PLAN COMPLETION REPORT FOR THE VB 4 AREA

BRAIDWOOD GENERATION STATION
BRACEVILLE, ILLINOIS

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EXECUTIVE SUMMARY

The information and data contained in this Plan Completion Report for Vacuum Breaker 4 (VB 4) demonstrates the remedial objectives have been achieved. More specifically:

- Concentrations of tritium in groundwater in the area of VB 4 are approximately 5,000% below USEPA's drinking water standard of 20,000 pCi/L; and
- As demonstrated by BIOSCREEN Transport Modeling Data, the residual levels of tritium in the VB 4 area will not migrate onto private property at levels above the LLD of 200 pCi/L.

1.0 INTRODUCTION

1.1 BACKGROUND AND PURPOSE

This document has been prepared for the Illinois Environmental Protection Agency (IEPA) to address on-going groundwater remediation at the Exelon Generation Company LLC's (Exelon) Braidwood Generating Station property located in Braceville, Illinois.[1] More specifically, this Plan Completion Report addresses the Vacuum Breaker 4 (VB 4) area (Site) and discusses the groundwater investigation, monitoring, and remedial actions that were implemented in accordance with the Agreed Preliminary Injunction Order (PIO) dated May 24, 2006. Information collected to date as a result of Action Plan implementation is sufficient to determine that remediation at the VB 4 area is complete and can be concluded.

Among other things, the May 24, 2006, PIO required Exelon to submit a Groundwater Action Plan to address tritium in groundwater near Braidwood Station's VB 4. As a result, in November 2006, Exelon submitted to the IEPA a Minimize Impairment Plan, hereinafter referred to as the "Action Plan", for VB 4. Upon the IEPA's approval of the Action Plan, the plan was implemented.

As a result of the implementation of the approved Action Plan, the concentrations of tritium detected in groundwater have been reduced to less than 200 picocuries per liter (pCi/L) in the VB 4 area, with one exception at monitoring well VB-4-6D (at 408 pCi/L). Additionally, a significant amount of environmental data has been collected as part of the Action Plan implementation. Analyses of these data have revealed the geologic and hydrogeologic characteristics of the subject area, providing an understanding of the groundwater movement and tritium migration. This Plan Completion Report for the VB 4 area is based on Site characterization data collected through June 2011 which indicate a substantial reduction in tritium levels through passive remediation.

Information collected to date as a result of the Action Plan implementation is sufficient to determine that remediation at the VB 4 area is complete and can be concluded.

Section 5.0 of this Plan Completion Report provides a list of references specific to the VB 4 area as well as pertinent documents related to the other areas on the Braidwood Station property where remediation of tritium in groundwater is being performed.

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[1] The Braidwood Station property includes lands listed under the Station's Nuclear Regulatory Commission (NRC) licensed property along the blowdown line and property recently purchased by Exelon along Smiley Road and Center Street.

1.2 DESCRIPTION OF REMEDIATION AREA

Land surrounding the VB 4 area falls mainly into the agricultural, residential, and recreational use categories (Figure 1.1). The center of the Village of Braidwood is approximately 7,000 feet northwest from vacuum breaker VB 4. To the northwest of the Site, there are two main highways (Illinois State Highway 53 and Illinois Route 129) running parallel to each other with a railroad (Southern Pacific Railroad) between them. VB 4 is located approximately 1.5 miles east of Braidwood Station along the blowdown line. To the north and south of the Site is a forested area. The Will County Forest Preserve District (WCFPD) owns the property directly north and south of the right-of-way at the VB 4 area (Figure 1.2).

1.3 SUMMARY OF REMEDIAL ACTIONS TO DATE AND CURRENT GROUNDWATER CONDITIONS

The current groundwater remediation program for the VB 4 area utilizes passive techniques, which includes monitored natural attenuation (MNA). Groundwater flow and tritium concentrations are monitored quarterly and compared to predictive modeling. At this location, the tritium detected in groundwater is declining and migrating as predicted through previous BIOSCREEN groundwater models simulations (see Appendix A for BIOSCREEN Modeling Results memorandum).

Currently, there are five monitoring wells in the VB 4 area (MW-145D, MW-157D, VB-4-1, VB-4-5D, and VB-4-6D). Blowdown line monitoring well BL-21 is also in the vicinity of the VB 4 area and has been included in the analysis of the area. The concentration of tritium in groundwater at these monitoring wells has been reduced by as much as 100% since September 2006 (e.g., MW-157D). As of June 2011, the highest tritium concentration detected at the VB 4 area was detected in VB-4-6D at a concentration of 408 pCi/L, substantially less than the federal drinking water standard of 20,000 pCi/L. With the exception of VB-4-6D, the tritium concentrations detected in the monitoring wells continue to decline as a result of natural attenuation. For VB-4-6D, no trend could be identified for the period between February 2006 and June 2011 due to the fluctuation in tritium concentrations. These fluctuations are likely due to seasonal changes affecting the water table. However, since December 2009, tritium concentrations have decreased by 90% (from 3,920 pCi/L to 408 pCi/L).

2.0 CURRENT GROUNDWATER CONDITIONS AT THE VB 4 AREA

This section presents a description of the pre-remediation and current groundwater conditions at the VB 4 area.

2.1 BACKGROUND

Vacuum Breaker VB 4 is located on the blowdown line about 500 yards east of Cemetery Road and 400 yards north of Smiley Road on the Exelon transmission tower right-of-way (Figure 1.2). The WCFPD owns the property directly north and south of the right-of-way.

Following the installation of the blowdown booster pump in 2003, flow in the line increased. The increased flow raised the water level in the pipe at this vacuum breaker to the point where the valve would occasionally cycle to relieve air. Each time that a vacuum breaker cycles, it releases a small amount of water. Station engineers estimated that this valve cycled every 5 minutes, releasing about 8 ounces of water each time. The combined release resulted in a maximum of 130,000 gallons of water being discharged. The observations of Station personnel suggest that water did not overflow the VB 4 vault but was released directly to the subsurface.

The groundwater data collected demonstrate that a relatively small volume of the water released to the subsurface contained tritium. The bottom of the VB 4 vacuum breaker vault is significantly above the groundwater, 10 feet above the water table, and, therefore, the water was released to the vadose zone (unsaturated soils) and then to the shallow groundwater. The upward vertical groundwater gradient would also mean that the water would not flow to the base of the aquifer. The tritium concentrations detected in groundwater and the smaller plume size at VB 4 are consistent with the release records.

2.2 PRE-REMEDIATION GROUNDWATER CONDITIONS

Since late 2005, a total of 39 monitoring wells have been installed into the deep and shallow zones of the overburden sand aquifer in the VB 4 area. The majority of these monitoring wells have been abandoned. Currently, there are five monitoring wells in the VB 4 area. Figure 2.1 presents the current, existing monitoring well network in the vicinity of VB 4. Figure 2.1 presents the approximate locations of private water supply wells located in the vicinity of the VB 4 area. The nearest private wells, in a generally

downgradient location (northeast), are found at over 3,600 feet northeast of VB-4-6D [where tritium is detected above the Lower Level of Detection (LLD) of 200 pCi/L].

2.3 REMEDIAL ACTION PLAN IMPLEMENTED AT THE VB 4 AREA

The remedial action plan selected for the VB 4 area is monitored natural attenuation (MNA). An endangerment assessment was conducted which consisted of the review of the potential health effects of tritium, applicable groundwater standards, Site-specific background tritium concentrations, and exposure route pathways. The review was followed by the development and implementation of a performance-monitoring program designed to determine the effectiveness of the MNA remedial approach.

Performance monitoring consists of the collection of groundwater elevation data and the collection of groundwater samples for tritium analysis. Since December 2005, Exelon has been monitoring tritium concentrations in groundwater near the VB 4 area. In September 2006, Exelon implemented routine quarterly groundwater monitoring as part of the Action Plan described above. As a result, more than 5 years of data, including groundwater levels and tritium concentrations, have been collected. Since implementation of the Action Plan, an additional 19 quarters of sampling data have been collected, analyzed, and submitted to the IEPA for evaluation. This groundwater monitoring is in addition to the Nuclear Regulatory Commission (NRC) required groundwater sampling performed under the Station's Radiological Environmental Monitoring Program (REMP).

The MNA remedy will ultimately reduce tritium levels both on and off the Station property to below the LLD of 200 pCi/L or less than 1% of the established drinking water standard of 20,000 pCi/L. Groundwater levels and groundwater samples are currently collected at the VB 4 area on a quarterly schedule.

Groundwater flow and tritium transport modeling performed at the VB 4 area was presented in the report prepared by CRA entitled "Groundwater Flow and Tritium Transport Modeling, Braidwood Generating Station" (CRA, August 2006). The modeling performed at that time indicated that the tritium in the VB 4 area would not impact groundwater users off the licensed property or areas downgradient of the blowdown line property limits. The modeling results also suggest that 200 pCi/L would be reached through natural attenuation within 7 to 10 years at locations off the licensed property (i.e., within the Will County Forest Preserve property).

2.4 CURRENT GROUNDWATER CONDITIONS

Figure 2.2 presents the groundwater elevations and flow direction in the overburden sand aquifer for June 2011. As indicated by this figure, groundwater at the VB 4 area flows generally north-northeast.

Figure 2.3 presents the estimated horizontal distribution of tritium in the vicinity of VB 4 utilizing June 2011 data in the overburden aquifer. As illustrated on Figure 2.3, the highest tritium concentrations are downgradient of VB 4. The groundwater plume of tritium concentrations extends to the north from the VB-4-6D monitoring well location.

The current trends of decreasing tritium concentrations within groundwater at the VB 4 area (January 2006 through June 2011) are depicted on Figure 2.4 and in Table 2.1.

Table 2.1 includes monitoring wells that have been abandoned in the area, such as VB-4-15, VB-4-15D, VB-4-16, VB-4-16D, VB-4-17, VB-4-17D, VB-4-18, and VB-4-18D. These temporary monitoring wells were installed as part of the initial characterization in 2006 in order to delineate the plume from VB 4. Subsequently, other monitoring wells were selected for routine monitoring, and these wells are no longer used and were abandoned in late August 2006. VB-4-15, VB-4-15D, VB-4-16, and VB-4-16D were located upgradient of VB 4 and, as such, did not indicate elevated tritium concentrations. VB-4-17, VB-4-17D, VB-4-18, and VB-4-18D were located downgradient of VB 4 and did indicate elevated concentrations of tritium during the 2006 investigation. Due to the limited number of samples collected at each of these locations prior to abandonment, a full statistical analysis could not be performed for VB-4-17, VB-4-17D, VB-4-18, and VB-4-18D. These data are provided for informational purposes. Permanent monitoring wells, MW-145D and MW-157D, were installed within the vicinity of the downgradient abandoned wells for routine monitoring.

Table 2.1 provides a summary of the statistical analyses of the monitoring wells sampled between January 2006 and June 2011. Statistical analyses include the trend, percent reduction, and minimum and maximum concentrations for each monitoring well in the VB 4 area. Two monitoring wells in or near the VB 4 area, BL-21 and VB-4-5D, continue to indicate levels of tritium less than the LLD of 200 pCi/L from 2006 to June 2011 and, therefore, were excluded from the statistical analysis. Groundwater samples collected at four monitoring wells in the VB 4 area have contained tritium detected at levels above the LLD of 200 pCi/L between 2006 and June 2011, and these were utilized for statistical analysis. The overall percent reduction of tritium concentrations between 2006 and June 2011 is provided for each monitoring well in Table 2.1. Tritium concentrations near the source have been reduced by as much as 100%, from 17,000 pCi/L in December 2007 to less than the LLD of 200 pCi/L in June 2011, as shown at location MW-157D. Figure 2.4

presents the predominantly downward trend in tritium concentrations over time at select monitoring wells in the VB 4 area.

Concentrations of tritium detected at monitoring well VB-4-6D, which is located approximately 800 feet north and downgradient of VB 4, have until recently increased with time. Refer to Table 2.1 and Figure 2.4. This is attributed to the location of the center of the tritium plume, which was released at VB 4 and migrated downgradient with natural groundwater flow. However, since late 2009 the concentrations of tritium at VB-4-6D have decreased with time. This is evidence that the plume is being dispersed and attenuating naturally as it moves into the groundwater system.

The June 2011 tritium concentration data were utilized to run a BIOSCREEN model under current conditions. The model was run to determine the distance from the source concentration (VB-4-6D)[2] to the extent where the tritium plume concentrations are at background concentrations (200 pCi/L). The BIOSCREEN results indicated that steady state is achieved in 3 years. The distance from the source area (VB-4-6D) to the LLD for tritium is approximately 94 feet. Figure 2.5 illustrates the predicted plume extent to concentrations of less than the LLD of 200 pCi/L.

The nearest downgradient private well is located approximately 3,600 feet to the northeast from monitoring well VB-4-6D. Based upon modeling results, the private wells in the vicinity of the VB 4 area are not expected to be impacted with tritium concentrations greater than 200 pCi/L by the plume originating from the releases at VB 4. The residual levels of tritium in the groundwater in the VB 4 area remain either on the Station property or on the WCFPD property where institutional controls and deed restrictions prohibit groundwater use.

2.5 EVALUATION OF REMEDIAL ACTIVITIES TO DATE

A review of the data, evaluations, and graphical presentations provided in Table 2.1 and on Figures 2.2 through 2.5 provides sufficient information to demonstrate the following regarding the cleanup of tritium in the VB 4 area:

- There is no groundwater in this area that is above the drinking water standard of 20,000 pCi/L;
- The maximum concentration of tritium in this area as of June 2011 is 408 pCi/L;

[2] The source was assumed to be in the area of monitoring well VB-4-6D.

- Tritium concentrations have been reduced by 100% at all but one monitoring well (VB-4-6D). VB-4-6D has decreased 90% from the maximum concentration in December 2009 to the June 2011 concentration;
- Only one out of five monitoring wells sampled during the comprehensive sampling event in June 2011 indicated tritium concentrations above 200 pCi/L;
- With the exception of two of the four monitoring wells in this area utilized for statistical analysis, the trend in tritium concentrations in routine sampling events has been downward. The other two monitoring wells did not indicate a trend. A trend at VB-4-1 could not be determined since tritium has not been detected at that location since September 2006. An over all trend could not be determined at VB-4-6D due to the fluctuations in tritium concentrations; however, this location has exhibited a 90% decrease since December 2009;[3] and
- The limits of tritium in groundwater above 200 pCi/L are restricted to (1) the licensed nuclear property; and (2) property owned by the Will County Forest Preserve.

[3] As discussed previously, this location represents the center of the plume which has migrated from VB 4 to the north with natural groundwater flow.

3.0 CONCLUSIONS

The previous sections of this Plan Completion Report have identified the nature and extent of tritium in groundwater near VB 4 and the progress of the remediation completed over the last 5 years. This information demonstrates the success of the cleanup of tritium in groundwater at the VB 4 area.

Specifically, the following remedial objectives have been met for the VB 4 area:

- Concentrations of tritium in groundwater resulting from the vacuum breaker releases are below the drinking water standard of 20,000 pCi/L; and
- Residual concentrations of tritium above 200 pCi/L will not impact off-Site, private groundwater users.

These remedial objectives are documented through the following facts:

- Tritium concentrations at all VB 4 area monitoring wells are below 20,000 pCi/L and have been since March 2007;
- The highest concentration of tritium as of June 2011 is 408 pCi/L (VB-4-6D), and the tritium concentration at VB-4-6D has had a reduction of 90% since December 2009;
- BIOSCREEN transport modeling of this area indicates that residual levels of tritium in groundwater will not migrate onto private property at levels above the LLD of 200 pCi/L; and
- The closest private well receptor downgradient from the predicted plume extent is approximately 3,600 feet to the northeast and over 3,500 feet from the maximum simulated extent of the tritium plume.

4.0 PLANNED COMPLETION ACTIVITIES

Groundwater sampling and analyses for tritium at the VB 4 area will be eliminated, and all five monitoring wells will be plugged and abandoned. The monitoring wells to be abandoned are listed in Table 4.1.

5.0 REFERENCES

CRA, March 2006. Tritium Investigation, Exelon Generation, Braidwood Station, Braceville, Illinois.

CRA, April 2006. Investigation of Tritium in Groundwater in the Vicinity of Vacuum Breaker 4, Braidwood Station, Braceville, Illinois.

CRA, May 2006. Agreed Preliminary Injunction Order.

CRA, June 2006. Migration Control Plan Vacuum Breaker 4, Braidwood Generation Station, Braceville, Illinois.

CRA, August 2006. Groundwater Flow and Tritium Transport Modeling, Braidwood Generating Station, Braceville, Illinois.

CRA, September 2006. Hydrogeologic Investigation Report, Fleetwide Assessment, Braidwood Generating Station.

CRA, November 2006. Hydraulic Monitoring for the Will County Forest Preserve Work Plan Braidwood Generating Station Braceville, Illinois.

CRA, November 2006. Minimize Impairment Plan for Vacuum Breaker 4 Braidwood Generation, Station Braceville, Illinois.

CRA, December 2006. CRA Memorandum, Transient Groundwater Flow Model Calibration and Transport Model Scenario Update.

CRA, January 2007. Wedron Clay Till Investigation Report Braidwood Generating Station, Braceville, Illinois.

Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000. MODFLOW-2000, The U. S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process, United States Geological Survey Open-File Report 00-92, Reston, Virginia.

Harbaugh, A.W. and M.G. McDonald, 1996a. User's Documentation for MODFLOW-96, an update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model, United States Geological Survey Open-File Report 96-485, Reston, Virginia.

Harbaugh, A.W. and M.G. McDonald, 1996b. User's Documentation for MODFLOW-96, an update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model, United States Geological Survey Open-File Report 96-486, Reston, Virginia.

McDonald, M.G. and A.W. Harbaugh, 1988. A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, United States Geological Survey Open-File Report 83-875.

Pollock, D.W., 1994. User's Guide for MODPATH/MODPATH-PLOT, Version 3: A particle tracking post-processing package for MODFLOW, the U.S. Geological Survey finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 94-464.

Sargent and Lundy, 1988. Updated Final Safety Analysis Report (UFSAR) Revision 1.0, December 1994. Chapters 2.4 and 2.5.

Zheng, C., and P. Wang, 1999. MT3DMS: MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide. Prepared by University of Alabama, Prepared for US Army Corps of Engineers.

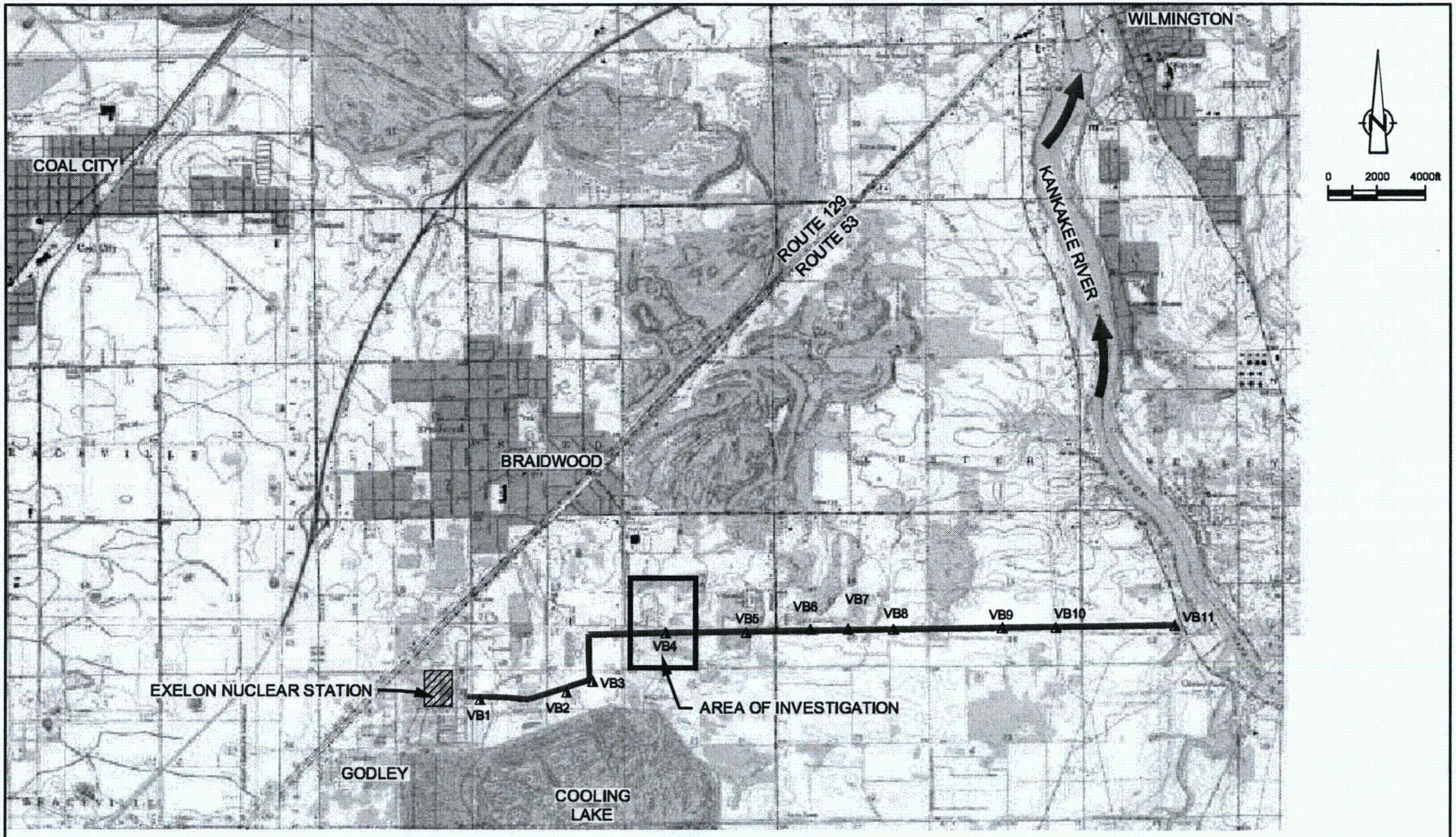
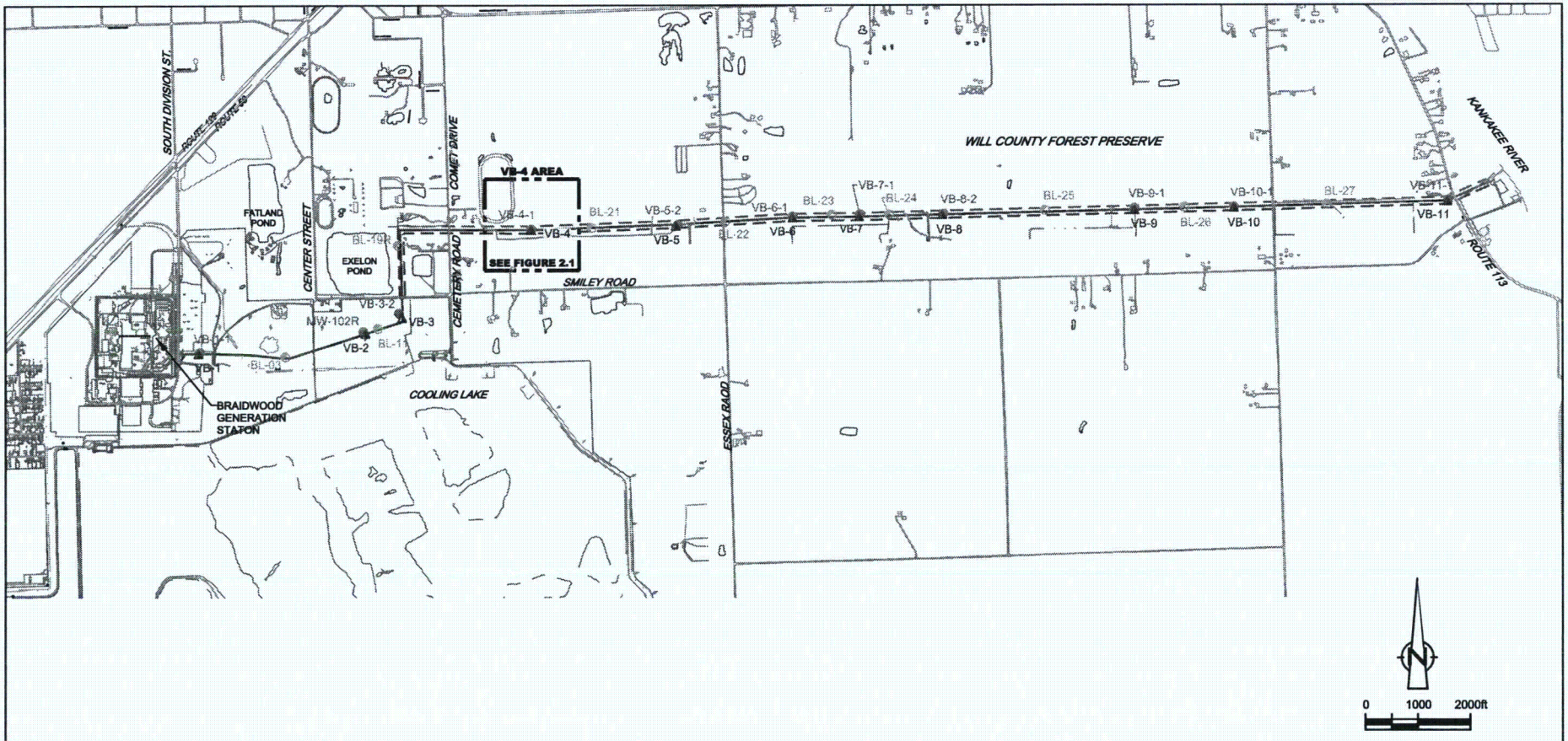


figure 1.1

VB 4 SITE LOCATION MAP
EXELON GENERATION BRAIDWOOD STATION
Braceville, Illinois

16841-44(040)GN-CO001 OCT 20/2011



LEGEND

- APPROXIMATE BLOWDOWN PROPERTY LINE
- BLOWDOWN LINE
- MAKEUP LINE
- VB-1 ▲ VACUUM BREAKER
- BL-03 ◐ MIDPOINT BLOWDOWN LINE MONITORING WELL LOCATION AND IDENTIFIER
- VB-1-1 ● VACUUM BREAKER MONITORING WELL LOCATION AND IDENTIFIER

figure 1.2

LOCATION MAP FOR VB 4 AREA
EXELON GENERATION BRAIDWOOD STATION
Braceville, Illinois

16841-44(040)GN-CO002 OCT 20/2011

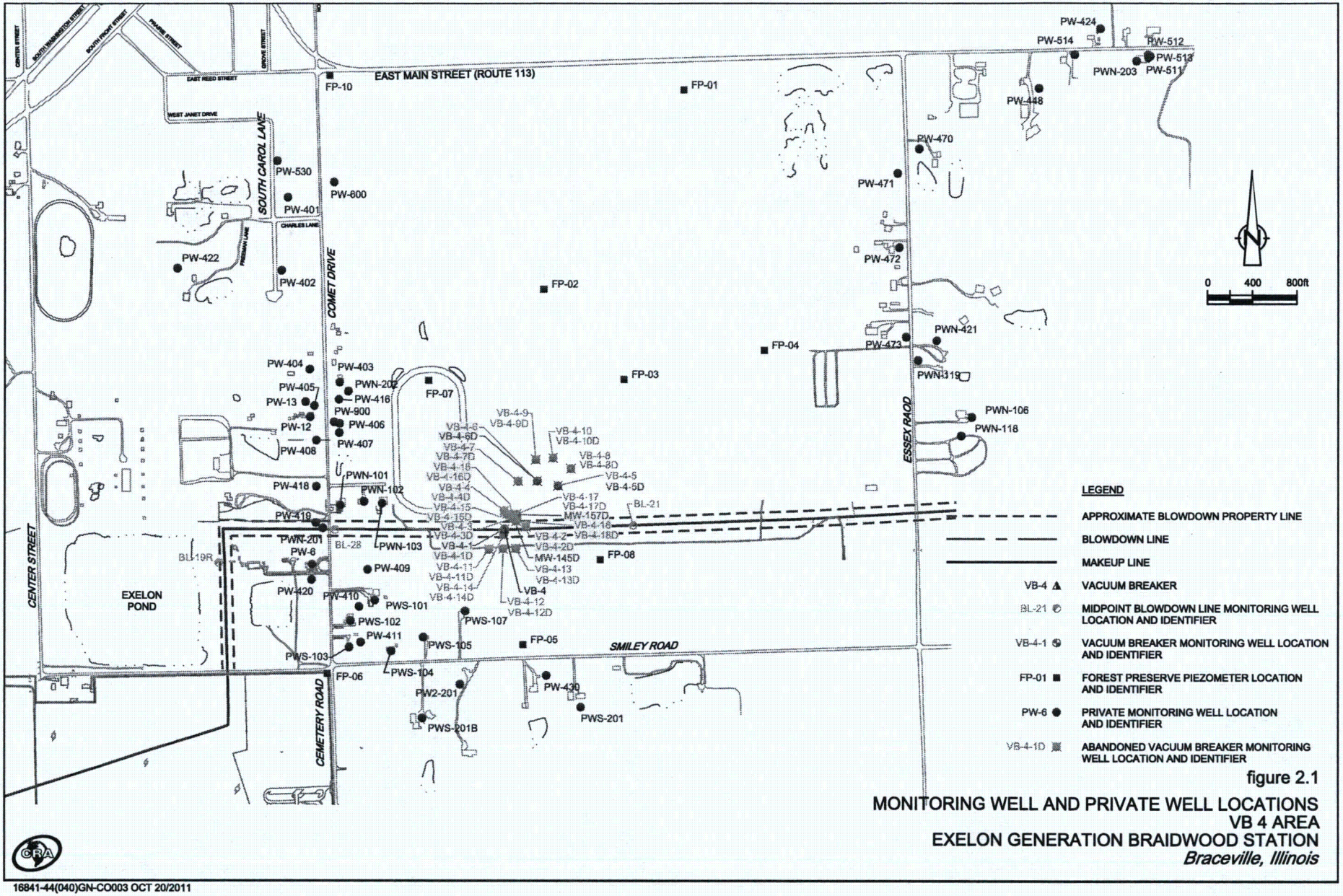


figure 2.1

MONITORING WELL AND PRIVATE WELL LOCATIONS
VB 4 AREA
EXELON GENERATION BRAIDWOOD STATION
Braceville, Illinois

16841-44(040)GN-CO003 OCT 20/2011

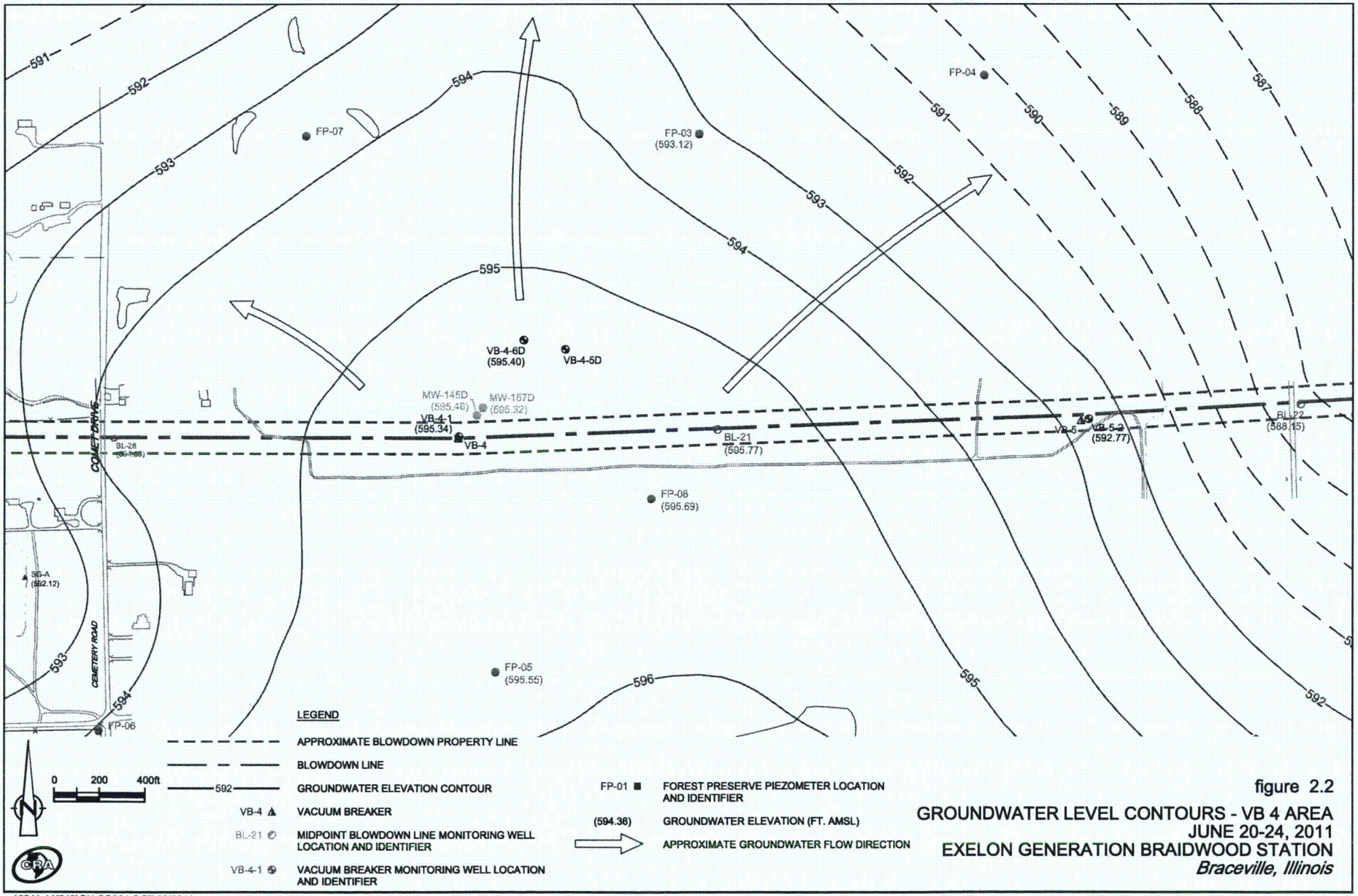


figure 2.2

GROUNDWATER LEVEL CONTOURS - VB 4 AREA
JUNE 20-24, 2011
EXELON GENERATION BRAIDWOOD STATION
Braceville, Illinois

16841-44(040)GN-CO004 OCT 20/2011

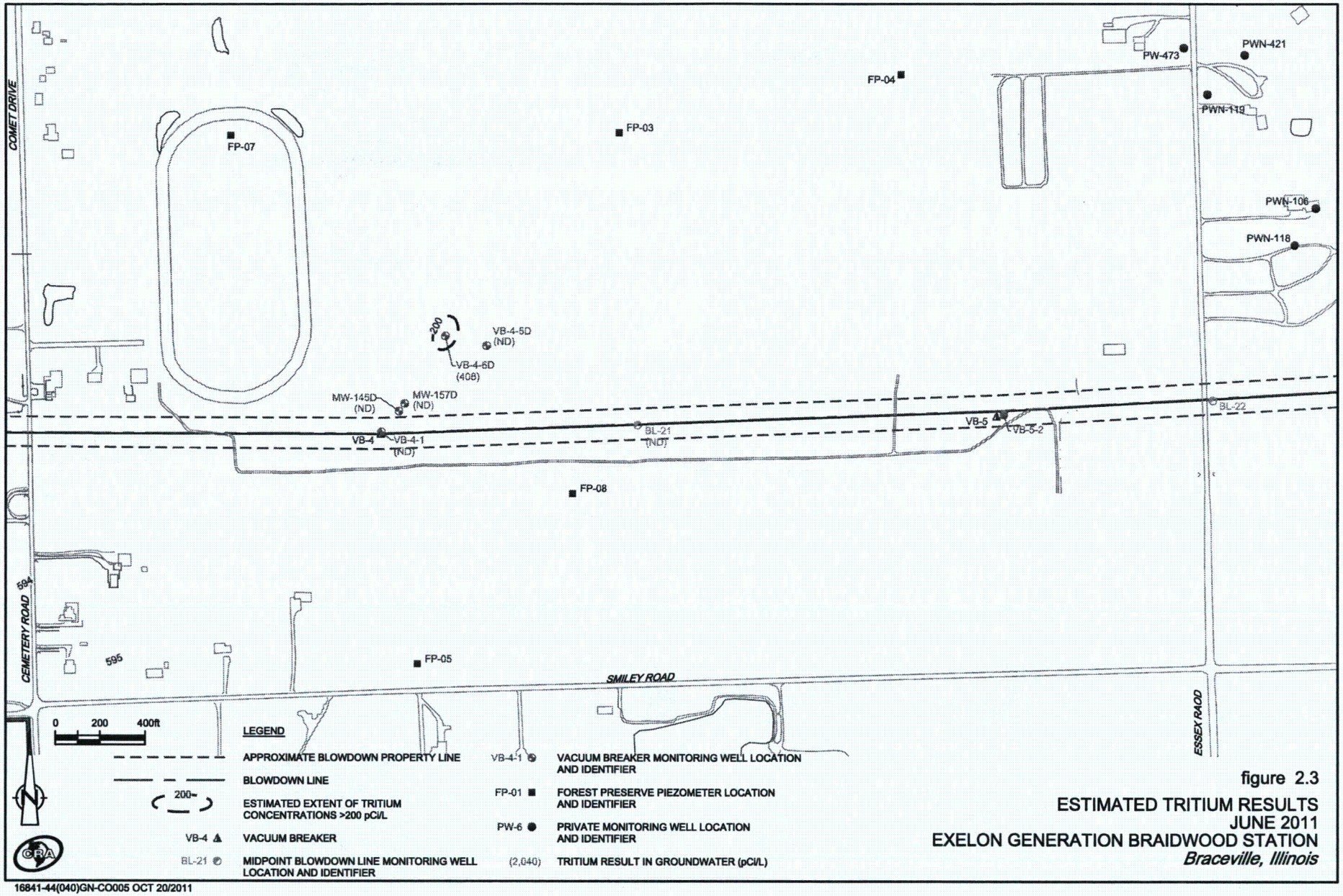


figure 2.3

ESTIMATED TRITIUM RESULTS
JUNE 2011
EXELON GENERATION BRAIDWOOD STATION
Braceville, Illinois

16841-44(040)GN-CO005 OCT 20/2011

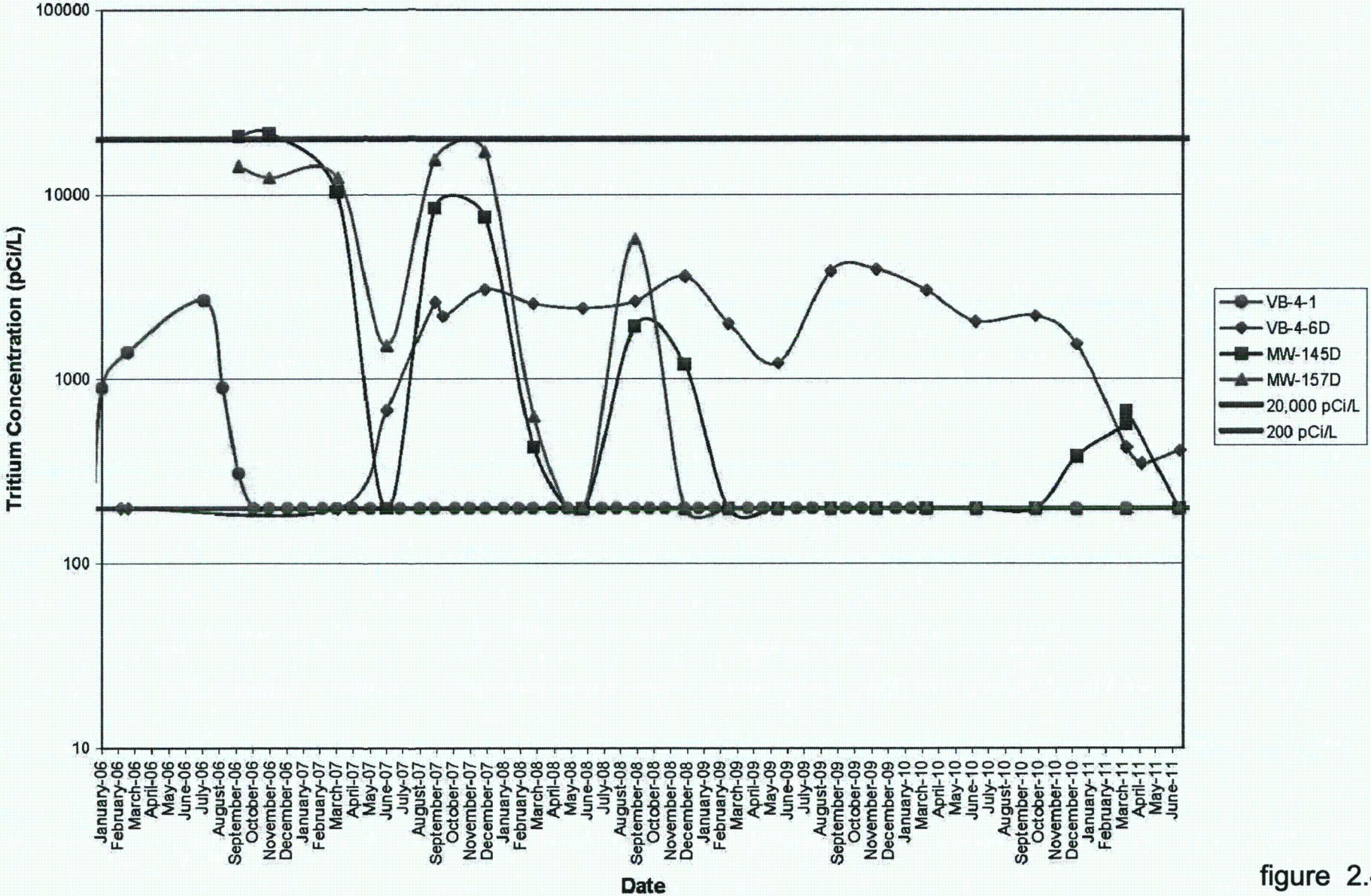


figure 2.4

TRITIUM CONCENTRATION TRENDS IN THE WELLS AT THE VB 4 AREA
EXELON GENERATION BRAIDWOOD STATION
Braceville, Illinois

16841-44(040)GN-CO006 OCT 20/2011

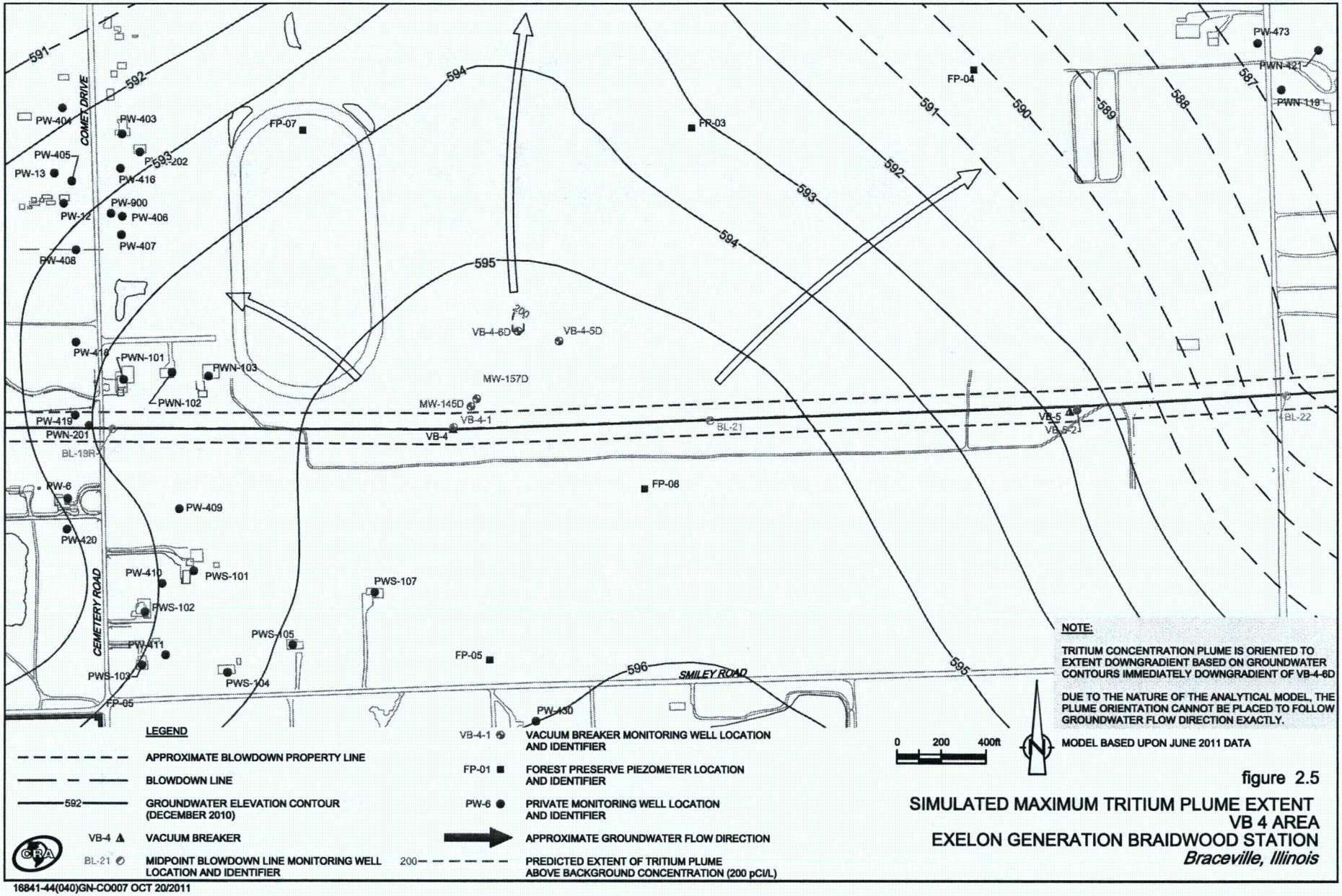


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figure 2.5

SIMULATED MAXIMUM TRITIUM PLUME EXTENT VB 4 AREA EXELON GENERATION BRAIDWOOD STATION

Braceville, Illinois

TABLE 2.1

SUMMARY OF TRITIUM AND STATISTICAL ANALYSIS NEAR VB 4
EXELON GENERATION BRAIDWOOD STATION
BRACEVILLE, ILLINOIS

Sample Location	*Sample Date*	*Result*[1]	*Trend*	*Percent Reduction*[2]	*Minimum*	*Maximum*
MW-145D	9/12/2006	20693				
MW-145D	11/7/2006	21420				
MW-145D	3/13/2007	10319				
MW-145D	6/14/2007	ND				
MW-145D	9/11/2007	8440				
MW-145D	12/12/2007	7560				
MW-145D	3/12/2008	428				
MW-145D	6/11/2008	ND				
MW-145D	9/16/2008	1940				
MW-145D	12/17/2008	1200				
MW-145D	3/10/2009	ND				
MW-145D	6/9/2009	ND				
MW-145D	9/15/2009	ND				
MW-145D	12/7/2009	ND				
MW-145D	3/10/2010	ND				
MW-145D	6/11/2010	ND				
MW-145D	9/29/2010	ND				
MW-145D	12/14/2010	381				
MW-145D	3/16/2011	568				
MW-145D	3/16/2011	666				
MW-145D	6/22/2011	ND				
			Downward trend	100%	ND	21420
MW-157D	9/12/2006	14290				
MW-157D	11/7/2006	12333				
MW-157D	3/15/2007	12275				
MW-157D	6/14/2007	1519				
MW-157D	9/11/2007	15399				
MW-157D	12/12/2007	17000				
MW-157D	3/12/2008	626				
MW-157D	6/11/2008	ND				
MW-157D	9/16/2008	5720				
MW-157D	12/18/2008	ND				
MW-157D	3/10/2009	ND				
MW-157D	6/9/2009	ND				
MW-157D	9/15/2009	ND				
MW-157D	12/7/2009	ND				
MW-157D	3/10/2010	ND				
MW-157D	6/11/2010	ND				
MW-157D	9/29/2010	ND				
MW-157D	12/14/2010	ND				
MW-157D	3/16/2011	ND				
MW-157D	6/22/2011	ND				
			Downward trend	100%	ND	17000

SUMMARY OF TRITIUM AND STATISTICAL ANALYSIS NEAR VB 4
EXELON GENERATION BRAIDWOOD STATION
BRACEVILLE, ILLINOIS

Sample Location	*Sample Date*	*Result*[1]	*Trend*	*Percent Reduction*[2]	*Minimum*	*Maximum*
VB-4-1	12/19/2005	ND				
VB-4-1	1/3/2006	895				
VB-4-1	2/20/2006	1401				
VB-4-1	7/10/2006	2673				
VB-4-1	8/14/2006	898				
VB-4-1	9/12/2006	309				
VB-4-1	10/10/2006	ND				
VB-4-1	11/7/2006	ND				
VB-4-1	12/11/2006	ND				
VB-4-1	1/9/2007	ND				
VB-4-1	2/15/2007	ND				
VB-4-1	3/13/2007	ND				
VB-4-1	4/11/2007	ND				
VB-4-1	5/14/2007	ND				
VB-4-1	6/12/2007	ND				
VB-4-1	7/9/2007	ND				
VB-4-1	8/15/2007	ND				
VB-4-1	9/12/2007	ND				
VB-4-1	10/18/2007	ND				
VB-4-1	11/14/2007	ND				
VB-4-1	12/13/2007	ND				
VB-4-1	1/16/2008	ND				
VB-4-1	2/13/2008	ND				
VB-4-1	3/11/2008	ND				
VB-4-1	4/15/2008	ND				
VB-4-1	5/13/2008	ND				
VB-4-1	6/11/2008	ND				
VB-4-1	7/16/2008	ND				
VB-4-1	8/13/2008	ND				
VB-4-1	9/16/2008	ND				
VB-4-1	10/14/2008	ND				
VB-4-1	11/11/2008	ND				
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VB-4-1	1/13/2009	ND				
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VB-4-1	4/15/2009	ND				
VB-4-1	5/13/2009	ND				
VB-4-1	6/10/2009	ND				
VB-4-1	7/13/2009	ND				
VB-4-1	8/12/2009	ND				
VB-4-1	9/16/2009	ND				
VB-4-1	10/13/2009	ND				

SUMMARY OF TRITIUM AND STATISTICAL ANALYSIS NEAR VB 4
EXELON GENERATION BRAIDWOOD STATION
BRACEVILLE, ILLINOIS

Sample Location	*Sample Date*	*Result*[1]	*Trend*	*Percent Reduction*[2]	*Minimum*	*Maximum*
VB-4-1	11/11/2009	ND				
VB-4-1	12/8/2009	ND				
VB-4-1	1/12/2010	ND				
VB-4-1	2/10/2010	ND				
VB-4-1	3/9/2010	ND				
VB-4-1	6/8/2010	ND				
VB-4-1	9/29/2010	ND				
VB-4-1	12/13/2010	ND				
VB-4-1	3/16/2011	ND				
VB-4-1	6/21/2011	ND				
			No trend identified[3]	100%	ND	2673
VB-4-6D	2/8/2006	ND				
VB-4-6D	2/21/2006	ND				
VB-4-6D	3/15/2007	ND				
VB-4-6D	6/14/2007	677				
VB-4-6D	9/12/2007	2614				
VB-4-6D	9/26/2007	2187				
VB-4-6D	12/12/2007	3060				
VB-4-6D	3/11/2008	2570				
VB-4-6D	6/10/2008	2430				
VB-4-6D	9/16/2008	2640				
VB-4-6D	12/18/2008	3590				
VB-4-6D	3/10/2009	1990				
VB-4-6D	6/9/2009	1220				
VB-4-6D	9/15/2009	3830				
VB-4-6D	12/7/2009	3920				
VB-4-6D	3/10/2010	3010				
VB-4-6D	6/9/2010	2040				
VB-4-6D	9/28/2010	2190				
VB-4-6D	12/14/2010	1540				
VB-4-6D	3/16/2011	422				
VB-4-6D	3/16/2011	430				
VB-4-6D	4/13/2011	349				
VB-4-6D	6/23/2011	408				
			No trend identified[3]	90.0%	ND	3920
VB-4-17[4]	7/13/2006	14482				
VB-4-17	7/24/2006	15229				
			N/A	N/A	14482	15229

SUMMARY OF TRITIUM AND STATISTICAL ANALYSIS NEAR VB 4
EXELON GENERATION BRAIDWOOD STATION
BRACEVILLE, ILLINOIS

Sample Location	*Sample Date*	*Result*[1]	*Trend*	*Percent Reduction*[2]	*Minimum*	*Maximum*
VB-4-17D[4]	7/13/2006	9940				
VB-4-17D	7/24/2006	10785				
			N/A	N/A	9940	10785
VB-4-18[4]	7/13/2006	2436				
VB-4-18	7/24/2006	3322				
			N/A	N/A	2436	3322
VB-4-18D[4]	7/13/2006	379				
VB-4-18D	7/24/2006	385				
			N/A	N/A	379	385
Non-Impacted Wells[5]						
BL-21	6/2/2006	ND				
BL-21	7/11/2006	ND				
BL-21	8/14/2006	ND				
BL-21	9/11/2006	ND				
BL-21	10/10/2006	ND				
BL-21	11/7/2006	ND				
BL-21	12/11/2006	ND				
BL-21	1/9/2007	ND				
BL-21	2/15/2007	ND				
BL-21	3/13/2007	ND				
BL-21	4/13/2007	ND				
BL-21	5/14/2007	ND				
BL-21	6/12/2007	ND				
BL-21	7/10/2007	ND				
BL-21	8/15/2007	ND				
BL-21	9/12/2007	ND				
BL-21	10/18/2007	ND				
BL-21	11/14/2007	ND				
BL-21	12/14/2007	ND				
BL-21	1/16/2008	ND				
BL-21	2/13/2008	ND				
BL-21	3/11/2008	ND				
BL-21	4/15/2008	ND				
BL-21	5/15/2008	ND				
BL-21	6/10/2008	ND				
BL-21	7/16/2008	ND				

SUMMARY OF TRITIUM AND STATISTICAL ANALYSIS NEAR VB 4
EXELON GENERATION BRAIDWOOD STATION
BRACEVILLE, ILLINOIS

Sample Location	*Sample Date*	*Result*[1]	*Trend*	*Percent Reduction*[2]	*Minimum*	*Maximum*
BL-21	8/12/2008	ND				
BL-21	9/18/2008	ND				
BL-21	10/15/2008	ND				
BL-21	11/11/2008	ND				
BL-21	12/17/2008	ND				
BL-21	1/13/2009	ND				
BL-21	2/10/2009	ND				
BL-21	3/13/2009	ND				
BL-21	4/15/2009	ND				
BL-21	5/12/2009	ND				
BL-21	6/9/2009	ND				
BL-21	7/14/2009	ND				
BL-21	8/12/2009	ND				
BL-21	9/16/2009	ND				
BL-21	10/13/2009	ND				
BL-21	11/11/2009	ND				
BL-21	12/8/2009	ND				
BL-21	1/12/2010	ND				
BL-21	2/10/2010	ND				
BL-21	3/10/2010	ND				
BL-21	6/8/2010	ND				
BL-21	9/28/2010	ND				
BL-21	12/14/2010	ND				
BL-21	3/16/2011	ND				
BL-21	6/21/2011	ND				
VB-4-1D[4]	12/22/2005	ND				
VB-4-1D	1/4/2006	ND				
VB-4-1D	2/20/2006	ND				
VB-4-5D	2/8/2006	ND				
VB-4-5D	2/21/2006	ND				
VB-4-5D	3/15/2007	ND				
VB-4-5D	6/14/2007	ND				
VB-4-5D	9/12/2007	ND				
VB-4-5D	12/12/2007	ND				
VB-4-5D	3/11/2008	ND				
VB-4-5D	6/10/2008	ND				
VB-4-5D	9/16/2008	ND				
VB-4-5D	12/18/2008	ND				
VB-4-5D	3/10/2009	ND				
VB-4-5D	6/9/2009	ND				
VB-4-5D	9/15/2009	ND				
VB-4-5D	12/7/2009	ND				

TABLE 2.1

SUMMARY OF TRITIUM AND STATISTICAL ANALYSIS NEAR VB 4
EXELON GENERATION BRAIDWOOD STATION
BRACEVILLE, ILLINOIS

Sample Location	*Sample Date*	*Result* [1]	*Trend*	*Percent Reduction* [2]	*Minimum*	*Maximum*
VB-4-5D	3/10/2010	ND				
VB-4-5D	6/9/2010	ND				
VB-4-5D	9/28/2010	ND				
VB-4-5D	12/14/2010	ND				
VB-4-5D	3/16/2011	ND				
VB-4-5D	6/23/2011	ND				
VB-4-15 [4]	7/14/2006	ND				
VB-4-15	7/24/2006	ND				
		ND				
VB-4-15D [4]	7/14/2006	ND				
VB-4-15D	7/24/2006	ND				
VB-4-16 [4]	7/14/2006	ND				
VB-4-16	7/24/2006	ND				
VB-4-16D [4]	7/14/2006	ND				
VB-4-16D	7/24/2006	ND				

Notes:
January 2006 data was used as initial concentrations for statistical analysis where available.

[1] Non-detect (ND) below 200 pCi/L.

[2] Monitoring well locations with the most current data at ND were assumed to have 100% reduction.

[3] Refer to text for detailed explaination.

[4] Monitoring well locations not sampled since July 2006 are not part of the sampling program and were abandoned in August 2006. Refer to text for further information.

[5] Non-impacted well results were generally below or near ambient levels and were excluded from statistical analysis.

TABLE 4.1

SUMMARY OF MONITORING WELLS TO BE ABANDONED
EXELON GENERATION BRAIDWOOD STATION
BRACEVILLE, ILLINOIS

Vacuum Breaker Area	*Sample Location*
Vacuum Breaker 4	MW-145D
	MW-157D
	VB-4-1
	VB-4-5D
	VB-4-6D

APPENDIX A

BIOSCREEN MODELING RESULTS MEMO

CONESTOGA-ROVERS & ASSOCIATES

8615 W. Bryn Mawr Avenue, Chicago, Illinois 60631
Telephone: (773) 380-9933 Fax: (773) 380-6421
www.CRAworld.com

MEMORANDUM

TO: File

REF. NO.: 016841

FROM: Kristine White/lg/63

DATE: March 28, 2011

RE: Modeling of Tritium Migration in Groundwater in VB 4 Area Using BIOSCREEN
Braidwood Generating Station
Braceville, Illinois

The purpose of this memorandum is to present results of an evaluation of the potential off-Site migration of tritium in groundwater downgradient of Vacuum Breaker # 4 (VB 4) at Braidwood Station (Site). Site-specific hydrogeological information was used to predict the extent of the tritium plume.

BIOSCREEN

The analytical solute transport model BIOSCREEN, developed by the United States Environmental Protection Agency (USEPA) for use at petroleum hydrocarbon release sites (USEPA, 1996; and Newell et al., 1997), was used for this study. BIOSCREEN is a two-dimensional solute transport model that simulates the processes of solute advection, dispersion, adsorption, and first-order decay under uniform groundwater flow conditions. The analytical solute transport model developed by Domenico (1987) forms the basis of the solution in BIOSCREEN.

In this particular study, the radioactive decay process of tritium was modeled using the first-order biodegradation term available in BIOSCREEN.

The BIOSCREEN model requires data entry including an average linear groundwater flow velocity, contaminant dispersivity, retardation and biodegradation (or radioactive decay, in this case) constants, and a source area condition (including the source size and source concentration). BIOSCREEN then calculates contaminant concentrations in groundwater at a specified time along the plume centerline over a specified distance downgradient from the source area. BIOSCREEN allows the entry of observed contaminant concentrations at specified distances down gradient from the sources area to which the calculated plume centerline concentration and concentration may be compared. This model also calculates contaminant concentrations in groundwater in the transverse direction.

MODEL SETTINGS

Parameters related to the hydrogeological properties for the modeling analysis are described below. Figure 1 shows the BIOSCREEN model input parameters. Further details of the parameters are described in the following paragraphs.

Seepage Velocity

The seepage velocity (Vs) at the Site was found to be 258.7 ft/year, which was based on the following equation:

$$V_S = K \cdot i / n_e$$

Where,

K is the hydraulic conductivity, which was set to 0.0254 centimeters per second (cm/s) (or 72 ft/day) based on slug tests performed at the Site in October 2005;

i is hydraulic gradient, which was set to be 0.003 ft/ft, estimated based upon January-March 2006 groundwater contours downgradient of VB 4; and

n_e is the effective porosity, which was set to be 0.30 based on the literature range for fine to medium sand (Domenico and Schwartz, 1990).

Dispersivities

Longitudinal and transverse dispersivities were estimated using an empirical relationship between plume length (Lp) and dispersivity. The following relationships were utilized to determine dispersivities (USEPA, 1996):

$a_x = 0.1\ Lp$	*(Pickens and Grisak, 1981)*
$a_y = 0.33\ a_x$	*(Based on high reliability points from Gelhar et al., 1992)*
$a_z = 0.025\ a_x$ to $0.1\ a_x$	*(EPA, 1986)*

Based on the above relationships, the longitudinal disversivity (α_x) was found to be 20.5 ft, based upon an estimated Lp of 205 ft; the transverse dispersivity in Y direction (α_y) was 6.8 ft; and the vertical dispersivity (α_z) was 1.0 ft.

Adsorption

The adsorption process is represented as a retardation factor in the BIOSCREEN model. A retardation factor of 1.0 (i.e., no retardation) was used in this simulation, since tritium binds readily with oxygen to form TOH or T_2O molecules and therefore travels at the same speed as groundwater would.

Radioactive Decay

Tritium decays naturally over time. The degradation process can be represented by a first order differential equation expressed as:

$$\frac{\partial c}{\partial t} = -\lambda c.$$

Here, c is the aqueous concentration of tritium (picoCuries per liter, or pCi/L), and t is time (years). λ is the first-order decay rate (1/year) that is related to the half-life, $t_{½}$ (years), by the following equation:

$$\lambda = \frac{\ln(2)}{t_{1/2}} = \frac{0.693}{t_{1/2}}$$

The natural radioactive decay rate for tritium was found to be 5.6×10^{-2} per year.

Model Domain

The model length was set at 225 ft and the model width was set at 150 ft in order to encompass the entire extent of the tritium plume in groundwater exceeding 200 pCi/L.

Tritium Source Settings

Based on the existing observed source conditions at VB 4, the tritium concentration of 1,540 pCi/L collected in December 2010 from VB-4-6D was utilized as the source concentration. The source thickness was estimated to be 10 ft and the source width was estimated to be 50 ft.

Simulation Time

A simulation time of 20 years was selected to ensure that the tritium plume could be stabilized within the selected time frame. The BIOSCREEN model was run until steady-state conditions were reached in order to determine the tritium concentration downgradient from the source.

MODEL RESULTS

The background level for tritium established for the area is 200 pCi/L. The BIOSCREEN model was run to determine the distance from the source at VB 4 to the extents where the background tritium concentration was attained, and to determine tritium plume widths at various distances along the modeled plume.

Steady-state conditions were achieved in 6 years. Figure 2 presents simulated tritium concentrations compared to distances from the source area at VB 4. As shown on Figure 2, the modeled maximum downgradient distance from the source area to the point where the tritium concentration in groundwater reaches the 200 pCi/L background level is approximately 205 feet.

REFERENCES

Domenico, P. A. An Analytical Model for Multidimensional Transport of a Decaying Contaminant Species, *Journal of Hydrology*, 91, pp. 49-58, 1987.

Domenico, P.A. and F.W. Schwartz, Physical and Chemical Hydrogeology, John Wiley & Sons, Inc. 1990.

Newell, J. c., R. K. McLeod, and J. R. Gonzales. *BIOSCREEN: Natural Attenuation Decision Support System -Version* 1.4 *Revisions*. Groundwater Services, Inc., Air Force Center for Environmental Excellence, July 1997.

Nicholas, J. R. and R. W. Healy. *Tritium Migration from a Low-Level Radioactive-Waste Disposal Site Near Chicago, Illinois* U. S. *Geological Survey Water-Supply Paper* 2333, Denver, CO, 1988.

USEPA. *BIOSCREEN: A Natural Attenuation Decision Support System User's Manual Version* 1.3 *EPA Report No. EPA/600/R-96/087*, Office of Research and Development, Cincinnati, OH, 1996.

USEPA. *EPA - Tritium - Information Page.* www.epa.gov/radiation/radionuclides/tritium.htm, November 30,2004, accessed on February 14, 2006.

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.4*

Braidwood
VB-4
Run Name

Data Input Instructions:

115
or
0.02

1. Enter value directly....or
2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.
20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	258.7	(ft/yr)
or		or	
Hydraulic Conductivity	K	2.5E-02	(cm/sec)
Hydraulic Gradient	i	0.003	(ft/ft)
Porosity	n	0.3	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	9.4	(ft)
Transverse Dispersivity*	alpha y	3.1	(ft)
Vertical Dispersivity*	alpha z	0.5	(ft)
or		or	
Estimated Plume Length	Lp	94	(ft)

3. ADSORPTION

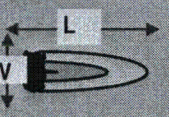
Retardation Factor*	R	1.0	(-)
or		or	
Soil Bulk Density	rho	1.7	(kg/l)
Partition Coefficient	Koc	38	(L/kg)
FractionOrganicCarbon	foc	5.7E-5	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	5.6E-2	(per yr)
or		or	
Solute Half-Life	t-half	12.30	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	100	(ft)
Modeled Area Width*	100	(ft)
Simulation Time*	20	(yr)



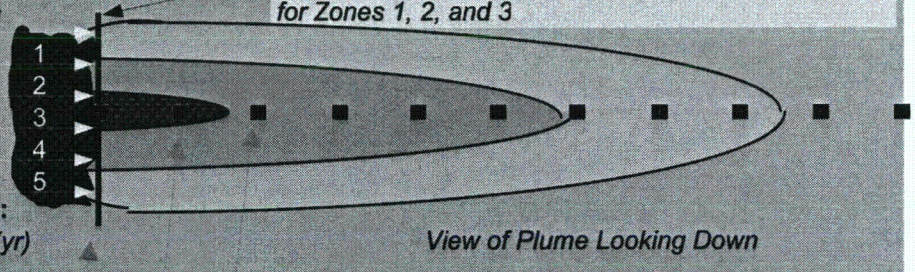
6. SOURCE DATA

Source Thickness in Sat.Zone* 10 (ft)

Source Zones:

Width* (ft)	Conc. (pCi/L)*
50	408
0	0
0	0

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Source Halflife (see Help):

Infinite	Infinite (yr)
Inst. React.	1st Order

Soluble Mass In Source NAPL, Soil: INFINITE (Kg)

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	0	10	20	30	40	50	60	70	80	90	100
Concentration (mg/L)											

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — **View Output**

RUN ARRAY — **View Output**

Help

Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

figure 1
BIOSCREEEN INPUT PARAMETERS
EXELON GENERATION BRAIDWOOD STATION
Braceville, Illinois

016841 (40)

TRITIUM CONCENTRATION ALONG PLUME CENTERLINE (pCi/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	10	20	30	40	50	60	70	80	90	100
1st Order Decay	408	406	387	355	321	290	264	241	221	204	189

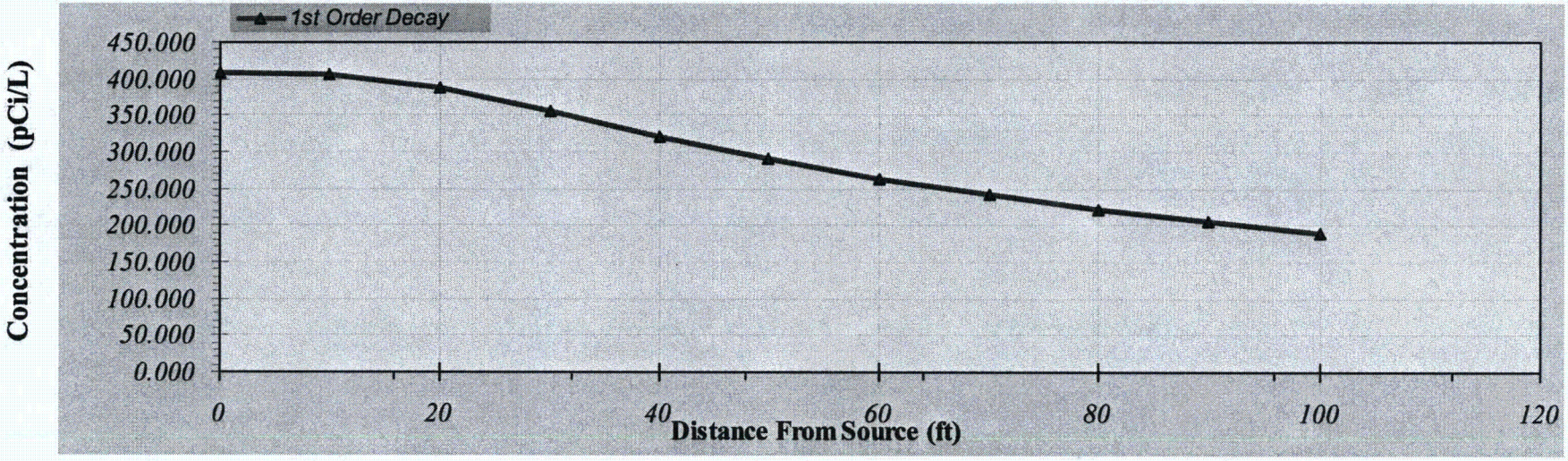


figure 2

CONCENTRATION FOR TRITIUM SOURCE OUT TO BACKGROUND CONCENTRATION
EXELON GENERATION BRAIDWOOD STATION
Braceville, Illinois