LETTER WORK PLAN
WATER LEVEL AND PUMPING TEST ACTIVITIES
TO SUPPORT GM-38 CAPTURE ZONE ANALYSIS
NAVAL WEAPONS INDUSTRIAL RESERVE PLANT
BETHPAGE, NEW YORK

1.0 INTRODUCTION AND BACKGROUND

This letter work plan has been prepared by Tetra Tech, Inc. (Tetra Tech) for the Naval Facilities Engineering Command Mid-Atlantic under Contract Task Order (CTO) 066 of the Comprehensive Long-Term Environmental Action Navy (CLEAN) contract number N62472-03-D-0057. This analysis is being conducted to support capture zone delineations for the GM-38 groundwater extraction system in the area of Operable Unit No. 2 (OU-2) Groundwater Record of Decision (ROD) (NAVFAC, 2003) at Naval Weapons Industrial Reserve Plant (NWIRP) Bethpage, Long Island, New York (Figures 1 and 2). Limited data collection is also being conducted in other areas that may be evaluated in the future. Regional groundwater flow is south-southeast, but is locally affected by the operation of recharge basins and public water supply wells.

Groundwater downgradient of NWIRP Bethpage and Northrop Grumman Corporation (NGC) is impacted by volatile organic compounds (VOCs), primarily trichloroethylene (TCE). The Navy started operation of an extraction system and groundwater treatment plant (GWTP) at the GM-38 Area in 2009, to remediate an off-site VOC-contaminated groundwater hot spot. In order to facilitate future planning and decisions, as a separate action, the Navy has requested the U.S. Geological Survey (USGS) to conduct groundwater flow modeling to determine the groundwater capture efficiency of the GM-38 system.

1.1 SCOPE AND OBJECTIVE

The primary objective of the activities described in this work plan is to support the USGS in their efforts to model the groundwater flow in the area. This model will be used to assist in an assessment of the horizontal and vertical capture zones achieved by the GM-38 extraction system. The data will be collected by Tetra Tech to support two separate, but related evaluations as follows:

- Area-wide potentiometric surface measurements from 14 groundwater wells (Figure 3) over an approximate 12-month period.
- Localized pumping tests using the existing GM-38 extraction wells RW01 and RW03 (Figure 4) over an approximate 3-week period to support capture zone analysis.

The data will also be used to assess:

- Variability in hydraulic heads due to seasonal influences (in precipitation and infiltration).
- Variability in hydraulic heads from hydraulic stresses resulting from operation of groundwater extraction wells.

2.0 FIELD ACTIVITIES

The following subsections will provide specific details and requirements for conducting field activities:

- Area-Wide, Long-Term Potentiometric Surface Measurements
- GM-38 Groundwater Extraction System Pumping Tests

2.1 COMMON ELEMENTS

The following information details common elements to both field activities:

- A Solinst® Levelogger Jr Edge data logger (Attachment 1) will be used to collect water level data (pressure heads) and temperature readings during field activities.
- A Solinst® Barologger Edge (Attachment 2) will be used to collect barometric pressure data throughout the course of the field activities. Barometric pressure data will be used correct/adjust observation well pressure head data for fluctuations in barometric pressure. The barometric data collection probe will be programed to collect readings at intervals consistent with the transducers.
- Because of the uncertainty with some of the existing survey coordinates (survey data collected over 18 months ago), select study wells will be resurveyed via global positioning system (GPS) by a professional land surveyor (PLS) for x, y, and z coordinates (including top of well casing and ground surface).
- Weather data (i.e., temperature, precipitation, and barometric pressure) will be tracked during the field activities. Weather data will be tracked during the collection of the area-wide, long-term potentiometric surface measurements will be from an existing fixed based weather station (e.g., local airport weather station); and during the pumping tests via a temporary portable weather station set up at the GM-38 GWTP.
- Daily pumping rates will be requested from Bethpage Water District (BWD) Plants 4, 5, and 6; South Farmingdale Water District (SFWD) Plants 1 and 3; Levittown Water District; and New York American Water (NYAW) (Formerly Aqua New York [ANY]).

2.1 AREA-WIDE, LONG-TERM POTENTIOMETRIC SURFACE MEASUREMENTS

Potentiometric surface measurements will be collected from 14 groundwater wells (Figure 3) over a 12 month period. Additional monitoring wells may be added to the study during the project. Well construction details are provided in Table 1. Details specific to the collection of long-term potentiometric surface measurements are as follows:

- During the initial set up, the transducers will be programed to collect a pressure reading every minute for the first two weeks. During the initial week of operation, data will be downloaded from the data loggers twice, approximately one day apart. This check is to ensure the equipment is recording/downloading data properly.
- After approximately 2 weeks of operation, the data will be downloaded and transducers reprogramed to collect data at 5 minute intervals for the remaining duration of the activity. Downloading events will then occur at approximately 8 week intervals. During the study, data recording intervals and frequency of downloading events may be modified as needed.
- Eight of fourteen wells used during the collection of area-wide, long-term potentiometric surface measurements will also be used during the GM-38 pumping test. During the GM-38 pumping test, transducers installed in these eight wells will be reprogramed to collect data at intervals as outlined in Section 2.2.

2.2 GM-38 GROUNDWATER EXTRACTION SYSTEM PUMPING TEST

The GM-38 extraction system pumping test will include pre-test water level monitoring, the pumping/recovery test, and some limited post-recovery data collection. The following provides a general overview of the testing process (additional details provide in subsequent subsections):

- Pumping test wells will be groundwater extraction wells GM-38 RW-1 and RW-3. Groundwater extraction well GM-38 RW-2 is currently not being used in the GM-38 treatment system (no pump installed). Well construction details for these extraction wells and nearby water supply wells are provided in Table 2, locations are presented in Figure 4.
- The pumping tests will be conducted over an approximate 7 day period, with additional pre- and post-test water level measurements.
- Groundwater generated from the extraction wells (GM-38 RW-1 and RW-2) will be treated through the GM-38 treatment system. The treated groundwater will be discharged in to the discharge basin west of extraction well GM-38 RW-3.
- Potentiometric surface measurements will be recorded during pumping tests from 19 groundwater wells (Figure 4). Well construction details are summarized in Table 3.

2.2.1 Pre-Pumping Tests Trend Activities

Fourteen days prior to the start of the pumping tests, transducers will be installed in 11 wells that do not have transducers. Transducers installed in the 19 wells to be monitored during the pumping tests (Table 3) will be programed to collect a reading every minute. At approximately 14 days prior to the pumping test, a portable weather station, with data logging capabilities for precipitation data will be set up at the GM-38 GWTP and begin collecting weather data.

2.2.2 Pumping Tests

The pumping tests will be started approximately 14 days after the transducers have been programed. Because the storativity of the portion of the aquifer to be tested is anticipated to be low, constant-rate test duration of approximately 24 hours may be adequate to obtain sufficient data to evaluate each pumping test, however up to 72 hours may be required for each test.

For the pumping tests, extraction wells RW-1 and RW-3 will be pumped at their typical pumping rates of 800 gpm and 300 gpm, respectively. The GM-38 pumping tests will proceed as follows:

- Baseline: GM-38 RW-1 and RW-3, and BWD wells 4-1 and 4-2 will be off for 24 hours prior to the start of the tests.
- Test 1: GM-38 RW-1 will operate for approximately 24 hours, and then be off for 24 hours.
- Test 2: GM-38 RW-3 will operate for approximately 24 hours, and then be off for 24 hours.
- Test 3: GM-38 RW-1 and 3 will then operate for approximately 24 hours operation, and then be off for 48 hours.
- Restart BWD 4-1 and 4-2 and operate for approximately 48 hours.
- Then remove 11 transducers and reprogram remaining transducers to record at 5-minute intervals.

During the constant-rate test, manual water level readings will be periodically collected from the pumping wells and nearby observation wells.

Observation wells were selected for monitoring at varying distances and orientations from the GM-38 extraction system. Table 3 identifies the selected observation wells, locations of these wells are shown on Figure 4. Water level data will be used to quantify transmissivity, storativity, and identify preferential drawdown patterns (if any). The data will also provide vertical profiles of pumping-related effects with depth, so the degree of hydraulic interconnection within shallow, intermediate, and deeper portions of the Upper Glacial and Magothy aquifers can be evaluated.

Distances from the pumping well to each of the observation wells and recorded in the field logbook. Distances to remote observation wells will be calculated using the newly surveyed well coordinates. Water level data will be collected using pressure transducers. The pressure transducers will be set in the wells at depths below the maximum anticipated pumping drawdown levels (approximately 20 feet below initial static water level measurement). In addition to monitoring the water levels automatically with pressure transducers, manual water level readings will be periodically obtained from wells that can be accessed with an electronic water level meter; these readings will be recorded and used as a check against the transducer water level data.

Immediately prior to beginning the constant-rate pumping test, a complete round of hand-measured water levels will be obtained from the observation wells. The pumping rate(s) and total gallons will be recorded at the following time intervals: at least every 15 minutes during the first hour of the test, at 30 minute intervals for the next 3 hours, hourly for the next 4 hours, then at least every 8 hours until test completion. The total flow rates will be also recorded during each check as an additional verification of the overall pumping rate(s) maintained throughout the test.

Selected drawdown data from the pumping and observation wells will be field-plotted during the test on semi-log and log-log paper, to allow for real-time evaluation of the data. The field data plots will be used to evaluate drawdown trends, look for boundary conditions, project drawdowns for latter stages of the test, and to determine whether steady-state drawdown conditions have been reached. Field personnel will be in frequent communication with senior technical personnel to provide updates of the test progress. The test will be run until sufficient data is collected to allow standard evaluation techniques to be applied to the data (i.e., until well-defined drawdown trends are established), or until conditions encountered otherwise deem it appropriate to terminate the test (i.e. a major weather event that renders additional data collection of questionable value/usefulness).

At the conclusion of the constant rate pumping test, water level recovery measurements will be collected from the pumping and observation wells for 48 hours to evaluate the rate of water level recovery back to static conditions and supplement the drawdown data, then the two nearby water supply wells (4-1 and N6916) will be restarted and pumped for another 48 hours to determine the effects of these wells on the portions of the aquifer that RW-1 and RW-3 withdraw water from.

3.0 REPORTING

3.1 AREA-WIDE, LONG-TERM POTENTIOMETRIC SURFACE MEASUREMENTS

After each download of data, it will be provided to USGS for evaluation.

3.2 PUMPING TEST

The drawdown and pumping rate data obtained from the wells monitored during the pumping test will be evaluated to determine aquifer transmissivity and storativity, evaluate hydraulic connections between shallow and deeper groundwater flow zones, and identify boundary conditions by USGS. If needed, the data will be adjusted for background trends and any identified anthropogenic influences (i.e., influences of other pumping wells in the general area) prior to analysis. The corrected data will be plotted in both semi-log and log-log formats, and analyzed using appropriate data analysis methods, which may include software designed for aquifer test analysis. Both time-drawdown and distance-drawdown methods will be considered for use. The final selection of the data analysis methods will be made based on a review of the data plots and the hydrogeological conditions of the site. Based on the pumping test results and on existing potentiometric surface data, capture zone estimates will be developed for the GM-38 extraction system using standard capture zone delineation calculations.

The data collected and aquifer characteristics determined from the pumping test will also be used by the USGS for subsequent numerical modeling of groundwater flow and in the evaluation of the GM-38 extraction system capture zone under a separate work assignment with the Navy.

A technical memorandum will be generated providing a summary of the field activities and the results of the testing activities. Trend data, pumping test drawdown and recovery data, pumping rate data, drawdown data plots, and calculations will be provided in the memorandum.

REFERENCE

NAVFAC, 2003. *Record of Decision Naval Weapons Industrial Reserve Plant Bethpage, New York, Operable Unit 2 – Groundwater, NYS Registry: I-30-003B*. April.

TABLES

TABLE 1
MONITORING WELLS
AREA-WIDE, LONG-TERM POTENTIOMETRIC SURFACE INVESTIGATION
NAVAL WEAPONS INDUSTRIAL RESERVE PLANT
BETHPAGE, NEW YORK

Well	Well Alias	Well Owner	Date Installed	TOC (ft MSL)	Screened Interval (ft bgs)	Well Diameter (inches)	Type
Well Depth 50 to 300 feet							
BPGMMW36D	GM-36D	NGC	pre-1999	91.63	204-214	4	MW
N-7164	N-7164	USGS	1961	TBD	28-83	4	MW
N-9929	N-9929	USGS	9/30/1981	85.87	33-37	4	MW
Well Depth 300 to 600 feet							
BPOW14	BPOW 1-4	NAVFAC	5/25/2011	44.54	340-400	4	OW
BPGMMW75D2	GM-75D2	NAVFAC	4/12/2001	93.63	505-525	4	MW
BPGMMW37D2	GM-37D2	NGC	pre-1999	97.17	370-390	4	MW
BPGMMW71D2	GM-71D2	NGC	pre-1999	98.45	444-464	4	MW
BPGMMW34D2	GM-34D2	NGC	pre-1999	71.19	510-520	4	MW
BPOW23	BPOW 2-3	NAVFAC	7/19/2011	44.39	564-594	4	OW
MW-116-5	MW-116-5	NGC	4/4/2008	93.58	570-590	4	MW
Well Depth Greater Than 600 feet							
MW-117-5	MW-117-5	NGC	1/22/2009	94.8	737-757	4	MW
MW-118-5	MW-118-5	NGC	5/11/2009	85.53	713-738	4	MW
BPOW41	BPOW 4-1	NAVFAC	12/9/2003	67.34	652-692	4/2[1]	OW
BPOW16	BPOW 1-6	NAVFAC	4/14/2011	44.92	700-750	4	OW

TOC - top of casing
ft - feet
bgs - below ground surface
MSL - mean sea level
TBD - to be determined

NGC - Northrop Grumman Corporation
USGS - United States Geological Survey
NAVFAC - Naval Facilities Engineering Command
MW - monitoring well (general purpose)
OW - outpost well (monitoring well for public water supplies)

footnotes
1 - well constructed with 4-inch diameter riser casing with a 2-inch diameter well screen

shaded cell indicates well to be used during Area-Wide, Long-Term Potentiometric surface and GM-38 Pumping Tests

TABLE 2
GROUNDWATER EXTRACTION WELLS
(PUBLIC WATER SUPPLIES AND GM-38 GROUNDWATER REMEDIATION SYSTEM)
GM-38 EXTRACTION SYSTEM PUMPING TEST
NAVAL WEAPONS INDUSTRIAL RESERVE PLANT
BETHPAGE, NEW YORK

Well	Well Alias	Well Owner	Date Installed	Screened Interval (ft bgs)	Well Diameter (inches)	Type
N6915	BWD 4-1	BWD	1961	561-611	-	PWS
N6916	BWD 4-2	BWD	1961	561-611	-	PWS
BWD-8004	BWD 5-1	BWD	-	679-740	20	PWS
BWD-3876	BWD 6-1	BWD	-	328-331	16	PWS
BWD-8941	BWD 6-2	BWD	-	710-770	20	PWS
GM38-RW01	GM38-RW01	NAVFAC	4/7/2005	335-395/410-435[1]	10	GRS
GM38-RW02	GM38-RW02	NAVFAC	1/13/2005	440-510	12	GRS
GM38-RW03	GM38-RW03	NAVFAC	11/26/2006	392-412/442-504[1]	12	GRS

Notes:
ft - feet
bgs - below ground surface
BWD - Bethpage Water District
NAVFAC - Naval Facilities Engineering Command
PWS - public water supply
GRS - groundwater remediation system

Footnote
1 - split screen constructed well

TABLE 3
OBSERVATION WELLS
GM-38 EXTRACTION SYSTEM PUMPING TEST
NAVAL WEAPONS INDUSTRIAL RESERVE PLANT
BETHPAGE, NEW YORK

Well	Well Alias	Well Owner	Date Installed	TOC (ft MSL)	Screened Interval (feet bgs)	Well Diameter (inches)	Type
Well Depth 50 to 300 feet							
BPGMMW36D	GM-36D	NGC	pre-1999	91.63	204-214	4	MW
N-10814	N-10814	USGS	3/10/1987	4/3/1900	68-72	2	MW
BPGMMW10821	N-10821	USGS	3/21/1987	91.58	52-56	2	MW
N-8522	N-8522	USGS	3/11/1969	TBD	105-125	10	MW
Well Depth 300 to 600 feet							
GM38D	GM-38D	NGC	pre-1999	91.75	320-340	4	MW
GM38D2	GM-38D2	NGC	pre-1999	91.56	475-495	4	MW
GM38 RW-02	GM38 RW-02	NAVFAC	1/13/2005	TBD	440-510	12	RW
BPGMMW36D2	GM-36D2	NGC	pre-1999	91.6	520-540	4	MW
GM38-RW1-MW1	RW1-MW1	NAVFAC	1/5/2005	85.87	395-435	4	MW
GM38-RW2-MW2	RW2-MW2	NAVFAC	11/23/2004	90.75	470-510	4	MW
BPGMMW71D2	GM-71D2	NGC	pre-1999	98.45	444-464	4	MW
BPGMMW37D2	GM-37D2	NGC	pre-1999	97.17	370-390	4	MW
BPGMMW70D2	GM-70D2	NGC	pre-1999	99.58	310-330	4	MW
BPOW14	BPOW 1-4	NAVFAC	5/25/2011	44.54	340-400	4	OW
MW-116-5	MW-116-5	NGC	4/4/2008	93.58	570-590	4	MW
Well Depth Greater Than 600 feet							
MW-117-5	MW-117-5	NGC	1/22/2009	94.8	737-757	4	MW
MW-118-5	MW-118-5	NGC	5/11/2009	85.53	713-738	4	MW
BPOW15	BPOW 1-5	NAVFAC	5/6/2011	44.61	600-650	4	OW
BPOW16	BPOW 1-6	NAVFAC	4/14/2011	44.92	700-750	4	OW

ft - feet
TOC - top of casing
bgs - below ground surface
TBD - to be determined
MSL - mean sea level
OW - outpost well (monitoring well for public water supplies)

MW - monitoring well (general purpose)
RW - recovery well
NGC - Northrop Grumman Corporation
USGS - United States Geologic Survey
NAVFAC - Naval Facilities Engineering Command

shaded cell indicates well to be used during Area-Wide, Long-Term Potentiometric surface and GM-38 Pumping Tests

FIGURES

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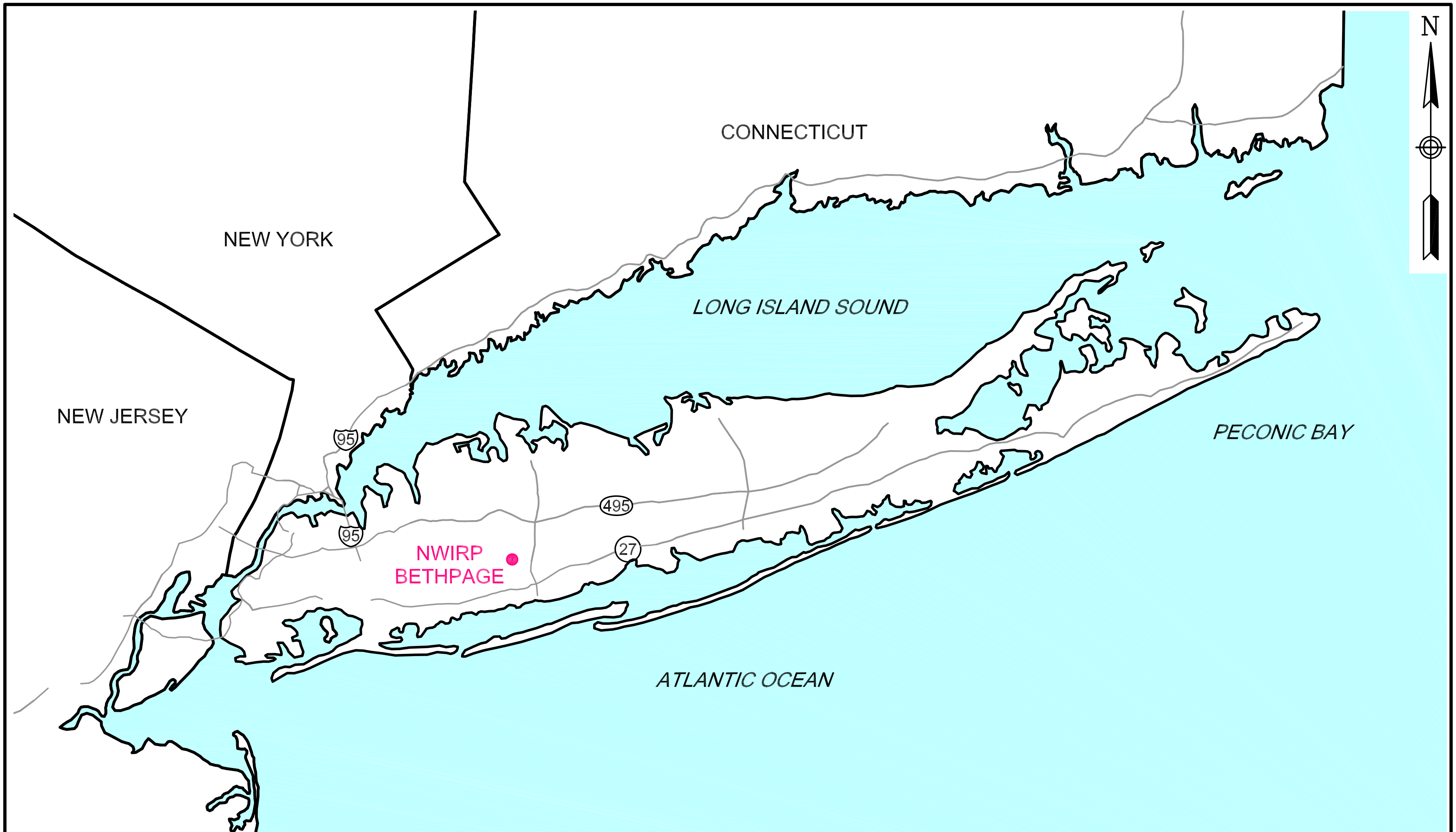

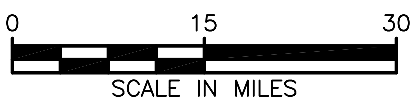

TETRA TECH, INC.

GENERAL LOCATION MAP
NWIRP BETHPAGE
BETHPAGE, NEW YORK

SCALE	
NOT TO SCALE	
FILE	
112G00622CM01	
REV	DATE
0	08/02/10
FIGURE NUMBER	
FIGURE 1	

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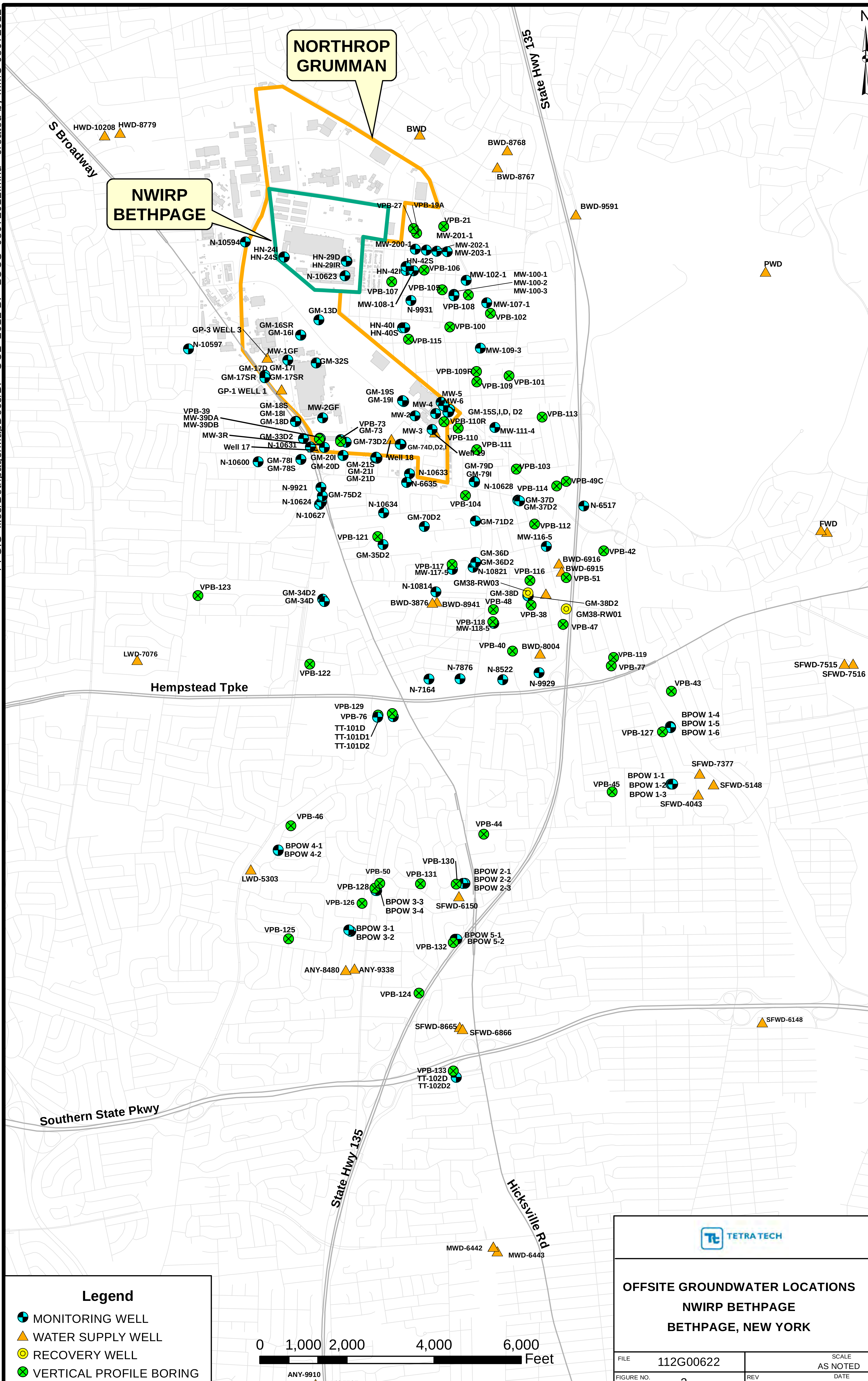
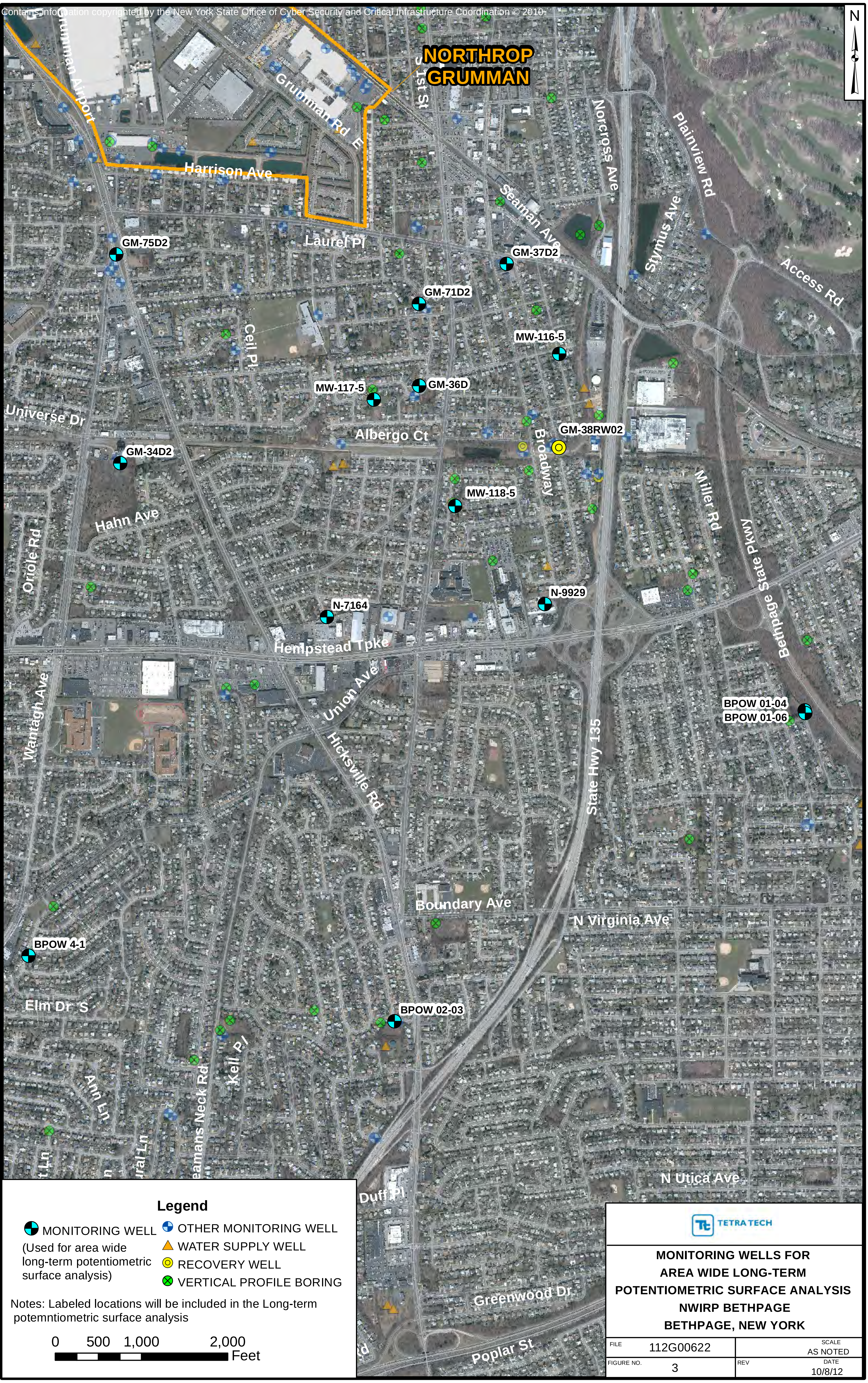


TETRA TECH

OFFSITE GROUNDWATER LOCATIONS
NWIRP BETHPAGE
BETHPAGE, NEW YORK

FILE	SCALE
112G00622	AS NOTED
FIGURE NO. 2	REV	DATE 8/7/12



Legend

- MONITORING WELL (Used for area wide long-term potentiometric surface analysis)
- OTHER MONITORING WELL
- WATER SUPPLY WELL
- RECOVERY WELL
- VERTICAL PROFILE BORING

Notes: Labeled locations will be included in the Long-term potemntiometric surface analysis

0 500 1,000 2,000 Feet

TETRA TECH

MONITORING WELLS FOR AREA WIDE LONG-TERM POTENTIOMETRIC SURFACE ANALYSIS NWIRP BETHPAGE BETHPAGE, NEW YORK

FILE	SCALE
112G00622	AS NOTED
FIGURE NO. 3	REV / DATE 10/8/12

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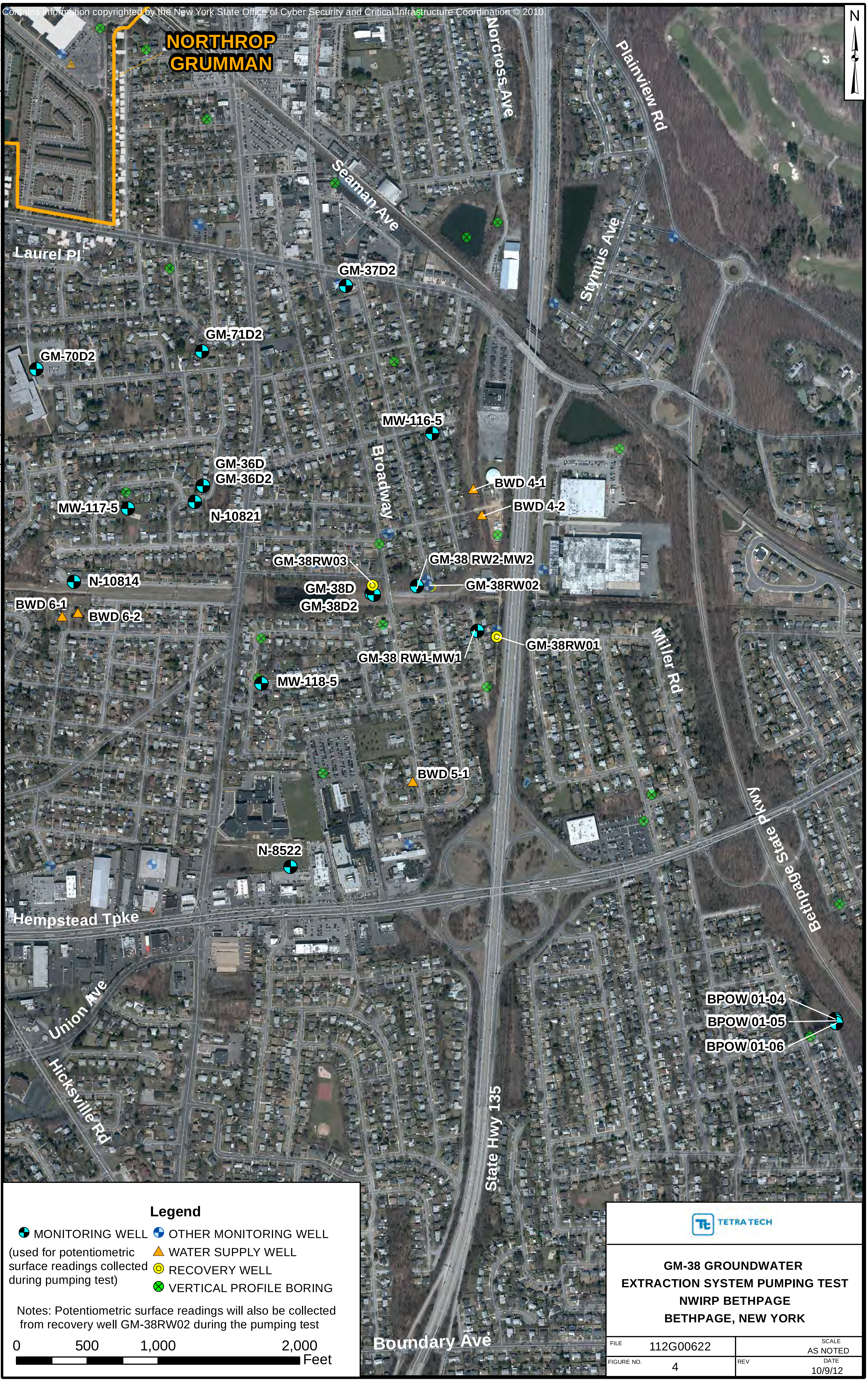

P: GIS files/Bethpage/MapDocs/BP OU2 2012 BP FIGURE4 08072012.mxd created by MMC 10092012

TETRA TECH

GM-38 GROUNDWATER EXTRACTION SYSTEM PUMPING TEST
NWIRP BETHPAGE
BETHPAGE, NEW YORK

FILE	SCALE
112G00622	AS NOTED
FIGURE NO. 4	REV	DATE 10/9/12

ATTACHMENT 1

SOLINST LEVELOGGER Jr EDGE SPECIFICATIONS

Solinst®

Levelogger Junior Edge

Model 3001 Data Sheet

Levelogger Junior Edge

Model 3001

The Levelogger Junior Edge provides an inexpensive alternative for measuring groundwater and surface water levels and temperature. The Levelogger Junior Edge combines pressure and temperature sensors, a datalogger, and 5-year battery in one compact 7/8" x 5.6" (22 mm x 142 mm) stainless steel housing.

The Levelogger Junior Edge records absolute pressure using the same durable Hastelloy pressure sensor as the Levelogger Edge. The Hastelloy sensor has excellent performance in harsh environments with better temperature compensation and thermal response time, and can withstand 2 times overpressure without permanent damage.

The Levelogger Junior Edge features FRAM memory, with an increased capacity of 40,000 sets of temperature and water level data points. Readings are linear at a user-defined interval between 0.5 second to 99 hours. Accuracy is 0.1% FS, with 20 bit resolution and lifetime factory calibration.

If greater accuracy, more sampling options, or wider depth ranges are required, the Solinst Levelogger Edge has the functionality to suit your application (see Model 3001 Data Sheet). For conductivity datalogging, Solinst also offers the LTC Levelogger Junior (see Model 3001 LTC Levelogger Junior Data Sheet).

Technical Specifications	
Level Sensor:	Piezoresistive Silicon with Hastelloy Sensor
Ranges:	F15/M5, F30/M10
Accuracy (typical):	0.1% FS
Units of Measure:	cm, m, ft, psi, kPa, mBar, ºC, ºF
Resolution:	20 Bit Resolution
Normalization:	Automatic Temp Compensation
Temp Compensation Range:	0ºC to 40ºC
Temperature Sensor:	Platinum RTD
Accuracy:	± 0.1ºC
Resolution:	0.1ºC
Battery Life:	5 Years
Operating Temperature:	- 20ºC to 80ºC
Clock Accuracy:	± 1 minute/year (- 20ºC to 80ºC)
Memory:	FRAM
Maximum Readings:	40,000 sets of readings
Communication:	Optical Infrared to USB, RS232, or SDI-12
Size:	7/8" x 5.6" (22 mm x 142 mm)
Weight:	4.2 oz. (119 grams)
Wetted Materials:	316 Stainless Steel, Delrin®, Viton®, Hastelloy
Sampling Mode:	Linear and Real Time View
Measurement Rates:	0.5 sec to 99 hours
Barometric Compensation:	Software Wizard and Barologger Edge

Features

Get Quote | More Info

- Low cost
- 5 year battery life
- Accuracy of 0.1% FS
- Increased memory to 40,000 data points
- New robust Hastelloy pressure sensor
- Compatible with Solinst Telemetry Systems and SDI-12

Operation

Programming the Levelogger Junior Edge is the same as with the Levelogger Edge. An Optical Reader or PC Interface Cable connects the Levelogger to a laptop or desktop PC. The intuitive Levelogger Software automatically detects the type of Levelogger that is connected. Programming, downloading, data management and export are intuitive tasks. The Real Time View option allows immediate viewing of live water level and temperature readings, independent of the scheduled programming intervals.

The Levelogger Junior Edge outputs temperature and temperature compensated water level readings. Using the Data Compensation Wizard in the Levelogger Software, you can barometrically compensation multiple Levelogger Junior Edge files simultaneously, with just one Barologger Edge file.

The Levelogger Junior Edge is compatible with Levelogger Series accessories, including the Leveloader Gold data transfer device, SDI-12 Interface Cable, and Solinst Telemetry Systems (see Model 9100/9200 Data Sheet).

These compact dataloggers are straightforward to deploy. Installation can be with direct read cables, by stainless steel wireline or Kevlar® cord suspension, with the option of using Solinst 2" Locking Well Caps.

Applications

- Monitoring water levels in wells and surface water
- Pump and slug tests
- Reservoir and stormwater runoff management
- Watershed and drainage basin monitoring
- Stream gauging, lake and wetland monitoring
- Tank level measurement

Levelogger Edge Comparison

Model 3001	 CE WEEE	 CE WEEE
	Levelogger Edge	Levelogger Junior Edge
Backwards Compatible	YES (with limitations) See http://www.solinst.com/Downloads/	YES (with limitations) See http://www.solinst.com/Downloads/
Warranty	3 Years	1 Year
Pressure Transducer	Piezoresistive Silicon with Hastelloy Sensor	Piezoresistive Silicon with Hastelloy Sensor
Calibrated Ranges:	15, 30, 65, 100, 300 ft, Atmospheric Barologger 5, 10, 20, 30, 100 m, Atmospheric Barologger	15, 30 ft 5, 10 m
Accuracy (typical)	± 0.05% FS (Barologger Edge ±0.05 kPa)	± 0.1% FS
Resolution	24 Bit Resolution	20 Bit Resolution
Normalization	Automatic Temperature Compensation	Automatic Temperature Compensation
Calibration	Factory – Lifetime calibration	Factory – Lifetime calibration
Response Time (90% Thermal Δ)	1 minute/10ºC change	1 minute/1ºC change
Temp Comp Range	0 to +50°C (Barologger Edge -10 to +50ºC)	0 to +40°C
Over-pressure Range	2 X	2 X
Temperature Sensor	Platinum RTD	Platinum RTD
Temperature Accuracy	± 0.05°C	± 0.1°C
Temperature Resolution	0.003°C	0.1°C
Operating Temp Range	-20 to +80°C	-20 to +80°C
Clock Accuracy	± 1 minute / year (-20ºC - +80ºC)	± 1 minute / year (-20ºC - +80ºC)
Battery Life	10 Years (based on 1 reading/minute)	5 Years (based on 1 reading/minute)
Size	7/8" x 6.25" (22 mm x 159 mm)	7/8" x 5.6" (22 mm x 142 mm)
Weight	4.6 oz. (129 grams)	4.2 oz. (119 grams)
Memory	40,000 readings in FRAM memory, or up to 120,000 readings using data compression option	40,000 readings in FRAM memory, no data compression option
Communication Speed	9600 bps, 38,400 bps with HS USB Optical Reader	9600 bps
Com Interface	Optical infra-red: USB, RS232, SDI-12	Optical infra-red: USB, RS232, SDI-12
Memory Modes	Continuous or Slate	Slate
Logging Rates	0.125 sec to 99 hours	0.5 sec to 99 hours
Logging Modes	Linear, Event & User-Selectable Schedules with Repeat Mode, Future Start, Future Stop, Real Time View	Linear, Real Time View
Barometric Compensation	Barologger Edge	Barologger Edge
Corrosion Resistance	Titanium based PVD coating and Hastelloy Sensor	316 L Stainless Steel and Hastelloy Sensor
Other Wetted Materials	Delrin, Viton, Hastelloy, 316L Stainless Steel	Delrin, Viton, Hastelloy, 316L Stainless Steel
Direct Read Capability	Yes	Yes
Leveloader Compatible	Yes (ensure the latest firmware is installed)	Yes (ensure the latest firmware is installed)

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For further information contact: Solinst Canada Ltd.
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ATTACHMENT 2

SOLINST BAROLOGGER EDGE SPECIFICATIONS

NOTE

To use the Barologger Edge with Software Version 4.0.3, ensure you are using version 3.002 firmware.

1.1.2 Barologger Edge

The Barologger Edge uses algorithms based on air pressure only. It measures and logs changes in atmospheric pressure, which are then used to compensate water level readings recorded by a Levelogger Edge.

Barologger Edge Technical Specifications	
Level Sensor:	Piezoresistive Silicon with Hastelloy Sensor
Accuracy (Typical):	± 0.05 kPa
Resolution:	24 Bit Resolution
Normalization:	Automatic Temperature Compensation
Temperature Sensor:	Platinum Resistance Temperature Detector (RTD)
Temp. Sensor Accuracy:	± 0.05ºC
Temp. Sensor Resolution:	0.003ºC
Temp. Comp. Range:	-10ºC to 50ºC
Battery Life:	10 years (based on 1 reading/minute)
Clock Accuracy:	±1 minute/year (-20ºC to 80ºC)
Operating Temperature:	-20ºC to 80ºC
Maximum # Readings:	40,000 (120,000 using data compression)
Memory:	FRAM, Continuous or Slate mode
Communication Speed:	9600 bps, 38,400 bps with USB optical reader
Com Interface:	Optical Infra-red: USB, RS-232, SDI-12
Size:	7/8" x 6.25" (22 mm x 159 mm)
Weight:	129 grams (4.5 oz.)
Corrosion Resistance:	Titanium based PVD coated body and superior corrosion resistant Hastelloy sensor
Other Wetted Materials:	Delrin®, Viton®, 316L Stainless Steel
Sampling Modes:	Linear, Event & User-Selectable Schedule with Repeat Mode, Future Start, Future Stop, Real Time View
Measurement Rates:	0.125 second to 99 hours

Barologger Edge Models	Accuracy
Air Only	± 0.05 kPa

SOLINST TECHNICAL BULLETIN

Automatic or Manual Barometric Compensation of Your Levelogger Data

Why Use a Barologger?

Submersed absolute Leveloggers measure total pressure (water column equivalent + barometric pressure). In order to accurately determine the true changes in water level only, barometric pressure fluctuations must be removed from the data. The simplest method to accomplish this is by the use of a Barologger suspended above high water level in one well on site. The approximate site compensation coverage is 20 miles (30 km). This records ambient barometric fluctuations over time and allows quick and accurate barometric compensation using the data files from both the Barologger and any Leveloggers in the area.

Manual Barometric Compensation

If an on-site Barologger is not available, your data can be compensated using alternate barometric data (e.g. from a local weather station).

To accomplish an accurate manual barometric compensation, the atmospheric pressure station should not be greater than 20 miles (30 km) away and within an elevation change of 1000 ft (300 m). In addition, the date and time of the barometric data should cover the range of data collected by the Levelogger.

To begin compensation, your Levelogger data and barometric data must be in the same units, and assure that any offsets or normalization values are accounted for. Previous Levelogger and Barologger models (e.g. Gold) produce data with an offset of 31.17 ft or 9.5 m (lowest expected pressure at mean sea level) removed from the level values. Levelogger Edge data does not contain this offset. Although not shown in our examples, it is also important to remember that weather station barometric data will often contain a different offset or normalization. Manual data conversation and barometric compensation should account for any variation of the normalization or offset used between the barometric data sourced and Solinst Leveloggers.

Note: The Levelogger Edge can be programmed to record in kPa, psi, or mbar. This makes compensation using other atmospheric pressure devices easier.

1. Conversion from **Inches of Hg to Feet** of water column equivalent: Example: 30 inches of Hg (for Levelogger Edge):

   30 inches Hg x 1.1330 = 33.99 ft H_2O

2. Conversion from **kPa to meters** of water column equivalent: Example: 101.40 kPa (for older Levelogger):

   101.4 kPa x 0.1022 = 10.36 - 9.50 = 0.86 m H_2O

** Values in red denote pressure conversion factors; consult the table below to obtain common pressure conversions*

In an example where the uncompensated Levelogger Edge data is a water level of **41.17 ft,** from the calculation above, the manual compensation would be: **41.17 ft – 33.99 = 7.18 ft.**

In an example where the uncompensated older Levelogger data is a water level of **3 m,** from the calculation above, the manual compensation would be: **3 m – 0.86 = 2.14 m.**

Pressure Conversion Factors

Barometric Unit	FOOT Water Column Equivalent	METRIC Water Column Equivalent
1 psi	2.3108	0.7043
1 atm	33.959	10.351
1 kPa	0.3352	0.1022
1 mm - Hg	0.04469	0.01362
1 in - Hg	1.1330	0.3453
1 mbar	0.03352	0.01022

Water Column Equivalents to Common Barometric Units

Once the final calculated barometric pressure values are obtained, they are subtracted from the Levelogger data set. Since the Levelogger data can be easily exported as a .csv or .xml file using Levelogger Software, all manual corrections can be performed in external programs.

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Approach to Modeling the Capture Zone of the Bethpage GM-38 Extraction System

-*Paul Misut*, U.S. Geological Survey, Coram NY

OVERVIEW: At Bethpage, New York, the Navy installed an extraction system at GM-38 (figs. 1 and 2) to partially contain an off-site VOC hot spot, and requested that USGS conduct numerical flow simulation to determine the associated capture zone. A secondary modeling objective is to determine the influence of nearby Bethpage Water District (BWD) supply wells on GM-38 capture. Stress from supply wells of other distant water districts, such as Massapequa Water District well 4442(fig. 2), are not expected to significantly impact the GM-38 capture zone.

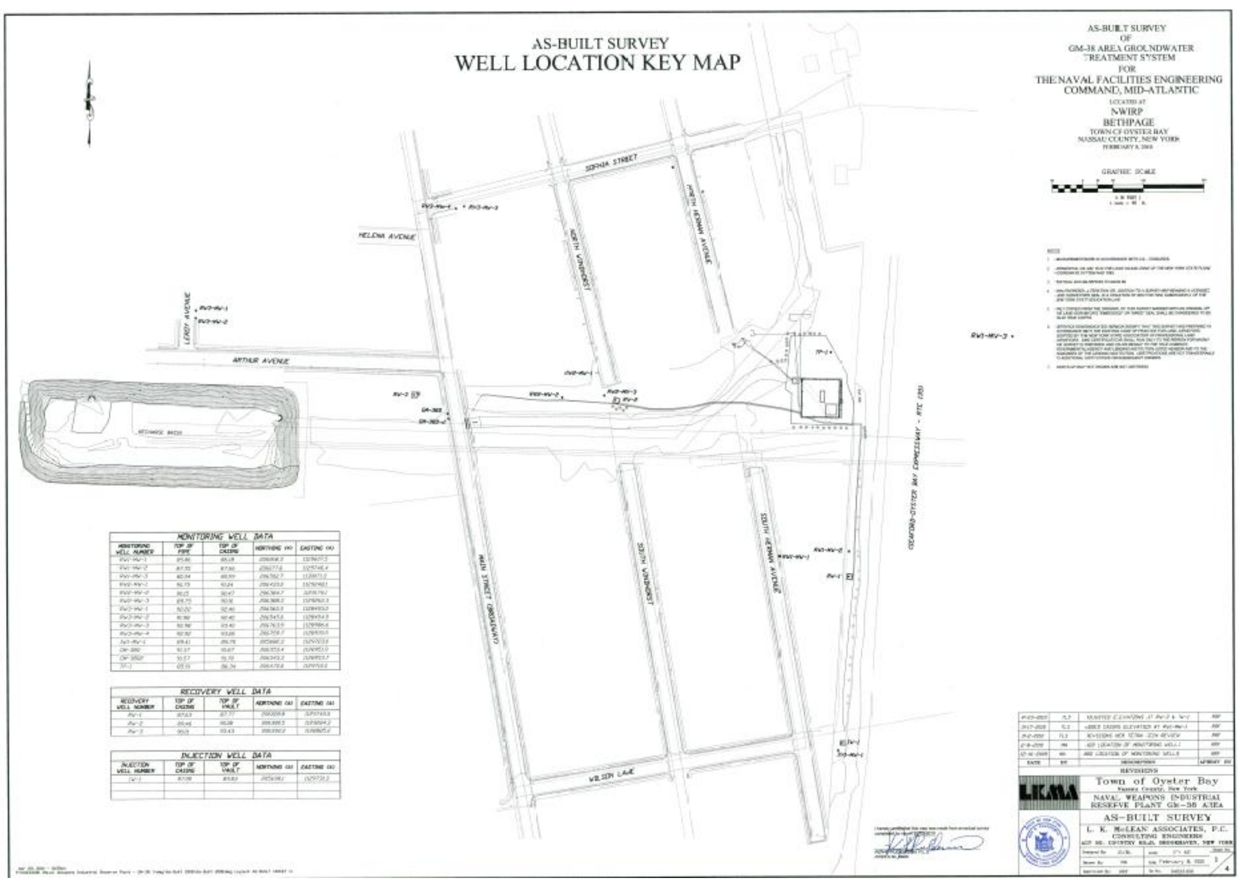

Figure 1. As-built survey of GM-38 project (written communication, A. Gavaskar, 2012

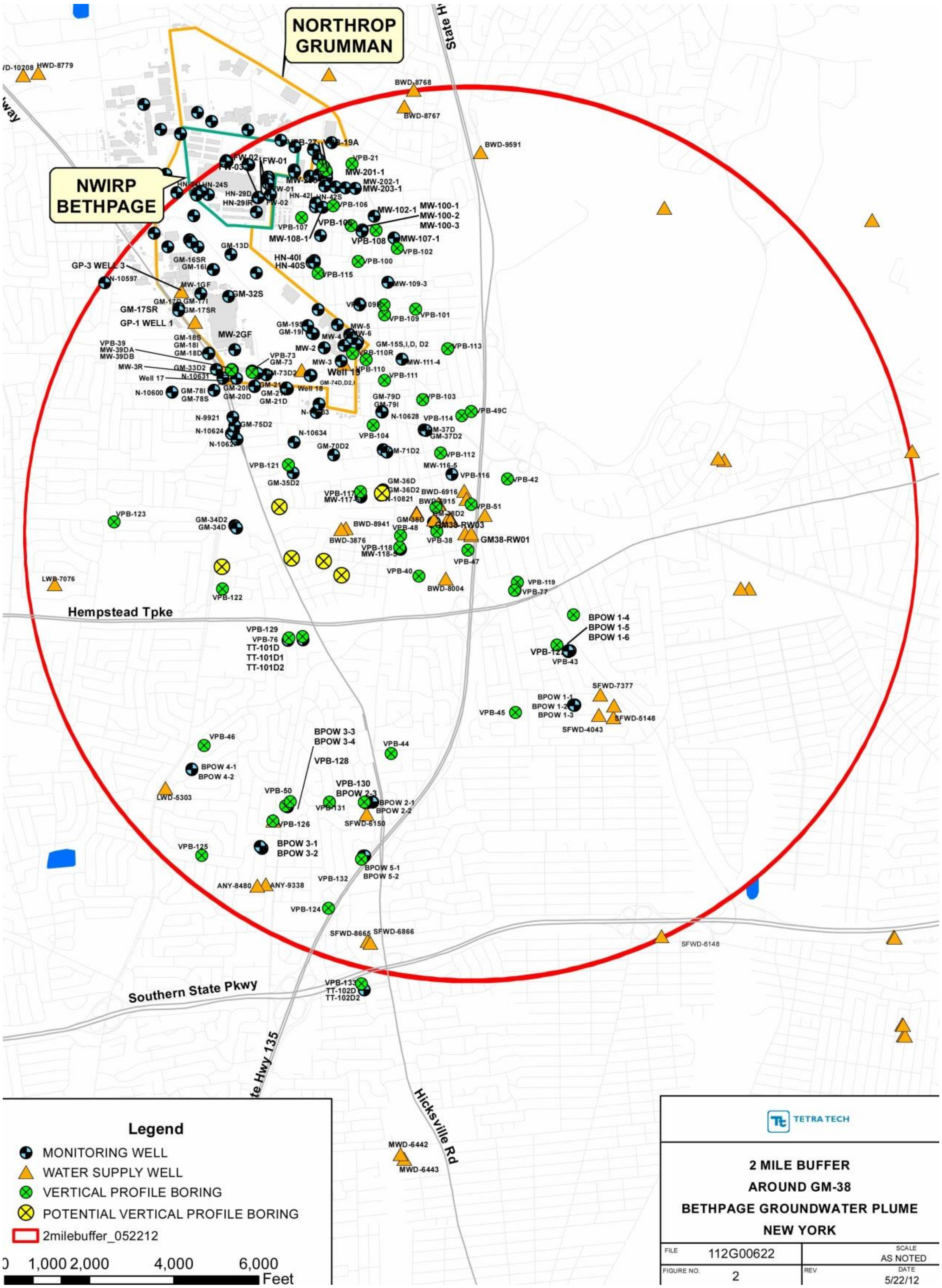

Figure 2. Wells and borings in a 2 mile radius around GM-38 (written communication, David Brayack, 2012)

Accurate determination of capture zones may prevent failures such as illustrated below (fig. 3)

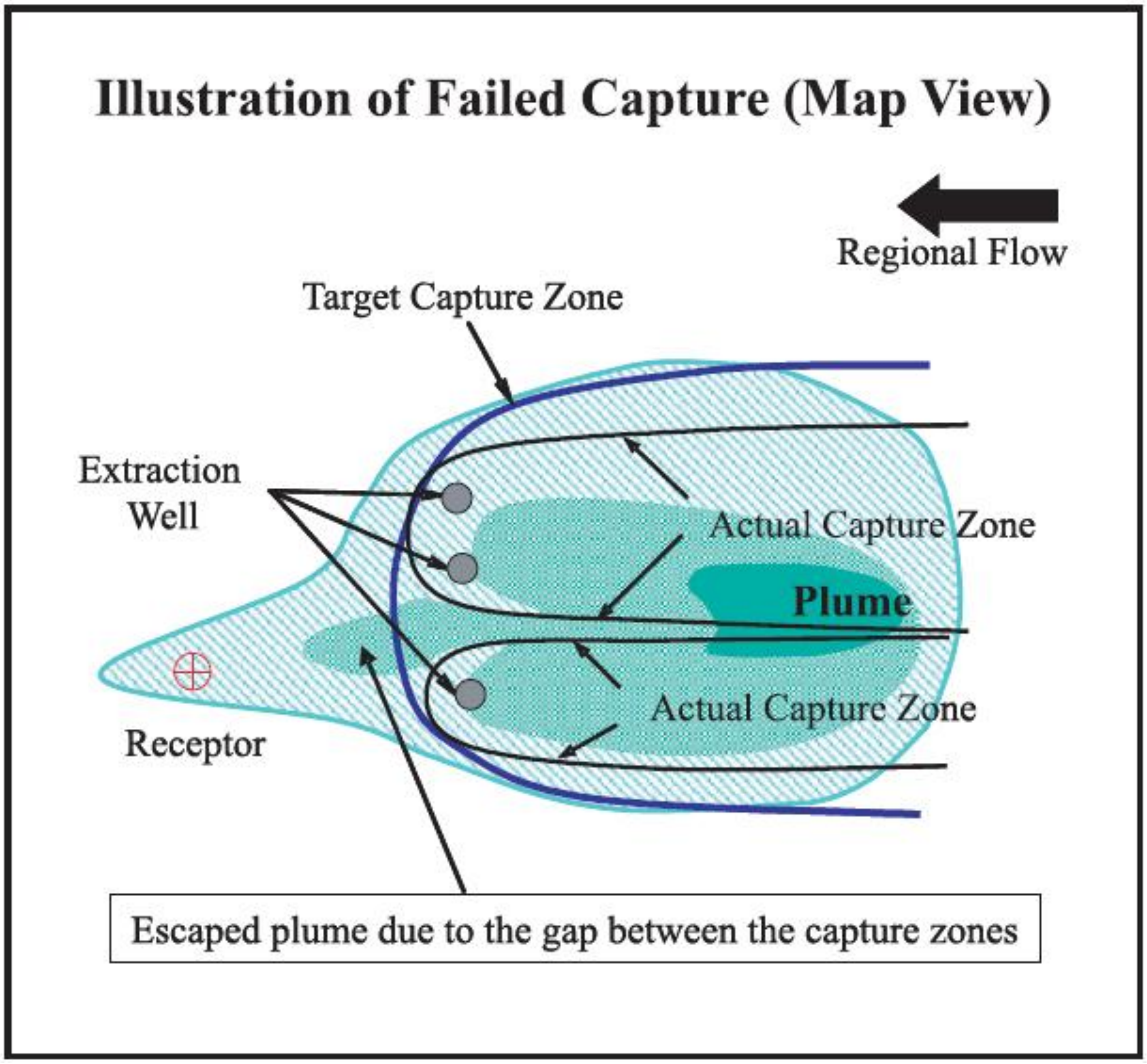

Figure 3. Failure of extraction wells to capture a plume (EPA 600/R-08/003, pg. 2)

The suite of USGS MODFLOW simulation codes (http://water.usgs.gov/nrp/gwsoftware/modflow.html) represents three dimensional geometry and complex boundary conditions, allows for fine model grids to be nested within coarse regional model grids, and can be utilized by particle tracking methods to delineate capture zones. MODFLOW applications often seek to accurately represent groundwater flow but not necessarily to represent solute transport mechanisms such as chemical diffusion. The USGS approach to delineation of the GM-38 capture zone is to use particles to represent pure water flow, not solute transport.

TYPE OF MODEL -- MODFLOW and associated software including graphical user interfaces have been developed by the USGS and are available to the public at no charge. An online guide to MODFLOW is available at http://water.usgs.gov/nrp/gwsoftware/modflow2000/MFDOC/index.html?introduction.htm. The basic governing partial differential equation used in MODFLOW is:

$$\frac{\partial}{\partial x}\left[K_{xx}\frac{\partial h}{\partial x}\right]+\frac{\partial}{\partial y}\left[K_{yy}\frac{\partial h}{\partial y}\right]+\frac{\partial}{\partial z}\left[K_{zz}\frac{\partial h}{\partial z}\right]+W=S_S\frac{\partial h}{\partial t}$$

where

- K_{xx}, K_{yy} and K_{zz} are the values of hydraulic conductivity along the *x*, *y*, and *z* coordinate axes (L/T)
- h is the potentiometric head (L)
- W is a volumetric flux per unit volume representing sources and/or sinks of water, (T^{-1})
- S_S is the specific storage of the porous material (L^{-1}); and
- t is time (T)

Limitations of MODFLOW include the following

- The water must have a constant density, dynamic viscosity (and consequently temperature) throughout the modeling domain.
- The hydraulic conductivity tensor does not allow distributed non-orthogonal anisotropies.

The graphical user interface Modelmuse (http://water.usgs.gov/nrp/gwsoftware/ModelMuse/ModelMuse.html) is used to aid the input of data for creating MODFLOW models, and the post processing of model results.

MODEL GRID – The initial coarse model grid is shown below (fig. 4) The model grid is 80 columns by 90 rows by 36 layers, or about 259,000 cells. The model grid is fined to 57 columns by 71 rows within the capture zone of GM-38 (shown in red, fig. 4). The model grid is rotated to be orthogonal to regional flow patterns. This model is purposely coarse to facilitate early model development tasks which require frequent model runs (and fast model run times, about 5 minutes).

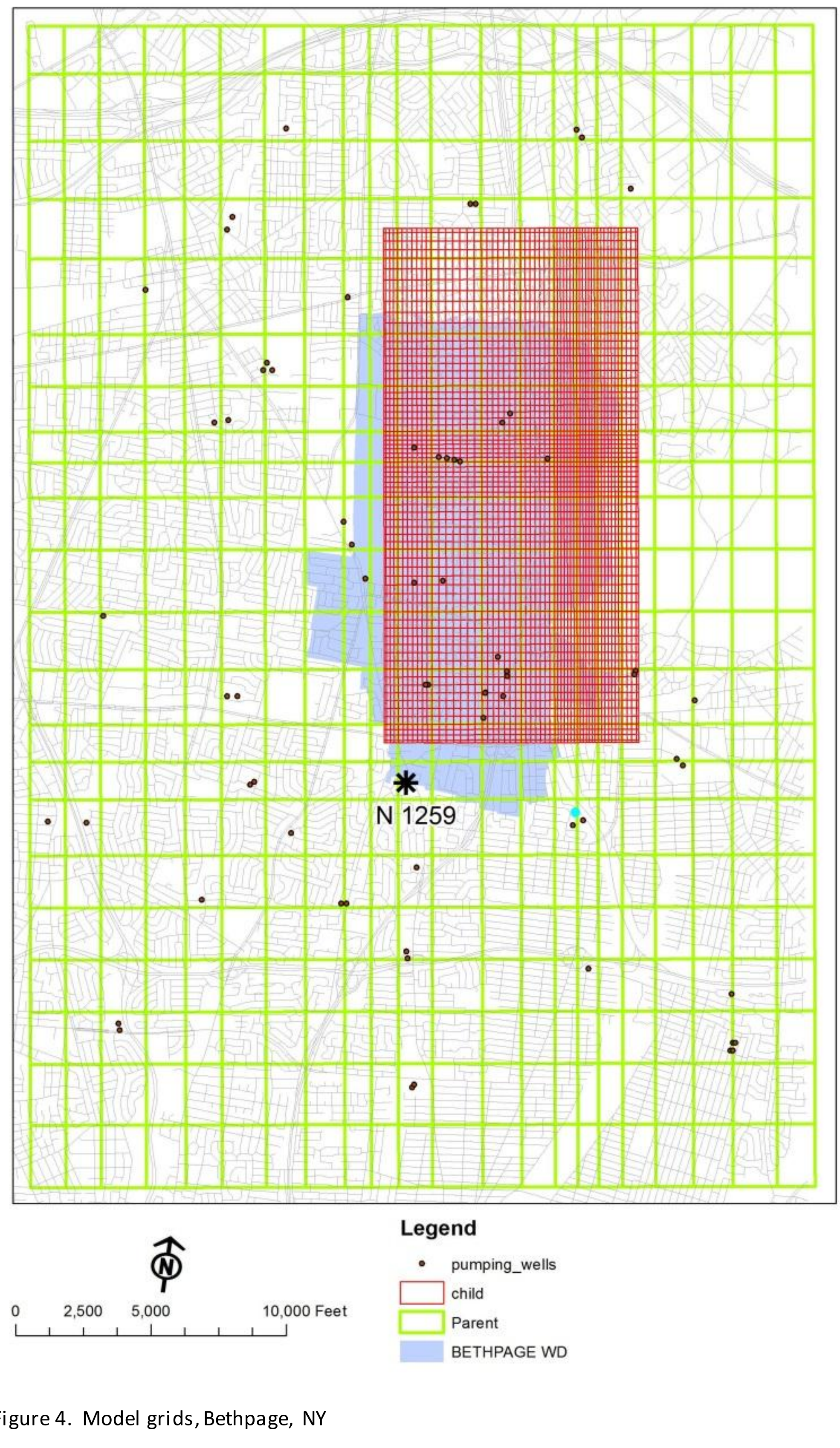

Figure 4. Model grids, Bethpage, NY

The graphical user interface Modelmuse represents all groundwater system features independently of the grid, thus facilitating grid modification. More information is available at http://water.usgs.gov/nrp/gwsoftware/ModelMuse/ModelMuse.html. USGS expects to refine grid to about 2,000,000 cells (about 250 X 250 X 36) after the initial phase of model calibration is completed.

MODEL LAYERING AND HYDRAULIC PROPERTIES – A fundamental aspect of MODFLOW models is the representation of the real world by discrete volumes of material referred to as cells. The size of cells determines the extent to which hydraulic properties and stresses can vary throughout the modeled region. Hydraulic properties and stresses are specified for each cell, so the more cells in a model, the greater the ability to vary hydraulic properties and stresses (USGS SIR2004-5038, pg. 10). The Navy has collected numerous vertical profile boring data and generated an interpretive cross section through the GM-38 area indicating greater than 20 zones throughout the aquifer column (fig. 5).

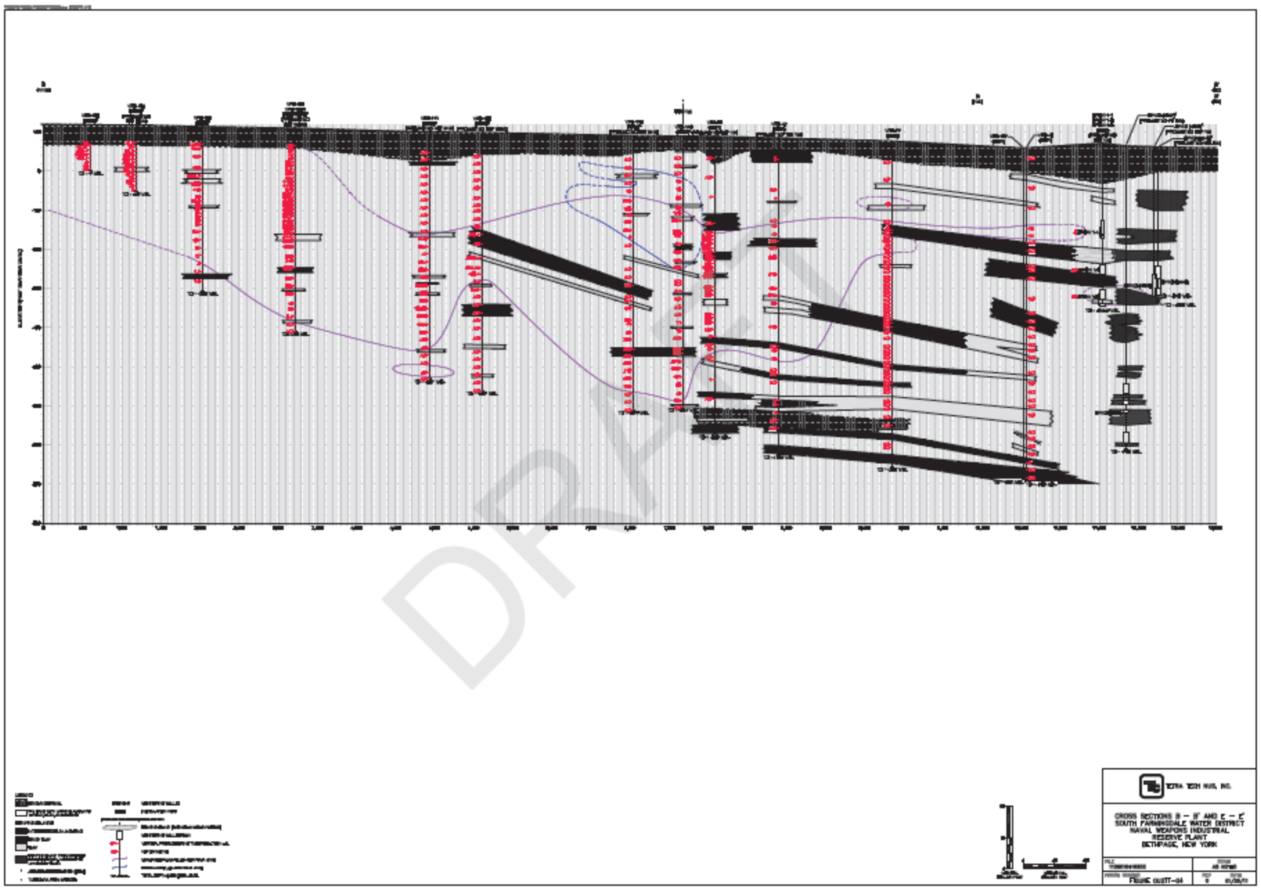

Figure 5. Cross section through GM-38 area (written communication, A. Gavaskar, 2012)

Previously, the GM-38 has been represented with 8, then 11 groundwater flow model layers (fig. 6)

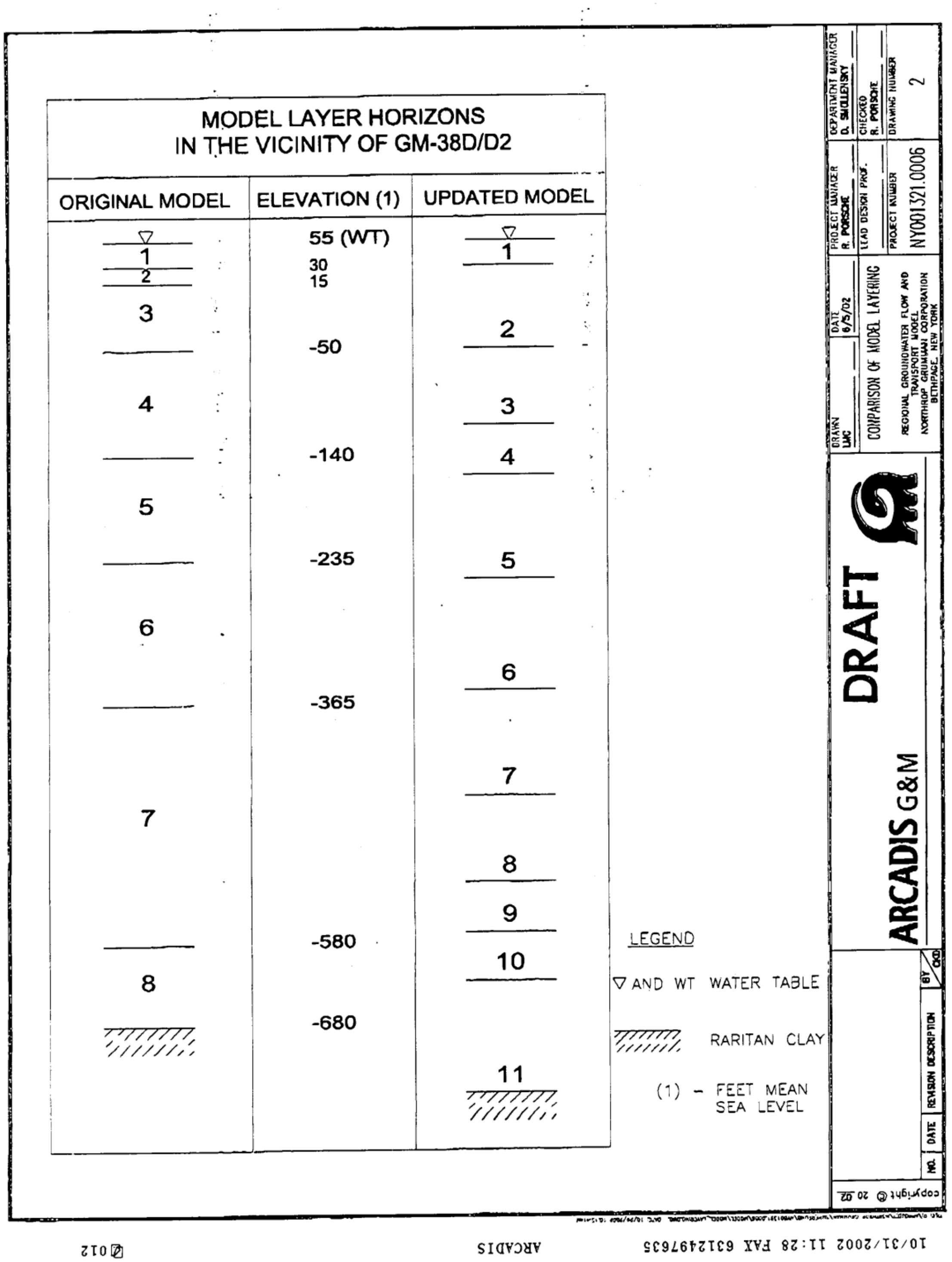

Figure 6. Model layers at GM-38 (from Arcadis Comprehensive groundwater model report, 2003)

The initial USGS model grid uses 36 layers. Initial layer thicknesses are about equal (20 ft), as follows at GM-38:

Upper glacial aquifer: layer 1

Upper Magothy aquifer: layers 2 to 32,

Lower Magothy aquifer: layers 33 to 36.

Initial hydraulic conductivity is estimated for the hydrogeologic units using specific capacity data from drillers' logs and other methods and is summarized at http://pubs.er.usgs.gov/publication/pp627E. A pumping test of GM-38 wells is planned to support this project. Initial effective porosity values for all aquifers are 30 percent. Storage parameters applied in previous modeling studies on Long Island are summarized at http://pubs.usgs.gov/wri/wri984069/pdf/wrir_98-4069_f.pdf, with specific yield values ranging from 0.1 (Magothy aquifer) to 0.3 (glacial outwash) and a specific storage of 6.0 x 10^{-7}/ft for all confining units. Misut and Busciolano (http://pubs.usgs.gov/sir/2009/5190/) estimated the storativity of the upper Magothy to be 0.003. The initial hydraulic conductivities (Kh and Kz) at GM-38 are:

Upper glacial aquifer: layer 1, Kh = 200 ft/d, Kz = 20 ft/d

Upper Magothy aquifer: layers 2 to 32, Kh = 50 ft/d, Kz = 1 ft/d

Lower Magothy aquifer: layers 33 to 36, Kh = 75 ft/d, Kz = 1 ft/d

Raritan confining unit: Kh = 0.1 ft/d, Kz = 0.001 ft/d

The above values imply implicit representation of local confining layers through anisotropy factors (ratio of Kh to Kz). However, local confining layers will be represented as explicitly as possible through use of additional property zones. The graphical user interface Modelmuse will represent all groundwater system features independently of the model layering, thus facilitating layer modification. More information is available at http://water.usgs.gov/nrp/gwsoftware/ModelMuse/ModelMuse.html.

BOUNDARY CONDITIONS, PUMPAGE, and RECHARGE – In evaluating the appropriateness of a groundwater flow model, boundary conditions are important because they determine where the water enters and leaves the system (USGS SIR2004-5038, pg. 17). If the boundaries are inappropriate, the model will be a poor representation of the actual groundwater flow system. When groundwater systems are stressed, the physical features that bound the system can change in response to the stress. Any representation of these features must account for these potential changes, either by understanding the limitations of the simulation or by representing the dynamic physical feature as realistically as possible.

Specified head boundaries at the north and south model boundaries represent regional groundwater flow. The head values may be interpolated from published USGS regional head maps of 2006. An online mapper of this data is available at: http://ny.water.usgs.gov/projects/gisunit/Long_Island_SIM3066.html.The east and west model boundaries are oriented orthogonal to regional flow and are considered no-flow boundaries.

Streams flowing out of the southern extent of the model are represented by MODFLOW "drain" type boundary conditions, which are head-dependent flux boundaries. The heads for these boundary conditions are also taken from USGS regional head maps. Flow at some of these streams is measured by USGS with data available at http://nwis.waterdata.usgs.gov/ny/nwis/sw.

Wells and known recharge basin flows are represented by specified flow boundary conditions. Pumpage rates and well characteristics are compiled by NYSDEC with additional detail available directly from water suppliers. Public supply pumping rates vary seasonally, maximized during summer (example shown in fig. 7; location of Bethpage well 6-2, also known as N 3876, shown in fig. 2). Some discharges to recharge basins are also reported to the NYSDEC.

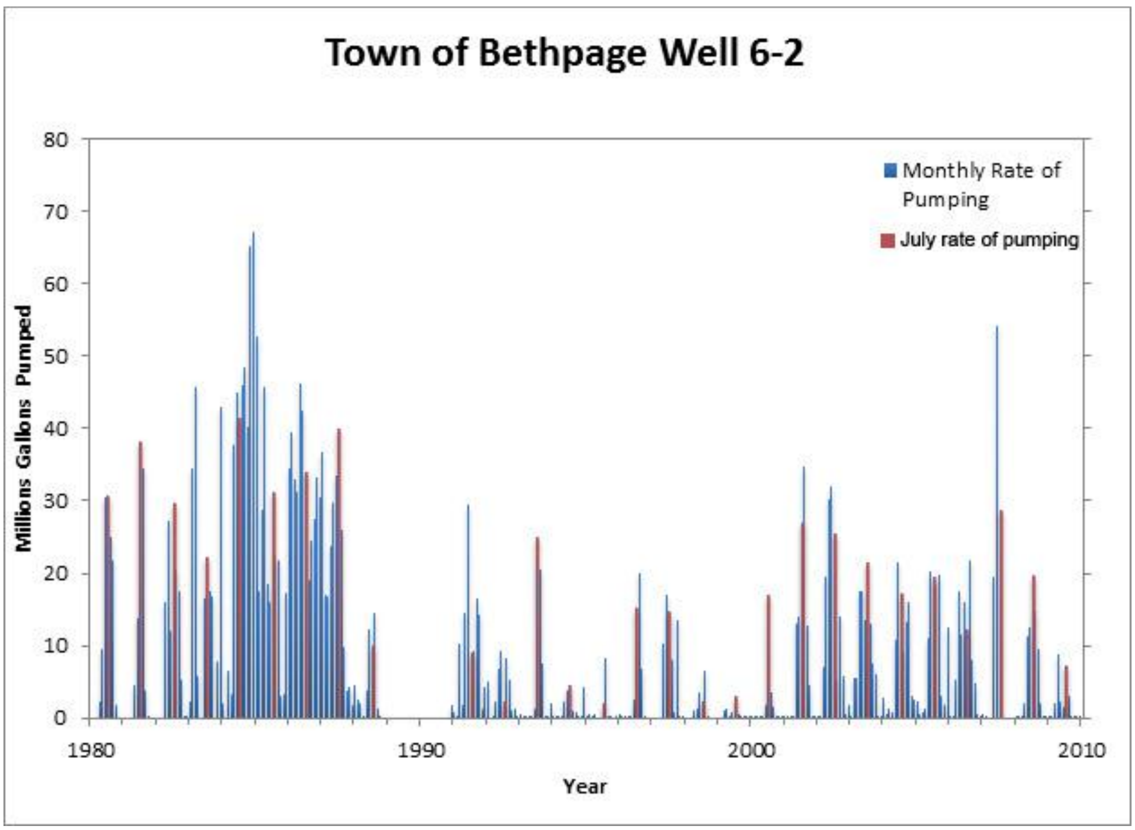

Figure 7. Rate of pumpage at Bethpage Well 6-2 (from USGS OFR 2011-1128, pg. 7)

Groundwater recharge is represented by a specified flux boundary condition applied to the top model cells. Factors affecting rates of recharge include (1) spatial and temporal variations in precipitation, (2) permeability of surficial hydrogeologic units, (3) land-cover characteristics, and (4) discharge of domestic and industrial wastewater into cesspools and septic tanks. Irrigation water is typically evaporated or transpired except in extreme cases of over-watering when recharge may occur. Average precipitation is about 42 inches annually (http://pubs.er.usgs.gov/publication/wri864181.) Under predevelopment conditions, about 50 percent of the precipitation reached the aquifers, mainly during the non-growing season. Under developed conditions, ground-water recharge results mainly from (1) infiltration of precipitation through unpaved areas, (2) infiltration of storm runoff through recharge basins, and (3) infiltration of wastewater through septic systems.

MODEL CALIBRATION AND SENSITIVITY ANALYSIS– The model will be calibrated to the Northrup Grumman bi-annual water level synoptic datasets, available in the "Operation, Maintenance, and Monitoring" reports, and additional water level data collected in support of this project. Below is an excerpt of "OM&M" water level data:

ARCADIS

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Table 3. Water-Level Measurement Data, April 20 to 21, 2006, Operable Unit 2, Northrop Grumman Corporation, Bethpage, New York.

Well Identification	Measuring Point Elevation (ft msl)	Depth to Water (ft bmp)	Water-Level Elevation (ft msl)
Outpost Wells			
BPOW1-1	73.65	28.14	45.51
BPOW1-2	73.54	29.57	43.97
BPOW1-3	73.37	29.57	43.80
BPOW2-1	60.06	20.62	39.44
BPOW2-2	59.96	22.70	37.26
BPOW3-1	63.19	26.29	36.90
BPOW3-2	63.72	27.50	36.22
BPOW4-1	67.34	25.85	41.49
BPOW4-2	67.18	25.55	41.63

(1) Water level was measured by inflating airline set at 120 ft bmp (gauge at wellhead) and subtracting the reading on the gauge from 120 to obtain the depth to water in ft bmp.

(2) Water level was measured by inflating an airline set at 150 ft bmp (gauge at well head) and subtracting the reading on the gauge from 150 to obtain the depth to water in ft bmp.

(3) Water level was measured by inflating airline set at 110 ft bmp (gauge at wellhead) and subtracting the reading on the gauge from 110 to obtain the depth to water in ft bmp.

(4) Water level was measured by inflating airline set at 110 ft bmp (gauge at wellhead) and subtracting the reading on the gauge from 110 to obtain the depth to water in ft bmp.

(5) Wells GM-39_A and GM-39_B are screened at the approximate midpoint and basal portion of the deep zone, respectively.

(6) Water level measurement was collected on April 21, 2006.

ft msl feet relative to mean sea level

ft bmp feet below measuring point

Water level contour maps have been occasionally generated, such as in figure 8.

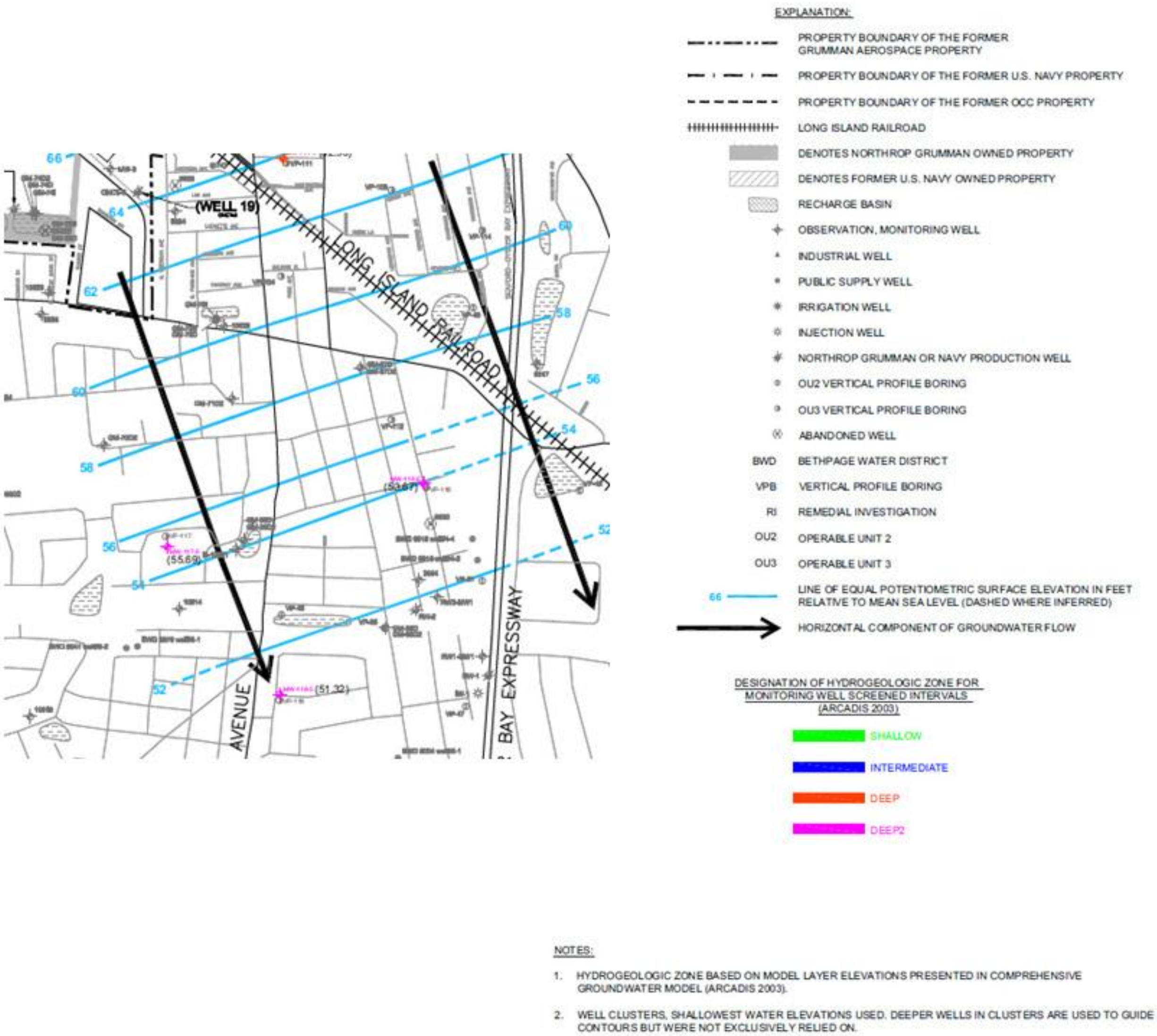

Figure 8. Water Level contour map, July 2009 (From Arcadis Project number NY001493.0809.0008)

As required by the NYSDEC record of decision for Bethpage Operable Unit 2, contour maps of a larger region showing the effect of the OU2 onsite containment system on the GM-38 area have also been generated, as in figure 9.

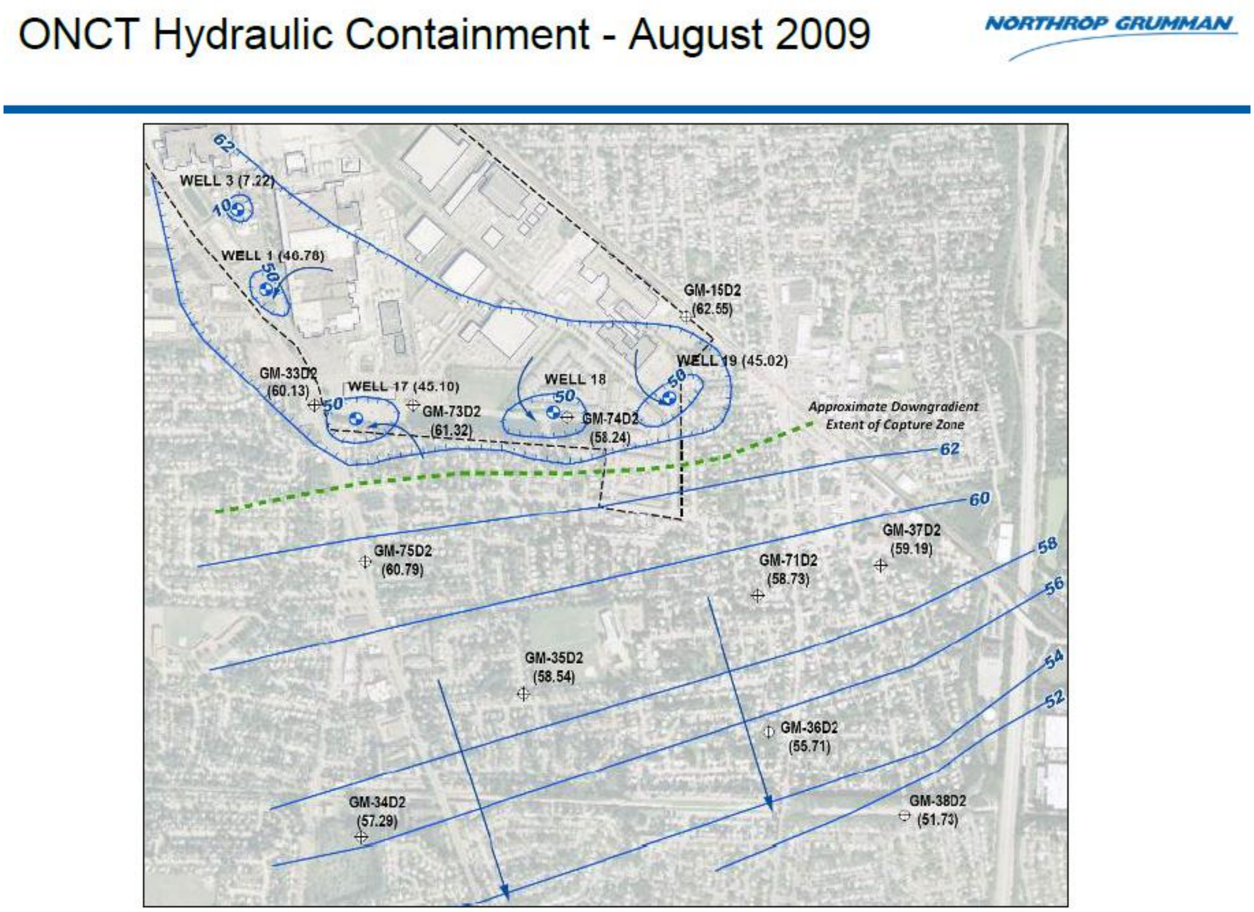

Figure 9. Water Level contour map, August 2009 (From Grumman presentation to Navy Optimization Team, February 2011)

The Northrup Grumman April 2006 water level synoptic dataset appears to reasonably represent long-term average conditions, as shown in the following graph of well N 1259 (fig. 8), as is consistent with boundary conditions derived from http://ny.water.usgs.gov/projects/Ygisunit/Long_Island_SIM3066.html.

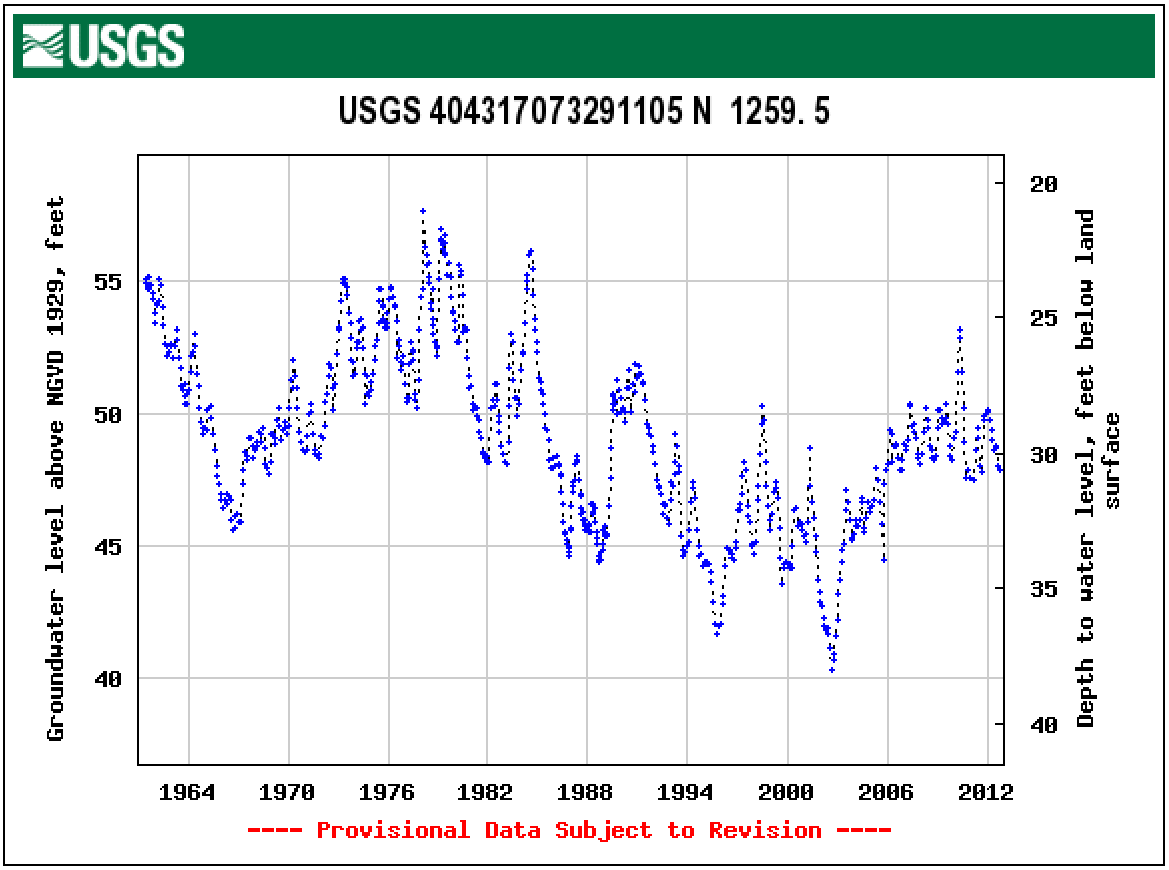

Figure 8. Water levels at USGS well N 1259 (location near VPB 129, shown in fig. 4)

USGS plans to focus on water level data, not detailed plume water quality data during flow model calibration. USGS guidelines for MODFLOW calibration are available at: http://pubs.usgs.gov/sir/2004/5038/PDF.htm .

After completion of model calibration, sensitivity analysis is used to formally evaluate how the finalized set of model input parameters affect the model outputs of heads and flows. The relative effect of the parameters helps to provide fundamental understanding of the simulated system. The most sensitive parameters will be the most important parameters for causing the model to match observed values. Sensitivity analysis will be conducted manually with multiple model simulations. The changes to the model output for parameter changes will be displayed in tables or graphs. Parameters to be analyzed include: horizontal and vertical hydraulic conductivity, porosity, recharge rate, and streambed conductivity.

FIELD DATA GATHERING – Contracted data collection activities in support of this project include deployment of continuous water level and water temperature loggers at about 20 monitoring wells, and a pump test of GM-38 extraction wells (written communication, David Brayack, TetraTech, 2012). The pump test will be coordinated with local water districts and includes (1) control of Bethpage production wells at nearby plant 4, and (2) increased precision and accuracy of public supply pumping rate logging.

By placing continuous water level loggers in observation wells and interpreting these data collected in conjunction with records of pumping and other hydrologic stresses, it is possible to gain insight into many characteristics of the groundwater system including hydraulic properties, geometry of the hydrogeologic framework, and the functioning of model boundary conditions. Ultimately, improved understanding of these characteristics may lead to more accurate delineation of capture zones. Water levels change rapidly in response to stress and the magnitude of change is generally related to distance from stress; therefore, it is necessary to collect data which are finely discretized in time, and as precise as possible. These data include water level logs and records of pumpage variation. Water level loggers are set to collect as much data as possible between planned field visits, about once per 4 to 8 weeks. During field visits, data are uploaded from loggers and the wells are manually measured to control logger drift. A corresponding level of precision and accuracy is necessary for logging of pumping rates.

HYPOTHETICAL SCENARIOS -- Starting from a baseline model, hypothetical scenarios will be simulated to demonstrate capture zones for the most efficient plume containment, and to explore questions about the utility of further data collection and analysis activities. Questions which may be answered by hypothetical simulation include the following:

1. Do GM-38 well capture zones fully overlap plume or hot spot delineations such that there is not significant escape of groundwater contaminants from these areas?
2. To what extent can the zones of public supply well capture be influenced by GM-38 pumping rates and locations?
3. To what extent can GM-38 well capture zones be influenced by other potentially-controllable factors such as operation of public water supply wells or other engineered systems that affect groundwater flow?
4. To what extent are well capture zones influenced by seasonal and climactic variations in recharge?
5. To what extent can further field-data collection and analysis result in improved capture-zone delineation?

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