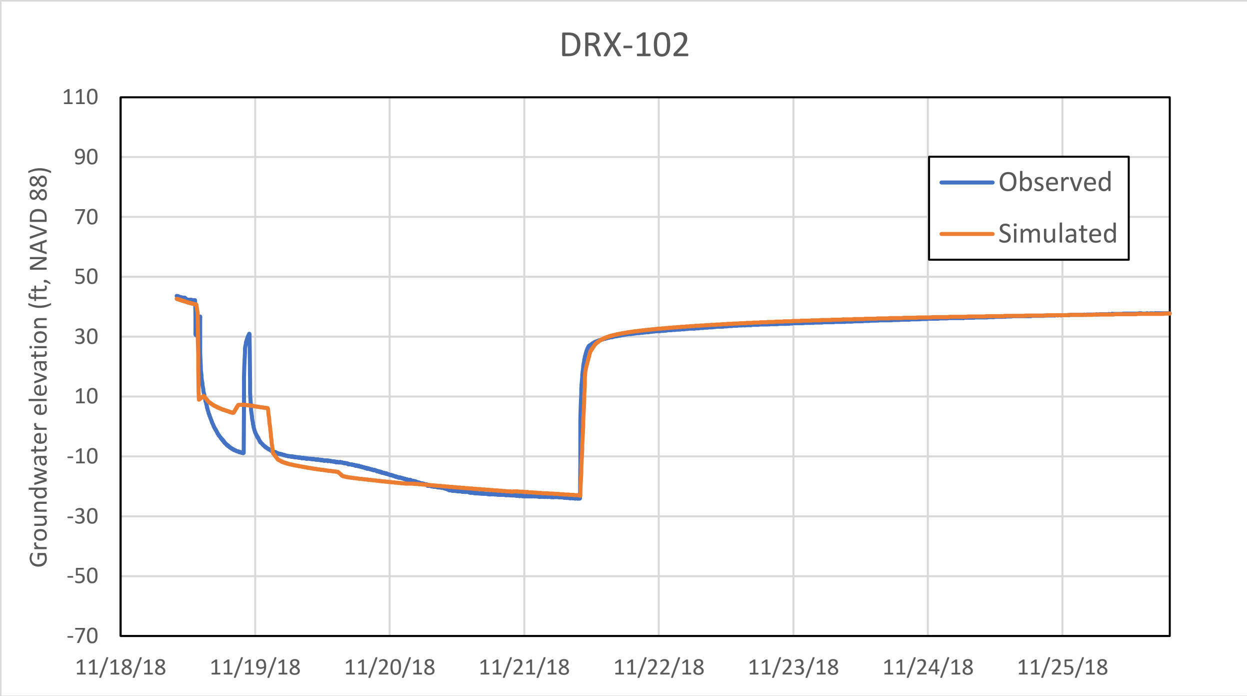

Figure A22. Observed and simulated groundwater elevation at pumping well DRX-102 during pump test 3 (11/18/2018 – 11/29/2018).

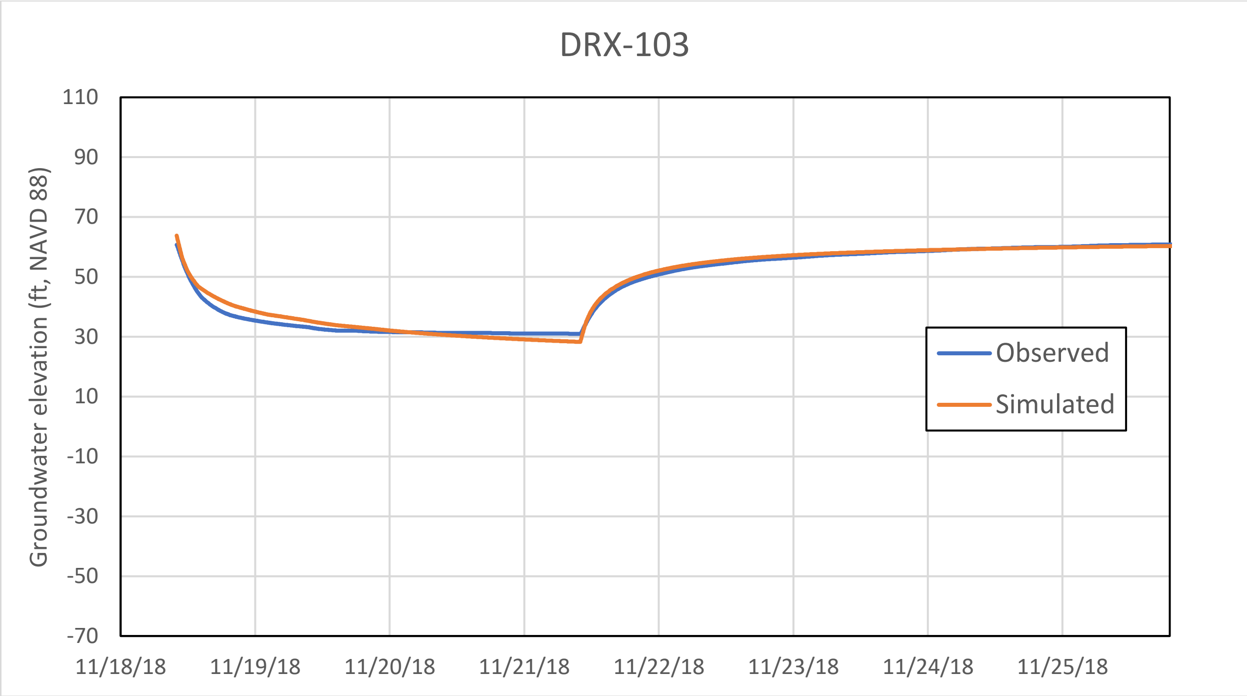

Figure A23. Observed and simulated groundwater elevation at bedrock well DRX-103 during pump test 3 (11/18/2018 – 11/29/2018).

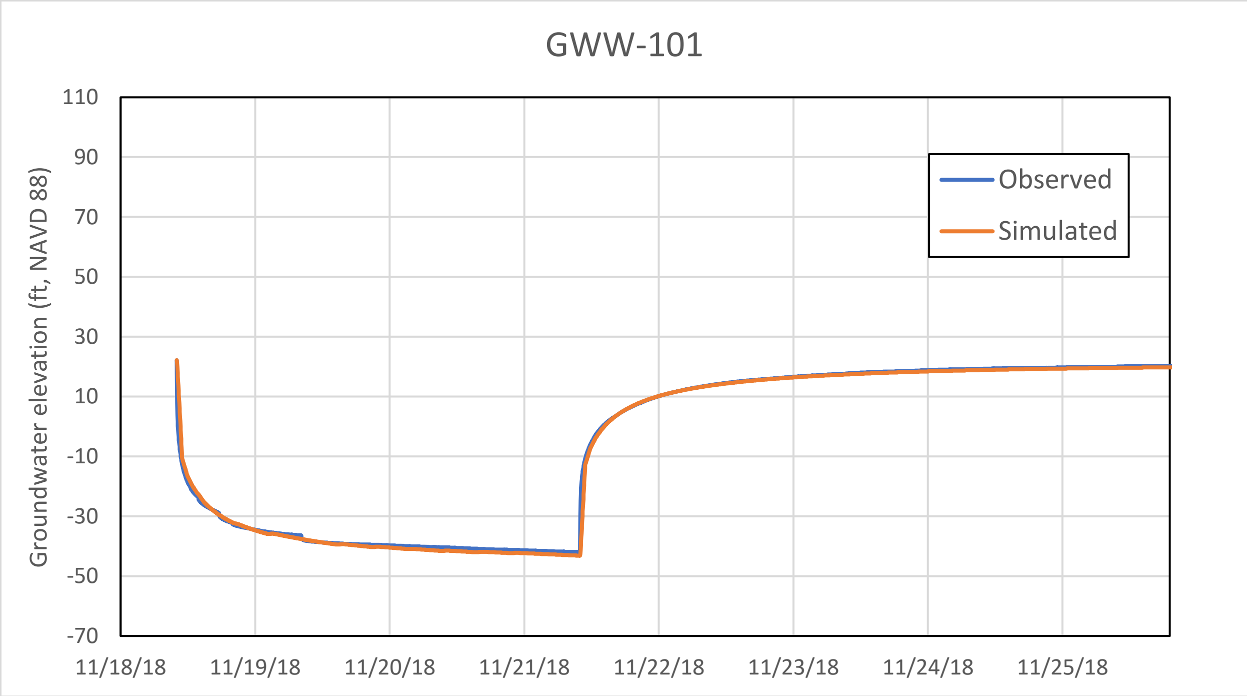

Figure A24. Observed and simulated groundwater elevation at pumping well GWW-101 during pump test 3 (11/18/2018 – 11/29/2018).

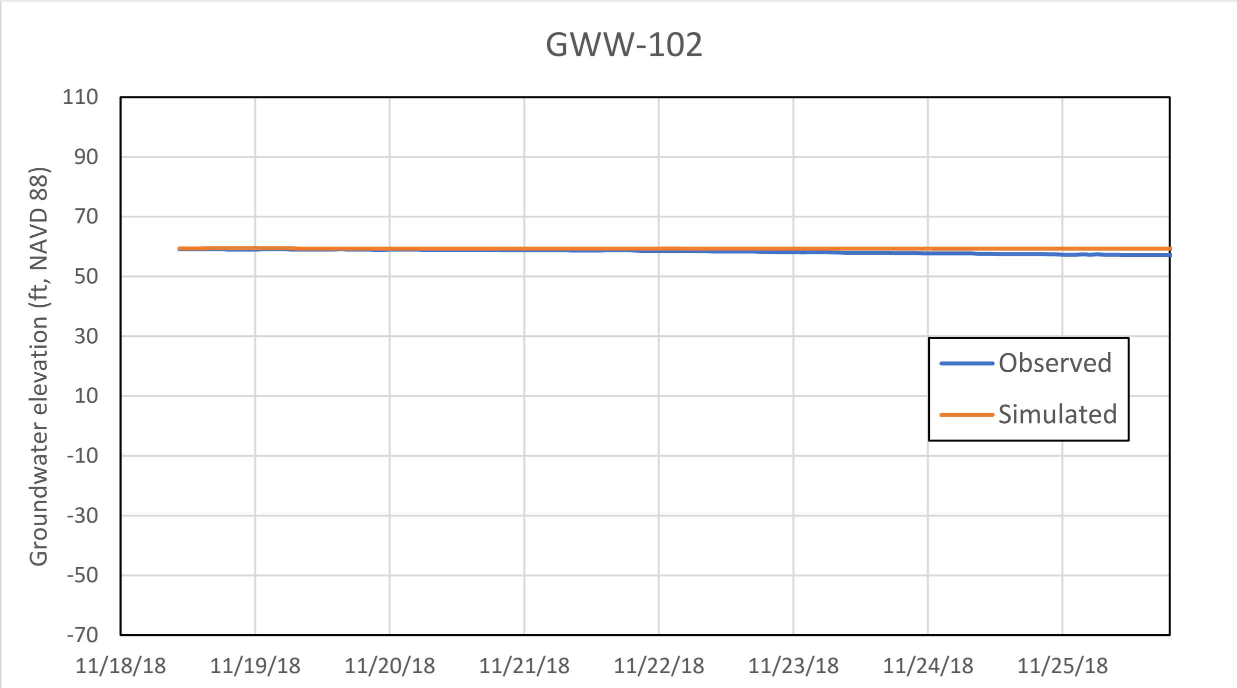

Figure A25. Observed and simulated groundwater elevation at bedrock well GWW-102 during pump test 3 (11/18/2018 – 11/29/2018).

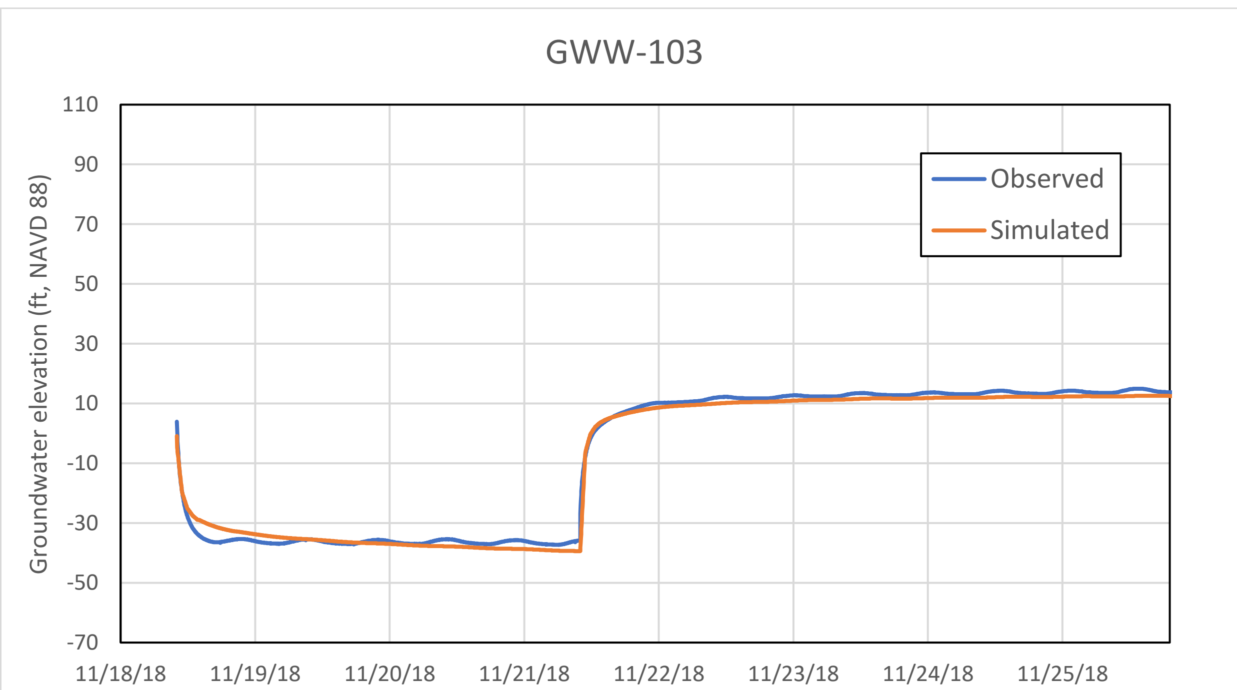

Figure A26. Observed and simulated groundwater elevation at pumping well GWW-103 during pump test 3 (11/18/2018 – 11/29/2018).

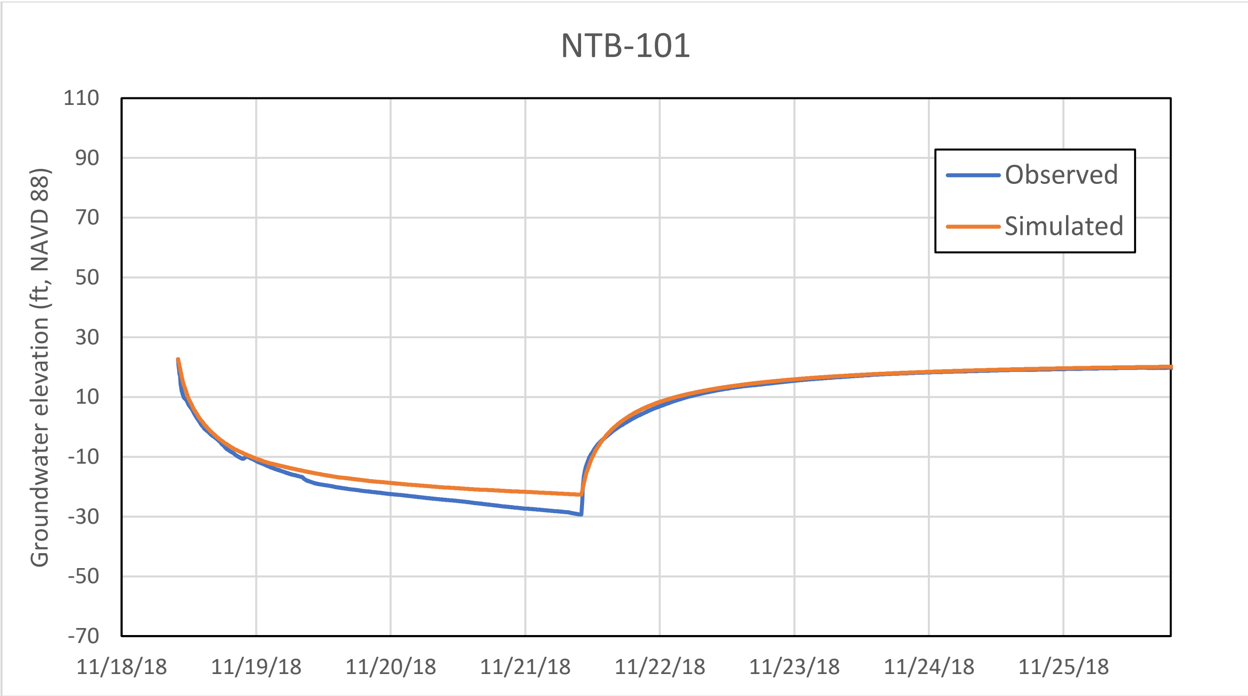

Figure A27. Observed and simulated groundwater elevation at bedrock well NTB-101 during pump test 3 (11/18/2018 – 11/29/2018).

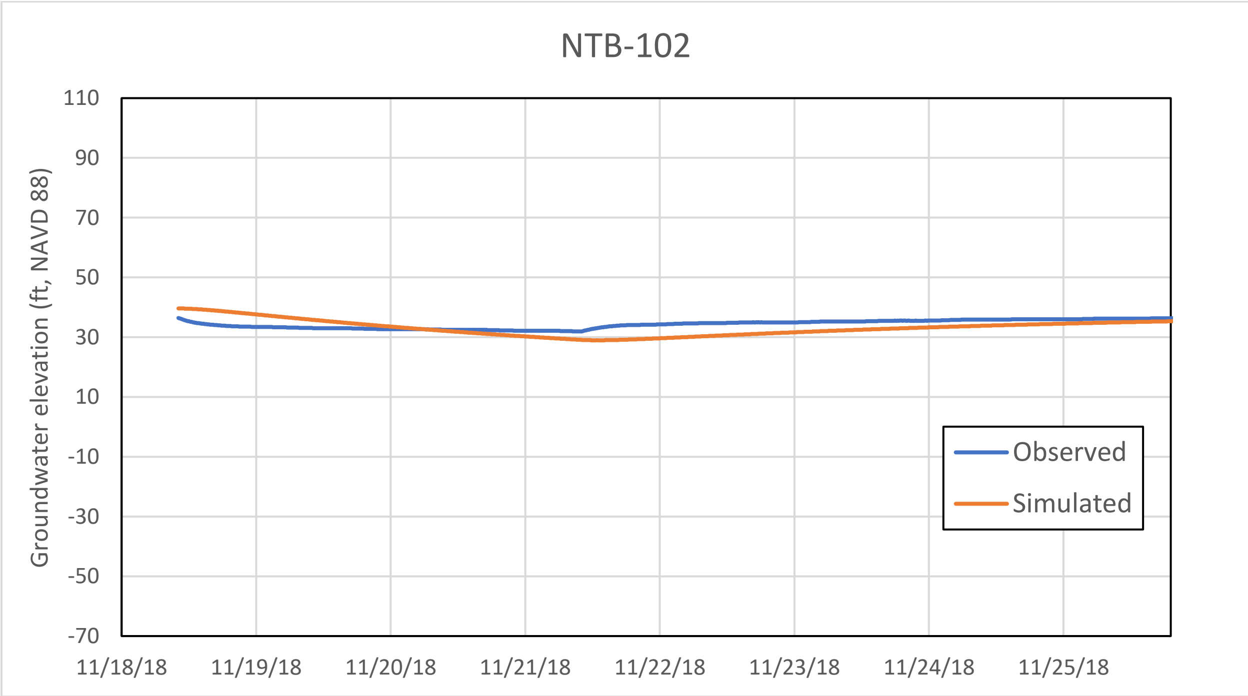

Figure A28. Observed and simulated groundwater elevation at bedrock well NTB-102 during pump test 3 (11/18/2018 – 11/29/2018).

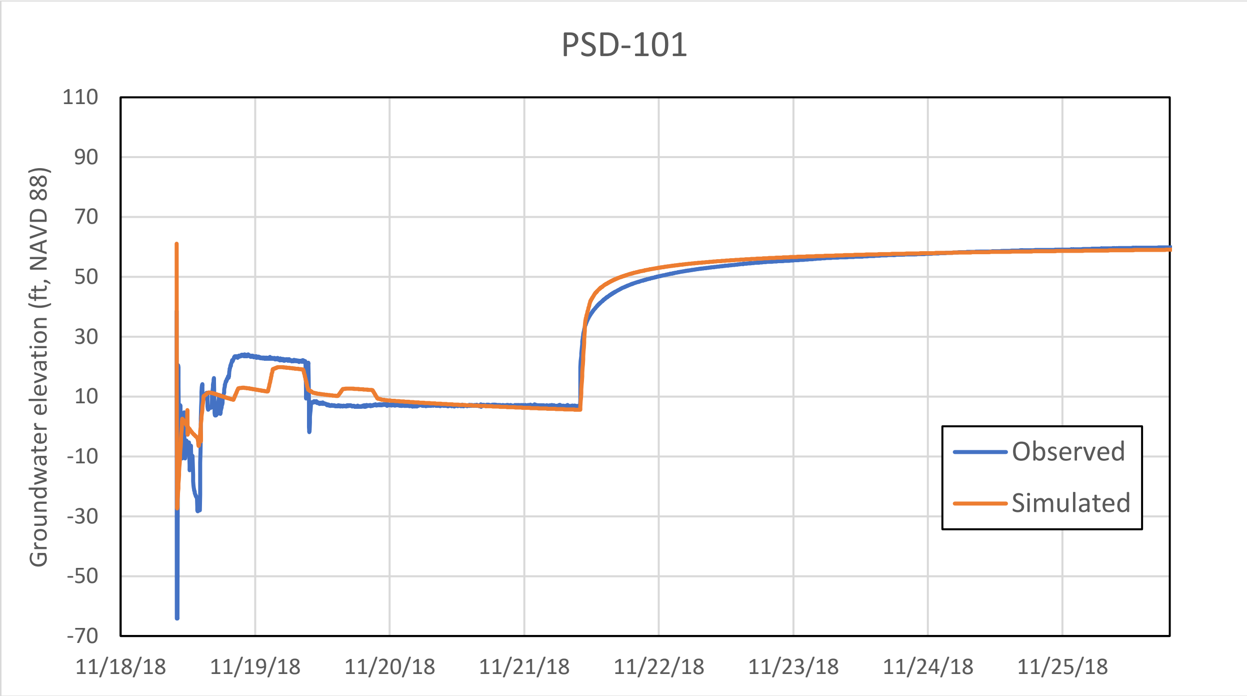

Figure A29. Observed and simulated groundwater elevation at pumping well PSD-101 during pump test 3 (11/18/2018 – 11/29/2018).

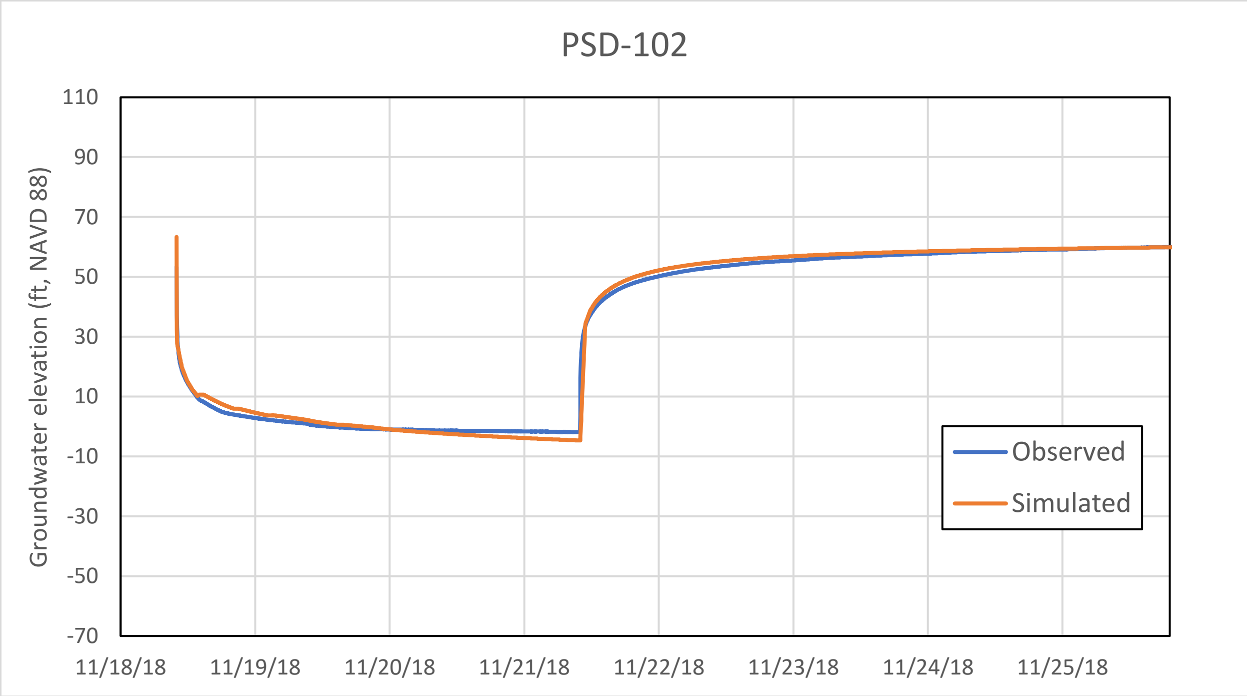

Figure A30. Observed and simulated groundwater elevation at pumping well PSD-102 during pump test 3 (11/18/2018 – 11/29/2018).

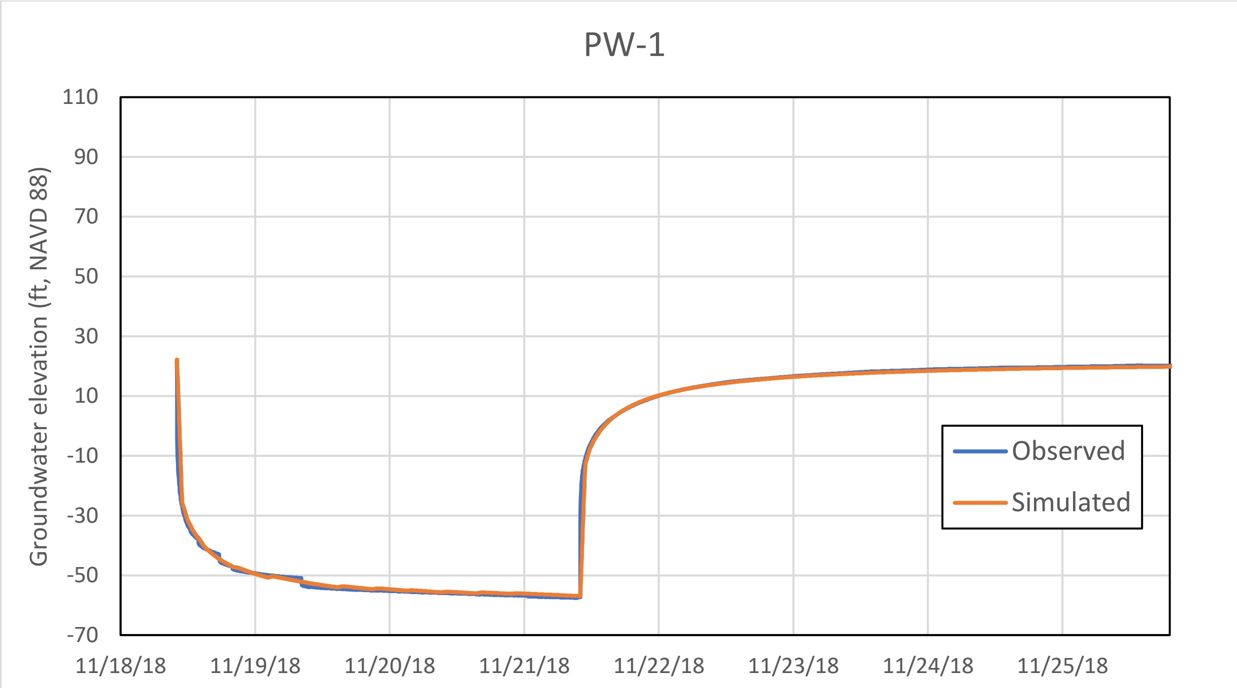

Figure A31. Observed and simulated groundwater elevation at pumping well PW-1 during pump test 3 (11/18/2018 – 11/29/2018).

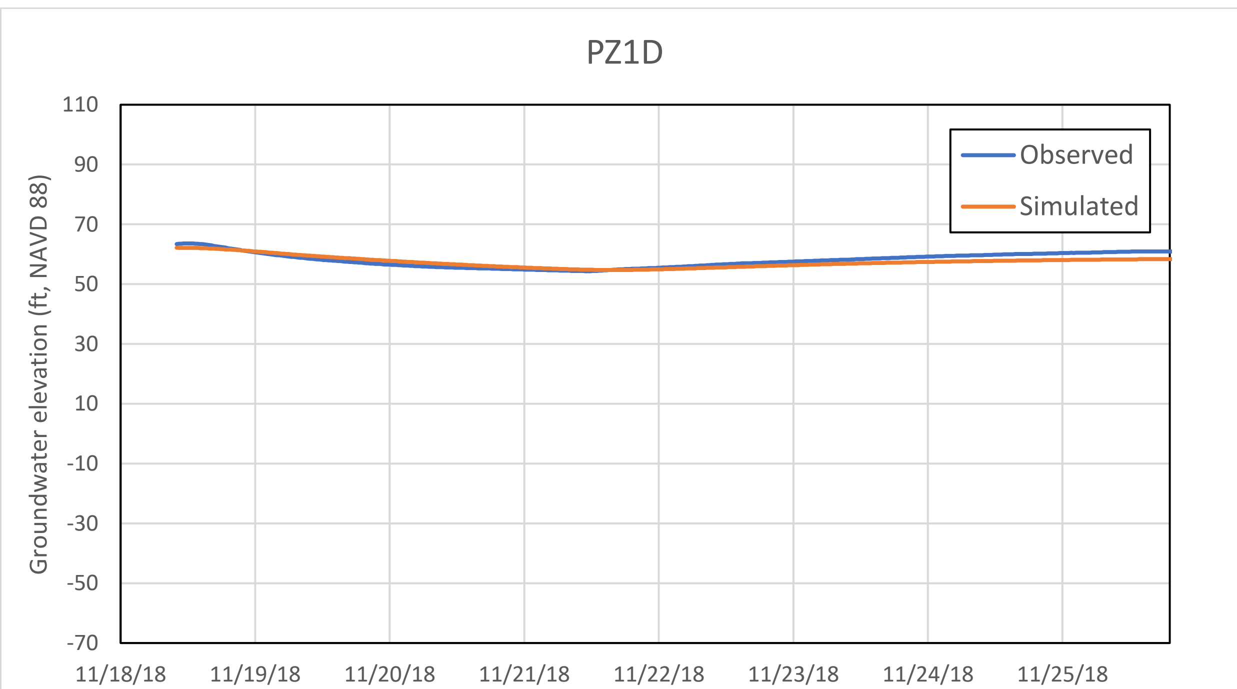

Figure A32. Observed and simulated groundwater elevation at piezometer PZ1D during pump test 3 (11/18/2018 – 11/29/2018).

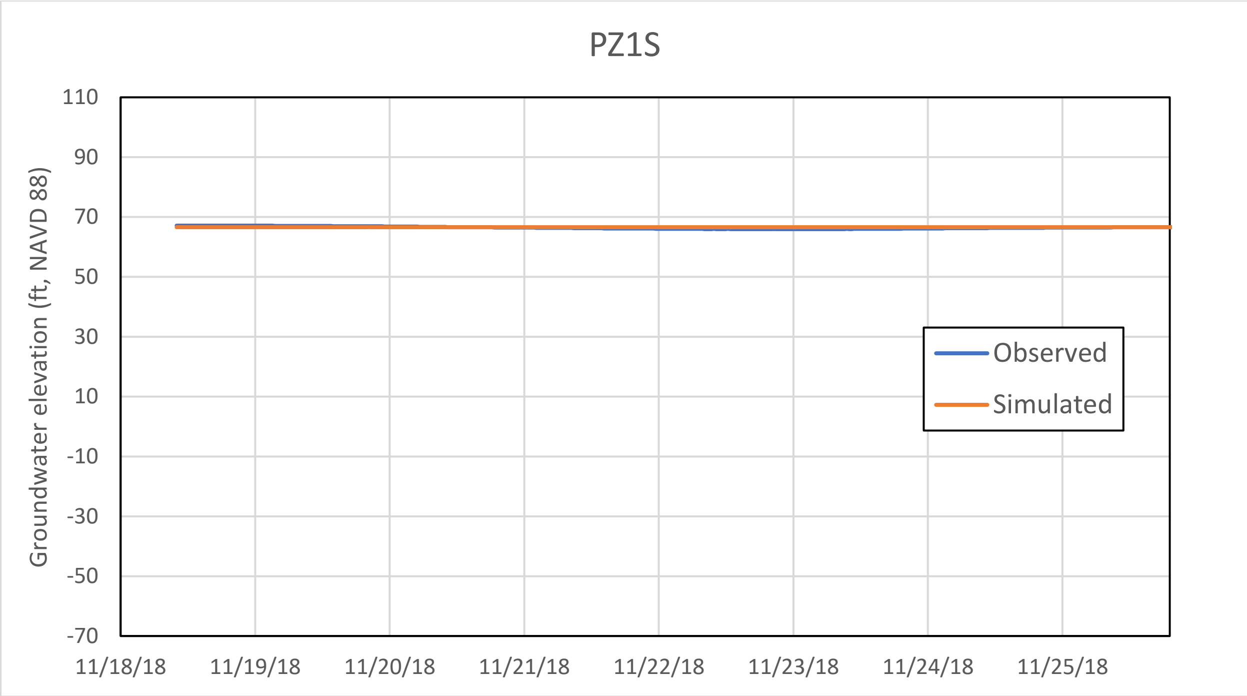

Figure A33. Observed and simulated groundwater elevation at piezometer PZ1S during pump test 3 (11/18/2018 – 11/29/2018).

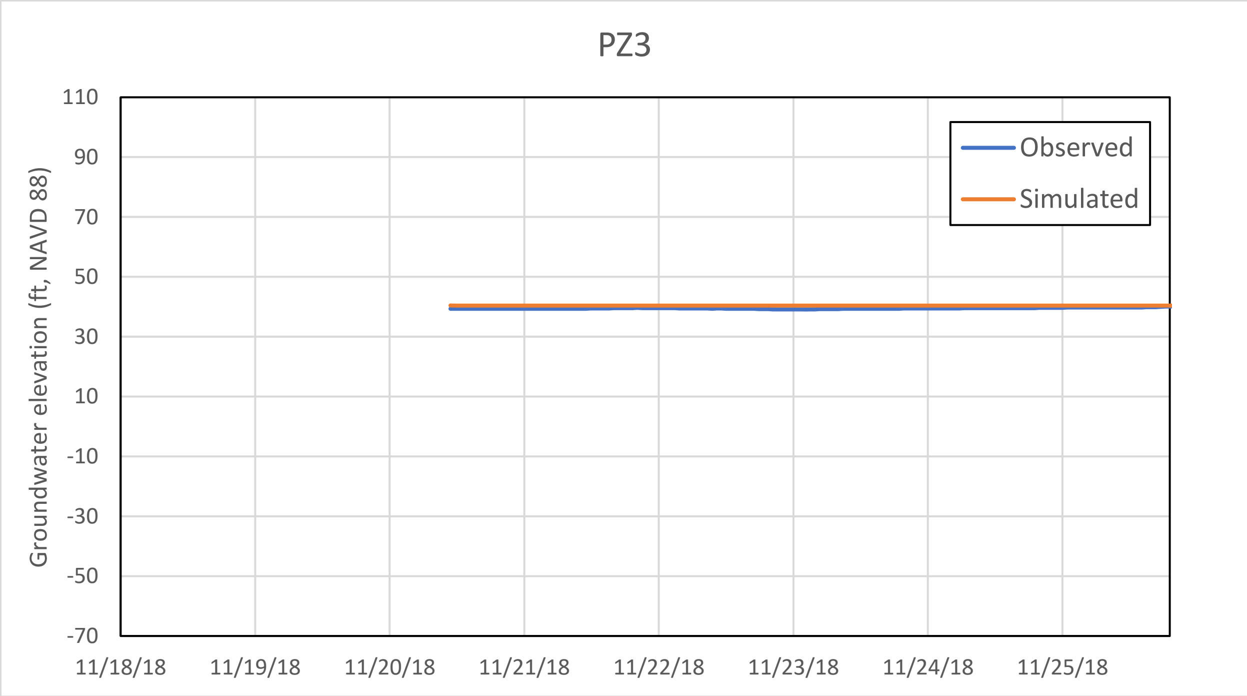

Figure A34. Observed and simulated groundwater elevation at piezometer PZ3 during pump test 3 (11/18/2018 – 11/29/2018).

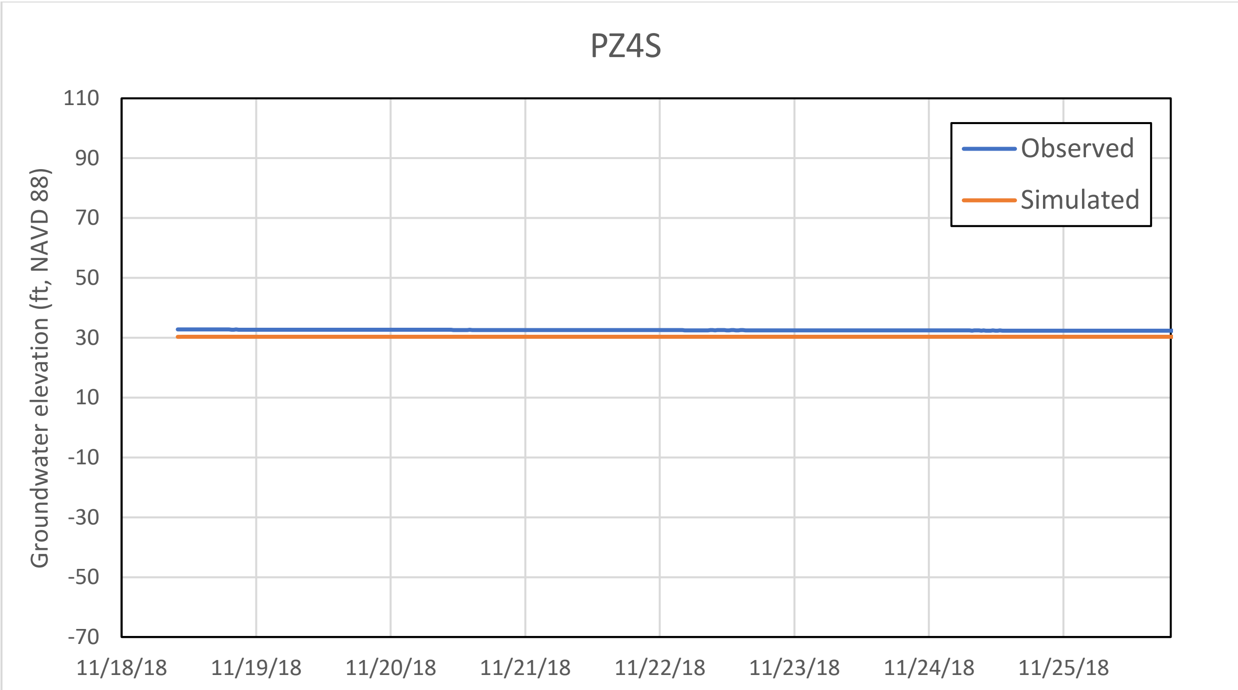

Figure A35. Observed and simulated groundwater elevation at piezometer PZ4S during pump test 3 (11/18/2018 – 11/29/2018).

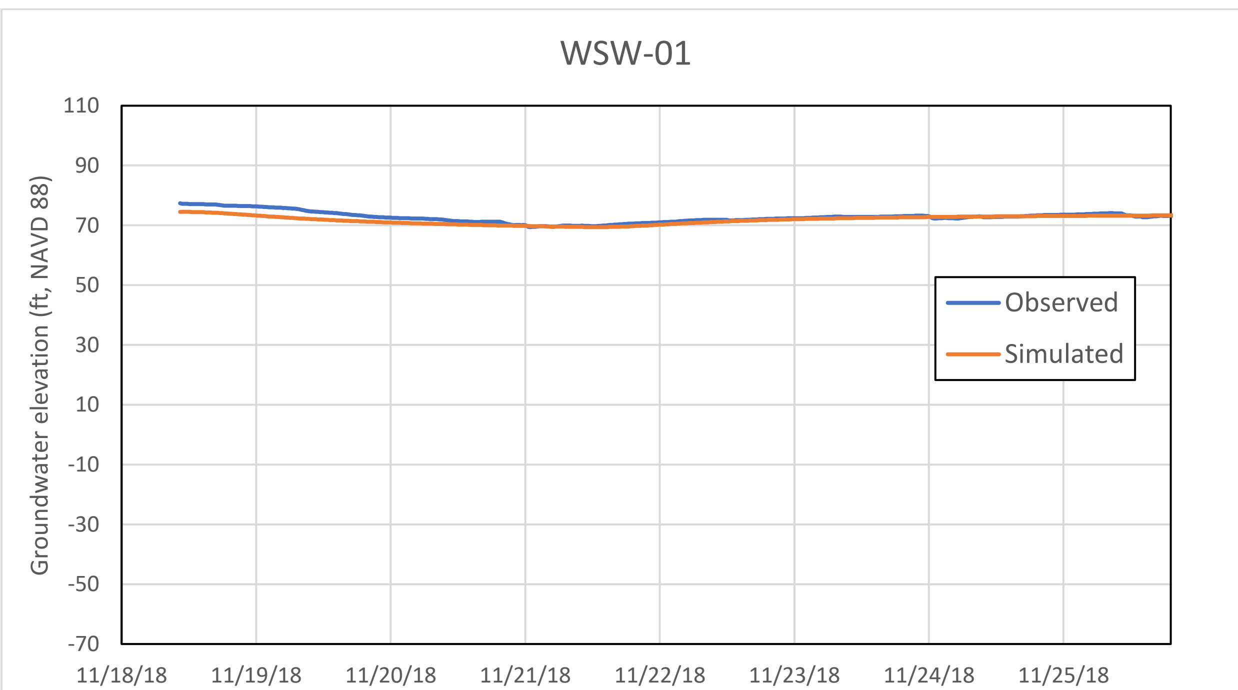

Figure A36. Observed and simulated groundwater elevation at bedrock well WSW-01 during pump test 3 (11/18/2018 – 11/29/2018).

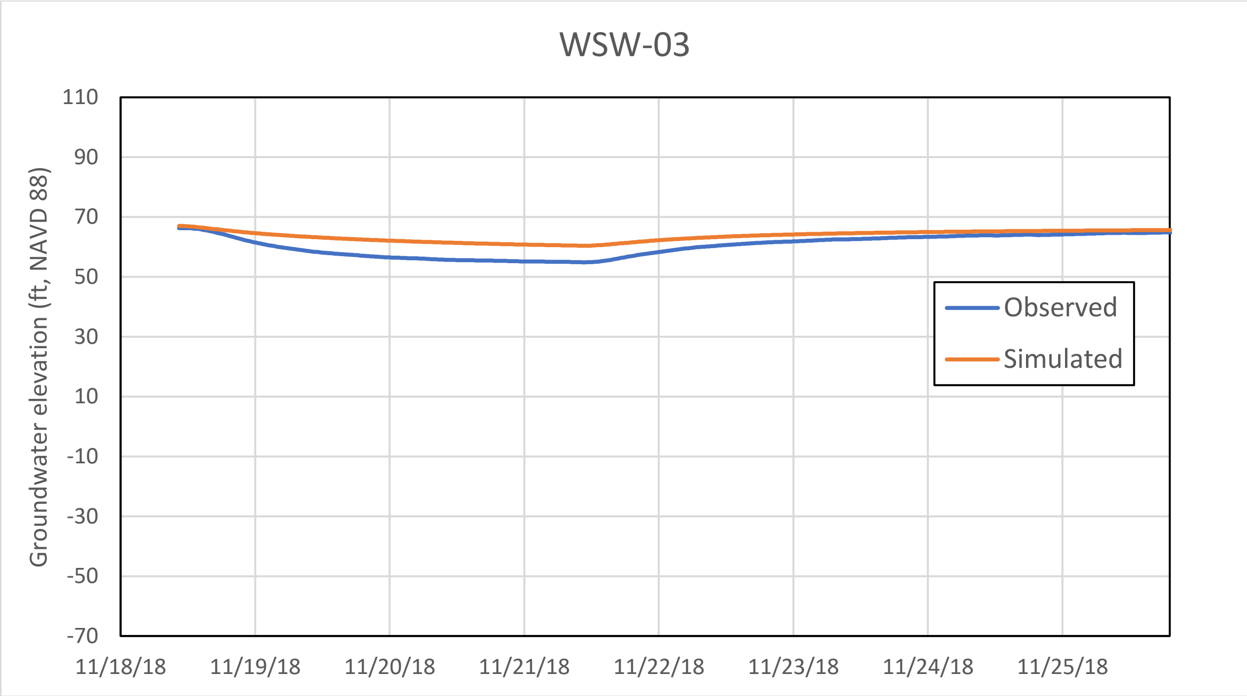

Figure A37. Observed and simulated groundwater elevation at bedrock well WSW-03 during pump test 3 (11/18/2018 – 11/29/2018).

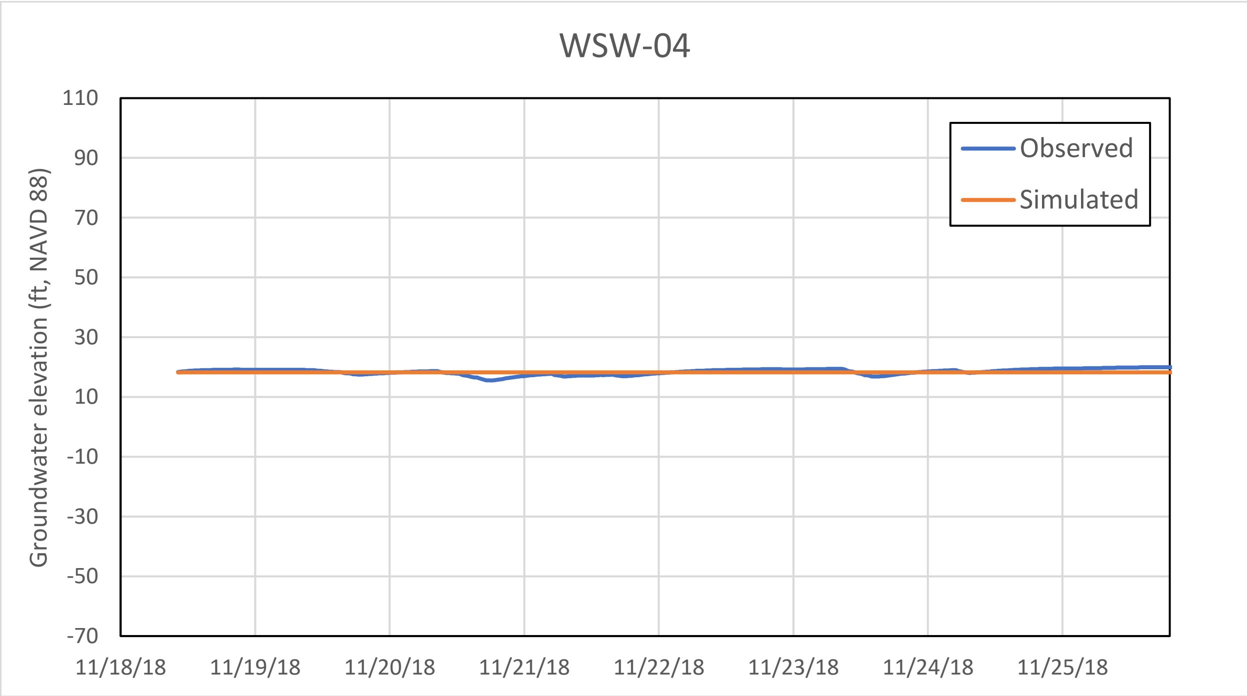

Figure A38. Observed and simulated groundwater elevation at bedrock well WSW-04 during pump test 3 (11/18/2018 – 11/29/2018).

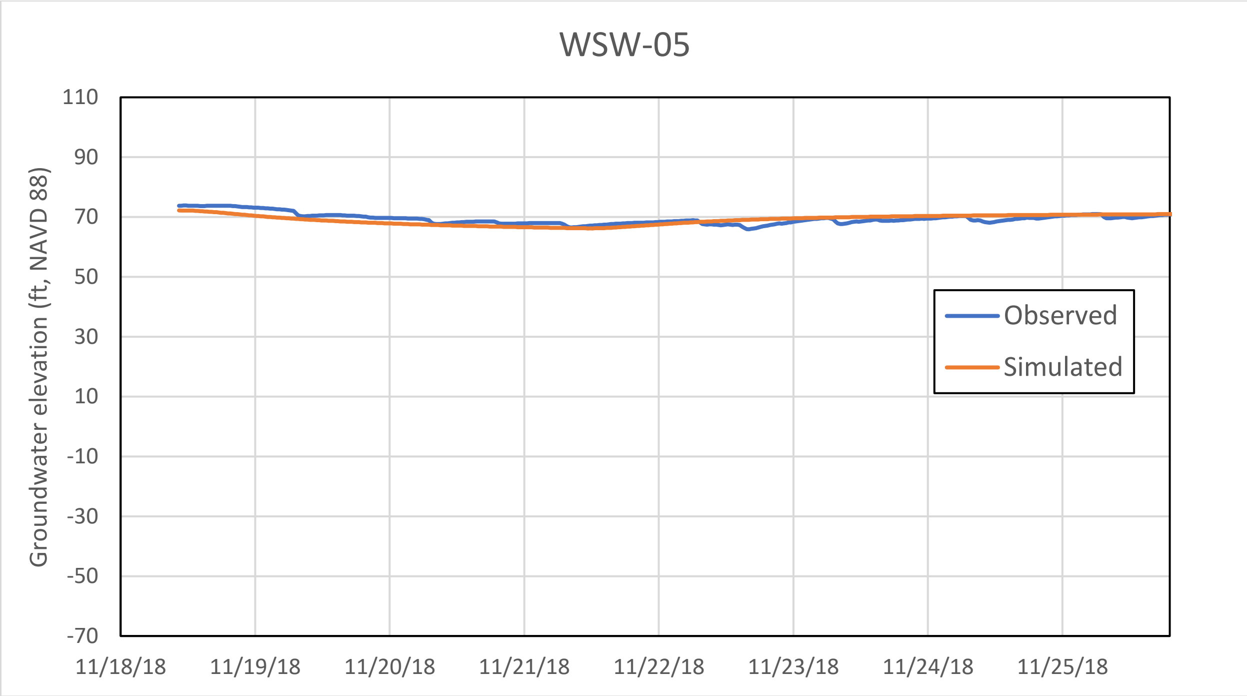

Figure A39. Observed and simulated groundwater elevation at bedrock well WSW-05 during pump test 3 (11/18/2018 – 11/29/2018).

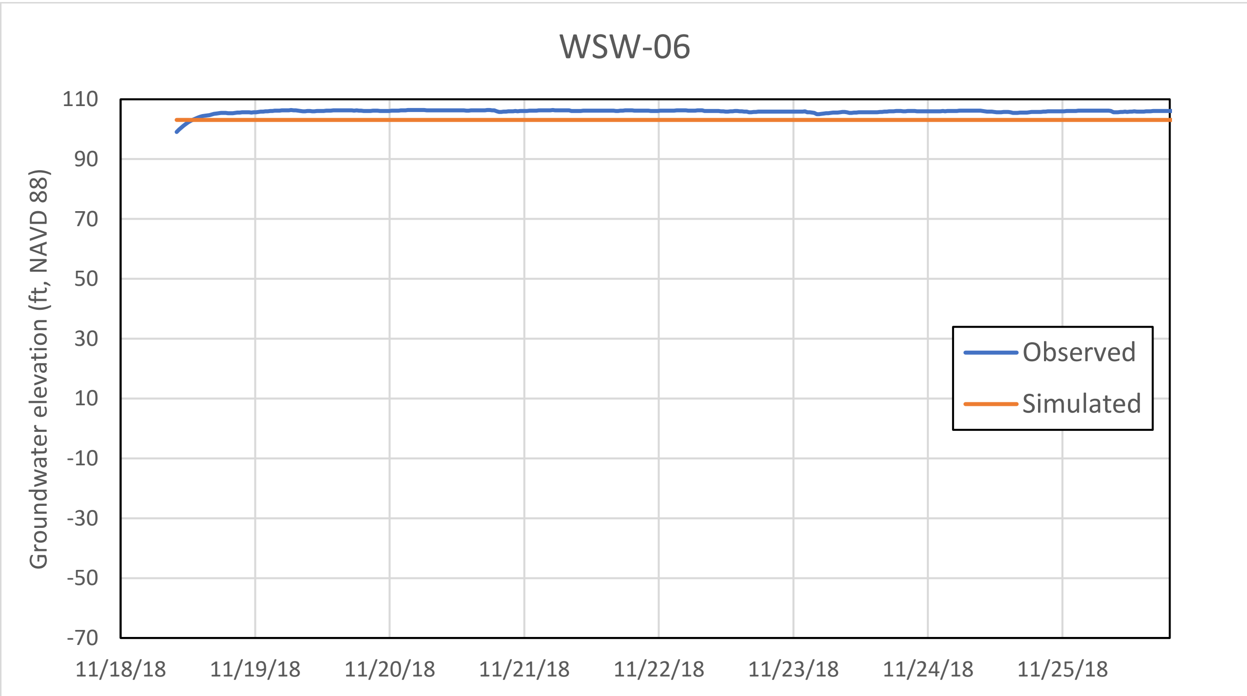

Figure A40. Observed and simulated groundwater elevation at bedrock well WSW-06 during pump test 3 (11/18/2018 – 11/29/2018).

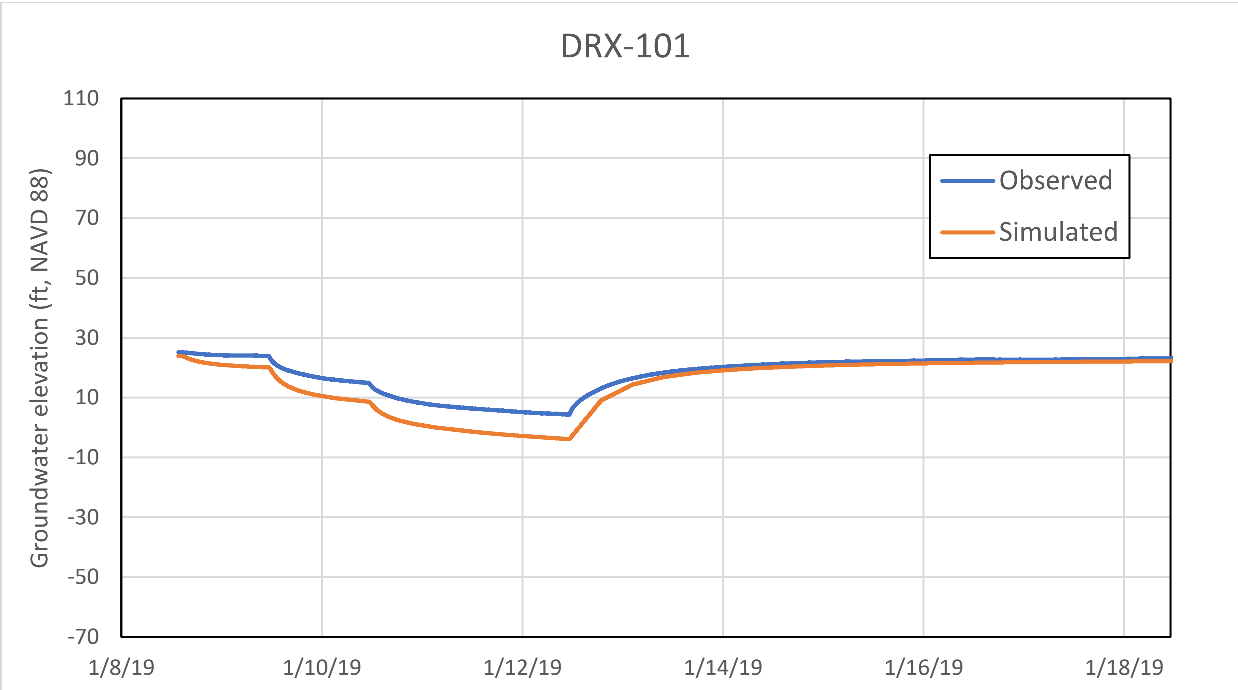

Figure A41. Observed and simulated groundwater elevation at pumping well DRX-101 during pump test 4 (1/8/2019 – 1/18/2019).

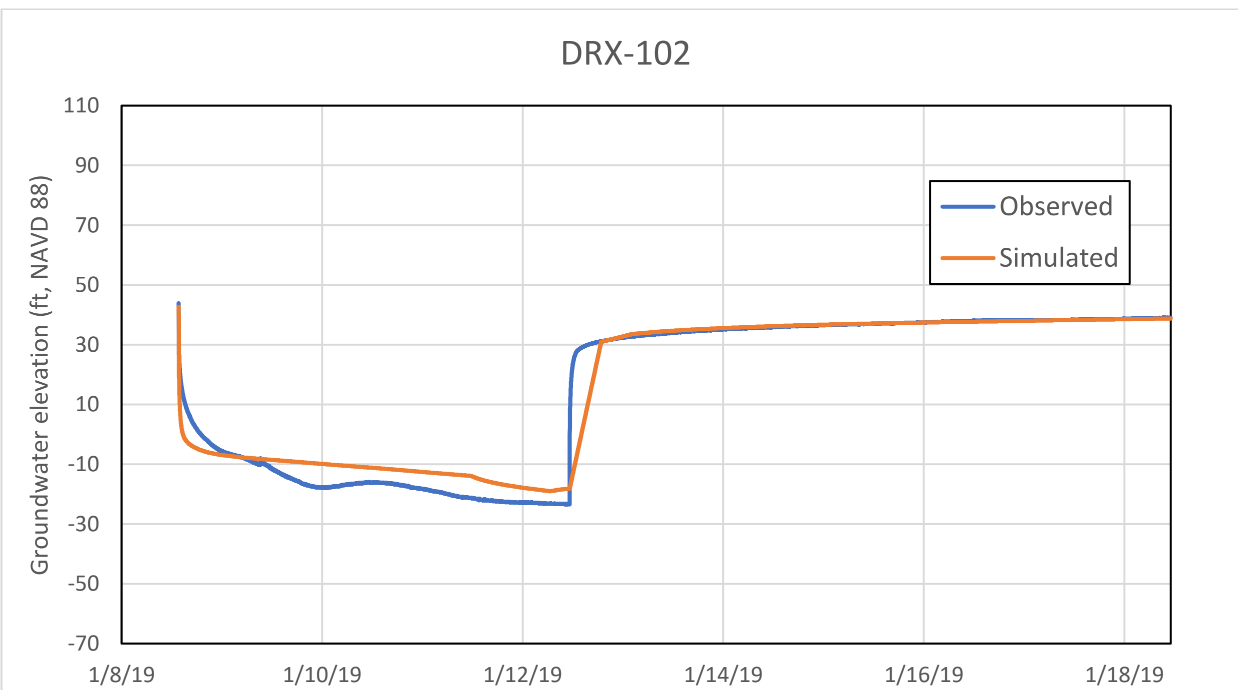

Figure A42. Observed and simulated groundwater elevation at pumping well DRX-102 during pump test 4 (1/8/2019 – 1/18/2019).

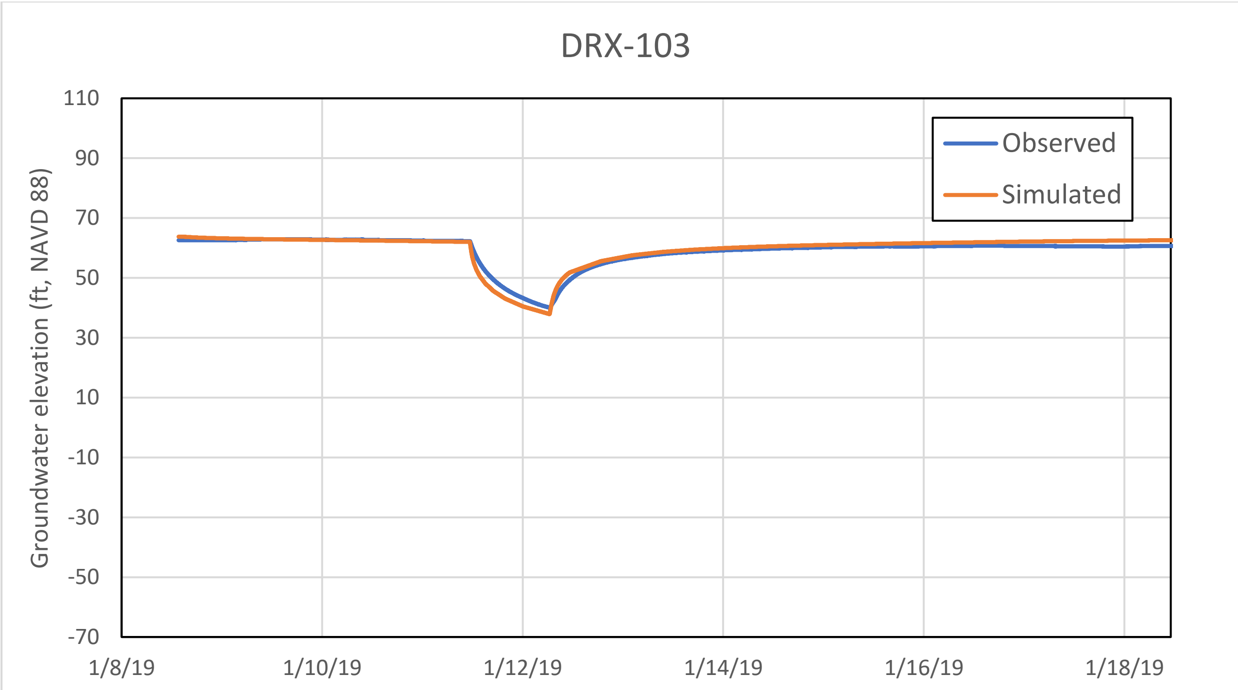

Figure A43. Observed and simulated groundwater elevation at bedrock well DRX-103 during pump test 4 (1/8/2019 – 1/18/2019).

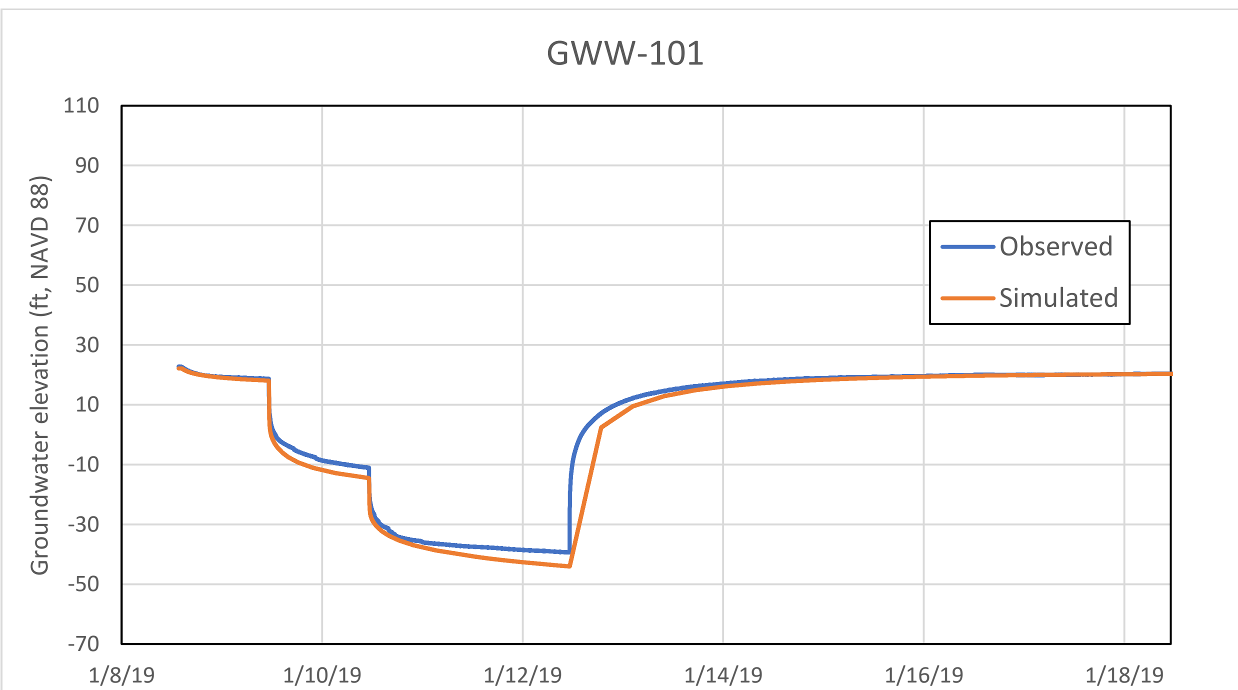

Figure A44. Observed and simulated groundwater elevation at pumping well GWW-101 during pump test 4 (1/8/2019 – 1/18/2019).

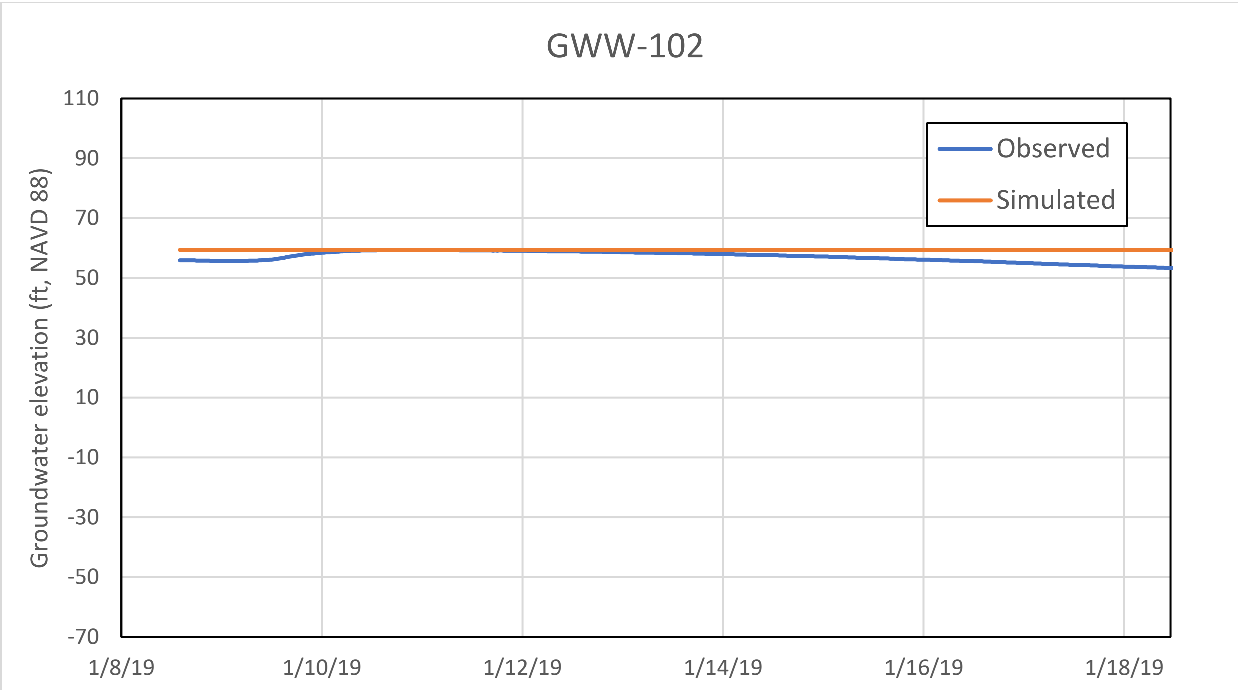

Figure A45. Observed and simulated groundwater elevation at bedrock well GWW-102 during pump test 4 (1/8/2019 – 1/18/2019).

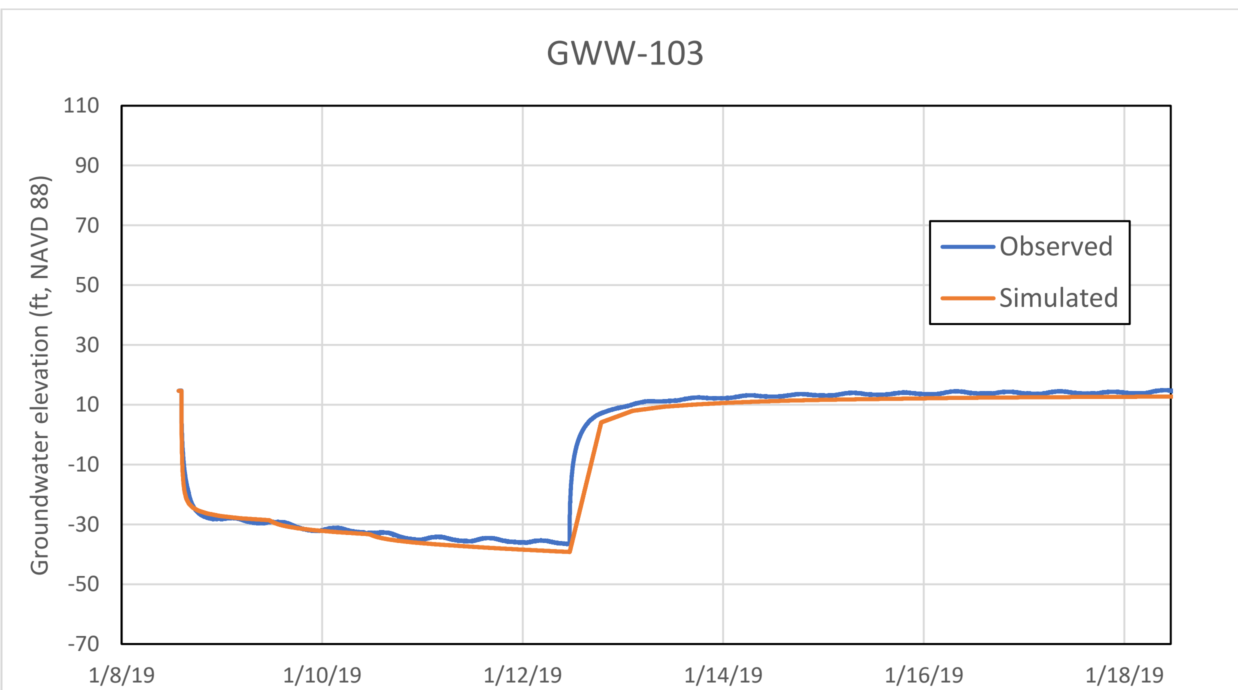

Figure A46. Observed and simulated groundwater elevation at pumping well GWW-103 during pump test 4 (1/8/2019 – 1/18/2019).

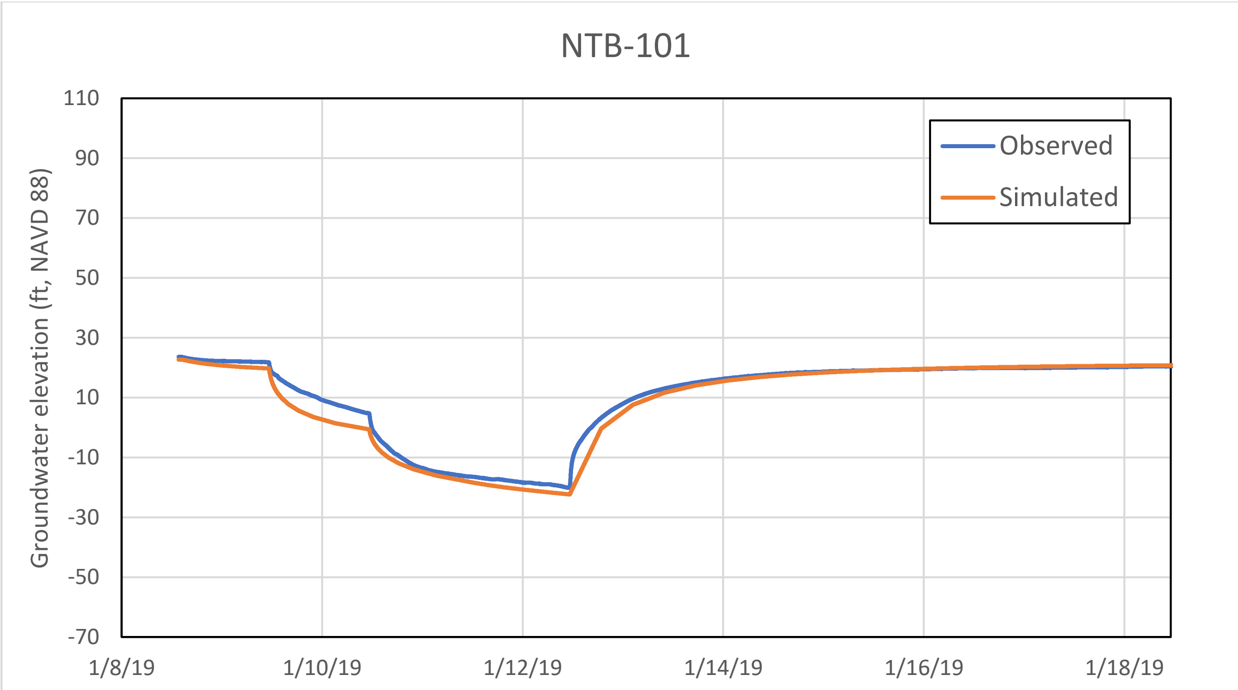

Figure A47. Observed and simulated groundwater elevation at bedrock well NTB-101 during pump test 4 (1/8/2019 – 1/18/2019).

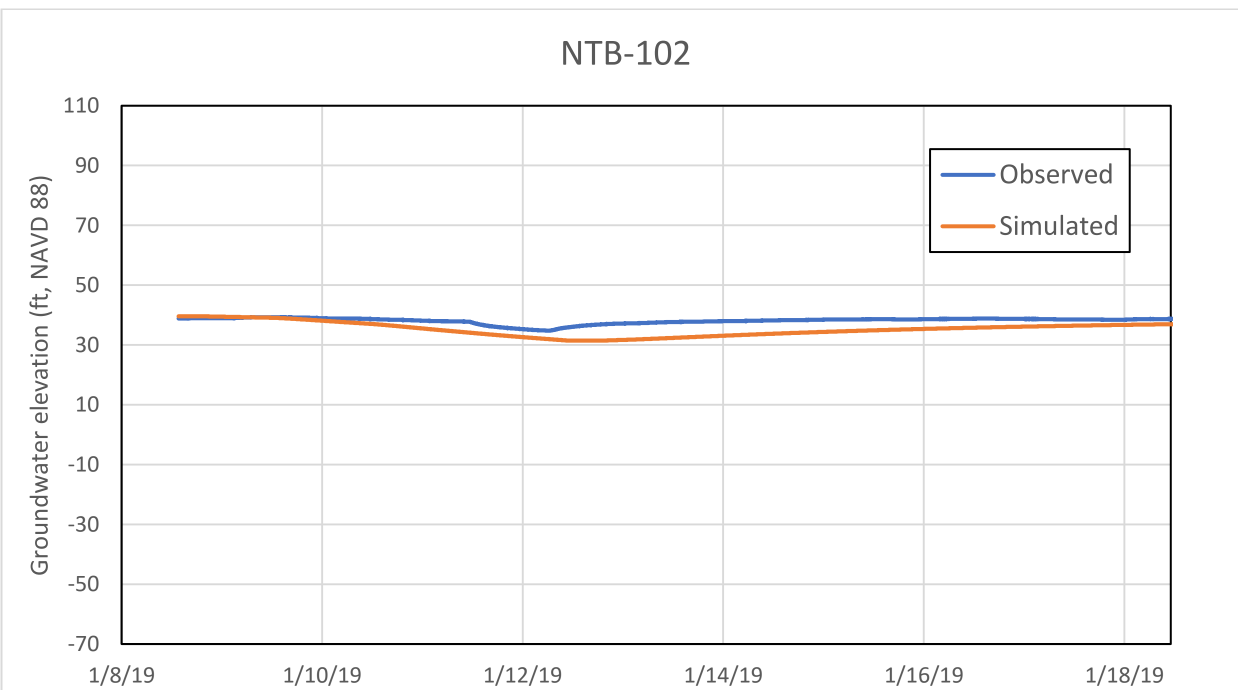

Figure A48. Observed and simulated groundwater elevation at bedrock well NTB-102 during pump test 4 (1/8/2019 – 1/18/2019).

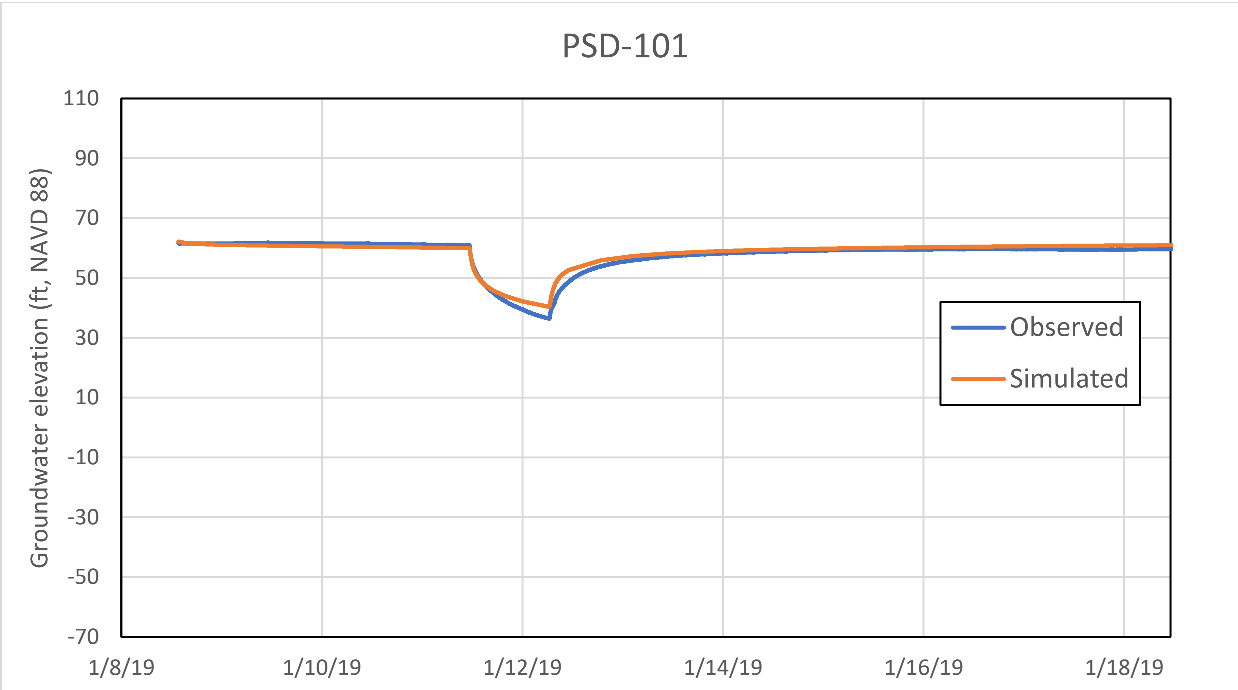

Figure A49. Observed and simulated groundwater elevation at pumping well PSD-101 during pump test 4 (1/8/2019 – 1/18/2019).

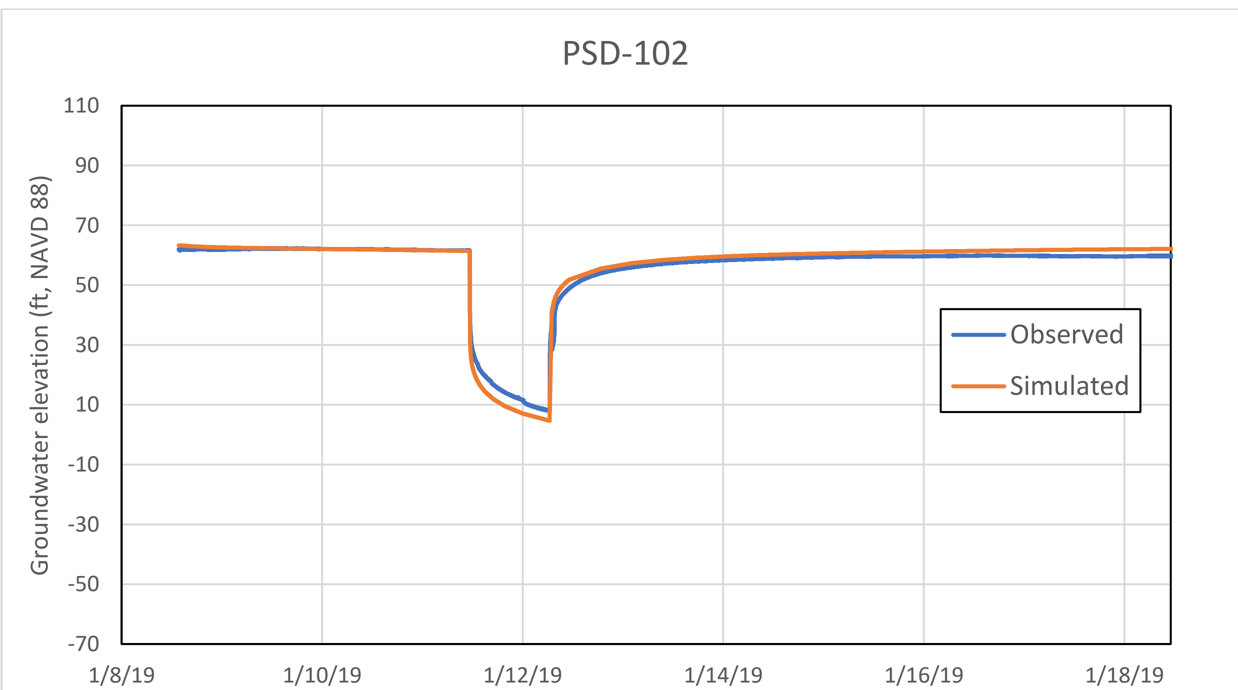

Figure A50. Observed and simulated groundwater elevation at pumping well PSD-102 during pump test 4 (1/8/2019 – 1/18/2019).

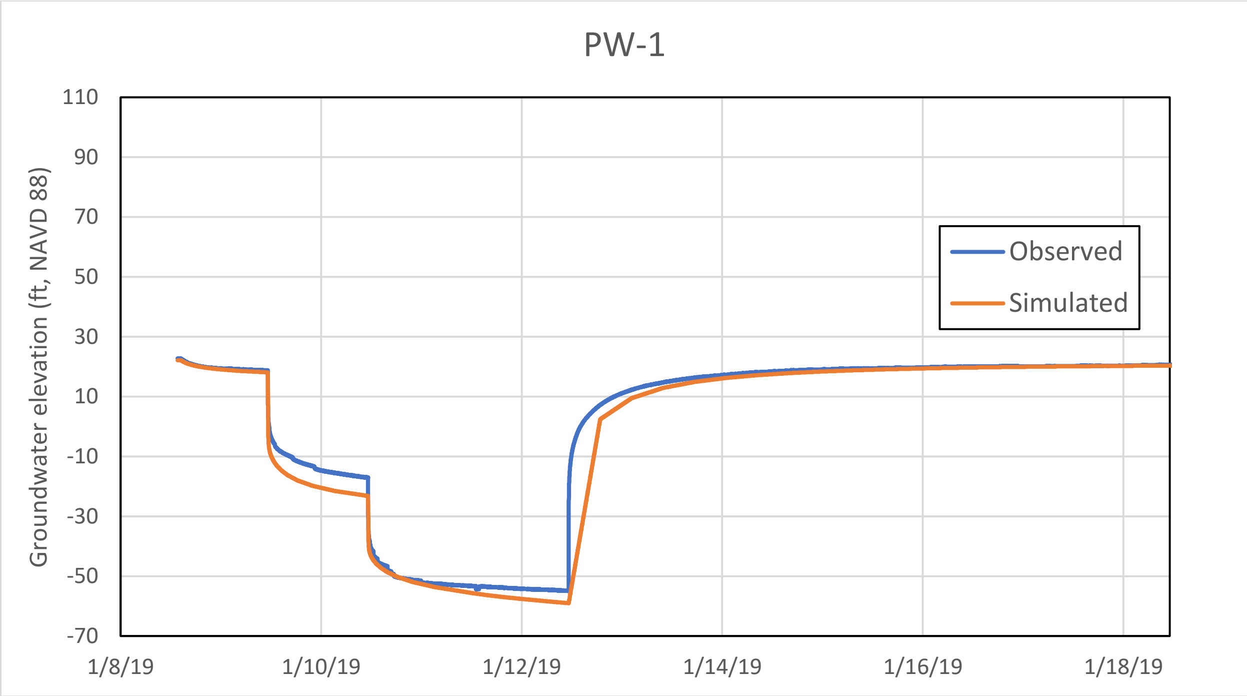

Figure A51. Observed and simulated groundwater elevation at pumping well PW-1 during pump test 4 (1/8/2019 – 1/18/2019).

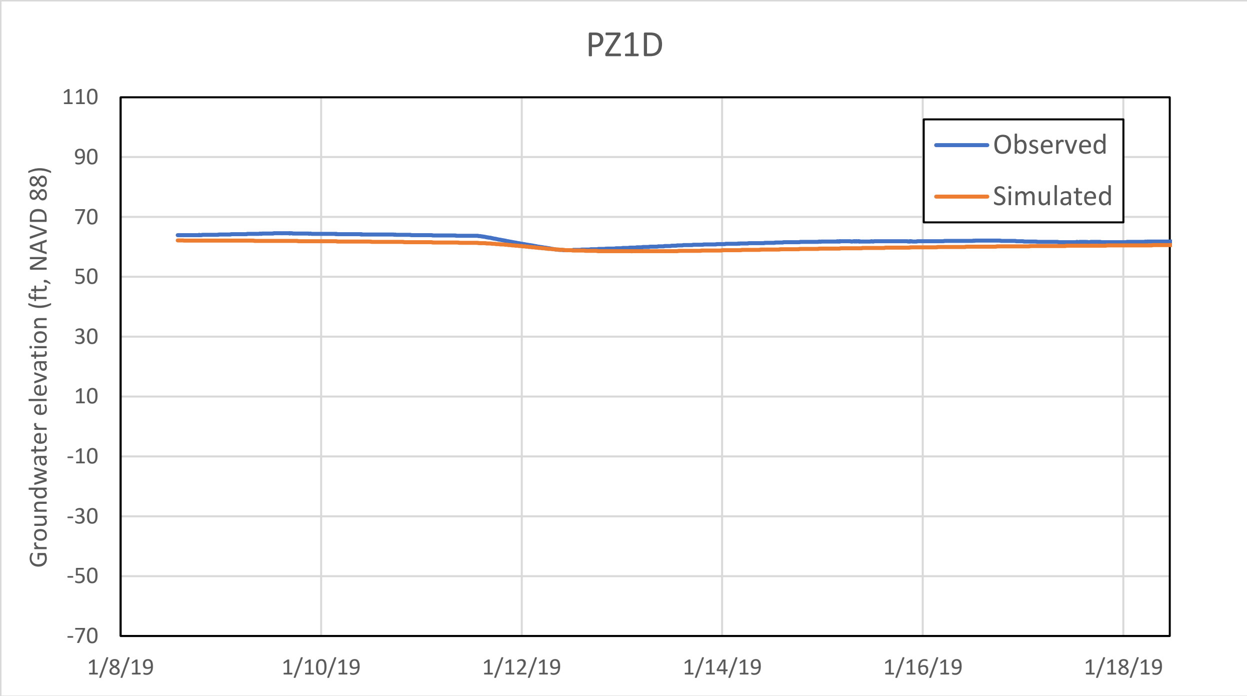

Figure A52. Observed and simulated groundwater elevation at piezometer PZ1D during pump test 4 (1/8/2019 – 1/18/2019).

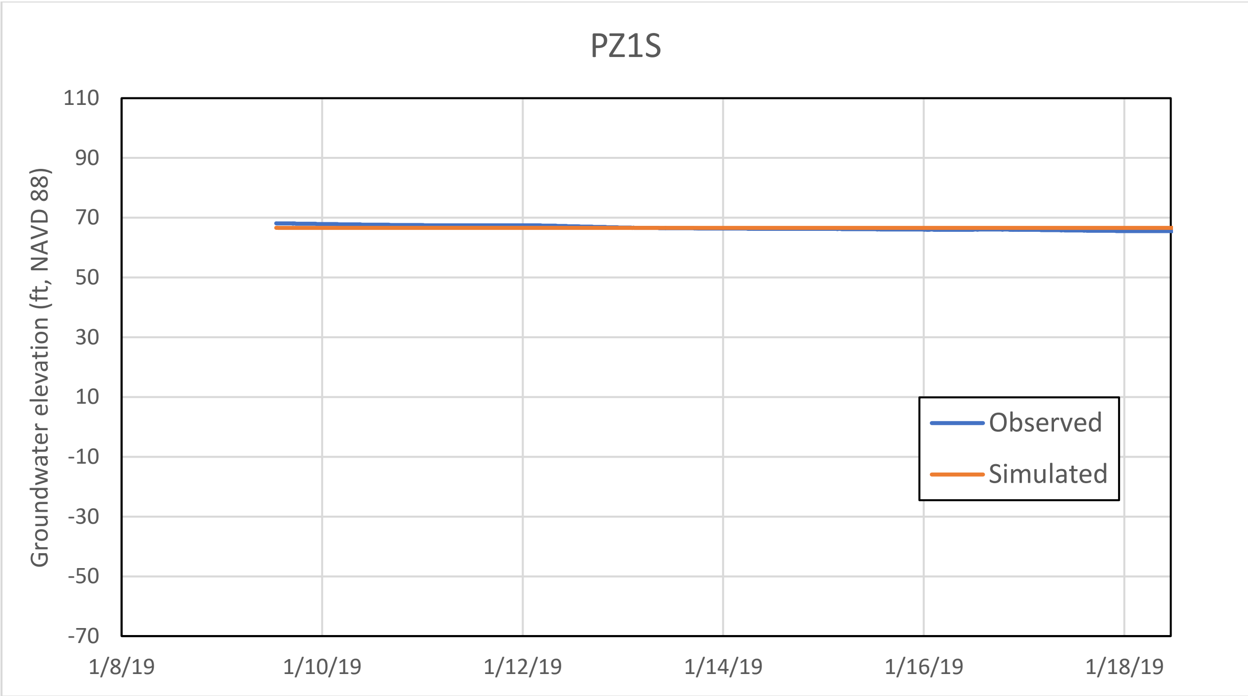

Figure A53. Observed and simulated groundwater elevation at piezometer PZ1S during pump test 4 (1/8/2019 – 1/18/2019).

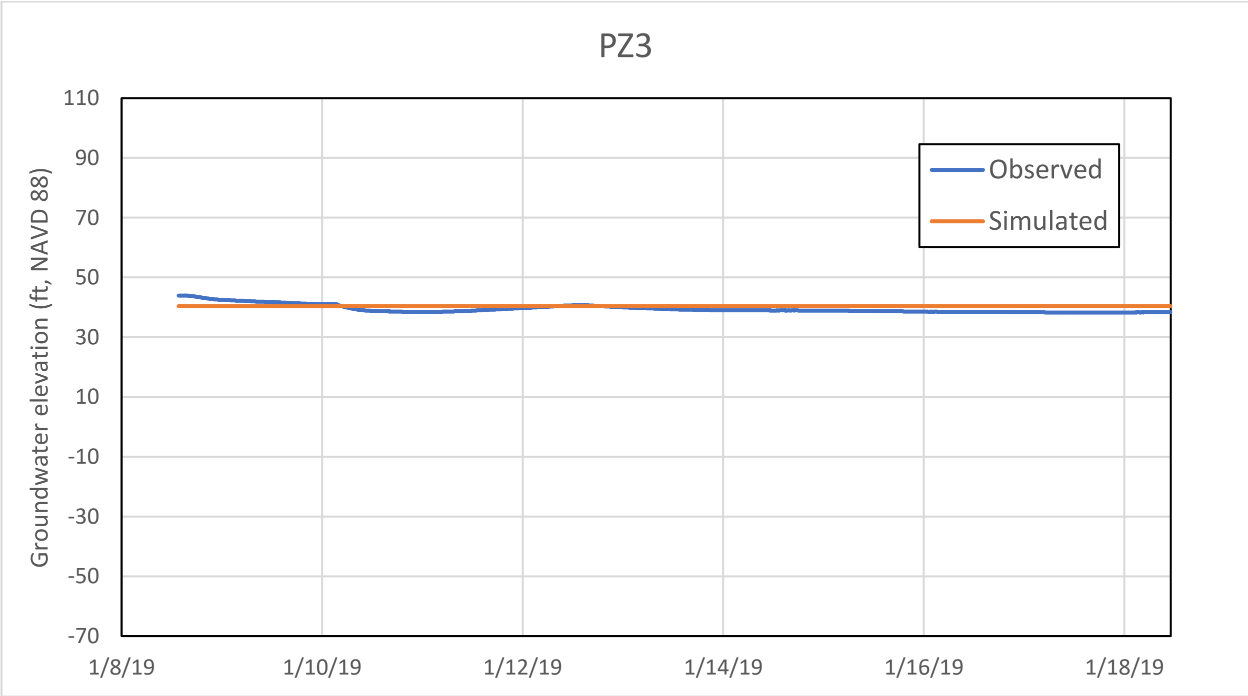

Figure A54. Observed and simulated groundwater elevation at piezometer PZ3 during pump test 4 (1/8/2019 – 1/18/2019).

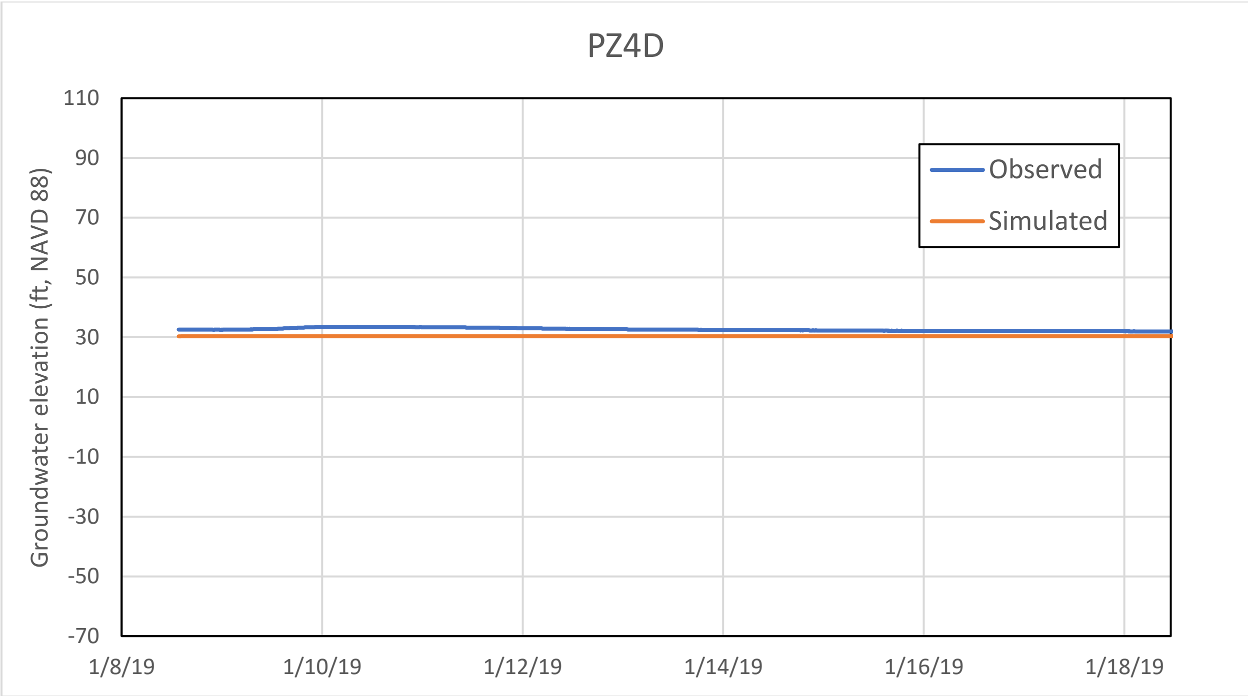

Figure A55. Observed and simulated groundwater elevation at piezometer PZ4D during pump test 4 (1/8/2019 – 1/18/2019).

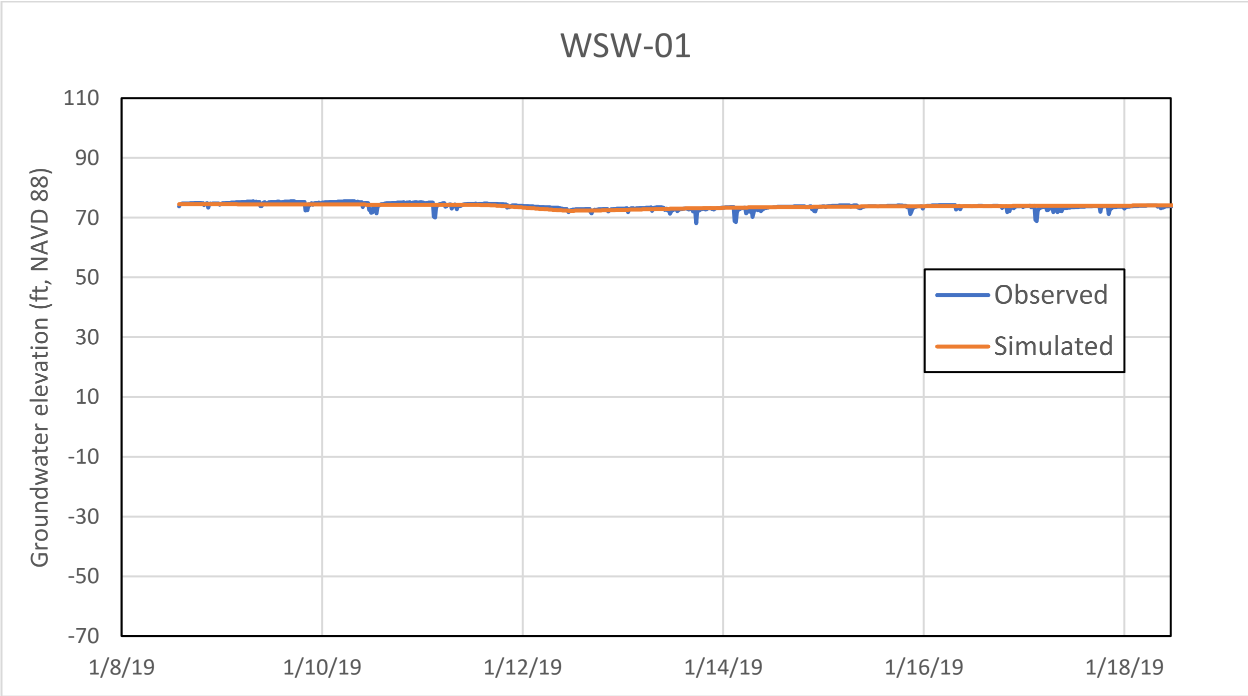

Figure A56. Observed and simulated groundwater elevation at bedrock well WSW-01 during pump test 4 (1/8/2019 – 1/18/2019).

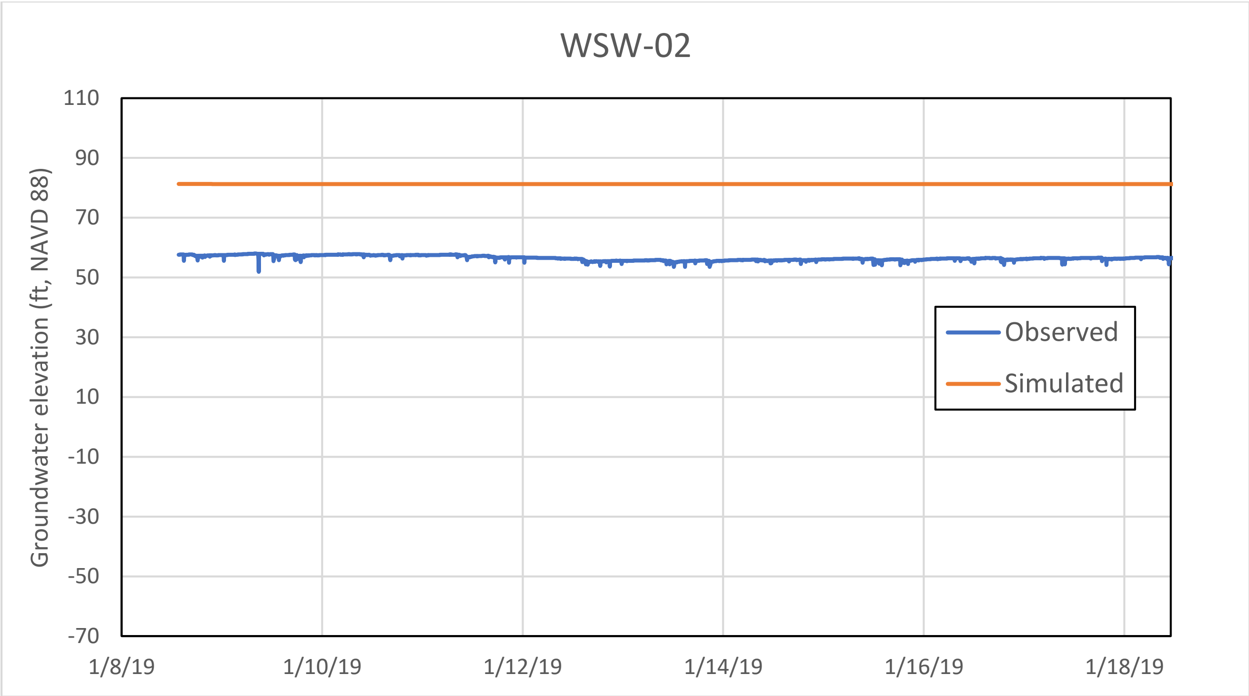

Figure A57. Observed and simulated groundwater elevation at bedrock well WSW-02 during pump test 4 (1/8/2019 – 1/18/2019).

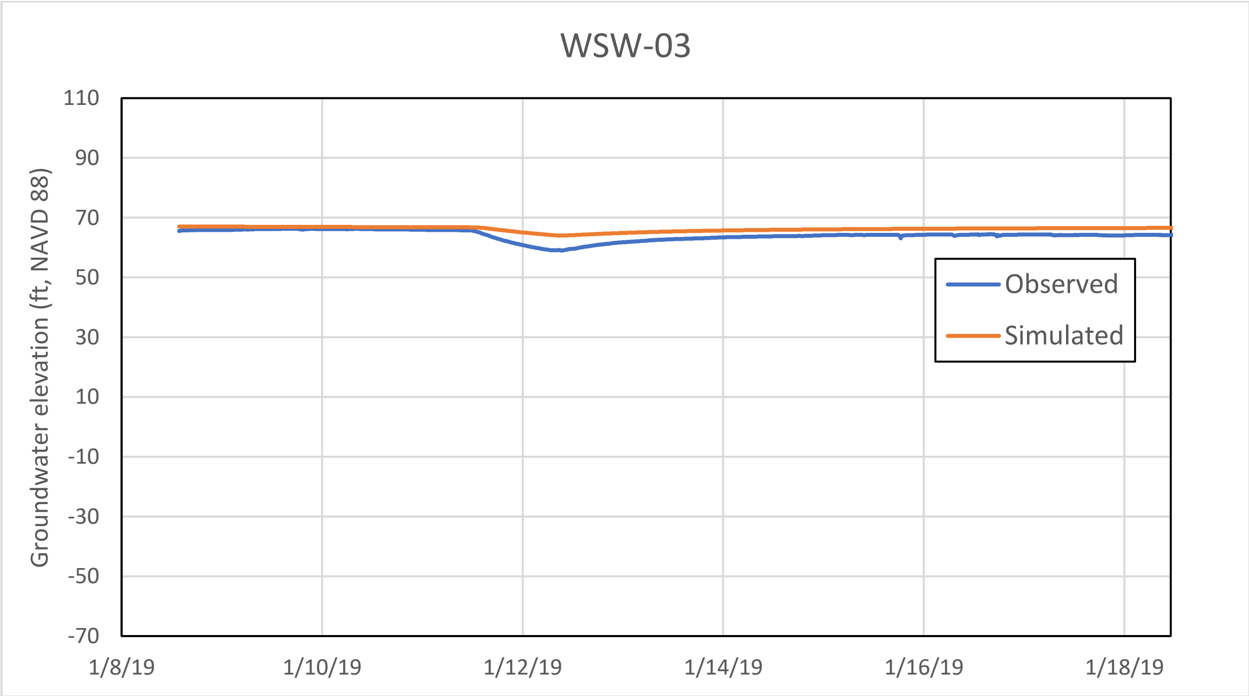

Figure A58. Observed and simulated groundwater elevation at bedrock well WSW-03 during pump test 4 (1/8/2019 – 1/18/2019).

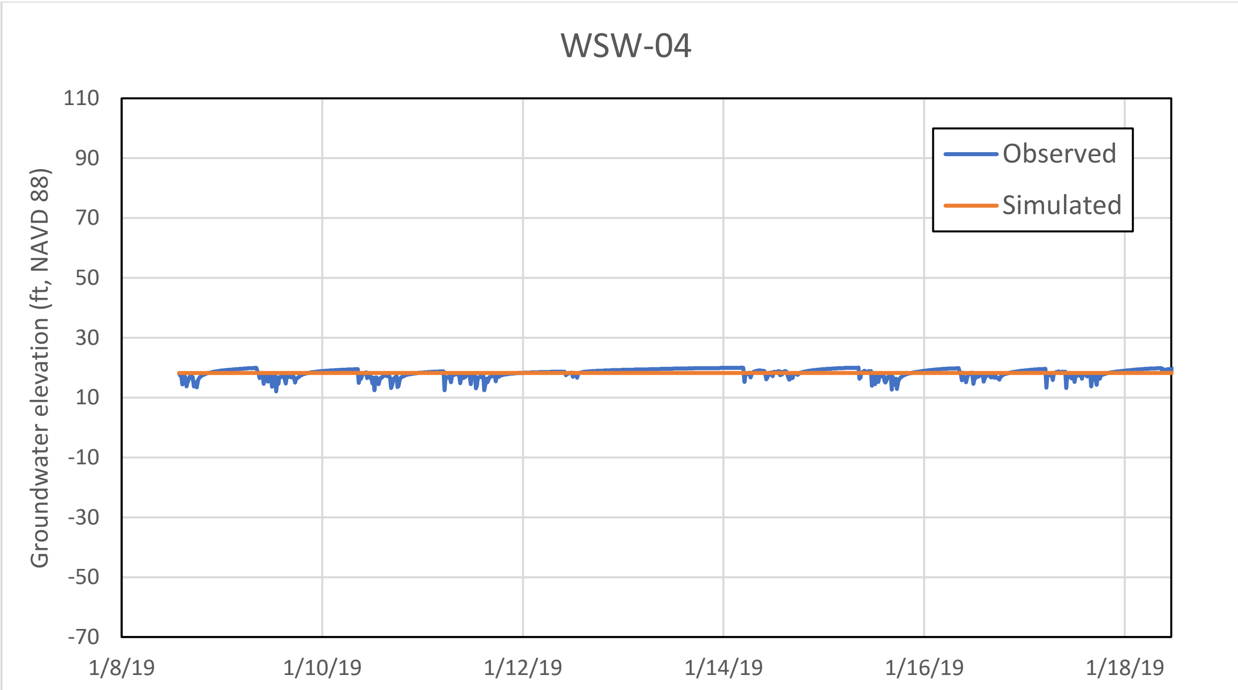

Figure A59. Observed and simulated groundwater elevation at bedrock well WSW-04 during pump test 4 (1/8/2019 – 1/18/2019).

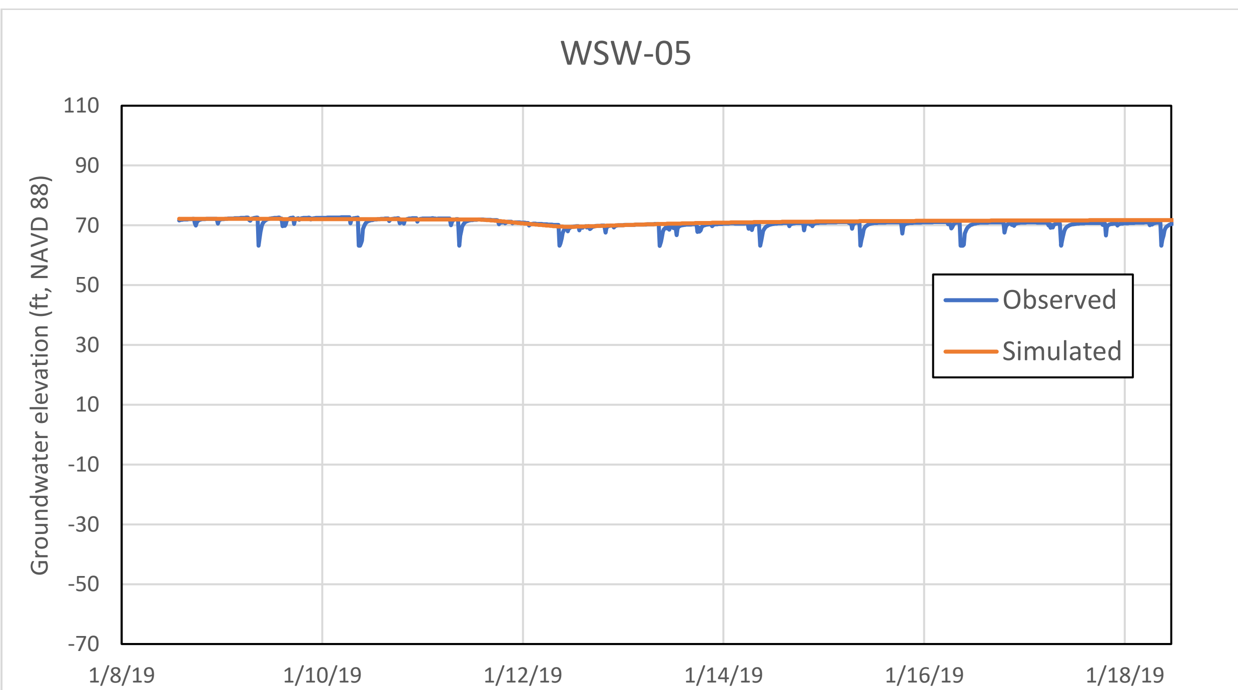

Figure A60. Observed and simulated groundwater elevation at bedrock well WSW-05 during pump test 4 (1/8/2019 – 1/18/2019).

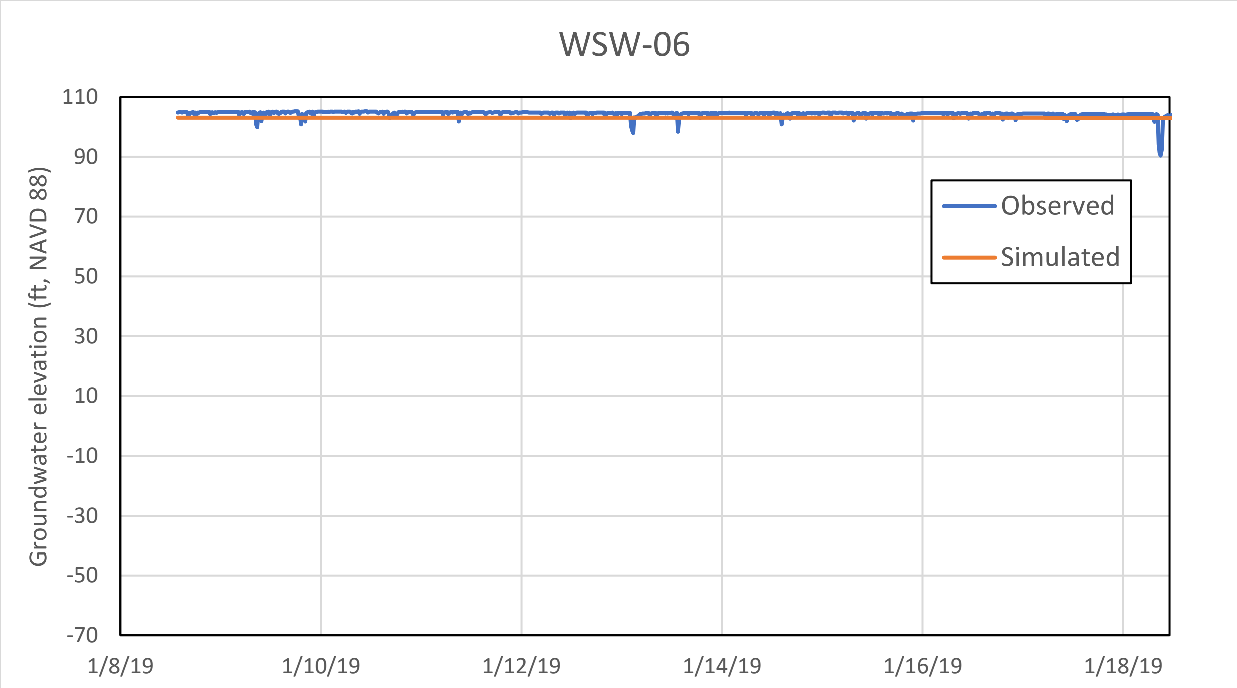

Figure A61. Observed and simulated groundwater elevation at bedrock well WSW-06 during pump test 4 (1/8/2019 – 1/18/2019).

REVIEW MEMORANDUM

September 17, 2019

To: Beth Callahan, Project Manager, Bureau of Land Resources
From: John Hopeck, Ph.D., Division of Environmental Assessment

Re: Nordic Aquafarms, Belfast

1) Monitoring Program

a) The applicant proposes in the water monitoring plan to download data on water level and conductivity quarterly, except following significant changes in the facility, "such as the start of Phase 1 and Phase 2 operations" in which case the data will be downloaded monthly. This frequency may not be sufficient to assess and allow responses to changes in water level or quantity, particularly for conductivity, and if the applicant intends to maintain relatively consistent fresh water quality. Many operators of large groundwater withdrawals in the state assess water level and water quality in near real-time. Reporting of these data to the Department should occur no less often than monthly during initial operation of the facility and after significant changes in water usage, although there should be a provision for more frequent reporting in the event that monitoring results suggest possible impacts on surface waters or offsite water supplies, or drawdowns significantly exceed those predicted by the model.

b) Data obtained during the pump tests suggest that the fine-grained overburden sediments may effectively separate some surface waters from connection with the bedrock aquifer. However, in part because the shallow wells installed during the pump test could not be developed, the quality of their connection to the surficial aquifer is not clear. The applicant proposes installation of three overburden monitoring wells (monitoring plan section 2.2.4) for measurement of water level and quality. It is not clear from the information if the intent is for these wells to be screened entirely within the fine sediment of the overburden or if they will extend to the apparently more permeable zone near the bedrock – overburden contact. It may be that this zone is important for maintenance of baseflow to larger streams in the area, and the pump test data indicate that this zone may be affected by pumping of the bedrock aquifer. Consequently, the proposed monthly data collection may not be sufficient to assess the impact of significant drawdown in the bedrock aquifer on head in this zone and possibly also on baseflow.

c) The applicant is proposing to install six piezometers "to monitor overburden groundwater levels at shallow…and deep…intervals" (Section 2.2.5). From Figure 3, these wells are not the same as the three overburden wells described in Section 2.2.4. The applicant also proposes wetland monitoring (Section 2.2.8) at wetlands W7 and W9. Figure 3 shows a nested pair of piezometers associated with wetland W9, but only the single proposed piezometer P5 in the area of wetland W7; shallow and deep piezometers should be located as close as possible to any wetland monitoring tract. Since the nested pair PZ-1S and PZ-1D would be eliminated by the proposed construction, they should be replaced by a nested pair in or adjacent to wetland W7. As noted in other cases previously, the proposed monthly measurement rate may not allow adequate assessment of changing groundwater conditions, particularly during significant changes in pumping rate or drought conditions.

d) According to Section 2.2.6, the applicant proposes measurement of river stage at three staff gauges (SG-2, SG-3, and SG-4), as well as at an additional location on the Little River (SG-Mid). The first three locations are to be monitored by pressure transducer when conditions permit, with data to be downloaded quarterly, and data to be collected monthly when transducers cannot be deployed. Data at station SG-Mid are proposed to be measured monthly with the applicant conducting a "feasibility assessment…regarding the installation of a remote monitoring system to measure stage in the Little River in real-time." Because surface water conditions are much more subject to rapid variation than groundwater conditions under most circumstances, quarterly data collection and monthly manual measurement of stage are not likely to identify long-term trends than can be masked by transient flow conditions; collection of data and comparison to relevant standards will need to be done more frequently. The Department has required surface water level and flow monitoring at several facilities conducting large-volume groundwater extraction; the applicant may wish to confer with staff at those facilities regarding experience with near real-time data collection, ice conditions, and other issues with stream monitoring.

e) The applicant proposes to monitor water usage at both the production wells (Section 2.2.1) and the surface water intake (Section 2.2.6). Both sections state that rate and volume measurements "will be recorded…on a monthly basis." Water intake data from all sources, including the water utility, should be recorded no less often than daily, both to allow better correlation with any variation seen in water levels or surface water flows, and also to provide more accurate timing of changes in withdrawal rate that may require more time to appear in slower-responding systems, particularly groundwater.

f) Changes to the monitoring program, such as proposed on page 6 of the plan, will require specific approval from the Department, based on its review of all data collected to that point and other available information. The potential change described on this page should not be included in the permit at this point, although the permit can note that, other than any changes necessary to address required replacement of monitoring locations due to damage or voluntary withdrawal of a homeowner from the program, or changes required by the Department to address specific issues, if any, that arise during operation, the approved monitoring program should continue for at least two years of groundwater extraction at full capacity.

g) The applicant proposes to use offsite data to determine precipitation amounts and other conditions in the watershed; an onsite station for collection of precipitation and other weather and climatic data should be established and in operation prior to occupancy of the facility.

h) The applicant proposes performance criteria and warning levels in Section 3.0 of the monitoring plan. However, in the absence of adequate background data or well construction information on the domestic wells in the proposed program, it is not appropriate to set specific criteria at this time. The Department also notes that, in general, depending on the amount and date of precipitation, the extent and depth of snow cover and timing of snow melt, and other factors, a month-to-month comparison of water levels for comparing wells in pre- and post-development conditions, as suggested on page 10 of the proposed monitoring plan, may not be the most suitable approach in all cases, and the Department will employ appropriate flexibility in making a determination that the monitoring data suggests that an unreasonable adverse impact has or could reasonably occur. Moreover, the warning levels proposed in Section 3.2 are generally ones at which a significant adverse impact on the affected resource or water supply well will have occurred, and the proposed response to this impact is generation of a report including the activities identified on page 12, but no specific action to mitigate the observed impact. Given the long proposed times between data collection, issues with which are described above, this could lead to an extended period of adverse impact. The monitoring plan should be revised to address issues identified above and this revised plan should propose warning levels which would identify the potential for adverse impact as well as measures to be implemented in order to prevent that impact. Such measures could include, but are not limited to, increased frequency of monitoring, reduced extraction of water from one or more sources, provision of alternate water supplies, and changes in production schedule. Correct setting of such warning levels requires sufficient pre-pumping data, and the applicant should begin collecting these data regarding seasonal variation in water level, domestic well construction, and other relevant information, and should include all such data in the revised monitoring plan, together with a justification for all proposed warning levels.

2) Blasting

a) The cover letter describing the blast plan assessment for this project is somewhat incomplete regarding the Department ground vibration standards. The standard of 1.25 in/sec applies only to certain distances and for blasts designed with a specific scaled distance value, as described in Table 1 of 38 MRS §490-Z(14)(K). The ground vibration standard of USBM RI 8507, Appendix B, Figure B-1 shows variable particle velocities depending on the frequency, and varies from 2.00 in/sec to slightly less than 0.2 in/sec at very low frequencies; the applicant has agreed in the "Blast Vibration & Air-Blast" section of the plan to comply with that standard. Note also that the language regarding air overpressure limits in this section of the proposed plan can be read to limit the developer to a total of four blasts; 38 MRS §490-Z(14)(H) reduces the air overpressure limit based on the number of blasts per day, so that the 123 dB limit applies to cases of four or more blasts per day.
b) Note that Section 7.2 of the geotechnical survey report recommends a pre-blast survey radius of 500 feet, which is not consistent with Site Location requirements or with the submitted blast plan; unless a lower pre-blast survey radius, based on a reduction of charge weight per delay as outlined in 38 MRS §490-Z(14), is requested and approved by the Department, the larger pre-blast survey radius of 2000 feet is required.

3) Geotechnical Survey

   a) No log or location is provided for any boring B303, and the listing of explorations in Section 3.0 of the geotechnical report suggests that this exploration may have been intentionally omitted or not performed. This should be clarified.
   b) The exploration logs note soft clays in several explorations, apparently associated with areas of locally lower bedrock elevation. The report correctly observes (Section 5.0, p. 8) that potential consolidation of these soils under the anticipated structural loading and other factors require "excavation and replacement of the …soils with compacted structural fill, and/or design of the buildings to bear at elevations corresponding to suitable bearing soils." (Note that any dewatering required during excavation of such unsuitable soils or placement of structural fill is likely to contain a large fraction of fines.) Section 2.2 of the geotechnical report states that the "structural loads, tolerable settlement amounts, and grading and drainage plans were not finalized when this report was prepared", although some preliminary values appear to have provided (p.3). It is not known if final values for these parameters have been provided to the geotechnical engineer. Although the proposed remedial actions would likely be similar or identical, any changes to the design, addenda to the geotechnical report, or similar information that may be based on final values for these and other design parameters must be submitted for review and approval.

4) Groundwater

   a) Section 15.4 of the application states that "the construction contractor will be required to provide a site-specific Spill Prevention, Control, and Countermeasures Plan…to be submitted to the MEDEP prior to construction." The order should specifically state that this plan should be submitted for review and approval prior to construction. This section also states that, prior to operation, "an operational SPCC plan will be developed by Nordic and submitted to the MEDEP for review"; any order should also specifically state that this plan must be reviewed and approved by the Department prior to the start operations at the facility.
   b) Part IV(C) (p. 6) of the Public Utilities Commission order approving transfer of land from the water district to the applicant refers to "environmental due diligence" and "environmental tests" to be performed on the property. Results of any such tests should be provided to the Department for review, since these could affect construction requirements, erosion control measures, and discharge of water from excavations or underdrains if any significant risks to human health or the environment were identified. Department staff have noted some cement pipe with fibrous material, possibly asbestos – cement pipe, in areas that would be excavated as part of the proposed project; if these or other tests identify or have identified this to be asbestos-containing material, the applicant would need to address measures for removal and proper disposal prior to construction.

5) Water Supply

   a) The applicant has provided information from a series of pump tests and detailed hydrogeologic modeling of the regional groundwater system. In general, this information is sufficient to demonstrate that the specified volume of water can be obtained from the bedrock aquifer, although substantial drawdown in that aquifer will result; the long-term consequences of this extraction on water level and water quality are somewhat beyond the scope of the model, although it does suggest some possibility of induced salt-water intrusion, reduced baseflow, and increase in the volume of the larger bedrock aquifer contributing to this watershed (with the consequent minor reduction in volume of that aquifer contributing to adjacent watersheds). The monitoring program, modified as discussed above, is intended to address specific issues associated with possible adverse effects of this withdrawal and to include measures to mitigate or prevent any such adverse effects. The model is generally consistent with the findings of the exploratory borings in the vicinity of the proposed project, that the overburden consists largely of the fine-grained sediments of the Presumpscot Formation, which overlay a somewhat discontinuous till unit of varying thickness. These units overly an apparently relatively thick zone of weathered bedrock above more competent bedrock. Data from monitoring conducted during the pump tests, as indicated in the discussion of the monitoring program above, suggest that water levels in this weathered zone and, to some extent, the overlying till may respond to groundwater withdrawal from the bedrock aquifer to a much greater extent than water levels in the overlying Presumpscot Formation. Consequently, there could be substantially greater potential for induced recharge or reduced baseflow to affect surface water resources located on or obtaining water from the till and/or fractured bedrock than would exist for those resources that may be in whole or part supported by the Presumpscot Formation. Assessment of the watershed by Department staff indicates that, within the area of greatest impact from the proposed groundwater withdrawal, only the reach of the Little River between the Upper Reservoir and the Lower Reservoir lies substantially within bedrock or weathered bedrock. This may impact the amount of baseflow to this reach, and could possibly result in some measurable volume of induced recharge. The water balance calculations related to withdrawals from the Lower Reservoir presented in Section 15 appear to assume non-pumping conditions in determination of the baseflow contribution to this reach, and the model cross sections do not, at least at the scale shown in Figures 6a and 6b of the technical memorandum, clearly indicate whether riverbed conductance along this reach is determined using values for the bedrock and fractured bedrock or through the till or Presumpscot Formation, which could have the effect of muting any induced recharge or reduction in baseflow due to the significant drawdown in the bedrock (See Figures 14a – c of the technical memorandum), possibly leading to an underestimate of the change in stream leakage outflow shown in Figure 15 and described in the memorandum. Any measurable effect of such changes should be determined by the operational monitoring plan, if this plan is revised to allow a greater degree of precision and the facility becomes operational; to this end, a minimum flow and suitable warning level above this flow should be established for this reach as a performance standard, as generally indicated in discussion of the proposed monitoring program. To the extent practical, however, the applicant should incorporate an estimate of this loss in a revised water budget for the Lower Reservoir as part of this application.

b) The applicant is proposing to obtain a significant component of freshwater from the Belfast Water District. Part IV(F)(1) (p. 12) of the Public Utilities Commission Order approving the land transfer notes that there are "no specific contractual curtailment provisions in the water supply agreement…during the first 6 years", under drought conditions or other circumstances, but that the utility states that it would apply "its general authority to curtail or reduce water sales…in the case of a drought or other water supply emergency." Maintenance of necessary environmental flows in the Goose River during drought conditions, however, is not the subject of this order and is not discussed in it. The 2018 capacity evaluation conducted for the utility notes (p. 8) that "a large portion of the water derived from the Goose River Aquifer is from induced infiltration" although data collected by the utility from a location downstream of the wells suggests that "at current pumping rates, the wells are not deriving much water from induced recharge" since these data also show that "under most circumstances…flow in the Goose River is greater downstream of the wells than it is at the dam." This report further notes, however, that "this might not be the case as pumping is increased from this aquifer in the future." It is not surprising to find that a system such as the Goose River and associated aquifer shows exchange of water in both directions between groundwater and surface water, under either natural or pumping conditions. However, these flow data are not provided in the capacity evaluation or the application, and the measurements techniques are not described. It is not clear that flows have been measured under pumping conditions within the immediate area of influence from the wells, and minimum required environmental flows from that area are also not known. The applicant recommends in Section 15 that the existing additional municipal well be brought online to support the increased water use, and this should have the effect of distributing the increased stress across a longer reach of the river – aquifer system in the vicinity of the pumping wells. However, existing data regarding flows and flow measurement locations in the Goose River should be provided for review, and minimum flows consistent with Department requirements should be identified and maintained in the affected reach.

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Memo

Date:	November 4, 2019
To:	Beth Callahan, Project Manager, Maine Department of Environmental Protection John Hopeck, Ph.D., Division of Environmental Assessment, Maine Department of Environmental Protection
From:	Elizabeth M. Ransom, P.G. Ransom Consulting, Inc.
Subject:	Nordic Aquafarms, Inc., Land-based Aquaculture Facility, Belfast, Maine L-28319-26-A-N, Review Comments
Project No.:	171.05027

This memo provides responses to the Technical Review Memorandum from John Hopeck to Beth Callahan dated September 17, 2019. For clarity, the entire comment from the technical memorandum has been copied below and italicized. Responses are in regular text, and on the attached plans and figures as referenced below.

1. Monitoring Program

a. The applicant proposes in the water monitoring plan to download data on water level and conductivity quarterly, except following significant changes in the facility, "such as the start of Phase 1 and Phase 2 operations" in which case the data will be downloaded monthly. This frequency may not be sufficient to assess and allow responses to changes in water level or quantity, particularly for conductivity, and if the applicant intends to maintain relatively consistent fresh water quality. Many operators of large groundwater withdrawals in the state assess water level and water quality in near real-time. Reporting of these data to the Department should occur no less often than monthly during initial operation of the facility and after significant changes in water usage, although there should be a provision for more frequent reporting in the event that monitoring results suggest possible impacts on surface waters or offsite water supplies, or drawdowns significantly exceed those predicted by the model.

It is important to consider the planned schedule of events that is anticipated to occur prior to initiation of freshwater withdrawals. This schedule includes approximately two years of site work and construction, during which monitoring would be conducted. Additionally, following construction, facility operations will be scaled in phases, the first of which will require a small fraction of the freshwater volume reflected in the submitted permit application. Thus, Nordic views the submitted Water Resource Monitoring Plan (WRMP) as being currently focused on refining the existing understanding of baseline/pre-pumping conditions, as there is ample opportunity (i.e., several years) to do so before rates of withdrawal approach those conservatively reflected in the analyses presented in the permit application, including the numerical groundwater modeling work. Furthermore, Nordic views the WRMP as being adaptable – information gathered through initial and future monitoring can and should be used to improve the quality and efficiency of the plan, when and where possible.

However, to proactively address potential future monitoring needs reflected by comments presented herein, Nordic is prepared to make significant alterations to the proposed WRMP. These modifications include:

1. Where practical for on-Site locations, Nordic will install pressure transducers or similar automated data logging equipment (i.e., including conductivity-capable transducers) and establish a networked monitoring system. Data gathered through this system will be centrally compiled in an electronic format that will be remotely accessible, provide significant flexibility and support near-immediate assessment, if necessary.

2. For off-Site monitoring locations, manual monthly data downloads and reporting will occur during initial operations and following significant changes in water usage (e.g., scaling to Phase 2). Nordic proposes that the monthly download and reporting frequency continue for a minimum of 12 months under generally static water use conditions. Should such a period elapse without significant changes in water use or deviation from anticipated conditions, a frequency reduction may be proposed (e.g., reducing from monthly to quarterly download and reporting frequency). Implementation of a reduced data download and reporting frequency would require DEP approval. Alternatively, frequency increases will be proposed should significant deviations from anticipated conditions be observed during reporting.

3. Modified techniques and frequencies associated with monitoring flow conditions within the reach of the Little River occurring between the Upper and Lower Reservoirs. Ultimately, Nordic intends to establish relationships that would allow flows (and changes relative to anticipated flows) to be inferred through near real-time monitoring of stage. These modifications are discussed in more detail below within the response to Item 1.D.

4. Provide measures for collecting daily intake rate data on a source-specific basis. This modification is discussed in more detail below within the response to Item 1.E.

b. Data obtained during the pump tests suggest that the fine-grained overburden sediments may effectively separate some surface waters from connection with the bedrock aquifer. However, in part because the shallow wells installed during the pump test could not be developed, the quality of their connection to the surficial aquifer is not clear. The applicant proposes installation of three overburden monitoring wells (monitoring plan section 2.2.4) for measurement of water level and quality. It is not clear from the information if the intent is for these wells to be screened entirely within the fine sediment of the overburden or if they will extend to the apparently more permeable zone near the bedrock - overburden contact. It may be that this zone is important for maintenance of baseflow to larger streams in the area, and the pump test data indicate that this zone may be affected by pumping of the bedrock aquifer. Consequently, the proposed monthly data collection may not be sufficient to assess the impact of significant drawdown in the bedrock aquifer on head in this zone and possibly also on baseflow.

The proposed overburden monitoring wells identified as OVB-101, OVB-102, and OVB-103 within the WRMP will be constructed as shallow and deep overburden pairings. The shallow wells within each pairing will be constructed with screens spanning the position of the water table based on observations made during boring advancements (i.e., likely within clay-and-silt glaciomarine deposits). The deeper wells within each pairing will be constructed with well screens spanning the transition zone between unconsolidated overburden deposits and the underlying weathered bedrock, as supported by observations made during boring advancement. This approach will support assessment of shallow/perched groundwater quality, as well as water quality and potential hydraulic responses within the more transmissive overburden/weathered bedrock transition zone.

Note the following relative to these proposed monitoring wells:

1. In certain locations and under certain seasonal conditions, groundwater may reside below the local vertical position of the overburden/weathered bedrock transition zone, limiting the practicality of installing wells in the manner described above.

2. It may be impractical to use common techniques to collect groundwater samples from shallow monitoring wells completed in the silt-and-clay deposits due to very low recharge rates.

As referenced within the response to Item 1.A, where possible and practical, these wells will be equipped with pressure transducers, which will be incorporated into the networked monitoring system.

c. The applicant is proposing to install six piezometers "to monitor overburden groundwater levels at shallow ... and deep ...intervals" (Section 2.2.5). From Figure 3, these wells are not the same as the three overburden wells described in Section 2.2.4. The applicant also proposes wetland monitoring (Section 2.2.8) at wetlands W7 and W9. Figure 3 shows a nested pair of piezometers associated with wetland W9, but only the single proposed piezometer P5 in the area of wetland W7; shallow and deep piezometers should be located as close as possible to any wetland monitoring tract. Since the nested pair PZ-1 S and PZ-1 D would be eliminated by the proposed construction, they should be replaced by a nested pair in or adjacent to wetland W7. As noted in other cases previously, the proposed monthly measurement rate may not allow adequate assessment of changing groundwater conditions, particularly during significant changes in pumping rate or drought conditions.

Shallow and deep piezometers will be installed in the vicinity of wetland W7 (i.e., PZ-5S and PZ-5D). As referenced within the response to Item 1.A, where possible and practical, these piezometers will be equipped with pressure transducers, which will be incorporated into the networked monitoring system.

d. According to Section 2.2.6, the applicant proposes measurement of river stage at three staff gauges (SG-2, SG-3, and SG-4), as well as at an additional location on the Little River (SG-Mid). The first three locations are to be monitored by pressure transducer when conditions permit, with data to be downloaded quarterly, and data to be collected monthly when transducers cannot be deployed. Data at station SG-Mid are proposed to be measured monthly with the applicant conducting a "feasibility assessment ... regarding the installation of a remote monitoring system to measure stage in the Little River in real-time." Because surface water conditions are much *more subject to rapid variation than groundwater conditions under most circumstances, quarterly data collection and monthly manual measurement of stage are not likely to identify long-term trends than can be masked by transient flow conditions; collection of data and comparison to relevant standards will need to be done more frequently. The Department has required surface water level and flow monitoring at several facilities conducting large-volume groundwater extraction; the applicant may wish to confer with staff at those facilities regarding experience with near real-time data collection, ice conditions, and other issues with stream monitoring.*

Relative to flow monitoring at location SG-Mid, consideration should be given to challenges presented by the steeply banked, rocky channel through which the Little River flows within the subject reach. These challenges limit the feasibility of regularly and safely producing reliable flow data from this location at a high (e.g., near real-time) temporal frequency. Additional consideration should be given to findings derived from aquifer testing conducted as part of hydrogeologic investigation activities, including observations of hydraulic responses within private supply wells located west of the river stemming from test well withdrawals (i.e., indicating limited connectivity between the local bedrock aquifer and the subject reach of the Little River). Thus, while the importance of collecting flow data is recognized, there is reasonable justification for developing a flexible plan that selectively targets lower flow conditions.

Based on this perspective, Nordic proposes to initially use the condition at a nearby USGS gaging station (USGS 01037380, Ducktrap River near Lincolnville, Maine) as an indicator for the need for higher frequency flow measurements. While conditions at this gage reside above the 10 percent duration flow condition (based on annual flow statistics), collection of flow data at SG-Mid will be conducted at a normal, monthly interval, if safe and practical. Should flows at the indicator gage fall below this threshold, the frequency of flow data collection at SG-Mid will be temporarily increased to weekly, if safe and practical, until flows at the indicator station recover.

To supplement these activities, a stilling well outfitted with a pressure transducer (or similar apparatus) will be established to measure the stage of the Little River in the vicinity of the SG-Mid section. Flow measurements gathered through initial monitoring and recorded stages will be used to develop a stage-discharge relationship. An assessment of the correlation between flows within the Little River and the Ducktrap River at the USGS gaging station will also be conducted.

Additionally, while transducers are deployed, data download frequency will be monthly for locations SG-2, SG-3, and SG-4. During pre-pumping periods where transducers cannot be reliably deployed, manual measurements of stage at monthly intervals are believed to be adequate, as such periods are likely to coincide with generally wetter, winter-season conditions.

The actions described above are intended to support refinement of the WRMP, particularly the methods used to monitor and assess flow conditions within the Little River and reservoirs, as the facility matures beyond construction and into phases associated with active withdrawals.

e. The applicant proposes to monitor water usage at both the production wells (Section 2.2.1) and the surface water intake (Section 2.2.6). Both sections state that rate and volume *measurements "will be recorded ... on a monthly basis." Water intake data from all sources, including the water utility, should be recorded no less often than daily, both to allow better correlation with any variation seen in water levels or surface water flows, and also to provide more accurate timing of changes in withdrawal rate that may require more time to appear in slower-responding systems, particularly groundwater.*

Intake rate data will be recorded on a source-specific basis at a daily frequency. Initially, these data will be reported on a monthly basis prior to operations and associated withdrawals.

f. Changes to the monitoring program, such as proposed on page 6 of the plan, will require specific approval from the Department, based on its review of all data collected to that point and other available information. The potential change described on this page should not be included in the permit at this point, although the permit can note that, other than any changes necessary to address required replacement of monitoring locations due to damage or voluntary withdrawal of a homeowner from the program, or changes required by the Department to address specific issues, if any, that arise during operation, the approved monitoring program should continue for at least two years of groundwater extraction at full capacity.

Nordic acknowledges this comment and understands that other than any changes necessary to address required replacement of monitoring locations due to damage or voluntary withdrawal of a homeowner from the program, or changes required by the Department to address specific issues, if any, that arise during operation, the approved monitoring program should continue for at least two years of groundwater extraction at full capacity.

g. The applicant proposes to use offsite data to determine precipitation amounts and other conditions in the watershed; an onsite station for collection of precipitation and other weather and climatic data should be established and in operation prior to occupancy of the facility.

The National Weather Service (NWS) COOP station located in Belfast provides weather condition information, including precipitation and air temperature data, measured daily (historical data of this type available since approximately 1948). This station is located only approximately 3.1 miles to the north of the Site. A comparison of monthly statistical descriptors for the Belfast station and other nearby stations (e.g., Belmont, Maine and Bangor, Maine) based on precipitation records for the last three complete calendar years (2016 through 2018) does not suggest significant local variability. Thus, Nordic considers the Belfast station to be a reliable source of weather condition information for the Site vicinity.

h. The applicant proposes performance criteria and warning levels in Section 3.0 of the monitoring plan. However, in the absence of adequate background data or well construction information on the domestic wells in the proposed program, it is not appropriate to set specific criteria at this time. The Department also notes that, in general, depending on the amount and date of precipitation, the extent and depth of snow cover and timing of snow melt, and other factors, a month-to-month comparison of water levels for comparing wells in pre- and post-development conditions, as suggested on page 10 of the proposed monitoring plan, may not be the most suitable approach in all cases, and the Department will employ appropriate flexibility in making a determination that the monitoring data suggests that an unreasonable adverse impact has or could reasonably occur. Moreover, the warning levels proposed in Section 3.2 are *generally ones at which a significant adverse impact on the affected resource or water supply well will have occurred, and the proposed response to this impact is generation of a report including the activities identified on page 12, but no specific action to mitigate the observed impact. Given the long proposed times between data collection, issues with which are described above, this could lead to an extended period of adverse impact. The monitoring plan should be revised to address issues identified above and this revised plan should propose warning levels which would identify the potential for adverse impact as well as measures to be implemented in order to prevent that impact. Such measures could include, but are not limited to, increased frequency of monitoring, reduced extraction of water from one or more sources, provision of alternate water supplies, and changes in production schedule. Correct setting of such warning levels requires sufficient pre-pumping data, and the applicant should begin collecting these data regarding seasonal variation in water level, domestic well construction, and other relevant information, and should include all such data in the revised monitoring plan, together with a justification for all proposed warning levels.*

Collection of baseline/pre-pumping data and information will commence following permit approval. As noted, these data and this information will be needed to refine proposed warning levels. Nordic anticipates that an addendum to the WRMP, subject to DEP review and approval, will be issued to establish specific warning levels prior to commencing operations requiring active withdrawals. The refined warning levels are anticipated to be appropriately indicative of conditions trending toward a potential adverse impact, as opposed to being confirmation of occurrence.

Refining warning levels, as described above, is anticipated to address DEP's comment pertaining to proposed responses. That is, a first phase of conditions and mitigation options assessment supplemented by the options presented in Section 3.3 (Action Plan) is generally appropriate. Nordic acknowledges that operational changes, including reduced withdrawals and/or redistribution of sourcing, would also be considered; thus, the language presented in Section 3.3 of the WRMP should be interpreted as: "Nordic acknowledges that under extreme scenarios this remedial action plan may require the installation of a water treatment system, alteration of an existing well and/or pump system, drilling of a new water supply well, new connection to the public water supply system, or operational changes should adverse impacts to water quantity or quality be documented".

2. Blasting

a. The cover letter describing the blast plan assessment for this project is somewhat incomplete regarding the Department ground vibration standards. The standard of 1.25 in/sec applies only to certain distances and for blasts designed with a specific scaled distance value, as described in Table 1 of38 MRS §490-Z(14)(K). The ground vibration standard of USBM RI 8507, Appendix B, Figure B-1 shows variable particle velocities depending on the :frequency, and varies from 2.00 in/sec to slightly less than 0.2 in/sec at very low frequencies; the applicant has agreed in the "Blast Vibration & Air-Blast" section of the plan to comply with that standard. Note also that the language regarding air overpressure limits in this section of the proposed plan can be read to limit the developer to a total of four blasts; 38 MRS §490-Z(14)(H) reduces the air overpressure limit based on the number of blasts per day, so that the 123 dB limit applies to cases of four or more blasts per day.

38 MRS §490-Z 14. I. states that the limits in Table 1 of Paragraph K and the "Bureau of Mines Report of Investigations 8507," Appendix B, Figure B-1 both must not be exceeded. We plan to

use seismic monitoring at the nearest off-site location for the project. Our plan is stating that we will use the "Bureau of Mines Report of Investigations 8507," Appendix B, Figure B-1 limits and we will not exceed the maximum peak particle velocities based on the distances listed in Table 1 of Paragraph K for blasting.

In the standard from the State on air blast from 38 MRS §490-Z 14. G: This statute limits us to 4 blasts per day and paragraph H limits us to the decibel levels that we provided. It was not our intent to limit the total number of blasts on the project to 4, while the plan may be read that way. The intent of our plan was to match the statute and limit us to 4 blasts daily at the lowering decibel levels provided.

b. Note that Section 7.2 of the geotechnical survey report recommends a pre-blast survey radius of 500 feet, which is not consistent with Site Location requirements or with the submitted blast plan; unless a lower pre-blast survey radius, based on a reduction of charge weight per delay as outlined in 38 MRS §490-2(14), is requested and approved by the Department, the larger pre-blast survey radius of 2000 feet is required.

As noted in our response to a. above, the project plans for blasting to adhere to 38 MRS *§490-2(14).*

3. Geotechnical Survey

a. No log or location is provided for any boring B303, and the listing of explorations in Section 3.0 of the geotechnical report suggests that this exploration may have been intentionally omitted or not performed. This should be clarified.

This boring was not performed.

b. The exploration logs note soft clays in several explorations, apparently associated with areas of locally lower bedrock elevation. The report correctly observes (Section 5.0, p. 8) that potential consolidation of these soils under the anticipated structural loading and other factors require "excavation and replacement of the ... soils with compacted structural fill, and/or design of the buildings to bear at elevations corresponding to suitable bearing soils." (Note that any dewatering required during excavation of such unsuitable soils or placement of structural fill is likely to contain a large fraction of fines.) Section 2.2 of the geotechnical report states that the "structural loads, tolerable settlement amounts, and grading and drainage plans were not finalized when this report was prepared", although some preliminary values appear to have provided (p.3). It is not known if final values for these parameters have been provided to the geotechnical engineer. Although the proposed remedial actions would likely be similar or identical, any changes to the design, addenda to the geotechnical report, or similar information that may be based on final values for these and other design parameters must be submitted for review and approval.

At this time, no additional design parameters have been provided to the geotechnical engineer for consideration, nor have any additional geotechnical evaluations been conducted.

4. Groundwater

a. Section 15.4 of the application states that "the construction contractor will be required to provide a site-specific Spill Prevention, Control, and Countermeasures Plan ... to be submitted to the MEDEP prior *to construction." The order should specifically state that this plan should be submitted for review and approval prior to construction. This section also states that, prior to operation, "an operational SPCC plan will be developed by Nordic and submitted to the MEDEP for review"; any order should also specifically state that this plan must be reviewed and approved by the Department prior to the start operations at the facility.*

Nordic understands and agrees that the construction contractor will be required to provide a site-specific SPCC Plan for review and approval by the DEP prior to construction, and that a site-specific SPCC plan for operations will also be submitted to the DEP for review and approval prior to operations. A draft hazardous materials SPCC plan has been included with this submittal.

b. Part IV(C) (p. 6) of the Public Utilities Commission order approving transfer off land from the water district to the applicant refers to "environmental due diligence" and "environmental tests" to be performed on the property. Results of any such tests should be provided to the Department for review, since these could affect construction requirements, erosion control measures, and discharge of water from excavations or underdrains if any significant risks to human health or the environment were identified. Department staff have noted some cement pipe with fibrous material, possibly asbestos - cement pipe, in areas that would be excavated as part of the proposed project; if these or other tests identify or have identified this to be asbestos-containing material, the applicant would need to address measures for removal and proper disposal prior to construction.

The results of groundwater testing performed at the site were included as part of the hydrogeologic study included in Section 15 of the Site Location of Development application. No such risks to human health or the environment are anticipated based on these results, as compounds detected were primarily at or below background and/or applicable standards. Three soil samples collected for polynuclear aromatic hydrocarbons (PAHs) in a former coal storage area behind the existing Belfast Water district office exceeded MEDEP standards for commercial workers. A copy of the laboratory results for these soil samples is attached as Attachment A. No impacts to soil were identified from hazardous building materials (i.e., lead-based paint, asbestos, PCBs) identified in the existing site buildings.

5. Water Supply

a. The applicant has provided information from a series of pump tests and detailed hydrogeologic modeling of the regional groundwater system. In general, this information is sufficient to demonstrate that the specified volume of water can be obtained from the bedrock aquifer, although substantial drawdown in that aquifer will result; the long-term consequences of this extraction on water level and water quality are somewhat beyond the scope of the model, although it does suggest some possibility of induced salt-water intrusion, reduced baseflow, and increase in the volume of the larger bedrock aquifer contributing to this watershed (with the consequent minor reduction in volume of that aquifer contributing to adjacent watersheds). The monitoring program, modified as discussed above, is intended to address specific issues associated with possible adverse effects of this withdrawal and to include measures to mitigate or prevent any such adverse effects. The model is generally consistent with the findings of the exploratory borings in the vicinity of the proposed project, that the overburden consists largely of the fine-grained sediments of the Presumpscot Formation, which overlay a somewhat discontinuous till unit of varying thickness. These units overly an apparently relatively thick zone of weathered bedrock above more competent bedrock. Data from monitoring conducted during the pump tests, as indicated in the discussion of the monitoring program above, suggest that water levels in this weathered zone and, to some extent, the overlying till may respond to groundwater withdrawal from the bedrock aquifer to a much greater extent than water levels in the overlying Presumpscot Formation.

Consequently, there could be substantially greater potential for induced recharge or reduced baseflow to affect surface water resources located on or obtaining water from the till and/or fractured bedrock than would exist for those resources that may be in whole or part supported by the Presumpscot Formation. Assessment of the watershed by Department staff indicates that, within the area of greatest impact from the proposed groundwater withdrawal, only the reach of the Little River between the Upper Reservoir and the Lower Reservoir lies substantially within bedrock or weathered bedrock. This may impact the amount of baseflow to this reach and could possibly result in some measurable volume of induced recharge. The water balance calculations related to withdrawals from the Lower Reservoir presented in Section 15 appear to assume non-pumping conditions in determination of the baseflow contribution to this reach, and the model cross sections do not, at least at the scale shown in Figures 6a and 6b of the technical memorandum, clearly indicate whether riverbed conductance along this reach is determined using values for the bedrock and fractured bedrock or through the till or Presumpscot Formation, which could have the effect of muting any induced recharge or reduction in baseflow due to the significant drawdown in the bedrock (See Figures 14a – c of the technical memorandum), possibly leading to an underestimate of the change in stream leakage outflow shown in Figure 15 and described in the memorandum. Any measurable effect of such changes should be determined by the operational monitoring plan, if this plan is revised to allow a greater degree of precision and the facility becomes operational; to this end, a minimum flow and suitable warning level above this flow should be established for this reach as a performance standard, as generally indicated in discussion of the proposed monitoring program. To the extent practical, however, the applicant should incorporate an estimate of this loss in a revised water budget for the Lower Reservoir as part of this application.

As noted above in the response Item 1.D, significant effort will be dedicated to refining the current understanding of flow conditions within the Little River. Initially, this work will focus on baseline/pre-pumping conditions. Like Item 1.H., the refined baseline/pre-pumping understanding is needed in order to appropriately establish a minimum flow criterion and an associated warning level. Nordic anticipates that an addendum to the WRMP detailing these items, subject to DEP review and approval, will be issued to prior to commencing operations requiring active withdrawals.

The water budget presented as part of the submitted application is consistent with current assessments of the system, including the hydrogeologic investigation findings referenced in response to Item 1.D.

b. The applicant is proposing to obtain a significant component of freshwater from the Belfast Water District. Part IV(F)(l) (p. 12) of the Public Utilities Commission Order approving the land transfer notes that there are "no specific contractual curtailment provisions in the water supply agreement … during the first 6 years", under drought conditions or other circumstances, but that the utility states that it would apply "its general authority to curtail or reduce water sales .. .in the case of a drought or other water supply emergency." Maintenance of necessary environmental flows in the Goose River during drought conditions, however, is not the subject of this order and is not discussed in it. The 2018 capacity evaluation conducted for the utility notes (p. 8) that "a large portion of the water derived from the Goose River Aquifer is from induced infiltration" although data collected by the utility from a location downstream of the wells suggests that "at current pumping rates, the wells are not deriving much water from induced recharge" since these data also show that "under most circumstances … flow in the Goose River is greater downstream of the wells than it is at the dam." This report further notes, however, that "this might not be the case as pumping is increased from this aquifer in the future." It is not surprising to find that a system such as the Goose River and associated aquifer shows exchange of water in both directions between groundwater and surface water, under either natural or pumping conditions. However, these flow data are not provided in the capacity evaluation or the application, and the *measurements techniques are not described. It is not clear that flows have been measured under pumping conditions within the immediate area of influence from the wells, and minimum required environmental flows from that area are also not known. The applicant recommends in Section 15 that the existing additional municipal well be brought online to support the increased water use, and this should have the effect of distributing the increased stress across a longer reach of the river – aquifer system in the vicinity of the pumping wells. However, existing data regarding flows and flow measurement locations in the Goose River should be provided for review, and minimum flows consistent with Department requirements should be identified and maintained in the affected reach.*

The Belfast Water District currently monitors both water quantity and water quality in the Goose River aquifer. Nordic and the BWD will obtain additional information regarding flows and flow measurement locations prior to initiation of the project and provide this information to ME DEP for review.