RESOLUTION CONSULTANTS

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Subject: **Trigger Values Development - Addendum #2 to the Operable Unit 2 (OU2) Offsite Groundwater Public Water Supply Contingency Plan (PWSCP)**

Date: August 2018

Introduction

Operable Unit 2 (OU2) consists of volatile organic compounds (VOCs) that have contaminated groundwater beneath the Navy's former 105 acre parcel, and VOC-contaminated groundwater that has migrated south and east off-property. It becomes mixed with contamination originating on the Northrop Grumman (NG) property and forms a 3,000-acre plus area of VOC-contaminated groundwater plumes at varying depths that extend south of Hempstead Turnpike. The groundwater contamination extends to a depth of approximately 750 feet (ft) but is not continuous throughout this area and is not present at all depths. Other non-OU2 sources of groundwater contamination that are known or believed to be contributing to the OU2 plumes include the Bethpage Community Park OU3 groundwater, Hooker Ruco Superfund Site, and potentially other smaller releases.

The Navy is conducting environmental investigation and cleanup under the Navy's Environmental Restoration Program (ERP), in compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The OU2 groundwater contamination was addressed in the Navy 2003 Record of Decision (ROD) (Naval Facilities Engineering Command [NAVFAC], 2003). The ROD specifies that the selected remedy includes institutional controls, groundwater remediation, and a Public Water Supply Protection Program as defined in the Public Water Supply Contingency Plan (PWSCP, Arcadis, 2003).

Outpost monitoring wells, designed and located to serve as early warning wells, are to be installed and monitored as an element of the 2003 PWSCP. One component of the outpost monitoring well system is the development of "trigger values", or concentration values for contaminants of concern in the OU2 ROD (NAVFAC 2003).

The 2003 PWSCP included trigger values for nine proposed outpost wells to provide early warning for the following wells: South Farmingdale Water District (SFWD) Plant 1 wells 4043, 5148 and 7377 and Plant 3 well 6150; New York American Water (NYAW) wells 8480 and 9338; and Levittown Water District (LWD) well 5303 (Table 1 section A and Figure 1). These wells were subsequently installed and are monitored quarterly by NG.

In 2014 and 2015, 13 outpost wells were installed to provide early warning for the SFWD Plant 6 wells 8480 and 9338 and Massapequa Water District (MWD) wells 6442 and 6443 (Table 1 section B and Figure 1). Trigger values for these wells were developed by Resolution Consultants (2016).

In 2011 and 2014, a total of eight outpost wells were installed to supplement (or replace) outpost wells included in the 2003 PWSCP (Table 1 section C and Figure 1). Three outpost wells (BPOW1-4, BPOW1-5, and BPOW1-6) were installed for SFWD Plant 1 to provide additional evaluation of groundwater north of the plant. One outpost well (BPOW2-3) was installed for SFWD Plant 3 to allow additional evaluation of deeper groundwater north of the plant. Two outpost wells (BPOW3-3 and BPOW3-4) were installed west of SFWD Plant 3 and north of the NYAW (formerly Aqua New York) Seamans Neck Road Plant to allow evaluation of groundwater that may be intercepted by both plants. Outpost wells BPOW4-1R and BPOW4-2R were installed to replace BPOW4-1 and BPOW4-2 (due to failed integrity testing) as early warning wells for LWD well 5303. Trigger values for these outpost wells were to be developed in a subsequent addendum and are provided herein.

The purpose of this report is to develop trigger values for the eight outpost monitoring wells installed since 2011 (described above) to provide an early warning that VOCs from the OU2 plume may impact SFWD Plant 1, SFWD Plant 3, NYAW wells 8480 and 9338 or LWD well 5303 (Table 1 section C and Figure 1). The trigger values should provide a minimum of 5 years notice before the VOCs are detected at a concentration of 0.5 micrograms per liter (ug/L) in the water supply. These trigger values may be replaced with final trigger values when location-specific pumping tests are performed to allow more accurate measurements of connectivity and hydrogeology, similar to that performed for Massapequa Water District outpost wells (Resolution Consultants, 2016).

Site Hydrogeology

Overburden at the site consists of well over 1,000 ft of unconsolidated deposits overlying crystalline bedrock of the Hartland Formation. Overburden is divided into four geologic units: the upper Pleistocene deposits, the Magothy Formation, the clay member of the Raritan Formation ("Raritan Clay") and the Lloyd Sand member of the Raritan Formation ("Lloyd Sand") (Geraghty and Miller, 1994).

The upper Pleistocene ranges in thickness from approximately 50 to 300 ft and consists of till and outwash deposits of medium to coarse sand and gravel with lenses of fine sand, silt and clay (Smolensky and Feldman, 1988); these deposits form the Upper Glacial Aquifer. Directly underlying this unit is the Magothy Formation with a thickness of 650 to 900 ft, as observed at the

former NWIRP and extending southeast to areas south of Southern State Parkway. The Magothy is characterized by fine to medium sands and silts interbedded with zones of clays, silty sands and sandy clays. Sand and gravel lenses are found in some areas between depths of 600 and 880 ft bgs; these deposits form the Magothy Aquifer.

Investigations performed by the Navy since 2012 indicate that the bottom of the Magothy (top of the Raritan Clay) can extend to depths of 700 to greater than 1,000 ft bgs. The Raritan Clay Unit consists of clay, silty clay, clayey silt, and fine silty sand and reportedly acts as a confining layer over the Lloyd Sand Unit.

The Magothy Aquifer is the major source of public water in Nassau County. The most productive water bearing zones are the discontinuous lenses of sand and gravel that occur within the siltier matrix located in the lower portion of the Magothy. Because of the presence of intermittent clay layers and the depths, the Magothy Aquifer is commonly regarded to function overall as an unconfined aquifer at shallow depths and a confined aquifer at greater depths. Groundwater flow is assumed to be primarily horizontal because of the stratified nature of the sand and gravel lenses and thin silty/clayey layers that are thought to reduce vertical flow. However, water supply wells in the area with high withdrawal rates impose a pumping stress at depth that likely induce some vertical flow within their area of influence.

Trigger values for outpost wells have been developed through groundwater modeling. The complex geology and pumping stresses that exist at the Bethpage site present challenges for estimating contaminant fate and transport. Simulating plume arrival times and concentrations with a model involves many uncertainties and assumptions, and should be regarded as approximate. Using conservative hydraulic parameters, the model can be applied to estimate plume movement and develop an early warning system for public supply wells with outpost wells.

Modeling Approach and Modeling Platform

The approach to develop trigger values for the outpost wells is to apply an analytical model to simulate transport from each outpost well to the supply wells. Figure 2 depicts the geometry of the model approach in which the source is located at the outpost well and transport is simulated from the outpost well to the supply well. An analytical model is constructed for each of the eight outpost wells (or well clusters). Applying appropriate aquifer parameters, the model is run iteratively to solve for and estimate what the concentration at the outpost well will be that results in a detection of 0.5 ug/L at the associated supply well, allowing for a 5 year travel time. This approach is consistent with that used for developing the trigger values for SFWD Plant 6 and the northern NED well fields (Resolution 2015).

The primary assumptions of this approach include:

1. Assuming the “source” of the presumed 0.5 ug/L detection at the supply well originates at the upgradient outpost well;
    i. The Source Distance parameter is the distance from outpost well to nearest supply well;

ii. The Source Width parameter is one half the Source Distance; this approach was taken because the outpost wells are clustered and it was not possible to use the distance from the midpoints between outpost wells (as was done in the 2015 Trigger Value document). One half the Source Distance was used in order to assign a consistent proportional Distance to Width configuration to the sources. This approach is consistent with the overall morphology of the offsite plume; that is, longitudinal dispersion is greater than transverse dispersion;

iii. The Source Thickness parameter is approximated as the screen length of the supply well;

2. Assuming no retardation and no decay; and

3. The model simulates advective travel and attenuation through longitudinal and transverse dispersion.

This approach is conservative for the following reasons:

- No retardation or decay;
- Negligible vertical dispersion; and
- Does not account for the dilution of plume concentrations with other non-contaminated water in the capture zone of the supply well.

The Quick Domenico (QD) analytical fate and transport model was used to develop trigger values. The analytical steady state solution to the groundwater flow equation was first proposed by P. A. Domenico (Domenico, 1987). The software platform for the QD Domenico solution is provided for download by the Pennsylvania Department of Environmental Protection (PADEP).

QD calculates the concentration of contaminant species at any point and time downgradient of a source area of known width, thickness and strength. The kinds of contaminants for which QD is intended are dissolved organic contaminants whose fate and transport can be described or influenced by advection and lateral and vertical dispersion. For spatial resolution within the model, QD calculates the concentrations in a two dimensional 5x10 grid network whose length and width are set by the user.

Key assumptions within the modeled area are:

1. Aquifer properties are homogeneous and isotropic;
2. Groundwater flow field is homogeneous and unidirectional;
3. Groundwater flow is steady state; and
4. Contaminant source remains constant in time.

Details of the solution in the Quick Domenico software and input parameters are provided in Appendix 1.

Model Development and Input Parameters

Model inputs were a combination of site-specific data for the OU2 offsite groundwater data and literature values as appropriate (PADEP, 2014). Where a range of values were available, conservative values were chosen. Table 2 provides a summary of the input parameters required within the model software. A few key aquifer parameters are discussed below.

Hydraulic conductivity (K):

Groundwater velocity (distance over time) is proportional to hydraulic conductivity (K), thus higher values of K predict faster travel time. To achieve conservative results, the highest reasonable K value of 75 ft/day was chosen based on the following references:

- The average K for the Magothy aquifer on Long Island is 56 ft/day (McClymonds and Franke, 1972);
- The K used in the calibrated United States Geological Survey (USGS) Bethpage model is 50 ft/day for the Upper Magothy and is 75 ft/day for the Basal Magothy (Misut, 2013);
- A pumping test conducted in 2013 at BWD6-2 yielded a K of 35 - 55 ft/day, based on 400 ft saturated thickness (TetraTech, 2014).
- A pumping test conducted in 2017 at RE137 yielded a K of 77 - 92 ft/day, based on 580 ft saturated thickness (Resolution Consultants, 2018).

Gradient:

Groundwater velocity (distance over time) is also proportional to hydraulic gradient (i), thus higher gradient values predict faster travel time. Numerous gradients were calculated between wells at the site using the synoptic water levels measured on March 29, 2018 (Figure 3). An average of (0.002) was selected as a representative gradient for the model.

Porosity:

Groundwater velocity (distance over time) is inversely proportional to porosity, thus lower porosity (n) values predict faster travel time. The USGS DRAFT report on the calibrated numerical groundwater model for the Bethpage site references values ranging from 0.15 and 0.35 (Misut, 2013). A value of 0.15 was chosen as conservative value within this range.

1st order decay: The model assumes no decay (biodegradation) thus a value of zero was assigned.

Fraction organic carbon (foc) and organic carbon partition coefficient (FOC): The model assumes no retardation (sorption) thus these two parameters used to estimate retardation were assigned a value of zero.

Model Results

The model simulations provide an estimate of the trigger concentrations at each outpost well predicted to result in a detection of 0.5 ug/L in the down gradient supply well in 5 years. The following inputs were selected to provide a conservative estimate of trigger values:

- Hydraulic conductivity of 75 ft/day is on the high end of the range of composite Ks;
- Gradient of 0.002 is within the range of estimated gradients on-site; and
- Porosity of 0.15 is on the low end of the range of estimated porosities for the site.
- No biodegradation or adsorption;
- Negligible vertical dispersion;

The resultant groundwater (seepage) velocity calculated by the QD model based on the above aquifer parameters is 365 ft/yr (1 ft/day).

Table 3 shows model simulated trigger values for SFWD Plant 1 outpost wells (BPOW1-4, BPOW1-5, BPOW1-6), SFWD Plant 3 outpost wells (BPOW2-3, BPOW3-3, BPOW3-4), New York American Wells 8480 and 9338 outpost wells (BPOW3-3, BPOW3-4) and Levittown Water District Well 5303 outpost wells (BPOW4-1R, BPOW4-2R). Table 3 also summarizes the dimensional inputs unique to each supply well: the distance from each outpost well(s) to the nearest downgradient supply well, the source width, and the source thickness. Model output is provided in Appendix 2 through 5.

Trigger concentration at outpost wells upgradient of the SFWD Plant 1 wellfield (BPOW1-4, BPOW1-5, BPOW1-6) is estimated to be 0.67 ug/L. Trigger concentrations at outpost wells upgradient of SFWD Plant 3 are estimated to be 0.54 ug/L at BPOW2-3 and 1.14 ug/L at BPOW3-3 and BPOW3-4. Trigger concentration at outpost wells upgradient of the New York American wells 8480 and 9338 (BPOW3-3 and BPOW3-4) is estimated to be 1.13ug/L. Trigger concentrations at outpost wells upgradient of Levittown Water District Well 5303 are estimated to be 0.54 ug/L at BPOW4-1R and 0.57 ug/L at BPOW4-2R.

Aquifer parameters (k, n, i) were constant for all the simulations thus differences in predicted trigger values are due to source dimensions (width, thickness) and distance to supply well. Trigger values are directly proportional to the distance between the outpost well and the supply well: the further away the outpost well, the more lead time is provided and thus the higher the “warning” concentration can be before a detection of 0.5 ug/L is predicted at the supply well. Source width and thickness contribute to the contaminant mass; the larger the contaminant mass, the greater the plume concentration which requires a lower trigger concentration.

Sensitivity Analysis

Given that K and porosity were the same for all simulations, a sensitivity analysis was conducted using a surrogate scenario model to determine how sensitive model predictions are to changes in input parameters. The surrogate model used for the sensitivity analysis was the NYAW Wells 8480 and 9339 trigger values simulation for outpost wells BPOW3-3 and BPOW3-4. Inputs were varied

one at a time by increasing and decreasing each input by a 1.5 multiplier. The resulting trigger values and % change in values are reported in Table 4. The following observations can be made about the effect of the parameter changes on predicted trigger values:

A sensitivity analysis was conducted on a base simulation to determine how much the model predictions of trigger values changed in response to changes in input parameters. Table 4 summarizes the sensitivity analysis based on the surrogate model simulations of the BPOW3-3 and BPOW3-4 well cluster. The following observations can be made about the effect of the parameter changes on predicted trigger values:

- Source thickness is related to source mass and has an inverse relationship to trigger concentration. Increasing source thickness by a factor 1.5 resulted in a 3% decrease in the trigger concentration. Decreasing source width by a factor of 1.5 resulted in a 2% increase in the trigger concentration.
- Source width is related to source mass and has an inverse relationship to trigger concentration. Increasing source width by a factor 1.5 resulted in a 7% decrease in the trigger concentration. Decreasing source width by a factor of 1.5 resulted in a 21% increase in the trigger concentration.
- Dispersion:
    - Increasing lateral dispersion by a factor of 1.5 caused the plume to broaden in all directions, reducing concentrations at the plume front, and increasing the trigger concentration by 8%.
    - Reducing lateral dispersion by a factor of 1.5 steepened the plume front, increasing concentrations at the plume front and decreasing the trigger concentration by 4%.
- Hydraulic conductivity (K), gradient (i) and porosity (n) are aquifer parameters that control groundwater (seepage) velocity and have a significant effect:
    - Increases in groundwater velocity (resulting from increases in K or i or decreases in n) result in higher downgradient concentrations, thus reducing the trigger concentration.
    - Increasing/decreasing any of the aquifer parameters by a factor of 1.5 resulted in the groundwater (seepage) velocity, originally 1 ft/day, to range from 0.66 to 1.5 ft/day. The resulting trigger concentration ranged from 0.67 ug/L (41% decrease) to 3.28 ug/L (190% increase), respectively.

To determine the sensitivity of trigger values to high velocity conditions, a scenario was run with k = 75 ft/day, porosity = 0.1 and gradient = 0.003 (v = 2.25 ft/day). The model predicted a 50% decrease in the trigger concentration from 1.5 to 0.75 ug/L.

Model Limitations

The following are limitations to applying the QD model:

- The model assumptions discussed above describe the approach of the Quick Domenico model and constrain the model's ability to represent site conditions.
- There is a significant volume of data for the Bethpage site, but understanding the fate and transport of the OU2 plume is very complex. Small-scale heterogeneities over the scale of a deep 700+ foot aquifer can influence plume fate and transport, thus predicting plume arrival times is uncertain in settings such as Bethpage. Such small scale heterogeneities are not represented in the model.

If the above limitations are understood, the modeling is constructive in that it applies a uniform set of conservative parameters to estimate plume movement and to develop early warning values for public supply wells with associated outpost wells.

References

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Attachments:

Table 1
Outpost Well
Construction Summary

PWS Affiliation	Outpost Well	Total Depth (ft bgs)	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	VPB affiliation	Outpost Well	Total Depth (ft bgs)	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	VPB Affiliation
	A. Wells with trigger values developed in PWSCP (Arcadis, 2003)					**C. Wells installed in 2011 & 2014; trigger values developed by Resolution Consultants in this Addendum (2018)**				
SFWD Wells 4043, 5148, 7377 (Plant 1)	BPOW1-1	241	196	241	VPB45	BPOW1-4	405	340	400	VPB127
	BPOW1-2	335	310	335		BPOW1-5	655	600	650	
	BPOW1-3	419	374	419		BPOW1-6	755	700	750	
SFWD Well 6150 (Plant 3)	BPOW2-1	400	360	400	VPB130	BPOW2-3	599	564	594	VPB130
	BPOW2-2	495	455	495		BPOW3-3	625	580	620	VPB128
						BPOW3-4	695	640	690	
NYAW Wells 8480, 9338	BPOW3-1	516	446	516	none	BPOW3-3	625	580	620	VPB128
	BPOW3-2	647	612	647		BPOW3-4	695	640	690	
LWD Well 5303	BPOW4-1	692	652	692	VPB46	BPOW4-1R	697	652	692	VPB46
	BPOW4-2	765	725	765		BPOW4-2R	770	725	765	
	B. Wells installed in 2014-2015 with trigger values developed by Resolution Consultants (2016)									
SFWD Wells 8664, 8665 (Plant 6)	BPOW5-1	515	480	510	VPB132					
	BPOW5-2	585	540	580						
	BPOW5-3	665	620	660						
	BPOW5-4	575	545	570	VPB151					
	BPOW5-5	545	515	540	VPB152					
	BPOW5-6	615	585	610						
	BPOW5-7	555	525	550	VPB153					
MWD Wells 6442, 6443	BPOW6-1	580	550	575	VPB145					
	BPOW6-2	785	755	780						
	BPOW6-3	780	750	775	VPB146					
	BPOW6-4	575	545	570						
	BPOW6-5	555	525	550	VPB147					
	BPOW6-6	800	770	795						

Notes:

ft bgs = feet below ground surface
LWD = Levittown Water District
MWD = Massapequa Water District
NYAW = New York American Water; formerly Aqua New York (ANY)
SFWD = South Farmingdale Water District
PWS = Public Supply Wells
PWSCP = Public Water Supply Contingency Plan

Table 2
Input Parameters for Quick Domenico Analytical Model

Parameter	Value	Explanation of value	Source
Source concentration (ug/L) "Trigger Value"	C	concentration input at source that results in detection of 0.5 ug/L at downgradient supply well after 5 years travel time	Determined by trial through Quick Domenico modeling
Source Distance (ft)	unique for each OW; see Table 3	Distance along simulated plume trajectory from outpost well to supply well (to closest supply well if more than one)	project mapping
Source width (ft)	unique for each OW; see Table 3	50% of Source Distance	project mapping
Source thickness (ft)	unique for each OW; see Table 3	use total screen length of supply well(s) as approximate thickness of source at concentraton indicated	screen lengths from Arcadis PWS Contengency Plan, 2013 (NYSDEC Doc 743) for all except for LWD 5305 used original log from Town Engineer
Time (days)	1825	5 years	In accordance with Arcadis Public Water Supply Contingency Plan (2003)
longitudinal dispersivity A(x)	unique for each OW; see Table 3	typically 1/10 plume length	Estimated utilizing EPA methodology (http://www.epa.gov/athens/learn2model/part-two/onsite/longdisp.html)
transverse dispersitivity A(y)	unique for each OW; see Table 3	typically 1/10A(x)	Quick Domenico Manual, 2014
vertical dispersivity A(z)	unique for each OW; see Table 3	typically 1/1000 A(x) approximates 2-dimensional transport with minimal vertical dispersion	Quick Domenico Manual, 2014
hydraulic conducitivity (k) (ft/d)	75	Applied the highest reasonable i value for conservative results, supported by site data	1. McClymonds and Franke, 1972; 2. Tetra Tech, 2014; 3. Misut, 2013; 4. Resolution Consultants, 2018.
hydraulic gradient (i)	0.002	Applied the highest reasonable K value for conservative results, supported by site data	March 2018 synoptic water levels (Resolution Consultants)
porosity (n)	0.15	conservative value within reasonable range of 0.15 and 0.35	Misut, 2013
1st order decay constant (lambda)	0	decay or biodegredation; for simulations assuming no decay use lambda = 0	Quick Domenico Manual, 2014
Fraction organic carbon (foc)	0	organic content of soil; a variable in retardation; for simulations assuming no retardation use foc = 0	Quick Domenico Manual, 2014
Organic carbon parition coefficient (KOC)	0	chemical specific parameter; a variable in retardation; for simulations assuming no retardation use KOC = 0	Quick Domenico Manual, 2014

Notes:
ft = feet; ft/d = feet per day
ug/L = micro grams per liter
The QD model simulations for this project assume no biodegredation, adsorption or vertical dispersion.
Resultant groundwater (seepage) velocity: (k x i)/n = 1 ft/day

Table 3
Quick Domenico Model Results

SFWD Plant 1 Wells 4043, 5148, 7377	BPOW1-4, 1-5, 1-6
Distance from BPOW to closest SFWD Well 7377 (ft)	1260
Source width (ft)	630
Source thickness (ft) = total screen lengths of SFWD-4043 (312 - 372 ft bgs), SFWD-5148 (309 - 369 ft bgs) and SFWD-7377 (607 - 758 ft bgs)	214
Dispersion Ax, Ay, Az	126 / 12.6 / 0.126
Trigger concentration (ug/L) at BPOW	**0.67**

SFWD Plant 3 Well 6150	BPOW2-3	BPOW3-3, 3-4
Distance from BPOW to SFWD Well 6150 (ft)	330	1870
Source width (ft)	165	930
Source thickness (ft) = screen length SFWD-6150 (545 - 612 ft bgs)	67	67
Dispersion Ax, Ay, Az	33 / 3.3 / 0.03	187 / 18.7 / 0.187
Trigger concentration (ug/L) at BPOW	**0.54**	**1.14**

NYAW Wells 8480, 9338	BPOW3-3, 3-4
Distance from BPOW to closest ANY Well 7377 (ft)	1870 (from 8480)
Source width (ft)	936
Source thickness (ft) = total screen lengths of well 8480 (570 - 665 ft bgs) and well 9338 (585 - 646 ft bgs)	95
Dispersion Ax, Ay, Az	187 / 18.7 / 0.187
Trigger concentration (ug/L) at BPOW	**1.13**

LWD well 5303	BPOW4-1R	BPOW4-2R
Distance from BPOW to LWD Well 5303 (ft)	600	930
Source width (ft)	300	465
Source thickness (ft) = total screen length of LWD-5303 (620 - 736 ft bgs)	116	116
Dispersion Ax, Ay, Az	60 / 6 / 0.06	93 / 9.3 / 0.093
Trigger concentration (ug/L) at BPOW	**0.54**	**0.57**

Notes:
ft = feet; ft bgs = feet below ground surface
ug/L = micro grams per liter
LWD = Levittown Water District
MWD = Massapequa Water District
NYAW = New York American Water; formerly Aqua New York (ANY)
SFWD = South Farmingdale Water District

Table 4
Sensitivity Analysis

	Inputs							Model Prediction	
	K (ft/d)	**i**	**n**	**v (ft/d)**	**Dispersion: Ax/Ay/Az**	**Source thickness (ft)**	**Source width (ft)**	**OW trigger conc (ug/L)**	**% change in trigger conc**
Surrogate scenario: NYAW wells 8480, 9338; trigger at BPOW3-3, 3-4	75	0.002	0.15	1	187/18.7/0.187	95	936	1.13	
Sensitivity to source thickness (x 1.5, ÷1.5)	75	0.002	0.15	1	187/18.7/0.187	**142.5**	936	1.10	-3
	75	0.002	0.15	1	187/18.7/0.187	**63**	936	1.15	2
Sensitivity to source width (x 1.5, ÷1.5)	75	0.002	0.15	1	187/18.7/0.187	95	**1404**	1.05	-7
	75	0.002	0.15	1	187/18.7/0.187	95	**624**	1.37	21
Sensitivity to dispersion (x 1.5, ÷1.5)	75	0.002	0.15	1	**280/28/0.28**	95	936	1.22	8
	75	0.002	0.15	1	**125/12.5/0.125**	95	936	1.09	-4
Sensitivity to K (x 1.5, ÷1.5)	**112**	0.002	0.15	1.5	187/18.7/0.187	95	936	0.67	-41
	50	0.002	0.15	0.666	187/18.7/0.187	95	936	3.25	188
Sensitivity to i (x 1.5, ÷1.5)	75	**0.003**	0.15	1.5	187/18.7/0.187	95	936	0.67	-41
	75	**0.0013**	0.15	0.665	187/18.7/0.187	95	936	3.28	190
Sensitivity n (x 1.5, ÷1.5)	75	0.002	**0.225**	0.666	187/18.7/0.187	95	936	3.25	188
	75	0.002	**0.1**	1.5	187/18.7/0.187	95	936	0.67	-41
High velocity scenario	75	0.003	0.1	2.25	187/18.7/0.187	95	936	0.56	-50

Notes:

ft = feet; ft bgs = feet below ground surface; ft/day = feet per day
K = hydraulic conducitivity
i = hydraulic gradient
n = porosity
v = seepage velocity = (k x i)/n
ug/L = micro grams per liter

Bolded parameters indicate parameter that was varied in the sensitivity analysis while leaving remaining parameters the same.

Sensitivity analysis based on varying model inputs to surrogate scenario of BPOW3-3, 3-4 trigger values.

Other BPOW3-3, BPOW3-4 input: Length (distance from OW to MWD) = 1870 feet; time was 5 years.

Trigger concentration = contaminant concentration at BPOW estimated to result in 0.5 ug/L detection at Water supply well after 5 years travel time using analytical Quick Domenico fate and transport model (see text for assumptions and limitations).

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Former Naval Weapons Industrial Reserve Plant

Former Northrop Grumman Site

Old Bethpage

Bethpage

Plainedge

South Farmingdale

Levittown

North Massapequa

North Wantagh

Cherry Ave
Plainview Rd
S Broadway
S Oyster Bay Rd
Powell Ave
Broadway
Access Rd
Quaker Meeting House Rd
Central Ave
Fulton St
Conklin St
N Wantagh Ave
Hempstead Tpke
Union Ave
Stewart Ave
Hicksville Rd
State Hwy 135
Beach St
Miller Rd
Merritts Rd
Motor Ave
Bethpage State Pkwy
Miller Pl
Boundary Ave
E Service Rd
N Broadway
N Poplar St
N Linden St
N Jerusalem Rd
Southern State Pkwy

N

PWD-7438

0 750 1,500 3,000 Feet

BPOW2-3 Indicates outpost wells for which trigger values are developed in this memo.

Legend

- Monitoring Well
- Vertical Profile Boring
- Vertical Profile Boring - Proposed
- Water Supply Well
- Extraction Well

NAVFAC

FIGURE 1. WELL LOCATION MAP
NAVAL WEAPONS INDUSTRIAL RESERVE PLANT
BETHPAGE, NEW YORK

CONTRACT NUMBER	CTO NUMBER
N62470-11-D8013	WE15
APPROVED BY	DATE
PS	5/22/2018
APPROVED BY	DATE
—	—
FIGURE NO. 1	REV 0

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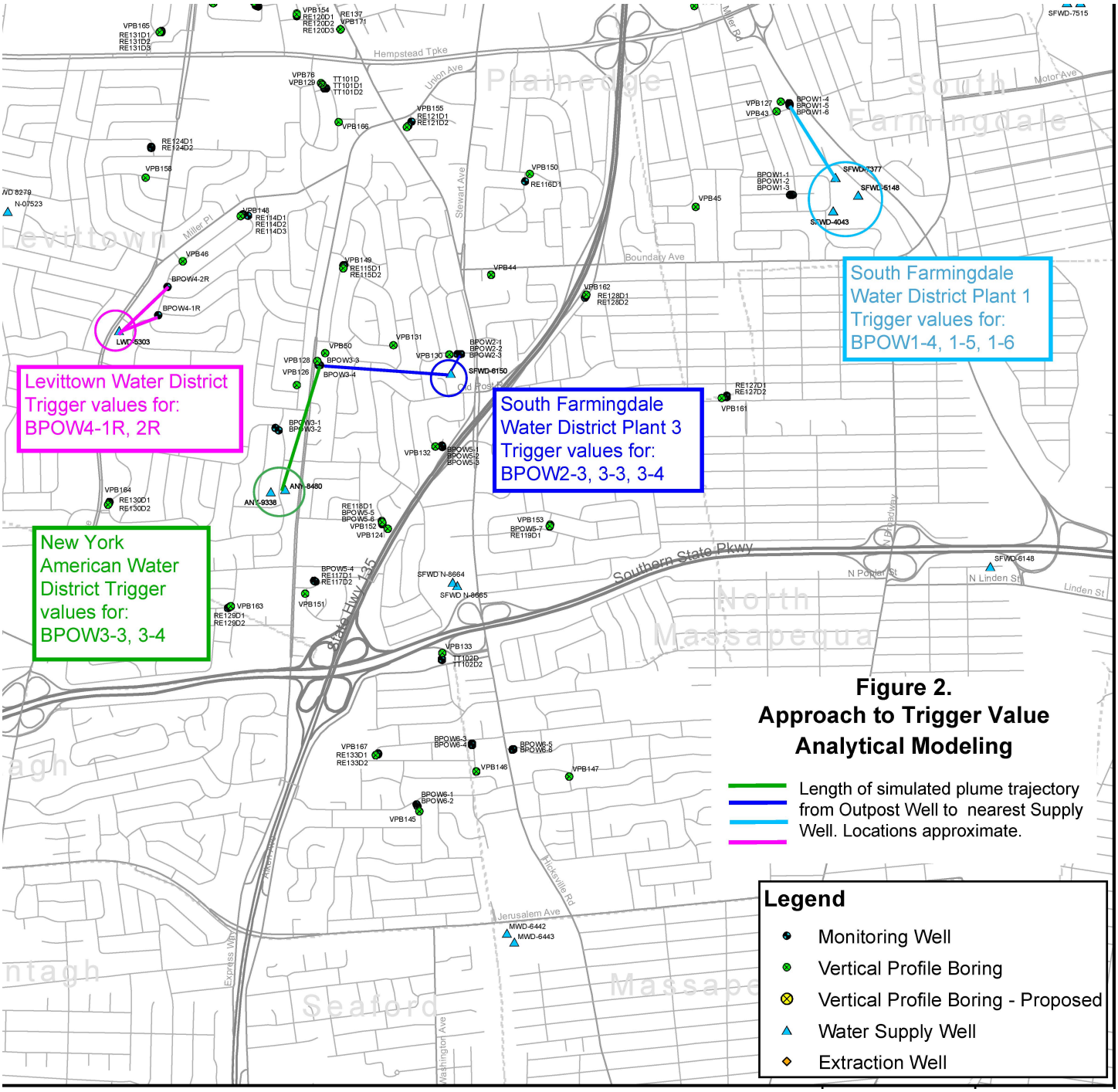

Figure 2.
Approach to Trigger Value Analytical Modeling

Length of simulated plume trajectory from Outpost Well to nearest Supply Well. Locations approximate.

Length of simulated plume trajectory from Outpost Well to nearest Supply Well, color coded by water district. Locations approximate.

NAVFAC	**Figure 2.** **Approach to Trigger Value Analytical Modeling** NAVAL WEAPONS INDUSTRIAL RESERVE PLANT BETHPAGE, NEW YORK	CONTRACT NUMBER: N62470-11-D8013 / CTO NUMBER: WE15 APPROVED BY: PS / DATE: 6/8/2018 APPROVED BY: — / DATE: — FIGURE NO. 2 / REV 0

F:\Projects\Navy\Bethpage WXE0817.0_Deliverables\7.2_CADDGIS_files\Bethpage\MAP DOCS\MXD\MISC\Wells inventory\GW Contours\2018 05\Contours_BaseMap 2018 05 01 D.mxd

mer Northrop
mman Site

GM-18D
GM-39D(A)
GM-39D2 (B)
GM-78I
GM-78S
RE106D2
RE106D1
RE106D3 57.9
GM-73D2 57.19
RE123D1 56.81
RE123D2 56.29
RE123D3 56.59
GM-15D
GM-15S
GM-15D2 58.31
GM-74D
GM-74I
GM-74D2 53.9
GM-24D
GM-24I
GM-21D2 54.77
RE107D1 56.31
RE107D2 56.09
RE107D3 55.89
GM-75D2 56.92
RE126D1 54.88
RE126D2 54.7
RE126D3 54.74
GM-79D
GM-79I
RE109D1 54.43
RE109D2 54.36
RE109D3 54.3
RE122D1 54.58
RE122D2 54.32
RE122D3 53.9
RE108D1 54.29
RE108D2 53.93
RE104D2 51.35
RE104D3 51.08
RE104D1
RE103D1 52.92
RE103D2 52.87
RE103D3 52.78
RW3-MW3
RW3-MW4
RW3-MW1
RW3-MW2
RW2-MW1 51.15
RW1-MW3
RW1-MW1
RW1-MW2
MW-118-5 49.17
RE105D1 49.87
RE105D2 49.24
RE120D1 49.51
RE120D2 49.54
RE120D3 49.49
RE125D2 49.63
RE125D3 49.68
RE125D1
RE131D2 49.31
RE131D3 49.1
RE131D1
RE137 49.18
TT101D1 47.32
TT101D2 46.92
TT101D
RE121D1 46.08
RE121D2 45.73
RE124D1 46.27
RE124D2 45.98
RE114D1 44.36
RE114D2 44.35
RE114D3 44.23
BPOW1-5 42.72
BPOW1-6 42.79
BPOW1-4
BPOW1-1
BPOW1-2
BPOW1-3
RE115D1 42.3
RE115D2 42.37
BPOW4-2R 42.84
BPOW4-1R 42.17
RE128D1 40.06
RE128D2 40.14
BPOW2-1
BPOW2-2
BPOW2-3 35.9
BPOW3-3 39.8
BPOW3-4 39.85
RE127D1 37.09
RE127D2 36.81
BPOW3-2 39.36
BPOW3-1
BPOW5-1 36.09
BPOW5-2 35.92
BPOW5-3 36.02
RE130D1 37.93
RE130D2 38.02
RE118D1 38.97
BPOW5-5 36.21
BPOW5-6 36.17
BPOW5-7 35.7
RE119D1 34.81
RE117D1 34.59
RE117D2 34.72
BPOW5-4 32.2
RE129D1 35.14
RE129D2 35.24
TT102D 31.48
TT102D2 33.6
BPOW6-3 29.32
BPOW6-4 29.7
BPOW6-5 29.38
BPOW6-6 29.03
RE133D1 29.73
RE133D2 29.51
BPOW6-1 28.38
BPOW6-2 28.28

55
50
45
40
35
30

Old Bethpage
Levittown
Plainedge
North Massapequa
North Wantagh

Hempstead Tpke
Central Ave
Powell Ave
Stewart Ave
Broadway
Plainview Rd
Access Rd
Hicksville Rd
N Wantagh Ave
Bethpage State Pkwy
Beech St
Union Ave
Miller Pl
Boundary Ave
E Service Rd
State Hwy 135
Southern State Pkwy
N Jerusalem Rd
Seamans Neck Rd

N

0 500 1,000 2,000 Feet

Note:
Water level elevations (ft amsl) are posted in green to the right of well name. Water levels measured March 29, 2018. Potentiometric contours (ft amsl) are dashed to indicate that they are approximate.

Legend
- Monitoring Well
- Deep
- Intermediate
- Shallow

Figure 3. Synoptic Water Levels March 29, 2018 in Deep Wells (screened >500 ft bgs)

NAVAL WEAPONS INDUSTRIAL RESERVE PLANT
BETHPAGE, NEW YORK

CONTRACT NUMBER	CTO NUMBER
N62470-11-D8013	WE15
APPROVED BY: PS	DATE: 5/1/2018
APPROVED BY: —	DATE: —
FIGURE NO. 3	REV 0

Appendix 1. Quick Domenico Model Documentation

The following Appendix was taken from the Pennsylvania Department of Environmental Protection QD Manual

Appendix 1. QD Model Background

A1.1. Model Derivation

Domenico [1987] published a solution to the three-dimensional differential equation for solute transport in a saturated porous medium with uniform steady-state flow, one-dimensional advection, three-dimensional dispersion, adsorption, and first-order decay [*van Genuchten*, 1985]:

$$\frac{\partial}{\partial t}\left(n_e C + \rho S\right) = \frac{\partial}{\partial x}\left(n_e D_x \frac{\partial C}{\partial x} - qC\right) + n_e D_y \frac{\partial^2 C}{\partial y^2} + n_e D_z \frac{\partial^2 C}{\partial z^2} - \lambda_w n_e C - \lambda_s \rho S \qquad \text{(A1-1)}$$

where:

Table A1.1.

Symbol	Definition	Units
C	solute concentration	M L^{-3}
S	adsorbed concentration	M M^{-1}
n_e	effective porosity	L^3 L^{-3}
ρ	bulk density	M L^{-3}
D_i	coefficients of dispersion	L^2 T^{-1}
q	groundwater flux (Darcy velocity)	L T^{-1}
λ_w	water decay coefficient	T^{-1}
λ_s	soil decay coefficient	T^{-1}
x	longitudinal horizontal distance	L
y	transverse horizontal distance	L
z	downward vertical distance	L
t	time	T

M: mass, L: length, T: time

The following assumptions apply:

- The dissolved and adsorbed contaminant decay coefficients are equal
  $\lambda = \lambda_w = \lambda_s$.

- Properties (n_e and q) are constant in space and time, so there is steady-state flow.

- Adsorption is described by a linear, reversible isotherm
  $S = K_d C$
  where K_d is an empirical distribution coefficient (M^{-1} L^3), and for organics
  $K_d = K_{oc} f_{oc}$
  where K_{oc} is the organic carbon partition coefficient and f_{oc} is the fraction of organic carbon.

See Section A.1.2 below for a further discussion of model assumptions.

The transport equation is then expressed as:

$$\frac{\partial C}{\partial t} = \frac{\alpha_x v}{R}\frac{\partial^2 C}{\partial x^2} + \frac{\alpha_y v}{R}\frac{\partial^2 C}{\partial y^2} + \frac{\alpha_z v}{R}\frac{\partial^2 C}{\partial z^2} - \frac{v}{R}\frac{\partial C}{\partial x} - \lambda C = 0 \qquad \text{(A1-2)}$$

where:

Table A1.2.

Symbol	Definition	Expression	Units
R	retardation	$1 + \frac{\rho K_d}{n_e}$	—
α_i	dispersivity	D_i/v	L
v	interstitial groundwater velocity	q/n_e	L T^{-1}

The following initial and boundary conditions are applied:

- $C(x, y, z, 0) = 0$ (A1-3)
- $C(0, y, z, t) = C_0$ for $-½Y \le y \le +½Y$ and $0 \le z \le Z$ (A1-4)
- $\lim_{x\to\infty} \frac{\partial C(x,y,z,t)}{\partial x} = 0$ (A1-5)
- $\lim_{y\to\pm\infty} \frac{\partial C(x,y,z,t)}{\partial y} = 0$ (A1-6)
- $\lim_{z\to\infty} \frac{\partial C(x,y,z,t)}{\partial z} = 0$ (A1-7)

The *Domenico* [1987] solution of Equation (A1-2) subject to these boundary conditions, and with the inclusion of adsorption, is as follows:

$$C(x,y,z,t) = \frac{C_0}{8}\exp\left[\frac{x}{2\alpha_x}\left(1-\sqrt{1+\frac{4\lambda R\alpha_x}{v}}\right)\right]\times \operatorname{erfc}\left(\frac{x - vt\sqrt{1+\frac{4\lambda R\alpha_x}{v}}}{2\sqrt{\frac{\alpha_x v t}{R}}}\right) \qquad \text{(A1-8)}$$

$$\times\left[\operatorname{erf}\left(\frac{y+Y/2}{2\sqrt{\alpha_y x}}\right) - \operatorname{erf}\left(\frac{y-Y/2}{2\sqrt{\alpha_y x}}\right)\right]\times\left[\operatorname{erf}\left(\frac{z+Z}{2\sqrt{\alpha_z x}}\right) - \operatorname{erf}\left(\frac{z-Z}{2\sqrt{\alpha_z x}}\right)\right]$$

Note that this is a truncated, and not an exact, solution to the problem. Here it is assumed that contamination resides at the top of the aquifer and the only vertical dispersion is downwards.

Quick Domenico and EPA's Bioscreen apply the above solution, Equation (A1-8). Papadopulos and Associates' Bioscreen-AT application performs an exact analytic solution to Equation (A1-2) using a program called ATRANS.

EPA's Biochlor spreadsheet employs a slightly different approach. First, the longitudinal solution is not truncated, so there is a second (smaller) term with a product of an exponent and complementary error function. This will be slightly more accurate, but will not make a significant difference in practice.

Above it was assumed that the dissolved and adsorbed contaminant decay coefficients are equal. A second difference with the Biochlor solution is that the sorbed phase coefficient is zero:

$\lambda_s = 0$

$\lambda = \lambda_w$.

The resultant transport equation is then:

$$\frac{\partial C}{\partial t} = \frac{\alpha_x v}{R}\frac{\partial^2 C}{\partial x^2} + \frac{\alpha_y v}{R}\frac{\partial^2 C}{\partial y^2} + \frac{\alpha_z v}{R}\frac{\partial^2 C}{\partial z^2} - \frac{v}{R}\frac{\partial C}{\partial x} - \frac{\lambda}{R}C = 0 \qquad \text{(A1-9)}$$

This is identical to Equation (A1-2) except for the last term, where λ is divided by R. Therefore, if one wishes to run Biochlor *without* assuming zero sorbed-phase decay, values of $R\lambda$ may be entered in place of λ.

A1.2. Model Assumptions

Domenico's solution to the advective–dispersive equation incorporates the following assumptions.

- Aquifer properties are homogeneous and isotropic. For instance, porosity and hydraulic conductivity are spatially uniform, and there is no directional dependence.
- The flow field is homogeneous and unidirectional. The hydraulic gradient and groundwater velocity are constant in magnitude and direction throughout the model space. There are no pumping or recharge conditions altering the natural flow. The flow field is not radial, convergent, or divergent. There are no vertical flow gradients.
- Groundwater flow is in steady state. The hydraulic gradient and groundwater velocity are constant in time.
- The source shape is defined as a vertical rectangle perpendicular to groundwater flow.
- The source dimensions and concentration are constant with time.
- The aquifer is initially free of the contaminant, other than at the source.
- Both the aqueous and sorbed contaminant phases may undergo first-order decay, and the decay rate is the same for both.
- There is no transverse or vertical contaminant decay.
- Contaminants undergo linear, reversible, isothermal adsorption.
- Flow velocities are sufficiently high that mechanical dispersion dominates diffusion.

A1.3. Mathematical Approximations

The approximations inherent to the Domenico solution have been examined by *West* et al. [2007] and *Srinivasan* et al. [2007]. They pointed out three significant mathematical inaccuracies.

- The three-dimensional solution is taken to be the product of three one-dimensional solutions. This approach does not conserve mass.

- The longitudinal solution $C(x,t)$ omits a secondary term in QD and Bioscreen. The error is large when the dispersivity (α_x) is large such that x/α_x is relatively small.

- Domenico made the time substitution $t = x/v$, where v is the groundwater velocity. This is only correct when $\alpha_x = 0$. For nonzero longitudinal dispersivity, there are sizable errors especially forward of the advective front. This time reinterpretation also exaggerates the plume width.

West et al. [2007] and *Srinivasan* et al. [2007] concluded that contaminant concentrations may be significantly underestimated on the plume centerline. Errors can be minimized when:

- longitudinal dispersivities are low (α_x)
- advection velocities are high ($v = Ki$)
- simulation times are long (t).

Users must practice caution when making site predictions using fate-and-transport models as discussed by *Konikow* [2010].

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Appendix 2. Model Output

South Farmingdale Water District Plant 1
Outpost Wells
BPOW1-4, BPOW1-5, BPOW1-6

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project:	Bethpage SFWD Plant 1, BPOW1-4, 1-5, 1-6		
Date:	4/10/2018	Prepared by:	P. Shattuck
		Contaminant:	

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

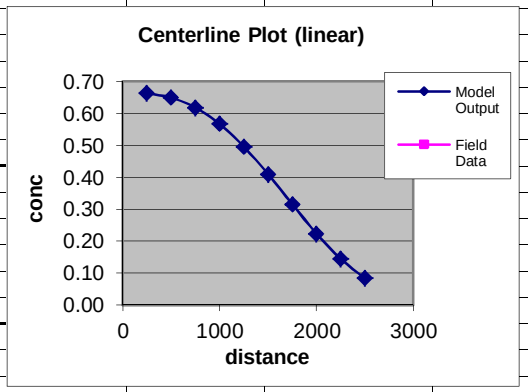
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
0.67	1.26E+02	1.26E+01	1.26E-01	0	630	214	1825

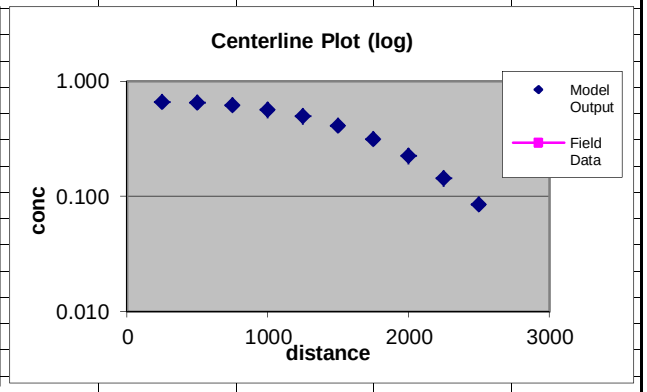
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
7.50E+01	0.002	0.15	1.8	0	0.00E+00	1	1

Point Concentration

x(ft)	y(ft)	z(ft)
1260	0	0

	x(ft)	y(ft)	z(ft)
Conc. At	1260	0	0
at	1825	days =	0.493 mg/l





AREAL MODEL CALCULATION DOMAIN

Length (ft) 2500

Width (ft) 600

	250	500	750	1000	1250	1500	1750	2000	2250	2500
600	0.000	0.004	0.012	0.022	0.029	0.033	0.032	0.027	0.021	0.014
300	0.381	0.361	0.344	0.320	0.287	0.243	0.192	0.140	0.093	0.055
0	0.663	0.650	0.618	0.567	0.496	0.410	0.316	0.224	0.145	0.085
-300	0.381	0.361	0.344	0.320	0.287	0.243	0.192	0.140	0.093	0.055
-600	0.000	0.004	0.012	0.022	0.029	0.033	0.032	0.027	0.021	0.014

Field Data: Centerline C Concentration

Distance from Source

Appendix 3. Model Output

South Farmingdale Water District Plant 3
Outpost Wells
BPOW2-3, BPOW3-3, BPOW3-4

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project:	Bethpage SFWD Plant 3, BPOW2-3		
Date:	4/10/2018	Prepared by:	P. Shattuck
		Contaminant:	

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

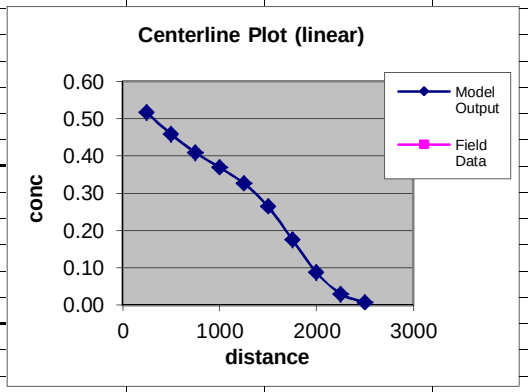
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
0.54	3.30E+01	3.30E+00	3.00E-02	0	165	67	1825

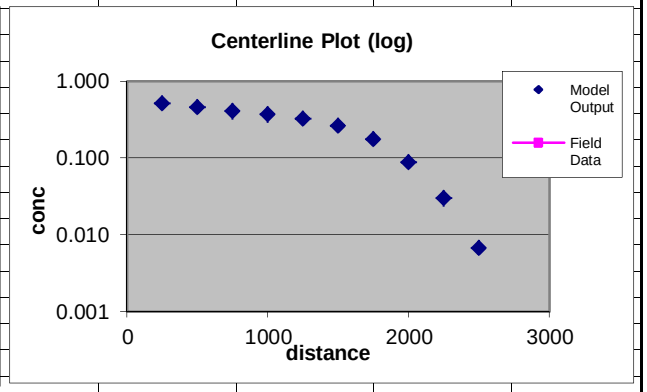
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
7.50E+01	0.002	0.15	1.8	0	0.00E+00	1	1

Point Concentration

x(ft)	y(ft)	z(ft)
330	0	0

	x(ft)	y(ft)	z(ft)
Conc. At	330	0	0
at	1825	days =	0.498 mg/l





AREAL MODEL DOMAIN CALCULATION

Length (ft) 2500
Width (ft) 600

	250	500	750	1000	1250	1500	1750	2000	2250	2500
600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
300	0.000	0.000	0.001	0.002	0.004	0.006	0.007	0.005	0.002	0.001
0	0.517	0.458	0.409	0.369	0.327	0.264	0.176	0.087	0.030	0.007
-300	0.000	0.000	0.001	0.002	0.004	0.006	0.007	0.005	0.002	0.001
-600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Field Data: Centerline C Concentration
Distance from Source

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project:	Bethpage SFWD Plant 3, BPOW3-3, 3-4		
Date:	4/10/2018	Prepared by:	P. Shattuck
		Contaminant:	

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

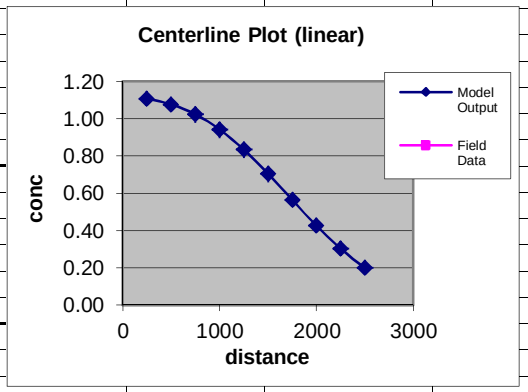
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
1.14	1.87E+02	1.87E+01	1.87E-01	0	930	67	1825

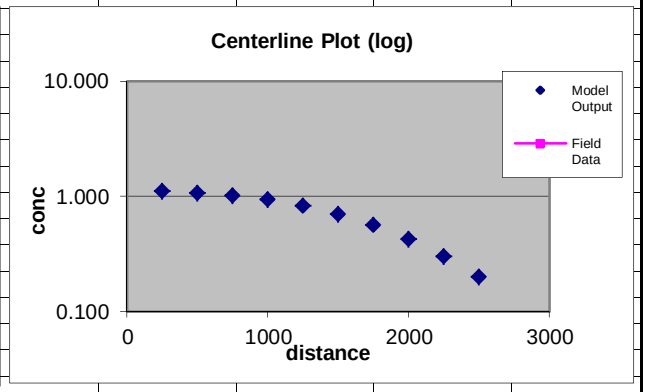
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
7.50E+01	0.002	0.15	1.8	0	0.00E+00	1	1

Point Concentration

x(ft)	y(ft)	z(ft)
1870	0	0

	x(ft)	y(ft)	z(ft)
Conc. At	1870	0	0
at	1825	days =	0.497 mg/l





AREAL MODEL CALCULATION DOMAIN

Length (ft) 2500

Width (ft) 600

	250	500	750	1000	1250	1500	1750	2000	2250	2500
600	0.090	0.174	0.216	0.232	0.229	0.211	0.181	0.145	0.109	0.075
300	1.059	0.955	0.863	0.770	0.669	0.560	0.448	0.339	0.241	0.160
0	1.108	1.077	1.024	0.943	0.834	0.704	0.564	0.426	0.302	0.200
-300	1.059	0.955	0.863	0.770	0.669	0.560	0.448	0.339	0.241	0.160
-600	0.090	0.174	0.216	0.232	0.229	0.211	0.181	0.145	0.109	0.075

Field Data: Centerline C Concentration

Distance from Source

Appendix 4. Model Output

Levittown Water District Well 5303
Outpost Wells
BPOW4-1R, BPOW4-2R

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project:	Bethpage LWD WELL, BPOW4-1R		
Date:	4/10/2018	Prepared by:	P. Shattuck
		Contaminant:	

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

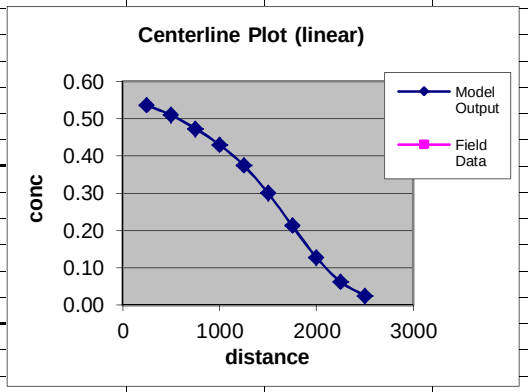
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
0.54	6.00E+01	6.00E+00	6.00E-02	0	300	116	1825

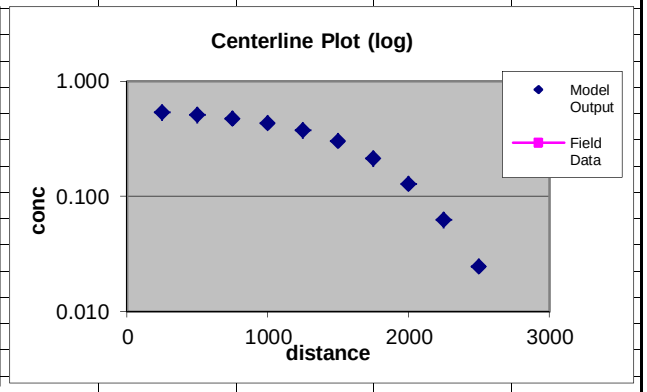
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
7.50E+01	0.002	0.15	1.8	0	0.00E+00	1	1

Point Concentration

x(ft)	y(ft)	z(ft)
600	0	0

	x(ft)	y(ft)	z(ft)
Conc. At	600	0	0
at	1825	days =	0.496 mg/l





AREAL MODEL DOMAIN CALCULATION

Length (ft) 2500
Width (ft) 600

	250	500	750	1000	1250	1500	1750	2000	2250	2500
600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
300	0.002	0.014	0.030	0.044	0.053	0.054	0.045	0.031	0.017	0.008
0	0.536	0.510	0.473	0.430	0.375	0.301	0.213	0.128	0.063	0.025
-300	0.002	0.014	0.030	0.044	0.053	0.054	0.045	0.031	0.017	0.008
-600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Field Data: Centerline C Concentration
Distance from Source

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project:	Bethpage LWD WELL, BPOW4-2R		
Date:	4/10/2018	Prepared by:	P. Shattuck
		Contaminant:	

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

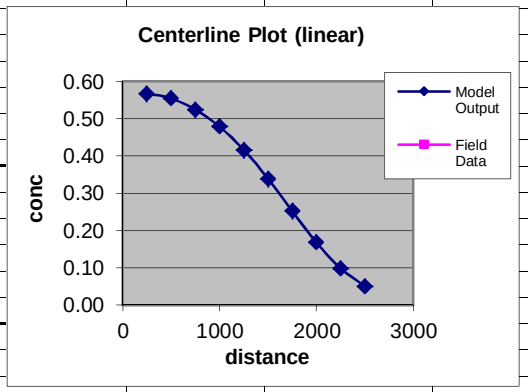
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
0.57	9.30E+01	9.30E+00	9.30E-02	0	465	116	1825

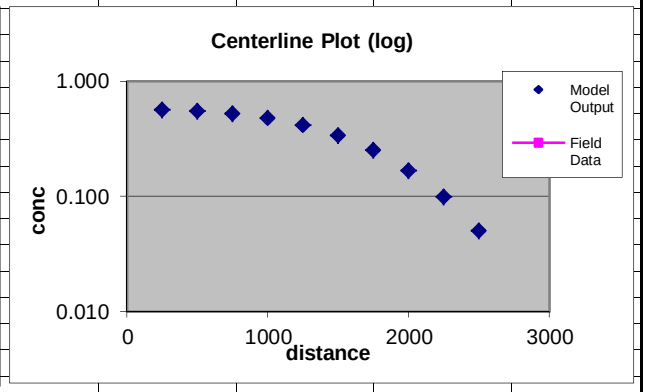
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
7.50E+01	0.002	0.15	1.8	0	0.00E+00	1	1

Point Concentration

x(ft)	y(ft)	z(ft)
930	0	0

	x(ft)	y(ft)	z(ft)
Conc. At	930	0	0
at	1825	days =	0.493 mg/l





AREAL MODEL CALCULATION DOMAIN

Length (ft)	2500
Width (ft)	600

	250	500	750	1000	1250	1500	1750	2000	2250	2500
600	0.000	0.000	0.001	0.002	0.004	0.006	0.007	0.006	0.005	0.003
300	0.092	0.136	0.157	0.163	0.157	0.139	0.111	0.078	0.049	0.026
0	0.568	0.554	0.524	0.479	0.417	0.339	0.252	0.168	0.099	0.051
-300	0.092	0.136	0.157	0.163	0.157	0.139	0.111	0.078	0.049	0.026
-600	0.000	0.000	0.001	0.002	0.004	0.006	0.007	0.006	0.005	0.003

Field Data: Centerline C Concentration
Distance from Source

Appendix 5. Model Output

New York American Water Wells 8480 and 9338
Outpost Wells
BPOW3-3, BPOW3-4

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project:	Bethpage NYAW WELLS, BPOW3-3, 3-4		
Date:	4/10/2018	Prepared by:	P. Shattuck
		Contaminant:	

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987)
Modified to Include Retardation

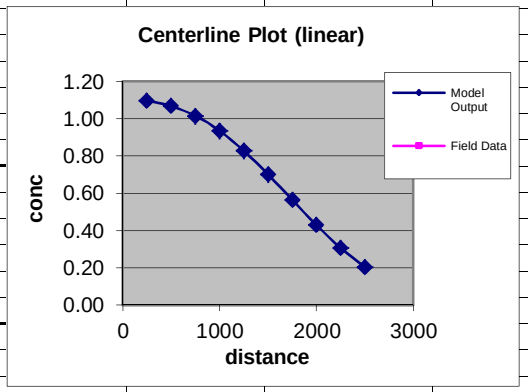
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
1.13	1.87E+02	1.87E+01	1.87E-01	0	936	95	1825

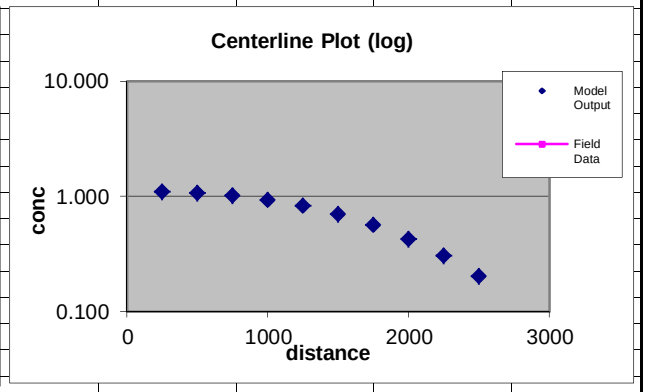
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
7.50E+01	0.002	0.15	1.8	0	0.00E+00	1	1

Point Concentration

x(ft)	y(ft)	z(ft)
1870	0	0

	x(ft)	y(ft)	z(ft)
Conc. At	1870	0	0
at	1825	days =	0.499 mg/l





AREAL MODEL CALCULATION DOMAIN

Length (ft)	2500
Width (ft)	600

	250	500	750	1000	1250	1500	1750	2000	2250	2500
600	0.095	0.179	0.220	0.235	0.232	0.213	0.183	0.148	0.111	0.078
300	1.053	0.951	0.860	0.767	0.668	0.561	0.450	0.342	0.245	0.164
0	1.098	1.068	1.016	0.936	0.829	0.702	0.565	0.429	0.306	0.204
-300	1.053	0.951	0.860	0.767	0.668	0.561	0.450	0.342	0.245	0.164
-600	0.095	0.179	0.220	0.235	0.232	0.213	0.183	0.148	0.111	0.078

Field Data: Centerline C Concentration
Distance from Source

NEW YORK PROFESSIONAL GEOLOGIST SEAL

As a New York-licensed Professional Geologist, I have reviewed and approve this Trigger Value Development Addendum #2 to the Operable Unit 2 Offsite Groundwater Public Water Supply Contingency Plan, and seal it in accordance with Article 145 Section 7209 of the New York State Education Laws. In sealing this document, I certify it was prepared under my direction, the geological information contained in it is true to the best of my knowledge and the geological methods and procedures included herein are consistent with currently accepted geological practices.

It is a violation of this law for any person to alter the contained drawings or the report in any way, unless he or she is acting under the direction of a NY-licensed Professional Geologist.

Name:	Brian E. Caldwell
NY PG License Number:	000511
State:	New York

Signature: _____

Date: 8/7/18