



Revision 1

HYDROGEOLOGIC INVESTIGATION REPORT

FLEETWIDE ASSESSMENT BRAIDWOOD GENERATING STATION BRACEVILLE, ILLINOIS

**Prepared For:
Exelon Generation Company, LLC**

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EXECUTIVE SUMMARY

This Hydrogeologic Investigation Report (HIR) documents the results of Conestoga-Rovers & Associates' (CRA's) May 2006 Hydrogeologic Investigation Work Plan (Work Plan) and associated correspondence pertaining to the Braidwood Generating Station in Braceville, Illinois. CRA prepared this HIR for Exelon as part of its Fleetwide Program to determine whether groundwater at and in the vicinity of its nuclear power generating facilities has been adversely impacted by any releases of radionuclides.

CRA collected and analyzed information on any historical releases, the structures, components, and areas of the Station that have the potential to release tritium or other radioactive liquids to the environment and past hydrogeologic investigations at the Station. CRA used this information, combined with its understanding of groundwater flow and sample locations at the Station to identify the Areas for Further Evaluation (AFEs) for the Station.

CRA collected 45 groundwater samples and six surface water samples at the Station. CRA also collected a full round of water levels on two occasions from the newly installed and existing wells and measured surface water levels. All groundwater and surface water samples were analyzed for tritium, strontium-89/90, and gamma-emitting radionuclides.

This HIR does not discuss the investigations of tritium in groundwater along the Braidwood Station Blowdown Line. This report focuses on the groundwater conditions in and near the Protected Area (PA). The results of this hydrogeologic investigation are:

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective Lower Limits of Detection (LLDs) in any of the groundwater or surface water samples obtained and analyzed during the course of this investigation;
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2.0 picoCuries per liter (pCi/L) in any of the groundwater or surface water samples obtained and analyzed during the course of this investigation;
- Tritium was not detected in any of the groundwater or surface water samples obtained during the course of this investigation at concentrations greater than the United States Environmental Protection Agency drinking water standard of 20,000 pCi/L;

- Low levels of tritium were detected at concentrations greater than the LLD of 200 pCi/L in 15 of 45 groundwater monitoring locations. These tritium concentrations ranged from 204 (± 112 pCi/L) to 1,040 (± 172 pCi/L);
- Most of the tritium that was detected in groundwater at the Station is on the west side of the Turbine building and is believed to be the result of isolated historical releases;
- Based on the results of this investigation, tritium is not migrating off the Station property at detectable concentrations;
- Based on the results of this investigation, there is no current risk from exposure to radionuclides associated with licensed plant operations through any of the identified potential exposure pathways; and
- Based on the results of this investigation, there are no known active releases into the groundwater at the Station.

Based upon the information collected to date, CRA recommends that Exelon conduct periodic monitoring of selected locations.

1.0 INTRODUCTION

Conestoga-Rovers & Associates (CRA) has prepared this Hydrogeologic Investigation Report (HIR) for Exelon Generating Company, LLC (Exelon) as part of its fleetwide program to determine whether groundwater at and near its nuclear power generating facilities has been adversely impacted by any releases of radionuclides. This report documents the results of CRA's May 2006 Hydrogeologic Investigation Work Plan (Work Plan), as well as, several other investigative tasks recommended by CRA during the course of the investigation. These investigations pertain to Exelon's Braidwood Nuclear Power Station in Braceville, Illinois (Station) (see Figure 1.1).

The Station is defined as all property, structures, systems, and components owned and operated by Exelon LLC located at 35100 South Route 53, Braceville, Illinois. The Station boundaries for all areas of the Station are depicted on Figure 1.2 and Figure 1.3.

Pursuant to the Work Plan, CRA assessed groundwater quality at the Station in locations designated as areas for further evaluation (AFEs). The process by which CRA identified AFEs is discussed in Section 3.0 of this report.

Since the spring of 2005, Exelon has performed investigations into the occurrence of tritium along the blowdown line, as discussed in the following Section 2.0. This report does not include discussions of hydrogeologic investigations related to the Braidwood Station's Cooling Lake blowdown line.

The objectives of the Work Plan were to:

- characterize the geologic and hydrogeologic conditions at the Station including subsurface soil types, the presence or absence of confining layers, and the direction and rate of groundwater flow;
- characterize the groundwater/surface water interaction at the Station, including a determination of the surface water flow regime;
- evaluate groundwater quality at the Station including the vertical and horizontal extent, quantity, concentrations, and potential sources of tritium and other radionuclides in the groundwater, if any;
- define the probable sources of any radionuclides released at the Station;
- evaluate potential human, ecological, or environmental receptors of any radionuclides that might have been released to the groundwater; and
- evaluate whether interim response activities are warranted.

2.0 STATION DESCRIPTION

The following section presents a general summary of the Station location and definition, overview of Station operations, surrounding land use, and an overview of both regional and Station-specific topography, surface water features, geology, hydrogeology, and groundwater flow conditions. This section also presents an overview of groundwater use in the area.

2.1 STATION LOCATION

The Station property consists of approximately 4,450 acres, of which approximately 52 acres are used for the generating facilities. The other approximately 4,400 acres of property encompasses an approximately 2,500-acre Cooling Lake and the land associated with the blowdown line. The Station address is 35100 South Route 53, Braceville, Illinois. The Station is owned and operated by Exelon. Figure 2.1 presents the Station Base Map, which includes the key features.

This HIR excludes land associated with the Cooling Lake and as discussed in Section 1.0, excludes the land associated with the blowdown line and the blowdown line's vacuum breakers. As such, this HIR does not discuss the groundwater investigations performed recently along the Station's blowdown line. These are discussed further in Section 2.5.

2.2 OVERVIEW OF COOLING WATER OPERATIONS

The Station contains a two-unit nuclear generating facility capable of generating 1,120 net megawatts of electricity per unit. Units 1 and 2 are pressurized water reactors (PWRs) designed by Westinghouse and began commercial operation in July and October 1988, respectively. A PWR plant consists of three separate loops of fluids. Each loop is designed to avoid mixing the fluids of one loop with the fluids of another. The three loops are called the primary loop, the secondary loop, and the tertiary loop.

The main purpose of the primary loop is to transfer the energy generated from fission in the fuel to the secondary loop steam generators. It is a closed loop system. Nuclear fission creates heat in the fuel. This heat is removed by the flow of reactor coolant water through the reactor vessel and into the steam generators. The heat is transferred to the secondary side where steam is generated. The water is then pumped back to the reactor vessel to cool the fuel again.

The main purpose of the secondary loop is to use the steam generated in the steam generators to turn the turbine generator, which makes electricity. It is also a closed system.

The main purpose of the tertiary loop is to use cooler lake water to condense the steam in the condenser and transfer the heat to the atmosphere. The lake loop needs makeup water to operate properly. Makeup water comes from the Kankakee River.

As the steam is condensed in the condenser, the circulating water becomes hotter. The circulating water is discharged to the Cooling Lake where it loses some of its heat through evaporation. The now cooler water is then pumped back to the condenser to start the loop over again.

The Braidwood Station employs a blowdown line to return water from the Cooling Lake back to the Kankakee River for the purposes of reducing the dissolved mineral concentration in the lake water. This blowdown line also serves as a permitted discharge point for the site's sewage treatment plant and the liquid Radwaste system. The discharge is approved under the Station's National Pollutant Discharge Elimination System (NPDES) Permit IL 0048321 and Nuclear Regulatory Commission (NRC) Operating Licenses NPF-72 and NPF-77 for Units 1 and 2, respectively.

2.3 SURROUNDING LAND USE

To the north, south, east, and west, land surrounding the Station is primarily for agricultural, residential, and recreational use. Residential lots surround the Station to the north and to the east along Smiley Road and Center Street. Further to the north, there are several ponds or small lakes. The center of the Village of Braidwood is approximately 1.5 miles north of Braidwood Station measured from Smiley Road. 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. Within the southern portion of the Station is the Cooling Lake that is designated as a recreational area in the summer for boating and fishing under the auspices of the Illinois Department of Natural Resources (IDNR) (Refer to Figures 1.2 and 1.3). The town of Godley is located west and southwest of the PA.

2.4 STATION SETTING

The following sections present a summary of the topography, surface water features, geology, hydrogeology, and groundwater flow conditions in the region surrounding the Station. The information was primarily gathered from Sections 2.1 and 2.5 of the Braidwood Station Updated Final Safety Analysis Report (UFSAR) Revision 10, dated December 2004. The main references the UFSAR relies upon are listed in Section 10.0 of this HIR. CRA checked and verified all UFSAR references that apply to this HIR.

2.4.1 TOPOGRAPHY AND SURFACE WATER FEATURES

In general, the topography of the area slopes gently downward to the north toward the Illinois River and is relatively flat (see Figure 1.1 and United States Geological Topographic Quadrangle Map – Essex – 1973, Photo revised 1980).

The Cooling Lake was formed from former coal strip mining operations discussed further in Section 2.4.2. The average depth of the Cooling Lake is about 8 feet (UFSAR, 1994). It is isolated from the adjacent upper water bearing aquifer by a slurry wall constructed during building construction at the PA. The lake bottom consists of mine spoils left behind after strip-mining operations.

There are also remnants of former coal strip mining operations to the north of the PA (ISGS March 2005 and October 2003). There are also a number of ponds located northeast of the PA that were dug originally as sand borrow pits (for highway construction materials) that have subsequently filled with groundwater. These include the ponds located near Center Street and Smiley Road (Figures 1.1 and 2.2). The ponds are evident on the aerial photo presented on Figure 2.2.

Figure 2.3 presents portions of some of the relevant surface water features at the Station such as the Cooling Lake, pond, and perimeter ditch. Surface water drains via the storm water drainage system and man-made ditches (e.g., the perimeter ditch) and flows generally to the north within the PA. Surface water is conveyed away from the Cooling Lake via the perimeter ditch (Figure 2.3). This ditch eventually flows west and south past the PA and past the Village of Godley. This ditch intercepts the shallow groundwater table (CRA, September 2003).

The PA and surrounding land is generally flat and covered by paved areas, roadways, and parking lots. These areas are drained by a storm water drainage system that drains to the northwest corner of the PA (Figure 2.3). The storm water drainage system drains

to an Oil/Water Separator at the north end of the PA. The outfall from the Oil/Water Separator discharges to a small east-west ditch and flows west to the perimeter ditch.

Previous studies have documented that the storm water drainage system intercepts groundwater on the west side of the Turbine Building. These same studies have indicated that the perimeter ditch (Figure 2.3), which flows from the north to the south along the western Station property line, also intercepts the groundwater (CRA, September 2003). Hydrogeologic profiles of the storm water drainage system, Oil/Water Separator, and the perimeter ditch are provided on Figures 2.4 to 2.7. These figures are from the CRA September 2003 report.

2.4.2 GEOLOGY

The Natural Resource Conservation Service (NRCS) classifies the shallow soils surrounding the site as primarily fine sands and silt loams; typical soils of an outwash plain. The NRCS classified the soils around the Station in groups that primarily include the following soils: Oakville fine sand, Wateska loamy fine sand, Markham silt loam, and Orthents loamy soil. These soil groups all have similar characteristics and vary by the amount of silt in the material. These soils are moderately to well drained, have moderate to rapid permeability from 0 to 60 inches below ground surface (bgs), and contain 0.5 to 2 percent organic matter.

The local geology is composed of a relatively thin overburden layer overlying the bedrock. Figure 2.8 presents a stratigraphic cross-section of the local geology.

The overburden consists of the Equality Formation (silty sand) and the Wedron Clay Till Formation (glacial outwash and till) (UFSAR, 1994). The Equality Formation is Quaternary age and primarily consists of eolian and lacustrine sands and at the Station it is described as a homogenous, loose, gray to brown sand. This formation is approximately 20 feet thick at the site (Arnold et al., 1999). The Wedron Clay Till consists of glacial till and interbedded discontinuous glacial outwash deposits. At the site, the Wedron Clay Till is predominantly a silty clay. The Wedron Clay Till ranges from 15 to 20 feet thick at the site (Willman et al., 1975). A contour map of the top of the Wedron Clay Till around the Turbine Building and Reactors from the UFSAR is included on Figure 2.9 (UFSAR, 1994).

The important bedrock units in the site area can be divided into these three general sections (Willman and Frye, 1970):

- Pennsylvanian age siltstone, shale, and coal;
- Ordovician shale; and
- Cambrian- Ordovician sandstone and limestone/dolostone.

The Pennsylvanian age units are generally horizontal strata that act as an aquitard and barriers to vertical flow. The coal-bearing Carbondale Formation (Colchester Member) within this group was previously strip-mined in the area of the Station (Figure 2.8). The strip mining removed the overlying units to the bottom of this coal seam (Chapter 2.5.1.2.7, UFSAR, 1994; and ISGS, October 2003). The Carbondale Formation includes the Francis Creek Shale Member and the Colchester Coal Member. It is underlain by the Spoon Formation (Figure 2.8).

Coal was discovered in Braidwood in 1854. Underground mining began in the 1870s. Strip-mining began in the 1920s. Total production of coal is estimated at over 26 million tons. Approximately 6.2 million tons was produced from underground mines, and about 20.5 million tons from strip mines. Coal was produced mainly from the No. 2 Coal Seam (Figure 2.8). The coal seam is approximately 100 feet bgs. Overlaying the coal is 30 or more feet of the Francis Creek Shale Member of the Pennsylvanian Carbondale Formation. This seam is also known as the Colchester Coal No. 2, which has an average thickness of 3 feet. In the southwestern part of the area thin seams of coal lie closely above and below the Colchester No. 2 seam.

As a result of coal mining, there are several small lakes near the site, which formed when abandoned open-pit mines subsequently filled with groundwater and precipitation. The Cooling Lake south of the facility is one of these lakes (Figure 1.2). The Cooling Lake is filled with mine spoils consisting of fractured, fragmented deposits of clay shale and other excavated material.

The Ordovician shale is the Maquoketa Shale Group of varying thickness but generally at least 70 feet thick. The Maquoketa Shale separates upper shallower bedrock formations (limestone and dolomite) from the deep sandstone bedrock of Cambrian-Ordovician-Glenwood-St. Peter Formations and the Ironton-Galesville Formations (Figure 2.8).

2.4.3 HYDROGEOLOGY

Groundwater in the site area is mainly extracted from two primary aquifers:

- the upper sand aquifer; and
- the deep Cambrian and Ordovician age sandstone formations.

There is some indication, however, based upon well logs from private residences that water supply wells are sometimes completed in the sandstone and limestone of the Carbondale Formation and the Spoon Formation (Figures 2.2 and 2.10). The Carbondale Formation includes the Francis Creek Shale Member, an aquitard, siltstones, conglomerates, shale, and the Colchester No. 2 coal. Beneath the Carbondale Formation is the limestone of the Spoon Formation. Apparently some private wells are installed into the Carbondale Formation above the coal or into the underlying Spoon Formation based upon well depth. Figure 2.10 presents wells completed in the 80- to 120-foot depth that may represent the Spoon Formation.

The upper sand aquifer comprises Quaternary age eolian and lacustrine sands (20 to 30 feet deep) (UFSAR, 1994). There are numerous private wells screened within the surficial sand unit where well yields are highly variable. In general, on a regional scale, well yields range from 20 gallons per minute (gpm) to 100 gpm; the higher yields are in areas where the sand and gravel deposits are thickest. The shallow groundwater flow direction is typically north-northeast but is influenced by surface water bodies.

The deeper bedrock formations used regionally for municipal and private water supplies (depths of 600 to 1,600 feet) are separated from the shallow system by a number of regional aquitards (Visocky, 1985). These barriers include the Wedron Clay Till (located just beneath the shallow sands) and various shale formations including the Scales Shale, which is over 70 feet thick at the Station and found at depths of 400 feet. Groundwater flow in these deep bedrock formations is expected to be toward the northeast in response to regional pumping centers near Joliet, Illinois (Visocky, 1985).

The groundwater system of most interest at the Station is the upper sand aquifer. This is the zone where previous studies of tritium occurrence have indicated its migration on and off the Braidwood Station property (CRA, March 2006).

The groundwater in the upper sand aquifer occurs under unconfined (water table) conditions and the saturated thickness ranges from 20 to 22 feet. The groundwater in this aquifer is recharged by local precipitation and discharges to local ponds and streams, and to the bedrock near the Kankakee River.

Recently, over 300 permanent and temporary monitoring wells have been installed into the deep and shallow zones (as described in Section 4.0) of the upper sand aquifer at Braidwood Station along the blowdown line (refer to Figure 2.11). Several well nests have been installed in the upper sand aquifer to determine the vertical distribution of impacted groundwater, and also the vertical hydraulic gradient within the aquifer.

Previous investigations along the blowdown line did not indicate a systematic pattern of vertical hydraulic gradients within the upper sand aquifer. The data recently collected as part of the fleetwide investigation has indicated similar vertical hydraulic gradients with one area of exception. Monitoring well clusters located just west of the Turbine Building indicate a downward vertical hydraulic gradient.

Data collected from CRA's previous investigations (CRA, September 2003 and March 2006) indicate there is a significant interaction between the groundwater in the overburden and the surface water bodies such as the perimeter ditch and the ponds to the northeast of the Station (refer to Figures 2.6 and 2.7).

The results from single-well response tests performed as part of the blowdown line investigation indicate that the hydraulic conductivity of the overburden aquifer is in the range of 2.5×10^{-2} centimeters/second (cm/sec) to 3.7×10^{-2} cm/sec (CRA, March 2006). Average groundwater velocity in the overburden aquifer is 80 feet/year (ft/yr) to 170 ft/yr in the area of the blowdown line.

The Cooling Lake, which is on the upgradient side of the Station, is not in direct contact with the upper sand aquifer, but rather is separated by a slurry wall (a low permeability barrier) that was installed at the time the Station was built. The slurry wall was installed or keyed into the Wedron Clay Till. The Cooling Lake is surrounded by this slurry wall and is, therefore, isolated from the upper sand aquifer at the site.

The Cooling Lake, although on the average is only 8 feet deep, is underlain by mine spoils left over from the coal-strip mining activities discussed previously. These mine spoils typically contain shales, clays, and siltstones that have been excavated and re-deposited. The mine spoil permeability is expected to be extremely low based upon CRA experience with mine spoils in the region. Consequently, the vertical seepage out of the Cooling Lake should not be significant when compared to evaporation losses or the amount of water blown down to the Kankakee River. Finally, although the Colchester Coal No. 2 was mined in this area, the Maquoketa Shale was not disturbed and remains a barrier to vertical flow beneath the Cooling Lake.

Approximately 140 feet of relatively impermeable shale separate the overburden aquifer from the deep bedrock aquifer. The shale units act as aquitards, limiting the hydraulic communication between the groundwater in the overburden and the bedrock aquifer (Visocky, 1985). Most domestic wells in the area are completed within the Glenwood-St. Peter Formation, which is approximately 600 feet bgs.

The Station does not rely on groundwater for any of its water supplies; consequently, there is little information on the deeper groundwater bearing zones at the Station property. However, a review of the water well logs (Appendix A) for private and public supply wells in the area indicate similar groundwater conditions as discussed previously in Section 2.0. Water supply wells in the Station area are completed to depths of approximately 100 feet, 600 feet, and 1,600 feet in order to tap bedrock water bearing formations (refer to Figure 2.10).

Figure 2.12 presents the locations of a local regional cross-section presenting the regional geology, the location of the PA and deeper private and public water supply wells. Figure 2.13 is a regional cross-section in a southwest to northeast direction. Figure 2.14 is a regional cross-section in a more northerly direction. Both Figures 2.13 and 2.14 indicate the relative depths of PA features, the bedrock aquifers, aquitards and private and public water supply wells.

A former construction water supply well is located in the northeast area of the PA, just east of the Condensate Storage Tanks (Figure 2.1). This well was drilled to a depth of approximately 1,750 feet and is cased to approximately 260 feet bgs. The Braidwood Station does not use this former supply well and there are plans to plug and abandon the well in the near future. The pump inside the well casing restricts access to this well.

2.5 AREA GROUNDWATER USE

The groundwater beneath the Station is not used as a potable resource for its operations. The Station obtains its water from the Kankakee River. There are a number of domestic wells near the Station (see Figures 2.2 and 2.10 for private well locations) that obtain their water from the upper sand aquifer. The groundwater within this upper sand aquifer is under water table conditions with the depth to water ranging from 5 to 15 feet bgs. The shallow aquifer is recharged by precipitation and the shallow aquifer discharges to nearby surface streams and strip mines.

The upper sand aquifer is underlain by Pennsylvanian bedrock composed of siltstone, shale, sandstone, clay, limestone, and coal (Carbondale and Spoon Formations). The Pennsylvanian strata may locally yield up to 20 gpm from the interbedded sandstones.

The Cambrian and Ordovician aquifers in the Station area comprise the Mt. Simon, the Ironton Galesville and the Glenwood-St. Peter Sandstones. These deeper Cambrian and Ordovician aquifers consist of sandstones in contrast to the shallow Pennsylvanian formations, which consist mainly of shale and limestone (Visocky et al, 1985). Water supply wells completed in this aquifer are at depths of over 600 feet (Figures 2.10, 2.13, and 2.14). Most of the groundwater supply wells within the surrounding area of the Braidwood Station are finished within these deeper aquifers (depths of 100 feet, and 600 to 1,600 feet) (Figure 2.10).

The Village of Braidwood, which is approximately 1.5 miles north of the site, provides municipal water via at least one deep bedrock water supply well that has a depth of over 1,600 feet (Figure 2.14). The homeowners and businesses in the Village of Godley generally rely upon shallow sand-point type wells that are constructed into the upper sand aquifer. The Godley Park District uses a deeper bedrock well for its purposes.

2.6 BRAIDWOOD STATION BLOWDOWN LINE INVESTIGATIONS

Since the spring of 2005, Exelon has undertaken extensive efforts to investigate tritium impact in areas outside and east of the PA and along the Station's blowdown lines, including extensive sampling of groundwater, surface water, and private wells. The results are presented as follows:

- Tritium Investigation Report (CRA, March 2006);
- Investigation of Tritium in the Groundwater in the Vicinity of VB-4 (CRA, April 2006);
- Investigation of Tritium in the Groundwater in the Vicinity of VB-6 (CRA, April 2006);
- Investigation of Tritium in the Groundwater in the Vicinity of VB-7 (CRA, April 2006);
- Technical memorandum, "Evaluation of the Source of Tritium in Two Private Wells located Along the Kankakee River and Illinois Route 113" (CRA, June 2006); and
- Hydrogeologic investigation Turbine Building/Protected Area (CRA, June 2006).

The above documents have been submitted to the Illinois EPA.

3.0 AREAS FOR FURTHER EVALUATION

CRA considered all Station operations in assessing groundwater quality at the Station. During this process, CRA identified areas at the Station that warranted further evaluation or "AFEs". This section discusses the process by which AFEs were selected.

CRA's identification of AFEs involved the following components:

- Station inspection on March 24, 2006;
- interviews with Station personnel;
- evaluation of Station systems;
- investigation of confirmed and unconfirmed releases of radionuclides; and
- review of previous Station investigations.

CRA analyzed the information collected from these components combined with information obtained from CRA's study of hydrogeologic conditions at the Station to identify those areas where groundwater potentially could be impacted from operations at the Station.

CRA then designed an investigation to determine whether any confirmed or potential releases or any other release of radionuclides adversely affected groundwater. This entailed evaluating whether existing Station groundwater monitoring systems were sufficient to assess the groundwater quality at the AFEs. If the systems were not sufficient to adequately investigate groundwater quality associated with any AFE, additional monitoring wells were installed by CRA.

The following sections describe the above considerations and the identification of AFEs. The results of CRA's investigation are discussed in Section 5.0.

3.1 SYSTEMS EVALUATIONS

Exelon launched an initiative to systematically assess the structures, systems and components that store, use, or convey potentially radioactively contaminated liquids. Maps depicting each of these systems were developed and provided to CRA for review. The locations of these systems are presented on Figures 3.1 and 3.2. The Station identified a total of 21 systems that contain or could contain potentially radioactively contaminated liquids. The following presents a list of these systems.

<i>System Identification</i>	<i>Description</i>
AB	Boric Acid Process
AS	Auxiliary System Steam
CD	Condensate
CP	Condensate Cleanup
CW	Circulation Water Blowdown and Treated Runoff Return Portions
FC	Fuel Pool Cooling
HD	Feedwater Drains
OG	Off Gas
OD	Equipment/Floor Oil Drain
PW	Primary Water
RF	Reactor Building Floor Drains
SH	Station Heating
ST	Sewage Treatment
SX	Essential Service Water
TE	Turbine Building Floor Drains
TF	Turbine Building Floor Drains
TR	Treated Runoff
VF	Filtered Vents
WE	Auxiliary Building Equipment Drain
WF	Auxiliary Building Floor Drain
WX	Radwaste Disposal

After these systems were identified, Exelon developed a list of the various structures, components and areas of the systems (e.g., piping, tanks, process equipment) that handle or could potentially handle any radioactively contaminated liquids. The structures, components, and areas may include:

- aboveground storage tanks;
- condensate vents;
- areas where confirmed or potential historical releases, spills, or accidental discharges may have occurred;
- pipes;
- pools;
- sumps;
- surface water bodies (i.e., basins, pits, ponds, or lagoons);
- trenches;
- underground storage tanks; and
- vaults.

The Station then individually evaluated the various system components to determine the potential for any release of radioactively contaminated liquid to enter the environment. Each structure or identified component was evaluated against the following seven primary criteria:

- location of the component (i.e., basement or second floor of building);
- component construction material (i.e., stainless steel or steel tanks);
- construction methodologies (i.e., welded or mechanical pipe joints);
- concentration of radioactively contaminated liquid stored or conveyed;
- amount of radioactively contaminated liquid stored or conveyed;
- existing controls (i.e., containment and detection); and
- maintenance history.

System components, which were located inside a building or that otherwise had some form of secondary containment, such that a release of radioactively contaminated liquid would not be discharged directly to the environment, were eliminated from further evaluation. System components that are not located within buildings or did not have some other form of secondary containment were retained for further qualitative evaluation of the risk of a release of radioactively contaminated liquid to the environment and the potential magnitude of any release.

Exelon's risk evaluation took into consideration factors such as:

- the potential concentration of radionuclides;
- the volume of liquid stored or managed;
- the probabilities of the systems actually containing radioactively contaminated liquid; and
- the potential for a release of radioactively contaminated liquid from the system component.

These factors were then used to rank the systems and system components according to the risk for a potential release of a radioactively contaminated liquid to the environment. The evaluation process resulted in the identification of structures, components, and areas to be considered for further evaluation.

3.2 HISTORICAL RELEASES

CRA also reviewed information concerning confirmed or potential historical releases of radionuclides at the Station, including reports and documents previously prepared by Exelon and compiled for CRA's review. CRA evaluated this information in identifying the AFEs. Any historical releases identified during the course of this assessment that may have a current impact on Station conditions are further discussed in Section 3.4.

3.3 STATION INVESTIGATIONS

CRA also considered previous Station investigations in the process of selecting the AFEs for the Station. This section presents a summary of the pre-operational radiological environmental monitoring program, past station investigations, and the radiological environmental monitoring program.

3.3.1 PRE-OPERATIONAL RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

A pre-operational radiological environmental monitoring program (pre-operational REMP) was conducted to establish background radioactivity levels prior to operation of the Station. The environmental media sampled and analyzed during the pre-operational REMP were atmospheric radiation, fall-out, domestic water, surface water, marine life, and foodstuffs. The results of the monitoring were detailed in the report entitled, Environmental Radiological Monitoring for Braidwood Nuclear Power Station, Commonwealth Edison Company, Annual Report 1986, May 1987.

The pre-operational REMP at Braidwood commenced in July 1983. The fourth annual report in 1986 presented data acquired during the period from January through December 1985. Atmospheric radiation monitoring consisted of gas and air particulate radioactivity measurements; fall-out monitoring consisted of radioactivity measurements of soil, vegetation, and rain water; domestic water monitoring consisted of well water sample analysis; surface water samples were collected from the two Kankakee River locations and two cooling water locations. Foodstuffs were monitored by analyzing samples of cow's milk and vegetables from nearby farms.

The pre-operational REMP contained analytical results from samples collected from the surface water and groundwater. The samples were analyzed for gross beta content and were averaged for each quarter.

Surface water at the Kankakee River downstream collection point, BD-10, had gross beta concentrations that ranged from 2.8 ± 0.9 picoCuries per liter (pCi/L) to 3.2 ± 1.4 pCi/L. At the upstream Kankakee River collection point, BD-7, the average gross beta concentrations for the second and fourth quarters was 3.6 pCi/L and the average gross beta concentration during the third quarter was 18.8 pCi/L. Gross beta concentrations from the cooling water sample points ranged from unspecified LLDs to a maximum detection of 4.9 ± 1.0 pCi/L.

Monthly composites of weekly sample collections from all surface water locations indicated tritium concentrations were non detect at the LLD (200 pCi/L). Monthly composites of weekly sample collections from all surface water locations indicate (strontium-89, strontium-90, cesium-134, and cesium-137) concentrations less than their specified LLDs.

Groundwater was collected from one off-site well on a quarterly basis. Gross beta, gamma isotopic, radiostrontium, and tritium analyses were performed on all samples. Strontium-89, strontium-90, tritium and gamma emitters were below their respective LLDs. Gross beta activity was within the expected levels and ranged from 3.7 ± 1.7 pCi/L to 37.9 ± 3.2 pCi/L.

3.3.2 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

As part of its NRC operating license, Braidwood Station conducts a REMP. The REMP includes the collection of multi-media samples including air, surface water, groundwater, fish, sediment, and vegetation. The samples are analyzed for beta and gamma emitting radionuclides, tritium, iodine-131, and/or strontium as established in the procedures developed for the REMP. The samples are collected at established locations, identified as stations, so that trends in the data can be monitored.

An annual report is prepared providing a description of the activities performed and the results of the analysis of the samples collected from the various media. The latest report generated was prepared by Station personnel and is entitled Annual Radiological Environmental Operating Report for the Braidwood Station (period from January 1 to December 31, 2005), May 2006. This report concluded that the operation of the Braidwood Station had no adverse radiological impact on the environment.

As part of REMP, surface water samples are collected at two locations and groundwater samples are collected at six locations.

3.3.3 HISTORIC SITE INVESTIGATIONS

This section summarizes historic site investigations completed at the Station in regard to releases of radioactively contaminated liquid to the subsurface.

3.3.3.1 POWER PLANT DOCUMENTS-UFSAR REPORT

During the construction of the Station, a series of comprehensive investigations of regional and local geology, surface water, and groundwater conditions were conducted. These studies are documented in the UFSAR Rev. 10, December 2004.

3.3.3.2 BLOWDOWN LINE INVESTIGATION

The blowdown line, which runs from the PA and east to the Kankakee River, was previously evaluated by CRA. The results are presented in a series of reports listed in Section 2.6 and Section 10.0. Figure 2.11 presents locations of monitoring wells installed as of May 2006 along the blowdown line and in the PA as part of these previous studies.

3.4 IDENTIFIED AREAS FOR FURTHER EVALUATION

CRA used the information presented in the above sections along with its understanding of the hydrogeology at the Station to identify AFEs, which were a primary consideration in the development of the scope of work in the Work Plan. The establishment of AFEs is a standard planning practice in hydrogeologic investigations to focus the investigation activities at areas where there is the greatest potential for impact to groundwater.

Specifically, AFEs were identified based on these six considerations:

- systems evaluations;
- risk evaluations;
- review of confirmed and/or potential releases;
- review of documents;
- review of the hydrogeologic conditions; and
- Station inspection completed on March 24, 2006.

Prior to CRA completing its analysis and determination of AFEs, Station personnel completed an exhaustive review of all historic and current management of systems that may contain potentially radioactively contaminated liquids.

CRA reviewed the systems identified by the Station, which have the potential for the release of radioactively contaminated liquids to the environment, and groundwater flow at the Station. This evaluation allowed CRA to become familiar with Station operations and potential systems that may impact groundwater. CRA then evaluated information concerning historic releases as provided by the Station. This information, along with a review of the results from historic investigations, was used to refine CRA's understanding of areas likely to have the highest possibility of impacting groundwater. Where at risk systems or identified historical releases were located in close proximity or were located in areas which could not be evaluated separately, the systems and historical releases were combined into a single AFE. At times, during the Station investigation, separate AFEs were combined into one or were otherwise altered based on additional information and consideration.

Finally, CRA used its understanding of known hydrogeologic conditions (prior to this investigation) to identify AFEs. Groundwater flow was an important factor in deciding whether to combine systems or historical releases into a single AFE or create separate AFEs. For example, groundwater beneath several systems that contain radioactively contaminated liquids that flows toward a common discharge point were likely combined into a single AFE. The AFEs were created based on known groundwater flow conditions prior to the work completed during this investigation.

Based upon its review of information concerning confirmed or potential historical releases, historic investigations, and the systems at the Station that have the potential for release of radioactively contaminated liquids to the environment combined with its understanding of groundwater flow at the Station, CRA identified four AFEs (see Figures 3.1 and 3.2).

AFE-Braidwood-1- North of the Slurry Wall

This area was identified as an AFE to investigate the possibility that the slurry wall (slurry trench) is not providing sufficient hydraulic control to prevent tritium (if present) from migrating off the site property. Tritium has been detected in the groundwater within the slurry wall on the west side of the Turbine Building. It was necessary to assess if this tritium or other groundwater impacts had the potential to migrate north of the slurry wall and outside the PA.

On March 13, 2006, rain accumulated and mixed with tritiated water within the bermed area surrounding the Frac Tank storage area located on a concrete pad (Refer to Figure 3.2). The berm surrounding the tanks was breached and allowed water to spill over the berm and seep into soils near the pad. Most of the water was recovered.

AFE-Braidwood-2 - North/Northeast of Units 1 and 2

This area was identified as an AFE due to its proximity to Units 1 and 2 and the systems near these two units. More specifically, this area was identified as an AFE to monitor groundwater quality on the northeast of the reactors, the fuel handling building, and other systems.

AFE-Braidwood-3 - Auxiliary Construction Storage Tank

This area comprises the Auxiliary Construction Storage Tank, the blowdown line as it exits the PA, and the sewage treatment plant. This area was selected for groundwater monitoring to evaluate the quality of groundwater in this area of the PA and the potential impacts of historical releases documented by Exelon.

AFE-Braidwood-4 - West Side of Turbine Building

This area comprises the west side of the Turbine Building. The following five pieces of information provide support to this area being identified as an AFE:

- existing monitoring well data from the Winter of 2006 had indicated tritium impacts in wells located adjacent to the west side of the Turbine Building foundation;
- a seep, occurring intermittently, into the basement of the Turbine Building had indicated concentrations of tritium over the LLD of 200 pCi/L;
- prior to 1992, effluent from Turbine Building Fire and Oil Sump was released to the storm water drainage system;
- in December 1990, some tritiated water may have been periodically discharging to the storm sewer system through a heating system relief valve. The valves discharge to the Oil/Water Separator on the north end of the property. The separator then discharges into the drainage ditch; and
- on April 6, 2006, a release of steam (location is presented on Figure 3.2) from the west side of the Turbine Building discharged onto the ground surface near the waste treatment lagoons and north of the waste treatment plant. The release was partially remediated by collecting all available standing water, pumping water from the storm water drainage system, and blocking drainage paths for some site drainage ditches.

4.0 FIELD METHODS

The field investigations completed for this HIR were completed in April, May, and July 2006. CRA supervised the installation of monitoring wells and staff gauges, collected samples from the newly-installed and existing monitoring wells and from surface water locations, and collected a round of groundwater and surface water measurements. The field investigations were completed in accordance with the methodologies presented in the Work Plan (CRA, 2006).

4.1 STAFF GAUGES INSTALLATION

Figure 4.1 presents the location of the four new staff gauges and two surface water monitoring points installed as part of this investigation. CRA installed staff gauges at four locations (SG-BW-101 to 104) within the perimeter ditch and established two monitoring points (SG-105 and 106) on the Cooling Lake.

4.2 GROUNDWATER MONITORING WELL INSTALLATION

Twelve new monitoring wells were installed for the fleetwide hydrogeologic investigation. Monitoring well construction logs are provided in Appendix A. This included ten wells completed within the upper sand aquifer and two completed within the shallow bedrock. Figure 4.2 presents the location of the new monitoring wells. These locations were selected based on a review of all data provided, the hydrogeology at the Station, and current understanding of identified AFEs. Table 4.1 summarizes the well completion details.

Prior to completing any ground penetration activities, CRA completed subsurface utility clearance procedures to minimize the potential of injury to workers and/or damage to subsurface utility structures. The subsurface clearance procedures consisted of completing an electronic survey within a minimum of 10-foot radius of the proposed location utilizing electromagnetic and ground penetrating radar technology. Additionally, an air knife was utilized to verify utilities were not present at the proposed location to a depth to 10 feet bgs.

Specific installation protocols for the ten shallow monitoring wells are described below:

- the borehole was advanced to the target depth using 4.25-inch inside diameter hollow-stem augers (HSA) or Rotosonic techniques;

- a nominal 2-inch diameter (No. 10 slot) PVC screen, 10 feet in length, attached to a sufficient length of 2-inch diameter schedule 40 PVC riser pipe to extend to the surface, was placed into the borehole through the augers;
- a filter sand pack consisting of silica sand was installed to a minimum height of 2 feet above the top of the screen as the augers are removed;
- a minimum 2-foot thick seal consisting of 3/8-inch diameter bentonite pellets or chips was placed on top of the sand pack and hydrated using potable water;
- the remaining borehole annulus was sealed to within 3 feet of the surface using pure bentonite chips;
- the remaining portion of the annulus was filled with concrete and a 6-inch diameter protective above-grade casing. The well head will be fitted with a water-tight, lockable cap; and
- cement-filled bollard posts were installed around selected monitoring well locations.

Shallow monitoring wells included two types of wells completed within the upper sand aquifer. A shallow zone well was completed at depths of approximately 15 feet bgs into the upper sand zone and at the water table. The deep zone wells were completed at depths of approximately 25 to 30 feet bgs and into the lower portions of sand found on top of the Wedron Clay Till.

Specific installation protocols for the two bedrock monitoring wells are described below.

Each shallow bedrock well was drilled to and completed within the first water bearing zone encountered beneath the Francis Creek Shale Member. A sandstone was encountered below these shales and the screened interval for both MW-BW-201BD and MW-BW-208BD was set into this sandstone layer at a depth of approximately 80 to 95 feet bgs at MW-BW-201BD and from 85 to 100 feet bgs at MW-BW-208BD. This sandstone is expected to be part of the underlying Spoon Formation.

MW-BW-201D was installed using 8-inch HSA drilled to a depth of 39 feet bgs. A 6-inch protective casing was then installed through the augers and pushed to a depth of 40 feet bgs to ensure a proper seal into the till. A HQ coring bit was used to drill through the shale and siltstone formations to a depth of 100 feet bgs. Ten-foot core samples were recovered between 70 and 100 feet bgs. The core sample recovered in MW-BW-201BD between 84 and 91 feet bgs appeared to contain highly fractured and weathered sandstone, therefore the monitoring well screen was installed to straddle that zone (i.e., from 80 to 95 feet bgs) as shown on the well construction log. Similar conditions were encountered at MW-BW-208BD. At this location the well screen was

installed between 80 to 100 feet bgs. The monitoring well MW-BW-208BD was installed in July 2006 using Rotosonic drilling techniques.

Sand was installed in the borehole from the bottom of the hole to the bottom of the well screen to provide a base for the 2-inch monitoring well. A sand pack was then installed up to a depth of 2 feet above the top of the screen. Bentonite chips were installed to ensure a hydraulic seal above the sand pack. The protective casing and either the 8-inch augers (in the case of the HSA) or the drill steel (in the case of the Rotosonic) were then removed from the borehole. A bentonite gel and Portland cement slurry was then mixed and added to the borehole to 2 feet bgs. The monitoring wells were then finished with a Pro-cover protective casing.

4.3 GROUNDWATER MONITORING WELL DEVELOPMENT

In order to establish good hydraulic communication with the aquifer and reduce the volume of sediment in the monitoring well, monitoring well development was performed in accordance with the procedure outlined below:

- Monitoring wells were surged using a pre-cleaned surge block for a period of at least 20 minutes.
- Water was purged from the monitoring well using a pneumatic submersible pump.
- Groundwater was collected at regular intervals with the pH, temperature, and conductivity measured using field instruments. These instruments were calibrated daily according to the manufacturer's specifications. Additional observations such as color, odor, and turbidity of the purged water were recorded in the field book.
- Development continued until the turbidity and silt content of the monitoring wells was significantly reduced and three consistent readings of pH, temperature, and conductivity were recorded, or a minimum of ten well volumes were purged.

A summary of the well development parameters is provided in Table 4.2.

4.4 WELL INVENTORY

CRA performed a comprehensive private well survey/inventory along the length of the blowdown line and in areas north and west of the site. This well inventory was presented in the reports discussed in Section 2.6. The private well logs for wells near and surrounding the Site are provided in Appendix B. These wells are a subset of the

water supply wells sampled by Exelon. Figure 2.15 presents the locations and results for private wells, public wells, and monitoring wells.

4.5 SURVEY

The new monitoring wells and staff gauges were surveyed to establish reference elevations relative to mean sea level. The top of each well casing was surveyed to the nearest 0.01 feet relative to the National Geodetic Vertical Datum (NGVD), and the survey point was marked on the well casing. The survey included the ground elevation at each well to the nearest 0.10 feet relative to the NGVD, and the well location to the nearest 1.0 foot. A reference point was also marked on each staff gauge.

4.6 GROUNDWATER AND SURFACE WATER ELEVATION MEASUREMENTS

From May 9 to 11, 2006, CRA collected water level measurements from both existing monitoring wells, new monitoring wells, and from surface water locations in accordance with the Work Plan. CRA collected a second round of water levels from both existing and new monitoring wells on July 31, 2006. Based on the measured depth to water from the reference point and the surveyed elevation of the reference point, the groundwater or surface water elevation was calculated. A summary of groundwater elevations for the events is provided in Table 4.3.

Prior to the water level measurements, the wells were correctly identified and located. Once the well was identified, a thorough inspection of each well was conducted, and any deficiencies were noted. Water level measurements were collected using an electronic depth-to-water probe accurate to +/- 0.01 feet. The measurements were made from the designated location on each of the monitoring wells inner riser or steel casing. The water level measurements were obtained using the following procedures:

- The proper elevation of the meter was checked by inserting the tip into water and noting if the contact was registering correctly.
- The tip was dried, and then slowly lowered into the well until contact with the water was indicated.
- The tip was slowly raised until the light and/or buzzer just began to activate. This indicated the static water level.
- The reading at the reference point was noted to the nearest hundredth of a foot.

- The reading was then re-checked.
- The water level was then recorded, and the water level meter decontaminated prior to use at the next well location.

In early May 2006, as part of the fleetwide investigation, CRA collected a round of water level measurements from 43 of the Station monitoring wells and six surface water locations on the Station. On July 31, 2006, CRA collected a second round of water level measurements from 45 of the Station monitoring wells (including the two newly installed monitoring wells, MW-BW-207I and MW-BW-208BD). A summary of groundwater elevations for the two events is provided in Table 4.3.

During the May 2006 groundwater sampling program, the following monitoring wells (MW-4, MW-5, TB-1-3D, TW-6, and TW-8) were not measured for depth to water due to problems with the water level indicator meter. CRA subsequently has gone back at a later date to get these water levels. Also, water levels were not measured at TW-8 because TW-8 had broken riser.

Surface water elevations were measured at the four staff gages installed within the perimeter ditch (Figure 4.1) and at two locations on the north side of the Cooling Lake (Figure 4.1). The data from these measurements are provided in Table 4.4.

A pressure transducer was installed by CRA at TB-1-4D for approximately 6 weeks to evaluate water level changes near the Turbine Building close to where leaks have occurred within the basement. The purpose of the continuous monitoring was to determine if the system (pipe) water leaks were creating this basement seep, or, if precipitation/storm water system leaks were affecting flow into the basement.

Water level data were recorded for the period from June 6 to July 21, 2006. Precipitation data were also reviewed for this same period for the Village of Braidwood. Figure 4.3 presents a graphical presentation of the relative head (feet above the transducer) measurements from the transducer. Figure 4.3 also presents the precipitation (inches) for the monitored period. The pressure transducer was set at 10 feet below the top of the well casing. At the time of installation, the water table was 6.9 feet below the top of the well casing.

4.7 GROUNDWATER AND SURFACE WATER SAMPLE COLLECTION

CRA conducted two rounds of groundwater sampling during the completion of the Work Plan for these hydrogeologic investigations. A total of 43 monitoring wells were sampled between May 9 and May 22, 2006 and two monitoring wells were sampled on July 28, 2006. Of the 45 monitoring wells sampled, 12 were newly installed. The sampling was scheduled to allow for two weeks to elapse between well development and groundwater sample collection. The existing wells were selected for inclusion in this monitoring program based on their proximity to the AFEs. The new wells were installed to complete the monitoring network near the AFEs.

At the monitoring locations, CRA conducted the sampling using dedicated tubing and peristaltic pumps and employed low-flow purging techniques as described in Puls and Barcelona (1996).

The groundwater in the monitoring wells was sampled by the following low-flow procedures:

- The wells were located and the well identification numbers were verified.
- A water level measurement was taken.
- The well was sounded by carefully lowering the water level tape to the bottom of the well (so as to minimize penetration and disturbance of the well bottom sediment), and comparing the sounded depth to the installed depth to assess the presence of any excess sediment or drill cuttings.
- The pump or tubing was lowered slowly into the well and fixed into place such that the intake was located at the mid-point of the well screen, or a minimum of 2 feet above the well bottom/sediment level.
- The purging was conducted using a pumping rate between 100 to 500 milliliters per minute (mL/min). Initial purging began using the lower end of this range. The groundwater level was monitored to ensure that a drawdown of less than 0.3 feet occurred. If this criterion was met, the pumping rate was increased dependent on the behavior of the well. During purging, the pumping rate and groundwater level were measured and recorded every 10 minutes.
- The field parameters (pH, temperature, conductivity, oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity) were monitored during the purging to evaluate the stabilization of the purged groundwater. Stabilization was considered to be achieved when three consecutive readings for each parameter, taken at 5-minute intervals, were within the following limits:

- | | |
|--------------|--|
| pH | ± 0.1 pH units of the average value of the three readings; |
| Temperature | ± 3 percent of the average value of the three readings; |
| Conductivity | ± 0.005 milliSiemen per centimeter (mS/cm) of the average value of the three readings for conductivity <1 mS/cm and ± 0.01 mS/cm of the average value of the three readings for conductivity >1 mS/cm; |
| ORP | ± 10 millivolts (mV) of the average value of the three readings; |
| DO | ± 10 percent of the average value of the three readings; and |
| Turbidity | ± 10 percent of the average value of the three readings, or a final value of less than 5 nephelometric turbidity units (NTU). |
- Once purging was complete, the groundwater samples were collected directly from the pump/tubing directly into the sample containers.

All groundwater samples were labeled with a unique sample number, the date and time, the parameters to be analyzed, the job number, and the sampler's initials. The samples were then screened by the Station for shipment to Teledyne Brown Engineering, Inc. (Teledyne Brown).

A sample key is presented in Table 4.5; purging parameters for the fleetwide event are presented in Table 4.6.

CRA containerized the water purged from the monitoring wells during the sampling, as well as the water purged from all of the wells during the hydrogeologic investigation. The water was placed into 55-gallon drums, which will be processed by the Station in accordance with its NPDES permit.

Surface water samples were collected on May 17, 2006 a few days after a storm event. The surface water samples were collected under dry conditions in order to avoid dilution by rainwater. Six surface water samples were collected, four at staff gauges located on the perimeter ditch and locations on the north end of the Cooling Lake. The surface water sampling locations are presented on Figure 4.1.

The surface water samples were collected by submerging the sample container at the determined sample locations until completely filled. All samples were shipped to Teledyne Brown for analysis.

4.8 DATA QUALITY OBJECTIVES

CRA has validated the analytical data to establish the accuracy and completeness of the data reported. Teledyne Brown provided the analytical services. The Quality Assurance Programs for the laboratory is described in Appendix E. Analytical data for groundwater and surface water samples collected in accordance with the Work Plan are presented in Appendix F. Data validation reports are presented in Appendix G. The data validation included the following information and evaluations:

- sample preservation;
- sample holding times;
- laboratory method blanks;
- laboratory control samples;
- laboratory duplicates;
- verification of laboratory qualifiers; and
- field quality control (field blanks and duplicates).

Following the completion of field activities, CRA compiled and reviewed the geologic, hydrogeologic, and analytical data.

The data were reviewed using the following techniques:

- data tables and databox figures;
- hydrogeologic cross-sections; and
- hydraulic analyses.

4.9 SAMPLE IDENTIFICATION

Systematic sample identification codes were used to uniquely identify all samples. The identification code format used in the field was: WG - BW - 050806 - MB - 001. A summary of sample identification numbers is presented in Table 4.5.

WG	- Sample matrix -groundwater
SW	- Sample matrix - surface water
BW	- Station code
050806	- Date
MB	- Sampler initial
001	- Sample number

4.10 CHAIN-OF-CUSTODY RECORD

The samples were delivered to Station personnel under chain-of-custody protocol. Subsequently, the Station shipped the samples under chain-of-custody protocol to Teledyne Brown for analyses.

4.11 QUALITY CONTROL SAMPLES

Quality control samples were collected to evaluate the sampling and analysis process.

Field Duplicates

Field duplicates were collected to verify the accuracy of the analytical laboratory by providing two samples collected at the same location and then comparing the analytical results for consistency. Field duplicate samples were collected at a frequency of one duplicate for every ten samples collected. A total of seven duplicate samples were collected. The locations of duplicate samples were selected in the field during the performance of sample collection activities. The duplicate samples were collected simultaneously with the actual sample and were analyzed for the same parameters as the actual samples.

Split Samples

Split samples were collected for the NRC for tritium simultaneously with the actual sample at every sample location. Split samples were delivered to the Station personnel and made available to the NRC.

4.12 ANALYSES

Groundwater and surface water samples were analyzed for tritium and gamma-emitting radionuclides as listed in NUREG-1301 and strontium-89/90 as listed in 40 CFR 141.25.

5.0 RESULTS SUMMARY

This section provides a summary of Station-specific geology and hydrogeology, along with a discussion of hydraulic gradients, groundwater elevations, and flow directions in the vicinity of the Station. This section also presents and evaluates the analytical results obtained from activities performed in accordance with the Work Plan.

5.1 STATION GEOLOGY

The geology encountered during monitoring well installation is consistent with the geology described in Section 2.4.2 and the geology within areas to the east and along the blowdown line as described in the CRA reports previously listed (refer to Section 2.5). The geology beneath the site consists of overburden deposits of sand (Equality Formation) and clay (Wedron Clay Till) that overlies alternating layers of shale/siltstone and dolostone (Carbondale Formation) (refer to the site specific stratigraphic column on Figure 2.8). South-north and east-west hydrogeologic profiles (profiles) are presented on Figures 5.1 to 5.5. These profile locations were chosen because of their close proximity to structures potentially influencing groundwater flow patterns.

The three new shallow and seven intermediate depth wells (MW-BW-201S, MW-BW-201I, MW-BW-202S, MW-BW-202I, MW-BW-203S, MW-BW-203I, MW-BW-204I, MW-BW-205I, MW-BW-206I, and MW-BW-207I) were installed within the Equality Formation. The Equality Formation is primarily uniform fine-grained sand. The monitoring well logs for the new monitoring wells are presented in Appendix A.

The two bedrock wells, MW-BW-201BD and MW-BW-208BD, were installed through the Equality Formation, the Wedron Clay Till, the Francis Creek Shale Member of the Carbondale Formation and into the lower portion of the Francis Creek Shale Member. Refer to Figure 2.8 for the sequence of formations beneath the site. The top of the Wedron Clay Till was encountered at approximately 24 feet bgs, which is consistent with previous geological investigations. The bottom of the clay was approximately 54 feet bgs where shale bedrock was encountered and is considered to be the Francis Creek Shale Member. At a depth of approximately 85 feet bgs, a sandstone was encountered that was weathered. From 90 to 100 feet, the material included a conglomerate, sandstone, and shale. MW-BW-201BD and MW-BW-208BD were both completed in this lower zone from 80 to 95 feet bgs and 85 to 100 feet bgs, respectively. This is expected to be the bottom of the Francis Creek Shale Member of the Carbondale Formation and it is located just above the Colchester Coal (Figure 2.8).

Profile A-A' (Figure 5.2) is a west-east profile through the middle of the Station. It begins at the western fence line bordering the Station and terminates near the eastern perimeter ditch approximately 1,200 feet east of the eastern fence line of the site. The profile A-A' presents the relative elevations of the perimeter ditch water levels with groundwater levels on both sides of the PA. Higher water levels are measured in the eastern stretch of the perimeter ditch. The profile also indicates that the buildings extend to the top of the Francis Creek Shale Member (through the Wedron Clay Till) and will act as barriers to lateral flow. The backfilled area around the building is also indicated on this profile. Finally, the slurry wall is projected on this figure based upon information gathered from Station documents. The top of the slurry wall appears to be close to the current water table elevation.

Profile B-B' (Figure 5.3) is a north-south profile and parallels the storm sewer line that runs south-north. The profile B-B' indicates the relative elevation of the groundwater table and the approximate depth of the storm water drainage system. This figure clearly indicates that the storm water drainage system intercepts the water table as reported previously (CRA, August 2002 and September 2003). The limits of the construction excavation are also depicted on this profile along with the expected condition of the slurry wall. During drilling of the intermediate monitoring well MW-BW-207I on July 13, 2006, the Wedron Clay Till was not encountered. The material encountered included sands and other fill type material such as gravels and concrete. These observations indicate that the Station construction excavation went to a depth of approximately 44 to 45 feet bgs at this location. This depth of the excavation is indicated on Figure 5.3. Although the clay was missing in the location of MW-BW-207I, the top of the Francis Creek Shale Member was encountered where expected (45 feet bgs).

Profile C-C (Figure 5.4) is a north-south profile down the center of the PA area to the Cooling Lake. The bedrock well (MW-BW-201BD) is displayed on this figure, as well as the building foundation. The profile C-C' presents a more regional depiction of subsurface conditions from the Cooling Lake in the south to the north end of the PA. The slurry wall associated with the Cooling Lake and the slurry wall associated with the building construction are depicted on this profile. The depths of the various facility buildings are shown to extend down through the Wedron Clay Till and to the top of the Francis Creek Shale Member. As such, these buildings are barriers to lateral groundwater flow. The shallow bedrock monitoring well (MW-BW-201BD) is presented on this figure and indicates the bottom of the Francis Creek Shale Member.

Profile D-D' (Figure 5.5) is a west-east profile in the northern portion of the PA that transects the CST area. Hydrogeologic profile D-D' presents the locations and relative elevations of the groundwater, storm water drainage system, slurry wall, and

excavation/fill material. This profile is north of the Turbine Building and as such does not present subsurface building structures. The water levels on each side of the slurry wall on the west do indicate a slight difference in elevation. However, this is not as apparent in other areas in the PA.

5.2 SITE HYDROGEOLOGY

This section describes groundwater flow in the various hydrogeologic units identified at the site. Figure 5.1 presents the monitoring well network in relationship to the hydrogeologic profile locations. Hydrogeologic profiles are presented on Figures 5.2 to 5.5.

5.2.1 GROUNDWATER FLOW DIRECTIONS

Groundwater flow directions in the upper sand aquifer are presented on Figures 5.6 and 5.7 (the shallow zone) and on Figures 5.8 and 5.9 (the deep zone). Figures 5.6 and 5.8 represent water levels measured in May 2006. Figures 5.7 and 5.9 represent water levels measured in July 2006. CRA has identified four areas of differing flow within and around the PA based upon the May and July water levels. These four areas are a result of the man-made features presented in the previous section.

One flow system encompasses the east side of the PA. The second system is found along the west side of the Turbine Building within the perimeter of the slurry wall and within the limits of the former excavation. The third system is to the northwest of the slurry wall near the perimeter ditch. The fourth system includes the area west-southwest of the PA where groundwater flows to the southwest and discharges to the perimeter ditch. The groundwater flow is restricted by the basement walls and, to some degree, the slurry trench. Groundwater flow directions are provided on Figures 5.6 and 5.7 for the shallow zone of the upper sand aquifer and on Figures 5.8 and 5.9 for the deep zone of the upper sand aquifer.

Groundwater in the near west side of the Turbine Building predominantly flows to the north toward a storm water drainage system ditch north of the Oil/Water Separator. The storm water drainage system ditch is a tributary to the perimeter ditch (Figure 2.3).

To the west and southwest of the PA, the perimeter ditch acts as a discharge point for the shallow groundwater system (CRA, August 2002). Groundwater generally flows to the ditch from east to west. The water elevation within the ditch is measured to be

approximately 586 feet above mean sea level (AMSL) at a location northwest of the PA. Groundwater elevations are higher than ditch elevations along the length of the perimeter ditch as it flows to the south. There is no shallow groundwater flow to the west of the perimeter ditch under normal flow conditions (CRA, September 2003).

5.2.2 MAN-MADE INFLUENCES ON GROUNDWATER FLOW

There are a number of man-made features that influence the flow direction and velocity of groundwater as it moves through the site area. These features include:

- The perimeter ditch (Figures 2.3, 2.6, and 2.7), which was dug at the time of the Station Construction to drain surface water away from the Cooling Lake;
- The storm water drainage system (Figures 2.3, 2.4, and 2.5) located on the west side of the Turbine Building and its associated Oil/Water Separator;
- The slurry wall constructed around the footprint of the buildings in the PA (Figure 2.1);
- The former excavation now backfilled with material located around the current buildings (Figure 2.1);
- The various basements and foundations of the turbine, auxiliary, reactor, fuel handling, and other buildings, many of these extend through the water table (Figures 5.2 to 5.5); and
- The Cooling Lake and the slurry wall, which are located south of the PA (Figures 2.13, 2.14, and 5.4).

The figures listed above and the discussion presented below provide basic observations on the impact of these features on groundwater flow which was discussed previously in Section 5.2.2.

The PA (Figure 1.2) is located at the northwest area of the Station property and is surrounded by the perimeter ditch, which flows from the east, to the north of the PA, and then to the south. The perimeter ditch flows along the western boundary of the Station property (Figure 2.3). The elevation of the water in the ditch drops from about 593 feet AMSL on the east side to 586 feet AMSL on the west side. The water levels continue to drop as the ditch flows to the south and west. As the ditch exits the Braidwood Station Property, its surface water elevation is about 579 feet AMSL.

To the south of the PA is the Cooling Lake, which comprises over 2,500 acres of impounded water. A slurry wall constructed to keep surface water from seeping into

the upper sand aquifer surrounds the Cooling Lake. This is confirmed by the groundwater data monitored by the Station at various locations around the Lake.

During construction of the buildings within the PA, a slurry wall was constructed to minimize groundwater infiltration into the excavation. This excavation was within the confines of the slurry wall and in some areas the depth was greater than 40 feet and into the underlying bedrock shale formation (UFSAR, 1994).

The foundations or basements associated with the Reactors/ Auxiliary Building and the Turbine Building extend to depths below the water table. In fact, the foundations were completed through the Wedron Clay Till at this Station, as is shown on the hydrogeologic profiles presented on Figures 5.2 to 5.5 (i.e., the Wedron Clay Till was removed during building excavation). These basements are barriers to groundwater flow in the upper sand aquifer. There are no dewatering systems such as sump pumps used to manage groundwater inflow. As such, the basement walls are assumed to be impermeable to groundwater flow. Consequently, groundwater pressure on these foundations will create an inward gradient into the basement. The Francis Creek Shale Member was not disturbed during building construction and remains in place as an aquitard.

The PA and surrounding land is generally flat and paved areas, roadways, and parking lots now cover it. These areas are drained by a storm water drainage system that drains to the northwest corner of the PA. The storm water drainage system drains to an Oil/Water Separator at the north end of the PA (Figures 2.3 and 2.5). The outfall from the Oil/Water Separator discharges to a small east-west ditch and then flows west to the perimeter ditch.

Previous studies have documented that the storm water drainage system intercepts groundwater on the west side of the Turbine Building. These same studies have indicated that the perimeter ditch, which flows from the north to the south along the western Station property line, also intercepts the groundwater (CRA, August 2002 and September 2003). As such, groundwater flowing near the perimeter ditch will be intercepted by the ditch (Figures 2.6 and 2.7).

5.2.3 VERTICAL HYDRAULIC GRADIENTS

Several monitoring well nests have been installed in the upper sand aquifer not only to determine the vertical distribution of impacted groundwater, but also the vertical hydraulic gradient within the aquifer. The calculated hydraulic gradients for the site are

provided in Table 5.1 and the well locations used to calculate hydraulic gradients are shown on Figure 5.1.

Table 5.1 indicates that vertical hydraulic gradients are minor or slightly upward in areas away from the buildings and away from the former construction excavation. However, a few monitoring well clusters located on the west side of the Turbine Building indicate a downward vertical hydraulic gradient. This gradient varies from 0.005 feet/foot (ft/ft) at TB-1-4D/TW-3 location to 0.167 ft/ft at the TB-1-2D/MW-2 location. The locations with downward vertical hydraulic gradients are also near the storm water drainage system. The cause of the downward vertical hydraulic gradients is likely related to the additional recharge from the nearby storm water drainage system.

Vertical groundwater flow is restricted by the regional aquitards. However, due to the removal of the Wedron Clay Till beneath the buildings, one of the two regional aquitards was locally removed within the PA. Nevertheless, groundwater data indicate that the remaining aquitard (the Francis Creek Shale Member) is preventing vertical migration of tritium downward within the PA.

The downward vertical hydraulic gradients measured along the west side of the Turbine Building are likely caused by increased recharge into the fill material by precipitation that leaks from the storm water drainage system. A review of the precipitation and transducer data on Figure 4.3 suggests that there are small groundwater fluctuations that may be due to precipitation/storm water infiltration. The data presented on Figure 4.3 do not suggest that there are any types of systematic or routine events (i.e., operations) that are causing fluctuations in the water table elevations.

5.2.4 LATERAL GROUNDWATER FLOW AND VELOCITY

The groundwater flow directions depicted on Figures 5.6, 5.7, 5.8, and 5.9 for the upper sand aquifer indicate, to some degree, a radial pattern of flow from the center of the PA. Groundwater flow directions are similar to conditions measured in May and July 2006. This pattern is better explained by understanding the role of man-made features on the regional flow direction in this upper sand aquifer. Groundwater on a local or regional basis in the upper sand aquifer is to the north and northeast towards the surface waters that drain to the Kankakee and Illinois Rivers (CRA March 2006). This flow direction was confirmed in the blowdown studies discussed in Section 2.6.

Within and nearby the PA the man-made features have modified the local flow system to the north. First, the former construction excavation and the building basements force

a split or divide in flow as groundwater moves from south to north. Second, the perimeter ditch flows from east, to north to south and ultimately to the west around the PA and becomes a discharge point for groundwater. This ditch intercepts the groundwater table and groundwater discharges into this ditch along its whole length. The surface water elevation of the perimeter ditch as it exits the Braidwood Station property (south of Godley) is approximately 579 feet AMSL (CRA, September 2000). This is 11 to 16 feet lower than the groundwater elevation in the PA.

Consequently, the combination of structures in the PA and the presence of the perimeter ditch create the appearance of radial flow, but these influences are just a modification to the regional flow direction of south to north.

The average calculated horizontal hydraulic gradient in the upper sand aquifer along the east side of the PA is 0.004 ft/ft. The groundwater flow direction in this area is from the south to north. Figures 5.6 and 5.7 display the groundwater elevation contours in the shallow groundwater zone.

The average calculated horizontal hydraulic gradient in the upper sand aquifer along the west side of the Turbine Building is 0.007 ft/ft. The general groundwater flow direction in this area is from south to north (Figures 5.6, 5.7, 5.8, and 5.9).

The average calculated horizontal hydraulic gradient in the upper sand aquifer west of the slurry wall is 0.005 ft/ft. The general groundwater flow direction in this area is from the southeast to the northwest (Figures 5.6, 5.7, 5.8, and 5.9).

The overall, site-wide, average calculated horizontal hydraulic gradient is approximately 0.007 ft/ft within the upper sand aquifer. Results from previous single-well response tests performed east of the PA and along the blowdown line (previous investigations referred to in Section 1.0) indicate that the hydraulic conductivity of the overburden aquifer is 2.5×10^{-2} cm/s. Assuming an average effective porosity of 0.3, the average groundwater velocity in the upper sand aquifer is approximately 604 ft/yr.

The calculated hydraulic gradients and average groundwater velocity are greater than that observed east of the PA and along the blowdown line. It is likely that the groundwater velocity is influenced by steep hydraulic gradients toward the perimeter ditch flowing to the north and to the west of the PA.

5.3 GROUNDWATER QUALITY

CRA personnel collected groundwater samples from 45 of the monitoring wells located on the Station property, including 12 newly installed monitoring wells. This subset included all available existing monitoring wells in the PA but did not include those located along the blowdown line to the east. The groundwater samples were analyzed for tritium and additional radionuclides. Teledyne Brown provided the analytical services. The Quality Assurance Program for the laboratory is described in Appendix E. The analytical data reports are provided in Appendix F.

Table 5.2 presents a summary of tritium analyses for groundwater samples collected recently in May and July 2006. Table 5.3 presents a summary of radionuclides analyzed in groundwater samples collected in May and July 2006. Tables 5.4 and 5.5 present the tritium and radionuclide analyses for surface water samples, respectively. Table 5.6 presents a summary of groundwater analyses for tritium in samples collected previously at existing monitoring wells. Table 5.7 presents a summary of surface water analyses for tritium in samples collected previously at existing surface water locations.

The analytical data presented herein has been subjected to CRA's data validation process. CRA has used the data with appropriate qualifiers where necessary.

The data reported in the figures and tables does not include the results of recounts that the laboratory completed, except if those results ultimately replaced an initial report. The tables and figures, therefore, include only the first analysis reported by the laboratory. Where multiple samples were collected over time, then the most recent result has been used in the discussion, below.

5.3.1 SUMMARY OF BETA-EMITTING RADIONUCLIDES ANALYTICAL RESULTS

A summary of the tritium results for the groundwater samples collected during this investigation is provided in Table 5.2 and shown on Figure 5.10. Table 5.6 summarizes analytical results for previous sampling events performed at the site.

All tritium concentrations were below the USEPA drinking water standard of 20,000 pCi/L. Tritium was not detected at concentrations greater than at the LLD of 200 pCi/L in 34 of the 45 groundwater samples collected.

The highest concentrations of tritium (between 200 pCi/L and $1,040 \pm 172$ pCi/L) in test wells were predominantly from groundwater samples collected on the west side of the Turbine Building. The highest concentration of tritium at $1,040 \pm 172$ pCi/L was found at TW-3, which was installed in the deep upper sand aquifer. At five of these locations, the groundwater analyses indicated tritium concentrations just over 200 pCi/L and less than 250 pCi/L.

The groundwater samples collected from the bedrock monitoring wells MW-BW-201BD and MW-BW-208BD, which were completed to a depth of 95 feet bgs and 100 feet bgs, respectively, did not contain tritium at a concentration exceeding the LLD of 200 pCi/L. These wells were completed beneath the confining layers of the Wedron Clay Till and the Francis Creek Shale Member.

Strontium-89/90 was not detected in concentrations greater than the LLD of 2.0 pCi/L. A summary of the strontium-89/90 results for the groundwater samples collected as part of the investigation that is the subject of this HIR is provided in Table 5.3 and shown on Figure 5.11.

5.3.2 SUMMARY OF GAMMA-EMITTING RADIONUCLIDES ANALYTICAL RESULTS

Gamma-emitting target radionuclides were not detected in concentrations greater than their respective LLD. A summary of the gamma-emitting radionuclides results for the groundwater samples collected as part of the investigation that is the subject of this HIR is provided in Table 5.3 and shown on Figure 5.11.

Other non-targeted radionuclides were also included in the tables but excluded from discussion in this report. These radionuclides were either a) naturally occurring and thus not produced by the Station, or b) could be definitively evaluated as being naturally occurring due to the lack of presence of other radionuclides which would otherwise indicate the potential of production from the Station.

5.3.3 SUMMARY OF FIELD MEASUREMENTS

Table 4.6 presents of a summary of field measurements collected during the well purging and sampling activities. These field measurements included pH, dissolved oxygen, conductivity, turbidity and temperature. The field parameters were typical of a shallow sand aquifer with carbonate source rock (i.e., the underlying limestones and

shales). As such the pH values were found to be above 7.0 and the conductivity was indicative of a shallow water table system subject to surface water recharge.

Of note were the slightly elevated temperature readings (above 20 degrees Celsius) at TB-1-9D, which is located south of the wastewater treatment building and the treatment lagoon (Figure 3.1), TB-10-D, which is located adjacent to the Turbine Building, and just east of TB-1-9D, and MW-BW-207I, which is located adjacent to the Turbine Building, and north of TB-1-10D. It should also be noted that the conductivity of the water purged from MW-6, TB-1-3D, and TB-1-8D was an order-of-magnitude higher than the readings from other sampling locations.

5.4 SURFACE WATER QUALITY

Six surface water samples were collected from the four staff gauge locations on the perimeter ditch and from two locations along the north end of the Cooling Lake. The locations of the samples are shown on Figure 4.1. The samples were analyzed for tritium, gamma-emitting radionuclides, and strontium-89/90. Teledyne Brown provided the analytical services. The Quality Assurance Program for the laboratory is described in Appendix E. The analytical data reports are provided in Appendix F. Analytical data for these surface water samples are presented in Tables 5.4 and 5.5.

5.4.1 SUMMARY OF BETA-EMITTING RADIONUCLIDES ANALYTICAL RESULTS

A summary of the tritium results for the surface water samples collected in this investigation is provided in Table 5.4 and shown on Figure 5.10.

Surface water samples SW-101, SW-102, SW-103 had concentrations of tritium of 398 ± 129 , 365 ± 120 , and 230 ± 114 pCi/L, respectively. These concentrations are greater than the LLD of 200 pCi/L. Surface water samples SW-101 and SW-102 were collected from the perimeter ditch located just northwest of the PA. Surface water sample SW-103 was collected along the perimeter ditch near the northeast corner of the Cooling Lake. A summary of the tritium analytical results from six surface water samples is presented in Table 5.4. Surface water samples collected as part of the blowdown line investigations and as part of the interim routine monitoring program in the PA are provided in Table 5.7.

The results of analyses of numerous surface water samples, which were collected during the spring and summer of 2006, along the perimeter ditch, have shown that no tritium greater than detectable limits have left the Station.

Strontium-89/90 was not detected in concentrations greater than the LLD of 2.0 pCi/L. A summary of the strontium-89/90 results for the surface water samples collected in this investigation is provided in Table 5.5 and shown on Figure 5.11.

Surface water samples were collected within the perimeter ditch and analyzed for tritium at four monitoring points found north, west, and south of the PA. In addition, surface water was collected at the north end of the Cooling Lake at two locations just off the shoreline. Figure 4.1 presents these locations.

5.4.2 SUMMARY OF GAMMA-EMITTING RADIONUCLIDES ANALYTICAL RESULTS

Gamma-emitting target radionuclides were not detected in concentrations greater than their respective LLD. A summary of the gamma-emitting radionuclides results for the surface water samples collected in this investigation is provided in Table 5.5 and shown on Figure 5.11.

Other non-targeted radionuclides were also included in the tables but excluded from discussion in this report. These radionuclides were either a) naturally occurring and thus not produced by the Station, or b) could be definitively evaluated as being naturally occurring due to the lack of presence of other radionuclides which would otherwise indicate the potential of production from the Station.

6.0 RADIONUCLIDES OF CONCERN AND SOURCE AREAS

This section discusses radionuclides evaluated in this investigation, potential sources of the radionuclides detected, and their distribution.

6.1 GAMMA-EMITTING RADIONUCLIDES

Gamma-emitting target radionuclides were not detected at concentrations greater than their respective LLD. Other non-targeted radionuclides were also included in the tables but excluded from discussion in this report. These radionuclides were either a) naturally occurring and thus not produced by the Station, or b) could be definitively evaluated as being naturally occurring due to the lack of presence of other radionuclides which would otherwise indicate the potential of production from the Station.

6.2 BETA-EMITTING RADIONUCLIDES

Strontium-89/90 was not detected in any of the samples collected at concentrations that were greater than the LLD of 2.0 pCi/L. Concentrations of tritium ranged between 200 pCi/L and $1,040 \pm 172$ pCi/L.

Since only tritium was detected at concentrations greater than the LLDs, the following sections focus on tritium; specifically, providing general characteristics of tritium, potential sources, distribution in groundwater, and a conceptual model for migration.

6.3 TRITIUM

This section discusses the general characteristics of tritium, the distribution of tritium in groundwater and surface water, and the conceptual model of tritium release and migration.

6.3.1 GENERAL CHARACTERISTICS

Tritium (chemical symbol H-3) is a radioactive isotope of hydrogen. The most common forms of tritium are tritium gas and tritium oxide, which is also called "tritiated water." The chemical properties of tritium are essentially those of ordinary hydrogen. Tritiated water behaves the same as ordinary water in both the environment and the body.

Tritium can be taken into the body by drinking water, breathing air, eating food, or absorption through skin. Once tritium enters the body, it disperses quickly and is uniformly distributed throughout the body. Tritium is excreted primarily through urine within a month or so after ingestion. Organically bound tritium (tritium that is incorporated in organic compounds) can remain in the body for a longer period.

Tritium is produced naturally in the upper atmosphere when cosmic rays strike air molecules. Tritium is also produced during nuclear weapons explosions, as a by-product in reactors producing electricity, and in special production reactors, where the isotopes lithium-7 and/or boron-10 are bombarded to produce tritium.

Although tritium can be a gas, its most common form is in water because, like non-radioactive hydrogen, radioactive tritium reacts with oxygen to form water. Tritium replaces one of the stable hydrogen atoms in the water molecule and is called tritiated water. Like normal water, tritiated water is colorless and odorless. Tritiated water behaves chemically and physically like non-tritiated water in the subsurface, and therefore tritiated water will travel at the same velocity as the average groundwater velocity.

Tritium has a half-life of approximately 12.3 years. It decays spontaneously to helium-3 (^3He). This radioactive decay releases a beta particle (low-energy electron). The radioactivity of tritium is the source of the risk of exposure.

Tritium is one of the least dangerous radionuclides because it emits very weak radiation and leaves the body relatively quickly. Since tritium is almost always found as water, it goes directly into soft tissues and organs. The associated dose to these tissues is generally uniform and is dependent on the water content of the specific tissue.

6.3.2 DISTRIBUTION IN STATION GROUNDWATER

This section provides an overview of the lateral and vertical distribution of tritium detected in groundwater within and adjacent to the PA. Tritium has been the only parameter detected in the upper sand aquifer at concentrations exceeding background concentrations. This observation is based upon the studies recently completed within and adjacent to the PA and based upon the extensive studies performed along the blowdown line and reported previously to the Illinois EPA. A hydrogeologic profile of the tritium concentrations in groundwater is presented on Figure 6.1. In addition, a plan view of the tritium concentrations detected in the groundwater samples collected as part of this investigation is presented on Figure 6.2. As discussed later in this section, tritium

has not been detected in the deeper, bedrock groundwater at concentrations greater than the LLD of 200 pCi/L.

The detections of tritium in the shallow or deeper parts of the upper sand aquifer in the Station area, which were greater than the LLD of 200 pCi/L, occur within the confines of the slurry wall.

6.3.2.1 UPPER SAND AQUIFER

West Side of the Turbine Building

Generally, tritium concentrations that were greater than the LLD of 200 pCi/L are limited to an area along the west side of the Turbine Building, as summarized in Table 5.2 and illustrated on Figures 5.10 and 6.2. The tritium detected in the groundwater samples from monitoring wells located along the west side of the Turbine Building (TB-1-3D, TB-1-4D, TW-3, TW-6, MW-9, TW-21, and TB-1-5D) indicate consistent concentrations of tritium greater than the LLD. Tritium analytical data for groundwater samples collected from these monitoring wells are available back to January 2006 and have been included in Table 5.6.

Groundwater flow within the west side of the Turbine Building has been observed recently and historically to flow from south to north. The monitoring wells on the west side of the Turbine Building are located within the limits of the former excavated area (for Station construction) and are located within 150 feet of the main foundation of the Turbine Building. These wells are also located within 150 feet of the main storm water drainage system, which runs from the south to the north parallel to the Turbine Building (Figure 2.3). This storm water drainage system discharges to the Oil/Water Separator located at the north end of the PA as is shown on Figure 2.3.

The storm water drainage system intercepts groundwater and has been shown to be a preferential pathway for groundwater to migrate to the north (Figures 2.4 and 2.5). The sewer's ability to transmit groundwater and its contaminants was documented in various reports submitted to the Illinois EPA in the past (CRA, September 2003).

The more recent detections of tritium in groundwater samples from monitoring wells installed in the area along the west side of the Turbine Building are found both in the upper portions or shallow zone of the sand aquifer (e.g., TW-3 and TW-6) in the deeper portions (deeper zone) of the upper sand aquifer (e.g., TB-1-4D and TB-1-5D); and within the fill material (MW-BW-207I).

Other Areas

There are four monitoring wells where tritium has been detected in groundwater samples at concentrations greater than the LLD of 200 pCi/L in areas not associated with the Turbine Building. These wells are MW-BW-201S/I, MW-BW-205I and TW-24, and at TW-16. The tritium concentrations detected in groundwater samples from MW-BW-201S/I, MW-BW-205I and TW-24 were only slightly greater than the LLD of 200 pCi/L and below 250 pCi/L (refer to Figures 5.10 and 6.2).

The tritium concentration detected in a groundwater sample from TW-16, which is located approximately 300 feet due west of TW-3 (Figures 4.2, 5.10, and 6.2), is situated where water ponded from the April 6, 2006 steam release (Figure 4.2), was 893 ± 145 pCi/L. In this case, the tritium in the groundwater sample from TW-16 can be explained by the more recent release of tritiated water in the west area of the PA, as is discussed further below. Both TW-3 and TW-16 are located in an area near the point at which the relief valve vents outside of the Turbine Building. As shown on Figure 5.7, the groundwater beneath the western side of the PA generally flows from the south to north-northwest.

6.3.2.2 DEEPER BEDROCK GROUNDWATER

The first water bearing zone in the deeper bedrock, the zone below the Wedron Clay Till and the Francis Creek Shale Member of the Carbondale Formation was monitored by MW-BW-201BD and MW-BW-208BD. The screened intervals of these two monitoring wells are completed in the zone of conglomerates and sandstones found at the base of the Francis Creek Shale Member and just above the Colchester Coal No. 2. Some of the private wells located north and east of the PA are also completed in this zone (Figure 2.10). The two deeper bedrock monitoring wells were installed at locations expected to be downgradient of the reactor buildings and fuel handling building. The location of these wells is shown on Figure 4.2. Groundwater samples collected from the two bedrock monitoring wells (including samples and duplicates) indicated tritium concentrations less than the LLD of 200 pCi/L.

Additionally, there are a number of private and public wells located to the north of the PA, which have been sampled as part of the blowdown line investigations. The sample results for tritium from these wells indicated no concentrations greater than the LLD of 200 pCi/L.

Based upon the findings from the recent studies around the PA and those performed in the past along the blowdown line, the groundwater zones found below the Wedron Clay Till and the Francis Creek Shale Member do not indicate tritium impacts from releases within or adjacent to the PA.

6.3.3 DISTRIBUTION IN STATION SURFACE WATER

Surface water was collected within the perimeter ditch and analyzed for tritium at four monitoring points found north, west, and south of the PA. In addition, surface water was collected at the north end of the Cooling Lake at two locations just off the shoreline. Figure 4.1 presents these locations.

Surface water samples SW-101, SW-102, and SW-103 had concentrations of tritium of 398 ± 129 , 365 ± 120 , and 230 ± 114 pCi/L, respectively. These concentrations exceeded the LLD of 200 pCi/L. Surface water samples SW-101 and SW-102 were collected from the perimeter ditch located just northwest of the PA. Surface water sample SW-103 was collected along the perimeter ditch near the northeast corner of the Cooling Lake. A summary of the tritium analytical results from samples collected from surface water is presented in Table 5.4. Surface water samples collected as part of the blowdown line investigations and as part of the interim routine monitoring program in the PA are provided in Table 5.7.

6.3.4 CONCEPTUAL MODEL OF TRITIUM RELEASE AND MIGRATION

This section presents CRA's conceptual model of groundwater and tritium migration at the Station. This model is then used to discuss the historic detections of tritium within the PA and the more recent detections found during the hydrogeologic investigations presented in this report.

Hydrogeologic Framework

Groundwater flows within the upper sand aquifer (Equality Formation) at the site in response to regional discharge points located to the north and in response to the perimeter ditch located west and south of the site. Groundwater moving within the upper sand aquifer is separated from the regional bedrock aquifer zones by the Wedron Clay Till, the Francis Creek Shale Member and the Maquoketa Shale. The only exception is where the building basements were constructed through the Wedron Clay Till.

However, these building structures are considered impermeable barriers to flow in or out of their foundations.

As of the date of this report, no tritium has been detected at concentrations greater than the LLD of 200 pCi/L in samples from bedrock monitoring wells, bedrock private wells, or bedrock public wells located downgradient of the PA. These groundwater quality data further support the role of the Wedron Clay Till and the Francis Creek Shale Member as aquitards. As such, the focus of the conceptual hydrogeologic model presented herein is the migration of groundwater and tritium within the upper sand aquifer.

Groundwater flowing in the upper sand aquifer within the PA is restricted by the building foundations which, in some cases, extend through the Wedron Clay Till. As a result, groundwater flowing with the regional gradient from south to north is diverted to the east or west of the building structures (a divide). In addition, groundwater flowing on the west side of the Turbine Building discharges into and out of the storm water drainage system located in this area of the PA. Additional recharge of water from the sewer into groundwater is expected in this area.

The slurry wall, which surrounds the main Station buildings, appears to provide some limited hydraulic control on the west side of the PA. There is a noticeable drop in groundwater levels across the wall on the west side and groundwater flow changes direction from north to northwest in this area (Figures 5.6 and 5.7). However, the slurry wall's impact on groundwater flowing north toward the regional surface water discharge points is still unknown. The lateral hydraulic gradients to the north are consistent across the slurry wall.

To the west and south of the PA, the upper sand aquifer is influenced by the perimeter ditch which flows from north to south on the west side of the Station property. This man-made ditch intercepts the shallow aquifer and under normal flow conditions is a discharge point for groundwater. The water level in the ditch as it exits the Braidwood Station property is 11 to 16 feet lower than groundwater in the PA. As such, the perimeter ditch is acting similar to a gravity drain or "French Drain" within the upper sand aquifer. This is evident in the southwest and west flow of groundwater outside the slurry wall (Figures 5.6 and 5.7).

Sources and Migration of Tritium

Tritium has recently been detected at concentrations greater than background in groundwater samples from two areas within the PA and within the confines of the slurry wall:

- Along the west side of the Turbine Building; and
- 300 feet west of the Turbine Building.

Prior to the more recent release of tritium to the surface in the west area of the PA, the tritium detections were limited to the area near the west wall of the Turbine Building. The current distribution of tritium (both within the shallow water table zone and within the deeper portions of the upper sand aquifer) is likely related to the following tritiated water release history:

- previous releases of tritium to the surface or subsurface; and
- the April 6, 2006 release of steam containing tritiated water.

After April 2006 a number of groundwater samples from the same monitoring wells sampled in early 2006 indicated higher concentrations of tritium. The more recent groundwater sampling data that were collected in May and July 2006 show very good correlation with the release of steam which occurred on April 6, 2006 on the west side of the Turbine Building. The distribution of tritium in May 2006 groundwater samples matches with the location of ponded areas of the April 6 steam release and with groundwater and surface water (e.g., storm water) flow directions in this area of the PA. Refer to Figures 6.1 and 6.2 for a presentation of the vertical and lateral distribution of tritium in groundwater, respectively.

In the case of both the pre-April 2006 groundwater data and the post-April 2006 groundwater data the role of surface water infiltration and transport within the storm water drainage system is well documented. The previous discussions suggest that the tritium detected in the groundwater on the west side of the Turbine Building is a result of multiple isolated spills or releases to the surface that have occurred over time.

Groundwater samples were collected from the existing monitoring wells within the PA and the new monitoring wells in the first week of May 2006; a month after the April 6 steam release. This was a surface release that allowed tritiated water to both pond on the land surface and also to seep into the storm water drainage system.

The May 2006 groundwater sampling event very clearly shows the impact of the steam release waters as they ponded on the ground and drained into the storm water drainage system (Figure 3.1). Figure 5.10 and Table 5.2 present the May and July 2006 tritium data in groundwater. The highest concentration of tritium detected was in the groundwater sample from the shallow monitoring well TW-3 ($1,040 \pm 172$ pCi/L), which is near the valve which released the steam with the tritiated water. The concentration of tritium in the groundwater sample from this well in March 2006 was approximately 300 pCi/L. CRA considers the increase in tritium concentrations in TW-3 to be a result of steam/water entering the groundwater through the storm water drainage system, which is located near this well. Similarly, the tritium concentration in the groundwater sample from TW-16, which is directly west of the steam vent and where the tritiated water pooled on the ground, increased from 368 ± 94 pCi/L to 893 ± 145 pCi/L. This information indicates that within 30 days the steam release waters had impacted the shallow groundwater zone. The steam release event is also suspected to have affected the groundwater near TW-6, MW-9, and TB-1-5D, which are along or near the storm water drainage system.

Groundwater infiltrating the storm water drainage system will flow to the Oil/Water Separator to the north. This separator discharges water to small ditch which then flows to the west and discharges to the perimeter ditch (Figure 2.3). Surface water samples collected in the perimeter ditch as part of this investigation of the PA (Figure 4.1) and surface water samples collected in the perimeter ditch have indicated concentrations of tritium greater than background at locations north and west of the PA. The main source of the tritium in this area of the perimeter ditch is the plume of tritium migrating from historical releases at vacuum breaker VB-1 into the ditch at that location (CRA, March 2006).

In addition, as a result of the recent steam release, it is expected that some tritiated water has entered the Oil/Water Separator and migrated in the small ditch toward the larger perimeter ditch. Recent sampling of the Oil/Water Separator supports this pathway of tritiated water migration.

Table 5.7 presents the results of previous sampling of surface water in the perimeter ditch and samples from the Oil/Water Separator discharge after the April 6, 2006 steam release.

The following section provides further details supporting the conceptual model of groundwater flow and tritium transport discussed above.

6.3.5 ATTENUATION OF TRITIUM WITHIN THE SHALLOW GROUNDWATER SYSTEM

Within the PA consideration must be given to how long ago a release occurred and the effect of precipitation water infiltration on groundwater quality. During the previous hydrogeologic investigations the releases from vacuum breakers along the blowdown line where it became apparent that the distribution of a historical or older release of tritium into the groundwater system would be impacted by the infiltration from "clean" precipitation recharge (CRA, March 2006). This resulted in the upper, water table zone of the sand aquifer appearing to have lower concentrations of tritium from the deeper portions (these zones are only separated by 5 to 15 feet). This "cleaning up" of the shallow zone of the sand aquifer needs to be considered when evaluating the data collected within the PA. Specifically, the location of the storm water drainage system near the Turbine Building and the affected monitoring wells (TB-1-3D, TB-1-4D, TW-3, TW-6, MW-9, TB-1-5D, and MW-BW-207I) likely allows for both the flow in and out of the sewer line of tritiated water and clean precipitation waters.

Table 5.6 presents the history of sampling results in 2006 for the area west of the Turbine Building. Figure 6.2 presents a summary of these data on a plan view map. The highest concentrations detected prior to the April 6, 2006 steam release event are found in monitoring wells TW-6 and TB-1-4D. The detections in TB-1-4D in March 2006 (582 pCi/L) were greater than in the adjacent shallow well TW-3 (330 pCi/L) for the same sampling event. This suggests that the source for this deeper tritium is not recent but historical in nature. The tritium concentrations in March 2006 for groundwater samples collected at TW-6 were in the 600 to 800 pCi/L range and may indicate a more recent release, although of limited in extent. In both cases (TW-6 and TB-1-4D) the extent of tritium impacts in the upper sand aquifer appears to be limited to near these two wells along the west side of the Turbine Building. It has been determined that the vertical limits in the excavated area are restricted by the underlying shale formation (Figure 6.1).

The relatively high groundwater velocities measured in the site area of 600 ft/yr and the permeable nature of the upper sand aquifer also support attenuation of the tritium through lateral groundwater movement. The dispersion of the tritium as it flows through the sand along with its natural decay rate will allow for reduction in concentrations over time and with distance from a release into the groundwater. Simple fate and transport modeling performed for the blowdown line investigations using the USEPA BIOSCREEN Model (CRA, March 2006 and April 2006) provides evidence of the attenuation of tritium through dispersion and decay. Consequently, tritium released

within the west side of the PA and near the Turbine Building would also be expected to attenuate rapidly to lower concentrations as it flowed in the upper sand aquifer.

The natural decay rate of the tritium itself lends to further attenuation of its concentration in the groundwater. Tritium has a half-life of 12.3 years and as such its concentration would be reduced over the time period that it travels in the groundwater system. Consequently, as the tritium migrates with the groundwater, its concentration would be decreased by 50 percent in a 12.3-year time frame.

7.0 EXPOSURE PATHWAY ASSESSMENT

This section addresses the groundwater impacts from tritium and other radionuclides at the Station and potential risks to human health and the environment.

Based upon historical knowledge and data related to the Station operations, and based upon radionuclide analyses of groundwater samples, the primary constituent of concern (COC) is tritium. The discussions that follow are restricted to the exposure pathways related to tritium.

Teledyne Brown reports all samples to their statistically derived Minimum Detectable Concentration (MDC) of approximately 150 to 170 pCi/L, which is associated with 95 percent confidence interval on their hardcopy reports. However, the laboratory uses a 99 percent confidence range (± 3 sigma) for determining whether to report the sample activity concentration as detected or not. This 3-sigma confidence range typically equates to 150 (± 135.75) pCi/L.

Exelon has specified a LLD of 200 pCi/L for the Fleetwide assessment. Exelon has also required the laboratory to report related peaks identified at the 95 percent confidence level (2-sigma).

This HIR, therefore, screens and assesses data using Exelon's LLD of 200 pCi/L. As is outlined below, this concentration is also a reasonable approximation of the background concentration of tritium in groundwater at the Station.

7.1 HEALTH EFFECTS OF TRITIUM

Tritium is a radionuclide that decays by emitting a low-energy beta particle that cannot penetrate deeply into tissue or travel far in air. A person's exposure to tritium is primarily through the ingestion of water (drinking water) or through ingestion of water bearing food products. Inhalation of tritium requires the water to be in a vapor form (i.e., through evaporation or vaporization due to heating). Inhalation is a minor exposure route when compared to direct ingestion or drinking of tritiated water. Absorption of tritium through skin is possible, but tritium exposure is more limited here versus direct ingestion or drinking of tritiated water.

7.2 BACKGROUND CONCENTRATIONS OF TRITIUM

The purpose of the following paragraphs is to establish a background concentration through review of various media.

7.2.1 GROUNDWATER

Tritium is created in the environment from naturally occurring processes both cosmic and subterranean, as well as from anthropogenic (i.e., man-made) sources. In the upper atmosphere, "cosmogenic" tritium is produced from the bombardment of stable nuclides and combines with oxygen to form tritiated water, which will then enter the hydrologic cycle. Below ground, "lithogenic" tritium is produced by the bombardment of natural lithium isotopes ${}^6\text{Li}$ (92.5 percent abundance) and ${}^7\text{Li}$ (7.5 percent abundance) present in crystalline rocks by neutrons produced by the radioactive decay of uranium and thorium. Lithogenic production of tritium is usually negligible compared to other sources due to the limited abundance of lithium in rock. The lithogenic tritium is introduced directly to groundwater.

A major anthropogenic source of tritium comes from the former atmospheric testing of thermonuclear weapons. Levels of tritium in precipitation increased during the 1950s and early 1960s, coinciding with the release of significant amounts of tritium to the atmosphere during nuclear weapons testing prior to the signing of the Limited Test Ban Treaty in 1963, which prohibited atmospheric nuclear tests.

7.2.2 PRECIPITATION DATA

Precipitation samples are routinely collected at stations around the world for the analysis of tritium and other radionuclides. Two publicly available databases that provided tritium concentrations in precipitation are Global Network of Isotopes in Precipitation (GNIP) and USEPA's RadNet database. GNIP provides tritium precipitation concentration data for samples collected world wide from 1960 to 2006. RadNet provides tritium precipitation concentration data for samples collected at Stations through the U.S. from 1960 up to and including 2006.

Based on GNIP data for sample stations located in the U.S. Midwest including Chicago, St. Louis and Madison, Wisconsin, as well as Ottawa Ontario, and data from the University of Chicago, tritium concentrations peaked around 1963. This peak, which approached 10,000 pCi/L for some stations, coincided with the atmospheric testing of

thermonuclear weapons. Tritium concentrations showed a sharp decline up until 1975 followed by a gradual decline since that time. Tritium concentrations in Midwest precipitation have typically been below 100 pCi/L since around 1980.

The RadNet database for several stations in the U.S. Midwest (Chicago, Columbus, Indianapolis, Lansing, Madison, Minneapolis, Painesville, Toledo, and Welsch, MN) did not show the same trend, which can be attributed to pre-1995 data handling procedures. The pre-1995 data were rounded to the nearest 100 pCi/L, which dampened out variances in the data. The post-1995 RadNet data, where rounding was not applied, exhibit much more scatter, and similar to the GNIP data, the vast majority of the data were less than 100 pCi/L.

CRA constructed a non-parametric upper tolerance limit with a confidence of 95 percent and a coverage of 95 percent based on RadNet data for USEPA Region 5 from 2004 to 2005. The resulting upper tolerance limit is 133 pCi/L, which indicates that CRA is 95 percent confident that 95 percent of the ambient precipitation concentration results are below 133 pCi/L. The statistical confidence, however, must be compared with the limitations of the underlying RadNet data, which does not include the minimum detectable concentration for a majority of the measurements. Some of the RadNet values below 200 pCi/L may be approximated. Nevertheless, these results show a background contribution for precipitation of up to 133 pCi/L.

7.2.3 SURFACE WATER DATA

Tritium concentrations are routinely measured in large surface water bodies, including Lake Michigan and the Mississippi River. Surface water data from the RadNet database for Illinois sampling stations include East Moline (Mississippi River), Moline (Mississippi River), Marseilles (Illinois River), Morris (Illinois River), Oregon (Rock River), and Zion (Lake Michigan). As is the case for the RadNet precipitation data, the pre-September 1995 Illinois surface water data was rounded to the nearest 100 pCi/L, creating a dampening of variances in the data. The post-1995 Illinois surface water data, similar to the post-1995 Midwest precipitation data, were less than 100 pCi/L with the exception of the Moline (Mississippi River) station. Tritium surface water concentrations at this location varied between 100 and 800 pCi/L, which may reflect local natural or anthropogenic inputs.

For the Lake Michigan station, the surface water concentrations were less than 100 pCi/L, with the exception of a couple of occasions occurring around 1996 to 1997. Tritium concentrations in Lake Michigan would be expected to be lower than

precipitation concentrations given the 99-year surface water residence time within Lake Michigan, which corresponds to 8 half-lives of tritium and the dilution provided the large volume of the Lake (1,180 cubic miles) as well as seasonal mixing effects (WDNR, 1999).

The USEPA RadNet surface water data typically has a reported 'Combined Standard Uncertainty' of 35 to 50 pCi/L. According to USEPA, this corresponds to a ± 70 to 100 pCi/L 95 percent confidence bound on each given measurement. Therefore, the typical background data provided may be subject to measurement uncertainty of approximately ± 70 to 100 pCi/L.

7.2.4 DRINKING WATER DATA

Tritium concentrations in drinking water from the RadNet database for three Illinois sampling stations (Chicago, Morris, and East Chicago) exhibit similar trends as the precipitation and surface water data. As with the precipitation and surface water data, the pre-1995 data has dampened out variances due to rounding the data to the nearest 100 pCi/L. The post-1995 results show tritium concentrations in drinking water well below 100 pCi/L and less than the tritium concentrations found in precipitation and surface water.

7.2.5 EXPECTED TRITIUM BACKGROUND FOR THE STATION

As reported in the GNIP and RadNet databases, tritium concentrations in U.S. Midwest precipitation has typically been less than 100 pCi/L since 1980. Tritium concentrations reported in the RadNet database for Illinois surface water and groundwater, at least since 1995, has typically been less than 100 pCi/L. Based on the USEPA Region 5's 2004 to 2005 RadNet precipitation data, 95 percent of the ambient concentrations of tritiated water in Illinois are expected to be less than 133 pCi/L, based on a 95 percent confidence limit. Tritium concentrations in surface water and drinking water are expected to be comparable or less based on historical data and trends.

Concentrations in groundwater similar to surface water and drinking are expected to be less as compared to precipitation values. The lower groundwater concentrations are related to the age of the groundwater as compared to the half-life of tritium. Deep aquifers in proximity to crystalline basement rock, however, can potentially show elevated concentrations of tritium due to lithogenic sources.

As was noted in Section 7.0, the analytical laboratory is reporting tritium results to a LLD of 200 pCi/L. This concentration also represents a reasonable representation of background groundwater quality, given the data for precipitation, surface water, and drinking water.

Based on the evaluation presented above, the background concentration for tritium at the Station is reasonably represented by the LLD of 200 pCi/L.

7.3 IDENTIFICATION OF POTENTIAL EXPOSURE PATHWAYS AND POTENTIAL RECEPTORS

Three potential exposure pathways were considered during the evaluation of tritium in groundwater:

- groundwater migration off the Station Property to private and public groundwater users;
- groundwater migration off the Station Property to a surface water body; and
- potential exposure to surface water in the perimeter ditch at the Station.

The following section provides an overview of each of these three potential exposure pathways for tritium in groundwater.

7.3.1 POTENTIAL GROUNDWATER MIGRATION TO DRINKING WATER USERS OFF THE STATION PROPERTY

In this pathway groundwater flows to the north off Exelon's property and onto adjacent private property. There are a number of private landowners to the north that use private wells completed in the upper sand aquifer. These shallow water supply wells are considered potential pathways.

The concentrations of tritium in groundwater (within the upper sand aquifer and the deeper bedrock aquifer) are below the LLD of 200 pCi/L off the Station property. Consequently, there is no tritium in the groundwater currently migrating off the Station property.

With the exception of the blowdown line investigation there have been no samples collected from private or public water supply wells, to the north or west of the PA, that contained tritium at concentrations that exceed the LLD of 200 pCi/L. Therefore,

although there is a potentially complete exposure pathway, there is no current risk of exposure associated with groundwater ingestion from private wells in the upper sand aquifer.

Groundwater samples collected from private wells in the deep bedrock investigated did not contain tritium that exceeded the LLD of 200 pCi/L. This is to be expected because the vertical movement of tritiated water into deeper formations is restricted by the following three regional aquitards (see Figure 2.8):

- the Wedron Clay Till, which directly underlies the upper sand aquifer;
- the shales of the Carbondale Formation (Francis Creek Shale Member); and
- the Scales Shale of the Maquoketa Group.

The effectiveness of these aquitards is further supported by the recent data collected from the approximately 100 feet deep bedrock monitoring wells MW-BW-201BD and MW-BW-208BD on the Station property. Samples from these wells were from a water bearing zone just beneath the Francis Creek Shale Member and contained tritium at concentrations less than the LLD of 200 pCi/L. Therefore, the exposure pathway is incomplete and there is no current risk of exposure associated with groundwater ingestion from private wells in the deep bedrock aquifer.

7.3.2 POTENTIAL GROUNDWATER MIGRATION TO SURFACE WATER USERS OFF THE STATION PROPERTY

There is a potential exposure pathway in the upper sand aquifer to ponds, ditches, and other surface water bodies. Based on the results of this investigation tritium has not been detected at concentrations greater than the LLD 200 pCi/L in groundwater, which might discharge to these surface water bodies.

Although this is a potentially complete exposure pathway, there is no current risk of exposure associated with ingestion and recreational use off the Station property.

7.3.3 POTENTIAL EXPOSURE TO SURFACE WATER IN THE PERIMETER DITCH AT THE STATION

The perimeter ditch flows to the south on the west side of the Station Property and does not flow off the property until a point located approximately 2 miles southwest of the PA.

Under this potential exposure pathway, groundwater must migrate to the surface and into the perimeter ditch. Potential exposures could occur if the groundwater discharge to the surface water contains tritium. Although water in the perimeter ditch has contained trace amounts of tritium in the past, Station personnel are protected and monitored by the Radiation Protection Program, which is controlled by Federal guidelines. This is a potentially complete exposure pathway, but there is no current risk of exposure associated with ingestion, inhalation, or absorption on Station property.

7.4 SUMMARY OF POTENTIAL TRITIUM EXPOSURE PATHWAYS

There are three potential exposure pathways for tritium originating in or adjacent to the PA:

- groundwater migration off the Station Property to private and public groundwater users (drinking water exposure);
- groundwater migration off the Station Property to a surface water body (recreational exposure); and
- potential exposure to surface water in the perimeter ditch at the Station.

In summary, based upon the groundwater and surface water data provided and referenced in this investigation, none of the potential receptors are at risk of exposure to concentrations of tritium in excess of USEPA drinking water standards (20,000 pCi/L).

7.5 OTHER RADIONUCLIDES

Target radionuclides were not detected at concentrations greater than their respective LLD in the groundwater samples collected. Other non-targeted radionuclides were also included in the tables but excluded from discussion in this report. These radionuclides were either a) naturally occurring and thus not produced by the Station, or b) could be definitively evaluated as being naturally occurring due to the lack of presence of other radionuclides which would otherwise indicate the potential of production from the Station.

8.0 CONCLUSIONS

Based on all of the studies completed to date at this site, CRA concludes:

Groundwater Flow

- The deeper bedrock water supply aquifers are separated from the upper sand aquifer system by a number of aquitards, including the Wedron Clay Till and the regionally-identified Francis Creek Shale Member, and the Maquoketa Shale. These aquitards are present beneath the PA and continue to restrict downward vertical movement of groundwater.
- Groundwater at near-by properties is extracted from both the 20- to 30-foot thick upper sand aquifer and deeper bedrock formations at depths of 600 to 1,600 feet.
- Depth to groundwater in the upper sand aquifer ranges from 4 to 12 feet and it flows beneath the PA in a generally south to north manner, flowing from the Cooling Lake toward ponds and streams located north of the Station property.
- Groundwater in the upper sand aquifer flows to the west and southwest at locations west and south of the PA.
- Lateral groundwater flow within the PA is affected by the construction (basements/foundations) of the Reactor, Turbine, and Auxiliary Buildings, which were constructed through the Wedron Clay Till onto the top of the Francis Creek Shale Member. These buildings are barriers to lateral flow.
- Lateral groundwater flow within the PA is controlled by the slurry trench to some degree as is evident by the change in hydraulic gradients on the west side of the PA. However, the degree of its influence on flow to the north is not known at this time.
- Vertical groundwater flow is restricted by the regional aquitards, however, due to the removal of the Wedron Clay Till beneath the buildings, one of the two regional aquitards has been removed within the PA. Nevertheless, groundwater data indicate that the remaining aquitard (Francis Creek Shale Member) is preventing vertical migration of tritium downward within the PA.

Groundwater Quality

- Tritium concentrations in groundwater were not detected at concentrations greater than the USEPA drinking water standard of 20,000 pCi/L.
- Tritium was not detected at concentrations greater than the LLD (200 pCi/L) in 34 of the 45 samples collected as part of this investigation.

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in 45 of the 45 samples collected as part of this investigation.
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2.0 pCi/L in 45 of the 45 samples collected as part of this investigation.
- In the site area, tritium is not migrating off the Exelon property in the upper sand aquifer at concentrations greater than the LLD of 200 pCi/L.
- Deeper private water supply wells that are located downgradient of the PA contain concentrations of tritium less than the LLD of 200 pCi/L. The regional aquitards act as vertical barriers to migration of tritium from surficial aquifers to deeper bedrock aquifers.
- The depth of the tritium detected within the PA is defined by the top of the Wedron Clay Till with one exception. Along the west side of the Turbine Building and within the formerly excavated area, where the clay was excavated and backfilled, the vertical extent of the tritium is limited by the top of the Francis Creek Shale Member.
- Tritium has not been detected at concentrations greater than the LLD of 200 pCi/L in groundwater located beneath the Francis Creek Shale Member in the vicinity of the PA, downgradient of the buildings, and near the former building excavation.

Surface Water Quality

- Tritium concentrations in surface water were not detected at concentrations greater than the USEPA drinking water standard of 20,000 pCi/L.
- Tritium was not detected at concentrations greater than the LLD (200 pCi/L) in three of the six samples collected as part of this investigation.
- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in six of the six samples collected as part of this investigation.
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2.0 pCi/L in six of the six samples collected as part of this investigation.
- In the site area, tritium is not migrating off the Exelon property in surface water at concentrations exceeding the LLD of 200 pCi/L.
- Detections of tritium in the north and east stretches of the perimeter ditch can be attributed to the releases at vacuum breaker VB-1 located to the east along the blowdown line.

AFE-Braidwood-1 - North of the Slurry Wall

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the groundwater samples collected from the monitoring wells in the vicinity of AFE-Braidwood-1.
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2.0 pCi/L in any of the groundwater samples collected from the monitoring wells in the vicinity of AFE-Braidwood-1.
- In the area north of the slurry wall, tritium was detected in groundwater samples from the shallow and deeper zones of the upper sand aquifer at concentrations less than 250 pCi/L.
- The concentrations of tritium detected in groundwater samples from north of the slurry wall in the upper sand aquifer are less than or just slightly greater than the LLD of 200 pCi/L.
- The concentrations of tritium detected in groundwater samples from the deeper bedrock monitoring well completed just below the Francis Creek Shale Member was less than the LLD of 200 pCi/L.
- Private well samples collected downgradient of this area provide additional evidence that the deeper bedrock is not impacted by tritium greater than the LLD of 200pCi/L.
- There are currently three monitoring wells (and numerous private wells) located downgradient of this AFE. No additional data are needed in this area of the site. There have been no impacts to groundwater from AFE-Braidwood-1.

AFE-Braidwood-2 - North/Northeast of Units 1 and 2

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the groundwater samples collected from the monitoring wells in the vicinity of AFE-Braidwood-2.
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2.0 pCi/L in any of the groundwater samples collected from the monitoring wells in the vicinity of AFE-Braidwood-2.
- Groundwater samples collected downgradient of the fuel handling building, Units 1 and 2, and other systems on the east side of the PA did not contain tritium at concentrations greater than the LLD of 200 pCi/L.

- There are currently five monitoring wells (and numerous private wells) located downgradient of this AFE. There is no current impact to groundwater from AFE-Braidwood-2.

AFE-Braidwood-3 – Auxiliary Condensate Construction Storage Tank

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the groundwater samples collected from the monitoring wells in the vicinity of AFE-Braidwood-3.
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2.0 pCi/L in any of the groundwater samples collected from the monitoring wells in the vicinity of AFE-Braidwood-3.
- Groundwater samples collected from new monitoring wells located near and downgradient of this AFE area did not contain tritium at concentrations greater than the LLD of 200 pCi/L.
- There are two monitoring wells (and numerous private wells) located downgradient of this AFE. There is no current impact to groundwater from AFE-Braidwood-3.

AFE-Braidwood-4 – West Side of Turbine Building

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the groundwater samples collected from the monitoring wells in the vicinity of AFE-Braidwood-4.
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2.0 pCi/L in any of the groundwater samples collected from the monitoring wells in the vicinity of AFE-Braidwood-4.
- Tritium has been detected at concentrations greater than the LLD of 200 pCi/L in a localized area found along the west side of the Turbine Building. These detections are within the former excavation used during construction, adjacent to the deep basement of the Turbine Building and next to the storm water sewer.
- The lateral extent of tritium within this area of the Station has been defined by groundwater monitoring data to the north, west, and south, by the building basements to the east. The vertical extent of the tritium is limited by the Wedron Clay Till.

- The vertical extent of tritium within this area of the Station has been defined by groundwater monitoring data where the Wedron Clay Till has not been excavated and has been defined within the formerly excavated area.
- There are over 37 monitoring wells on the west side of the Turbine building that delineate the lateral and vertical extent of tritium in the upper sand unit and within the fill material.
- The source of the tritium detected on the west side of the Turbine Building is likely a result of multiple intermittent surface spills or releases of tritiated water.

Potential Receptors

- Based on the results of this investigation¹, there is no current risk from exposure to radionuclides associated with licensed plant operations through any of the identified potential exposure pathways.

General Conclusions

- Based on the results of this investigation, tritium is not migrating off the Station property at detectable concentrations.
- Based on the results of this investigation, there are no known active releases into the groundwater at the Station.

¹ Using the LLD specified in this HIR.

9.0 RECOMMENDATIONS

The following presents CRA's recommendations for proposed activities to be completed at the Braidwood Station

9.1 DATA GAPS

Based on the results of this hydrogeologic investigation, there are no data gaps remaining to support CRA's conclusions regarding the characterization of the groundwater regime and potential impacts from radionuclides at the Station.

9.2 GROUNDWATER MONITORING

Based upon the information collected to date, CRA recommends that Exelon conduct periodic monitoring of selected sample locations.

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