Revision 1

HYDROGEOLOGIC INVESTIGATION REPORT

FLEETWIDE ASSESSMENT
BYRON GENERATING STATION
BYRON, ILLINOIS

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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) pertaining to the Byron Generating Station in Byron, 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. This report also documents the results of CRA's and the Byron Station's investigation beginning in January 2006 in relation to the current and former blowdown lines.

CRA collected and analyzed information on 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 AFEs for the Station.

CRA collected 39 groundwater samples during the blowdown line investigation and 41 groundwater samples during the fleetwide investigation. CRA also collected two full rounds of water levels from the newly installed and existing wells. The Work Plan was completed in March and April 2006. All groundwater samples were analyzed for tritium, strontium-89/90 and gamma-emitting radionuclides.

The results of the 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 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 picoCuries per liter (pCi/L) in any of the groundwater samples obtained and analyzed during the course of this investigation;
- Tritium was not detected at concentrations that are greater than the United States Environmental Protection Agency (USEPA) 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 four out of 39 samples collected, which is considered background, but well below the applicable drinking water standard. These tritium concentrations ranged from 234 ± 128 pCi/L to 3,260 ± 367 pCi/L. These four samples were all

collected from monitoring wells near three vacuum breaker vaults: VB-2, VB-3, and VB-4. The source of the tritium concentrations in the groundwater was periodic leaks during re-seating of the blowdown line vacuum breaker valves;

- 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 sample locations.

1.0 INTRODUCTION

Conestoga-Rovers & Associates (CRA) has prepared this Hydrogeologic Investigation Report (HIR) for Exelon Generation Company, LLC (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. This report documents the results of CRA's May 2006 Hydrogeologic Investigation Work Plan (Work Plan). This investigation pertains to Exelon's Byron Generating Station in Byron, Illinois (Station) (refer to Figure 1.1). This report also documents the results of CRA's and the Station's investigation conducted beginning in January 2006 in relation to the current and former blowdown lines.

The Station is defined as all property, structures, systems, and components owned and operated by Exelon located at 4450 North German Church Road in Byron, Illinois, Rockvale and Marion Townships, Ogle County. The approximate property boundaries are shown on Figure 1.2.

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.

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 environment; 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 is located at 4450 North German Church Road in Byron, Illinois, Rockvale and Marion Townships, Ogle County. The Station consists of approximately 1,900 acres, of which approximately 1,200 acres are used for the generating facility. The other approximately 700 acres of property encompass a 'buffer zone' around the facility and property to the west of the facility.

The Byron Station is located approximately 2 miles east of the Rock River. The blowdown line extends from the Station to the Rock River, and discharges into the Rock River. Figure 1.2 presents a Station Property Map showing the Station structures and the approximate property boundary.

2.2 OVERVIEW OF COOLING WATER OPERATIONS

Operations at the Station began in 1985. The two nuclear reactors at the Station (Unit 1 and Unit 2) are both pressurized water reactors. The Station produces approximately 2,400 megawatts of electricity.

Non-contact cooling water from the Rock River that is used in the electricity generation process is cooled through the Station's two cooling towers. The water is then recirculated through the flume and discharged through the blowdown line back to the Rock River in accordance with an Illinois Environmental Protection Agency (Illinois EPA) National Pollution Discharge Elimination System (NPDES) permit (IL0048313) and Nuclear Regulatory Commission (NRC) Operating Licenses, NPF-37 (Unit 1) and NPF-66 (Unit 2).

Water from the Station's Radioactive Waste Treatment system is transferred to the liquid Radioactive Waste Storage Tank where it is sampled and analyzed. Once the analysis is reviewed and the water is determined to be in compliance with the NPDES permit and the NRC Operating License discharge limitations, it is batch released through the blowdown line.

The blowdown line and make-up line were constructed adjacent to each other and follow a northwest and then westerly path from the Station for approximately 2 miles to the Rock River. At the Rock River, the make-up line is located approximately 300 feet upstream of the blowdown line. Along the length of the two lines, there are six vacuum breaker (VB) locations (VB-1 through VB-6) for each line. The breakers are located within concrete vaults. There are two vaults at each breaker location, one for each line.

There are seven ponds in the northeast section of the Station. Six of these ponds are concrete-lined process catch basins and are aligned in an east-west trending series. These are referred to as the Treated Runoff ponds. The four western ponds collect water from the Station; the water from these four ponds is pumped to the waste treatment building for processing. The two eastern ponds collect rainwater from the storm water drain system; the water from these ponds is pumped to the Construction Run-off Pond (CROP) located north of the Treated Runoff ponds. The CROP is lined at the bottom with 1 foot of clay. Water from the CROP is eventually pumped back into the Station's cooling towers.

2.3 SURROUNDING LAND USE

The land surrounding the Station in all directions is primarily farmland. Approximately 0.3 mile north of the Station property along the Rock River is a small residential subdivision named Rock Terrace. In addition, there are two small residential areas along the Rock River approximately 0.1 mile and 0.8 mile south of the Station property.

The Byron Salvage Superfund Site (Byron Salvage Site) is immediately to the north of the west portion of the Station along Razorville Road. The Byron Salvage Site is administered by United States Environmental Protection Agency (USEPA) Region 5. It was placed on the National Priorities List (NPL) in 1982 and has the USEPA identification number ILD010236230. The Byron Salvage Site consists of two separate properties: the Byron Salvage Yard property and the Dirk's Farm property (see Figure 1.2). The Dirk's Farm property is currently owned by Exelon, and is a former farm located west of the Byron Salvage Yard property across Razorville Road.

Waste disposal at the Byron Salvage Site is known to have occurred on each of the two properties. From the mid 1960s to 1972, approximately 10 acres of the Byron Salvage Site were used as an automotive salvage yard and dump where miscellaneous waste and debris were disposed. Such wastes and debris included drums of electroplating wastes and other materials including oil sludges, cutting wheels, solvents, scrap metal, and industrial wastes. Plating waste containing cyanide was sprayed onto roads as dust control at the Byron Salvage Site.

At the direction of Illinois EPA, from 1974 through 1976 Exelon's predecessor, Commonwealth Edison Company (ComEd) removed the waste material from the Dirks Farm property. After 1976, ComEd continued monitoring the groundwater at the Dirks Farm property. Investigative and remedial actions were conducted at the Byron Salvage Yard portion of the Site beginning in 1983. Drums were present at the Byron Salvage Yard on the surface and buried underground. Hazardous wastes were found to contain lead, arsenic, cyanides, halogenated organics, zinc, nickel, and low concentrations of polychlorinated biphenyls (PCBs). Between 1986 and 1998, soil removal and cleanup activities were conducted on the Byron Salvage Site. The Byron Salvage Site remediation is in the long-term groundwater monitoring phase for volatile organic compounds (VOCs) and cyanides. ComEd resolved its alleged liability for the Byron Salvage Site in a settlement with USEPA.

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 Byron Station Updated Final Safety Analysis Report (UFSAR), Revision 10 dated December 2004, and from the well logs contained in the Byron Salvage Yard Remedial Design Work Plan (CRA, June 2001). The main references that the UFSAR relied 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

The Station's location is on the Oregon, Illinois 7.5-minute United States Geological Service (USGS) quadrangle topographic maps, dated 1976 (Stillman Valley) and 1983 (Oregon) (see Figure 1.1). The property boundaries fall within the following sections of the map: T24N R10E Sections 12, 13, 14, 15, 22, 23, and 24, and T24N R11E Sections 7, 18, and 19. The Byron, Illinois area is part of the Rock River Hill Country physiographic subsection. The Rock River Hill Country is characterized by gently rolling, dissected uplands covered by thin deposits of glacial drift overlain by a thin cap of loess. The southwest-trending Rock River valley passes through the eastern portion of the subsection. Bedrock is exposed locally along the Rock River and along small tributary streams and valleys of the Rock River. The topography that is indicated on the Oregon, Illinois 7.5-minute quadrangle is consistent with this physiography.

The Station was constructed on a local topographic high. In each direction from the Station, the topography undulates, with rolling hills and valleys. Along the Rock River, erosional valleys cut by tributary streams are present. The ground surface elevation at the Station is approximately 200 feet higher than the ground surface near the Rock River.

The Rock River, the largest body of water in the area, is located approximately 2 miles to the west of the Station. The river flows southward with an average flow of 4,000 cubic feet per second (cfs) and is primarily used for recreation, including boating, fishing, and water skiing. Streams in the Byron area discharge into the Rock River; the confluence of the Rock River with the Mississippi River is approximately 115 river miles south of the Station (Willman, et al., 1967).

The Woodland Creek is located to the north of the Station and flows to the northwest toward the Rock River. Additionally, an unnamed creek is located to the west of the Station and flows west toward the Rock River. Both of these creeks are ephemeral, flowing only during times of heavy rainfall.

2.4.2 GEOLOGY

The northern portion of the mid-western United States is in the Central Lowlands Physiographic Province (Willman et al., 1975). This physiographic province has been divided into several physiographic sections. Parts of northern Illinois are located in the Wisconsin Driftless Section, the Till Plains Section, and the Great Lake Section.

Byron Station is located within the Till Plains Section. The Till Plains Section is characterized, in general, by the presence of glacial deposits overlying the bedrock surface. Local outcrops of bedrock are present. The Till Plains Section in Illinois is further subdivided into the following physiographic subsections: the Rock River Hill Country, the Green River Lowland, the Bloomington Ridged Plain, the Galesburg Plain, the Kankakee Plain, and the Springfield Plain. The Byron Station is in the Rock River Hill Country physiographic subsection (Willman et al., 1975).

The soil units in the region, adjacent to the Station, are relatively thin or locally absent. They include alluvial deposits associated with the rivers and streams in the area, glacial deposits of till and outwash generally located in the upland areas, thin loess deposits that overlie the till, and locally, some thin residual soils developed from the weathering of the bedrock.

The Station is underlain by a veneer of overburden deposits that vary in thickness from less than 1 foot to approximately 12 feet and consist mainly of silty loam and loess, with alluvial deposits near the Rock River. The predominant soil types at the Station are the Martinsville Silt Loam, the Whalen Loam, and the Lamont Sandy Loam (Ogle County, 2006). These three soil types consist of loamy soil with varying amounts of silt and sand, with slopes ranging from 2 to 18 percent (United States Department of Agriculture, 2006).

The distribution of the rock units that form the bedrock surface within the region include a sedimentary sequence of Cambrian to Cretaceous-rocks and an igneous and metamorphic complex of Precambrian-aged rocks. The sedimentary sequence in northern Illinois near the Station includes Ordovician-aged and Cambrian-aged strata. These strata consist of 2,000 to 3,000 feet of dolomites, sandstones, and shales. The Precambrian basement in northern Illinois consists of granites and granodiorites (Bradbury and Atherton, 1965).

The Byron Station lies within the Central Stable Region tectonic province of the North American continent. This tectonic region is characterized by a sequence of southward-thickening sedimentary strata overlying the Precambrian basement and was subjected to a series of vertical crustal movements forming broad basins and arches during Paleozoic and early Mesozoic time. Local folding and faulting has modified the arches and basins (Buschbach, 1964) (Willman et al., 1975).

The bedrock under the Station is comprised of flat-lying Ordovician-aged dolomitic and sandstone layers progressing downward as follows:

- Galena Group Dolomites;
- Platteville Group Dolomites; and
- Ancell Group, consisting of:
  - Glenwood Formation (shale with sandy dolomite, semi-confining layer),
  - St. Peter Sandstone Formation, and
  - older Cambrian formations.

The generating facility was constructed on an area of a 'bedrock high', and the foundation was installed into the bedrock. Figures 2.1 and 2.2 present generalized cross-sections of the area geology prepared from geologic information gathered from boreholes advanced prior to construction of the Station. The locations of the cross-sections are shown on Figure 1.2.

CRA has prepared hydrogeologic cross-sections depicting the geology and groundwater elevations under the Station. These figures are discussed in Section 5.0 of this Report.

2.4.3 HYDROGEOLOGY

Ordovician-age Galena-Platteville dolomites and the older Ordovician-age Glenwood Formation and St. Peter Sandstone underlie the area. The most important aquifer in the region is the Cambrian-Ordovician Aquifer, made up of all bedrock between the top of the Galena-Platteville dolomites and the top of the Eau Claire Formation. These strata are, in descending order, the Ordovician-age Galena Formation, Platteville Formation, Ancell Formation (Glenwood, St. Peter, and older Cambrian formations), Prairie du Chien Formation, and Ironton and Galesville Sandstones. At the Bryon Station, the Galena-Platteville dolomites are separated from the rest of the Cambrian-Ordovician Aquifer by the Harmony Hill Shale Member of the Glenwood Formation. Available data indicate that, on a regional basis, the entire sequence of strata above the Eau Claire Formation behaves hydraulically as one aquifer. In places, pressure heads between the water bearing units differ, and the hydraulic connection is imperfect.

The Galena and Platteville Groups dolomites are extensively fractured near the top, with solutionally enlarged openings in places but become dense at depth. Water from the Galena-Platteville dolomites in the area is generally hard. Relatively low yields, water hardness, and susceptibility of the aquifer to contamination because of thin drift, fractures, and solution channels do not favor development of the Galena-Platteville dolomites.

Below the Galena-Platteville dolomites are the thin shales, sandstones, and limestones of the Glenwood Formation. This unit grades downward into the thick sandstones of the St. Peter Sandstone. The Ordovician-age St. Peter Sandstone is permeable and has a relatively uniform lithology throughout the area. The St. Peter Sandstone is recharged from overlying glacial deposits in the central and western parts of northern Illinois, and also by vertical leakage through the Maquoketa Shale Group in northeastern Illinois and by through-flow from the outcrop area in southern Wisconsin (Buschbach, 1964).

2.4.3.1 EXISTING WELL NETWORK

Groundwater (the water table) under the Station is first encountered within the Galena-Platteville limestones and dolomites. The depth to the groundwater varies with the topography, ranging from approximately 17 feet below ground surface (feet bgs) to 115 feet bgs. Near the Rock River, the water table is in the unconsolidated deposits.

There are 77 wells at the Station. Figure 2.3 presents the locations of the wells. Of the 77 wells, the Station owns 33 wells and the remaining 44 wells are owned by the Byron Salvage Site PRP Group. A summary of the existing well information is provided in Table 2.1. These wells were used during the investigations to provide information on the geology and groundwater levels at the Station.

The monitoring wells are set at different depths to screen all three hydrogeologic units located under the Station. CRA monitors the levels and water quality of the Byron Salvage Site wells at the Station as part of the long-term monitoring program for the Byron Salvage Site.

There are two deep wells in the Protected Area (PA). The wells are designated Deep Well 1 and Deep Well 2 and are used for the Station's water supply (see Figure 2.3). Both wells were installed during the construction of the Station and draw water from depths greater than 500 feet below grade at an average flow rate of 800 gallons per minute (gpm) per well. Water is pumped from each well at different times, and the piping from the wells combines into a common manifold to supply the Station's water supply.

There are two former farmhouse water supply wells on the Station. The wells are designated GW-9 and Well 7. During an investigation of the blowdown line, which began in early 2006 (refer to Section 3.3.2.2), 16 overburden monitoring wells and 13 bedrock wells were installed along the blowdown line and also within the PA. Further details regarding the most recent monitoring wells are provided in Section 3.4 of this report.

CRA expects most of the private wells in the vicinity of the Station are completed in the St. Peter Sandstone, however, well completion information was not available for all private wells identified by CRA, in order to confirm this observation.

2.4.3.2 GROUNDWATER FLOW

Groundwater flow in the Galena-Platteville dolomites occurs along joints and bedding planes. Solutioning along these pathways continues at an imperceptible rate due to the low solubility of the dolomite, the hardness of the groundwater, and the relatively low hydraulic gradient within the aquifer.

The general regional groundwater flow direction in the Galena-Platteville dolomites and the underlying Glenwood Formation and St. Peter Sandstone is to the west toward the Rock River. Local groundwater flow conditions are typically influenced by surface topography and aquifer thickness.

Groundwater flow patterns vary under the Station property. In July 1974, the Station assessed groundwater flow using a system of wells and piezometers installed prior to Station construction. Since the facility sits upon a bedrock high, groundwater flow directly beneath the facility was radially outward in all directions. Figure 2.4 presents the groundwater flow for the Station.

On the western portion of the Station near the blowdown line, groundwater flow was historically assessed as part of the Byron Salvage Site remedial investigation. CRA measured water levels at the Byron Salvage Site monitoring wells on March 23, 2006. Groundwater contours for the entire Station (both the blowdown line area and the generating facility), are shown on Figure 2.4 which presents a combined generalized contour map of the 1974 data (for the generating facility) and the March 2006 data (for the blowdown line area). There is a northwest/southeast trending groundwater divide near Razorville Road, west of the generating facility, and perpendicular to the blowdown line. The direction of groundwater flow at points along the blowdown line varies depending upon the location. However, the general groundwater flow direction is to the west toward the Rock River.

2.5 AREA GROUNDWATER USE

RETEC completed a water well search and survey for the Station property ("Residential Well Survey", RETEC Group, Inc, September 23, 2005). CRA expanded the water well search between March and May 2006 to identify the public and private water wells located within approximately 1 mile of Station property. CRA contacted the following sources for information:

- Illinois State Water Survey (ISWS);
- Illinois State Geological Survey (ISGS);
- Illinois EPA database; and
- Ogle County GIS system.

The ISGS (in association with the Illinois EPA) and the ISWS maintain databases of water well information. The ISWS and ISGS provided lists of water wells for the Station and for the area surrounding the Station. A figure of the approximate locations of the water wells surrounding the Station (Figure A.1), along with copies of the information gathered from the ISWS and ISGS are provided in Appendix A. All of the water wells listed are for residential use; none are listed for commercial, industrial, or public water supply uses.

The St. Peter Sandstone is the primary aquifer for residential potable water in the area. The most important aquifer in the region is the Cambrian-Ordovician Aquifer, made up of all bedrock between the top of the Galena-Platteville dolomites and the top of the Eau Claire Formation.

Potable water for the residences south, east, and some north of the Station is provided by private water wells at each property. As part of the Byron Salvage Site groundwater remediation, an alternate water supply and distribution system was provided to many of the residences located north of the Station.

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 21 and 22, 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 through 3.3. The Station identified a total of 30 systems that contain or could potentially contain radioactively contaminated liquids. The following presents a list of these systems.

System Identification	*Description*
AB	Boric Acid Process
AS	Auxiliary Steam
BR	Boron Thermal Regeneration
CD	Condensate
CP	Condensate Polishing
CW	Circulating Water
DM	Miscellaneous Building Drain
DV	Miscellaneous Drains and Vents
FC	Fuel Pool Cooling
FP	Fire Protection
GS	Turbine Gland Seals
HD	Feedwater Drains
MS	Main Steam
OD	Equipment/Floor Oil Drain
PS	Process Sampling
PW	Primary Water
RF	Reactor Building Floor Drains
SH	Station Heat
SI	Safety Injection
ST	Sewage Treatment
SX	Essential Service Water
TE	Turbine Building Equipment Drains
TF	Turbine Building Floor Drains
TR	Treated Runoff
VF	Filtered Vents
VR	Volume Reduction
WE	Auxiliary Building Equipment Drain
WF	Auxiliary Building Floor Drain
WS	Non-Essential Service Water
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 (pre-operational REMP), past Station investigations, and the radiological environmental monitoring program (REMP).

3.3.1 PRE-OPERATIONAL RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

A pre-operational REMP was conducted between 1981 and 1984 to establish background radioactivity levels prior to operation of the Station. While a summary report for the pre-operational REMP was not available to CRA, CRA reviewed the pre-operational REMP data. An April 1987 REMP report prepared by Teledyne Isotopes Midwest Laboratory entitled "Radioactive Waste and Environmental Monitoring Annual Report 1986" identifies that a comparison of the 1985 and 1986 data to the pre-operational REMP data indicates that there was no measurable amount of radioactivity due to the Station's operation.

3.3.2 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

The REMP at the Station was initiated in 1985. The REMP includes the collection of multi-media samples including air, surface water, groundwater, fish, sediment, vegetation, local cow milk, and residential potable water. 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 "Radioactive Effluent Release Report - January 2005 Through December 2005." This report concluded that the operation of the Station had no adverse radiological impact on the environment. The annual report is submitted to the NRC.

3.3.3 HISTORIC INVESTIGATIONS

This section summarizes historic investigations undertaken at the Station prior to this hydrogeologic investigation, related to actual or potential releases of radioactively contaminated liquids 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, dated December 2004 (Byron Station UFSAR, 2004).

3.3.3.2 BLOWDOWN LINE INVESTIGATION

In July 2005, water was observed in the concrete vault for vacuum breaker 6 (VB-6). A water sample collected from the concrete vault, at that time, contained less than 2,000 picoCuries per liter (pCi/L) of tritium.

In January 2006, the Station initiated an investigation into the blowdown line. A program of inspections of the concrete vaults, along with routine observations for water within the vaults was begun. Subsequent to the initial discovery of water in the vaults, Exelon performed construction upgrades on each of the six breaker vaults. These upgrades are intended to ensure that there will be no future releases of potentially contaminated liquid to the subsurface.

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 22 and 23, 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 three AFEs (see Figures 3.1 through 3.3).

<u>AFE-Byron-1 – Former Fiberglass Blowdown Line</u>

This AFE is the area in which, in April 1986, after the initial six months of Unit 1 operation, there were three separate ruptures of the original fiberglass blowdown line. The three ruptures were all in the same area, near River Road (Figure 3.1). Soil and water samples collected as part of the investigation of each rupture indicated the presence of minimal amounts of radioactive material. Following the ruptures, the Station replaced sections of the fiberglass blowdown line. The Station subsequently abandoned the entire line in place and installed a new carbon steel blowdown line in 1987.

<u>AFE-Byron-2 – Vacuum Breaker Vaults</u>

In December 2005/January 2006, water was observed in the vacuum breaker vaults. Exelon initiated an investigation into potential groundwater impact near all 12 vacuum breaker vaults (Figure 3.2), plugged the drainage holes and sealed all six blowdown line vaults.

<u>AFE-Byron-3 - Protected Area</u>

Based on the risk ranking, several systems within the PA scored high as systems in which tritiated water could be released to the environment if a failure or if a set of events were to occur. These systems include: systems located within the Auxiliary Building, Radwaste Building, Containment Building, and the Turbine Building, the Condensate and Condensate Polishing systems, the Fuel Handling Building systems, the Circulating Water Pump House systems, and the CROP.

To evaluate the groundwater quality in the area of these systems, monitoring wells were installed in locations that are hydraulically downgradient of the AFE (Figure 3.3). The downgradient locations of the monitoring wells were selected based on the radial groundwater flow outward from the PA (Figure 2.4) due to the topographic high on which the PA was constructed. These monitoring well locations were situated to provide for adequate indication of historic releases and future leak detection.

4.0 FIELD METHODS

CRA and Station personnel completed two investigations at the Station:

- the blowdown line investigation; and
- the fleetwide investigation.

During the blowdown line investigation conducted from February through April 2006, CRA oversaw the installation and development of 12 temporary and 17 permanent monitoring wells at the Station. CRA and Station personnel collected multiple samples from the vacuum breaker vaults, from nearby residential wells, from the blowdown line itself, from holding ponds, and from the existing and the CRA-installed monitoring wells.

During the fleetwide investigation completed in April and May 2006, CRA conducted a second round of groundwater sampling of 41 monitoring wells, collected a full round of water level measurements from 63 monitoring wells, and surveyed five monitoring wells that had not been surveyed as part of the blowdown line investigation. The field investigations were completed in accordance with the methodologies presented in the Work Plan (CRA, 2006).

The following sections discuss the field activities conducted during these two investigations.

4.1 BLOWDOWN LINE INVESTIGATION ACTIVITIES

4.1.1 GROUNDWATER MONITORING WELL INSTALLATION

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 within the PA to verify utilities were not present at the proposed location to a depth to 10 feet bgs.

From late February 2006 to early April 2006, CRA supervised the installation of 17 monitoring wells and 12 temporary wells along the blowdown line and at other locations at the Station to evaluate the quality of the groundwater in the areas of the three AFEs. The monitoring well locations are presented on Figure 2.3.

Monitoring wells TW-13 through TW-15 were installed to evaluate the groundwater quality near River Road, downgradient of the 1986 former fiberglass blowdown line ruptures (AFE-Byron-1). These wells were originally constructed as temporary wells, but were eventually converted to permanent monitoring wells.

For AFE-Byron-2, at each of the six vacuum breaker vault locations along the blowdown line, two temporary wells were installed adjacent to the concrete vault and within the bedding material of the blowdown line and make-up line (TW-1 through TW-12). These shallow overburden wells were installed to determine whether groundwater was present in the overburden materials above the bedrock. These 12 temporary wells were dry.

Twelve monitoring wells (AR-1 through AR-10, CAR-2, and CAR-3) were installed to screen the first occurrence of groundwater (the water table) within the Galena-Platteville limestones and dolomites. One well was placed adjacent to each vacuum breaker vault (AR-1 through AR-6) in an anticipated downgradient location as determined from historic groundwater elevations measured in the Byron Salvage Site monitoring wells and levels measured in early March 2006. Monitoring well CAR-2 was installed at a location at the bottom of the valley downgradient from the vault for vacuum breaker 4, which contained water with the highest concentrations of tritium. Five monitoring wells (AR-7 through AR-10 and CAR-3) were installed within and around the PA to evaluate the groundwater quality in the areas of the high-ranking systems (AFE-Byron-3).

Two additional monitoring wells were also installed. Monitoring well CAR-1 was screened in the alluvial sediments adjacent to TW-14 to evaluate the groundwater quality approximately 20 feet below the water table. Due to detections of tritium concentrations in groundwater samples from monitoring well AR-4, monitoring well AR-11 was screened to monitor the groundwater quality at the base of the Galena-Platteville aquifer. In total, 13 bedrock monitoring wells were constructed as part of the blowdown line investigation.

The bedrock monitoring wells were all installed using a combination of augering, coring, and air rotary drilling techniques. The monitoring wells with the AR designation were drilled using air rotary techniques, and the wells with the CAR designation were first cored prior to using rotary techniques. The coring was planned to be completed at three locations to confirm the geology that was already expected based on the drilling logs from the Byron Salvage Site monitoring wells. The exception to the nomenclature designation is monitoring well CAR-1. Because the bedrock was not encountered at the base of the hill near River Road, coring was not necessary, and CAR-1 was augered to the target depth.

Specific installation protocols for the monitoring wells (other than the shallow temporary wells TW-1 through TW-12) are described below:

- the borehole was advanced to the target depth using one of the drilling techniques listed above;
- a nominal 2-inch diameter (No. 10 slot) PVC screen, of varying 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;
- a filter sand pack consisting of silica sand was installed to a minimum height of 2 feet above the top of the screen;
- in most cases, a minimum 2-foot thick seal consisting of bentonite chips was placed on top of the sand pack;
- the remaining borehole annulus was sealed to within 1 foot of the surface using a cement-bentonite grout; and
- the remaining portion of the annulus was filled with concrete and a 6-inch diameter protective above-grade casing.

Table 2.1 presents a summary of the well information for the wells installed during the blowdown line investigation. All monitoring well locations are presented on Figure 2.3. Monitoring well stratigraphic and instrumentation logs are provided in Appendix B. The wells were surveyed for horizontal and vertical control by an Illinois-licensed professional surveyor.

4.1.2 GROUNDWATER MONITORING WELL DEVELOPMENT

After installation, CRA developed the 29 monitoring wells installed during the blowdown line investigation.

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 monitoring well development activities is provided in Table 4.1.

4.1.3 SURVEY

The new monitoring wells were surveyed to establish reference elevations relative to mean sea level. The top of each well casing was surveyed to the nearest 0.01 foot relative to the North American Vertical Datum 88 (NAVD). The survey included the ground elevation at each well to the nearest 0.10 foot relative to the NAVD, and the well location to the nearest 1.0 foot.

4.1.4 GROUNDWATER ELEVATION MEASUREMENTS

During the blowdown line investigation, CRA collected two full rounds of water level measurements from both the Station wells existing at the time and from Byron Salvage Site's monitoring wells located both on and off of the Station property. Synoptic water level measurements were collected on March 23, 2006 and April 4, 2006. Based on the measured depth to water from the reference point and the surveyed elevation of the reference point, the groundwater elevation was calculated. A summary of groundwater elevations for the two measuring events is provided in Table 4.2.

4.1.5 GROUNDWATER SAMPLE COLLECTION

CRA conducted one round of groundwater sampling during the blowdown line investigation. A total of 39 monitoring wells were sampled during the event. These wells included 19 of the 23 wells owned by the Station (TW-1 through TW-12 were dry and the two deep wells are sampled on a quarterly basis and have never indicated tritium impacts) and 20 selected Byron Salvage Site monitoring wells located at the Station. The Byron Salvage Site wells were selected based on the proximity of the wells to the blowdown line, their location downgradient of the blowdown line, and in order to provide a vertical characterization of the groundwater quality.

CRA conducted this round of sampling March 7, 2006 to April 18, 2006. Most of the monitoring wells were sampled on more than one occasion during this time period. Monitoring wells AR-11 and GW-9 were only sampled once. In addition, a total of 22 Byron Salvage Site monitoring wells were originally selected for sampling. However, Well 7 was not sampled because the old farmhouse pump and drop tube were still in the well and were not removed until April 2006, and well DF-13 could not be sampled due to an obstruction in the well that was later removed. CRA conducted the sampling using a combination of bailers and PVC and stainless steel submersible pumps, employing both slow purging and low flow purging techniques. A summary of the purging parameters is presented in Table 4.3, and a sample summary is presented in Table 4.4.

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 packed in a cooler for screening by the Station and shipment to the project laboratory, Environmental, Inc., via overnight courier under chain-of-custody protocol for tritium analysis. Split samples were also collected for the NRC and Illinois Emergency Management Agency (IEMA) for tritium analysis simultaneously with the actual sample at every sample location. The split samples were delivered to the Station personnel for delivery to the NRC and IEMA.

The water purged from the Byron Salvage Site wells during the sampling event was placed into two plastic holding tanks at the Station pending characterization and disposal in accordance with the Station's NPDES permit.

4.2 FLEETWIDE INVESTIGATION ACTIVITIES

4.2.1 GROUNDWATER ELEVATION MEASUREMENTS

On April 24, 2006, CRA collected a round of water level measurements from 63 of the 77 Station monitoring wells in accordance with the Work Plan. Based on the measured depth to water from the reference point and the surveyed elevation of the reference point, the groundwater elevation was calculated. A summary of groundwater elevations for the April 24, 2006 event is provided in Table 4.5. Water level measurements were collected using a portable electronic depth-to-water probe accurate to ± 0.01 foot. The measurements were made from a designated location at the highest point on each well's 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; and
- the water level was then recorded, and the water level meter decontaminated prior to use at the next well location.

4.2.2 GROUNDWATER SAMPLE COLLECTION

CRA conducted a second round of groundwater sampling from April 24 through April 28, 2006. A total of 41 monitoring wells were sampled during the second event. These included the 39 wells sampled during the first event and wells DF-13 and Well 7. At these monitoring well locations, CRA conducted the sampling using pneumatic bladder pumps or peristaltic pumps and dedicated polyethylene tubing to employ 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 correctly located and identification numbers were verified;
- a water level measurement was taken;
- the well was sounded by carefully lowering the electronic depth-to-water probe to the bottom of the well (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 foot 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 into the sample containers; and
- in the event that the groundwater recharge to the monitoring well was insufficient to conduct low flow sampling procedure, the well was pumped dry and allowed to sufficiently recharge prior to sampling.

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 packed in a cooler for screening by the Station and shipment to Teledyne Brown Engineering, Inc. (Teledyne Brown). A sample summary is presented in Table 4.6; field measurements for the fleetwide event are presented in Table 4.7.

CRA containerized the water purged from all of the wells during the fleetwide event. The water was placed into the two plastic holding tanks at the Station, pending characterization. The water was processed by the Station in accordance with their NPDES permit.

4.2.3 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 are described in Appendix C. Analytical data for groundwater samples collected in accordance with the Work Plan are presented in Appendix D. Data validation reports are presented in Appendix E. The data validation included the following information and evaluations:

- sample preservation;
- sample holding times;
- laboratory method blanks;
- laboratory control samples;
- laboratory duplicates;
- verify 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.

4.2.4 SAMPLE IDENTIFICATION

For the fleetwide sampling, systematic sample identification codes were used to uniquely identify all samples. The identification code format used in the field was:

WG-BYN–042506-SS-01. A summary of sample identification numbers for the fleetwide investigation is presented in Table 4.6.

WG	-	Sample matrix -groundwater
RB	-	Sample matrix – rinse blank
BYN	-	Station code (for Byron)
042506	-	Date (month/day/year)
SS	-	Sampler's initials
01	-	Sample number

4.2.5 CHAIN-OF-CUSTODY RECORD

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

4.2.6 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. 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.

Rinsate Blank Samples

Rinsate blanks were collected during the fleetwide investigation to verify that decontamination procedures conducted in the field were adequate. Rinsate blanks were collected by routing Station-supplied demineralized water through decontaminated sampling equipment. Rinsate blanks were collected at a frequency of one rinsate blank for every day samples were collected using non-disposable or non-dedicated equipment. A total of four rinsate blanks were collected.

Split Samples

Split samples were collected for the NRC and IEMA 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 and IEMA.

4.2.7 ANALYSES

Groundwater 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 during the blowdown line and fleetwide investigations.

5.1 STATION GEOLOGY

Bedrock under the Station is generally found within the top 10 feet, under a veneer of unconsolidated deposits, except near the Rock River, where the bedrock has been eroded and is encountered at deeper depths. The Station geology is consistent with the regional geology and is comprised of flat-lying Ordovician-aged dolomitic and sandstone layers progressing downward as follows:

- Galena Group Dolomites;
- Platteville Group Dolomites; and
- Ancell Group, consisting of:
  - Glenwood Formation (shale with sandy dolomite, semi-confining layer),
  - St. Peter Sandstone Formation, and
  - older Cambrian formations.

The generating facility was constructed on an area of a 'bedrock high', and the foundation was installed into the bedrock.

5.2 STATION HYDROGEOLOGY

There are two aquifers within the first 230 feet beneath the Station property:

- the upper aquifer is the Galena-Platteville aquifer consisting of Galena-Platteville limestones and dolomites; and
- the lower aquifer is the St. Peter Sandstone aquifer.

The Glenwood Formation separates the above two aquifers. The Glenwood contains shale at the top and sandy dolomite at its base. The shale acts as a semi-confining aquitard between the upper Galena-Platteville aquifer and lower St. Peter Sandstone aquifer. The first occurrence of groundwater (the water table) is encountered within the unconsolidated deposits near the Rock River, and within the upper fractured portions of the Galena-Platteville aquifer in the upland areas, east of the Rock River.

The monitoring wells at the Station were installed to monitor three intervals within the two aquifers (see Table 2.1):

- wells screened across the water table, either in the unconsolidated sediments near the Rock River or in the upper portions of the Galena-Platteville aquifer;
- wells screened at the bottom of the Galena-Platteville aquifer, just above the shale unit; and
- wells screened in the St. Peter Sandstone aquifer.

Figure 5.1 presents the locations of four hydrogeologic cross-sections prepared for the Station. The four cross-sections depict the relationship between the geology and measured groundwater elevations. Figure 5.2 presents an east-west cross-section parallel to the groundwater flow direction, along the blowdown line. Figure 5.3 presents a north-south cross-section perpendicular to the groundwater flow, through vacuum breaker 4 (VB-4). This location was chosen because water with the highest concentrations of tritium was encountered in the concrete vault at VB-4. Also indicated on Figures 5.1 through 5.3 are the approximate limits of the historical Byron Salvage Site groundwater plumes. Figure 5.4 presents two cross-sections through the PA, one trending to the northeast through Unit 2 and the other to the east through Unit 2.

5.2.1 GROUNDWATER FLOW DIRECTIONS

CRA used a commercially available contouring program (Surfer, Version 8.02, 2002) to provide an initial contouring of the measured groundwater elevations. CRA then refined the initial contours, using professional judgment, to prepare final contour maps. Figure 2.4 presents the water table groundwater contours in the upper portion of the Galena-Platteville aquifer based on data collected by CRA on March 23, 2006 for the blowdown line area, along with historical data collected in 1974 for the generating facility area. Figures 5.5 through 5.7 present the groundwater contours based on April 24, 2006 data for the upper portion of the Galena-Platteville aquifer, the bottom of the Galena-Platteville aquifer, and the St. Peter Sandstone aquifer, respectively.

The general groundwater flow direction in all three intervals is to the west toward Rock River. This is consistent with the regional flow pattern, which is to the west toward the

Rock River, since the Rock River is the major water body in the area (UFSAR, 2004 and CRA, 2001).

Within the upper portions of the Galena-Platteville aquifer, the direction of groundwater flow typically follows the topographic relief at points along the blowdown line. There is a northwest/southeast trending groundwater divide within the Former Dirk's Farm property, near Razorville Road, that is generally perpendicular to the blowdown line (Figures 2.4 and 5.5).

5.2.2 MAN-MADE INFLUENCES ON GROUNDWATER FLOW

The PA sits upon a bedrock high, and as such, the groundwater beneath this area of the Station flows radially outward in all directions. The bedrock below the generating facility foundations was pressure grouted for structural reasons prior to constructing the foundation. The pressure grouting sealed the pore space of the bedrock, thus causing the groundwater to be observed at a deeper depth than that under normal conditions in AR-7. Therefore, the groundwater elevation from AR-7 was not used in the contouring of Figure 5.5.

5.2.3 VERTICAL HYDRAULIC GRADIENTS

CRA calculated vertical hydraulic gradients at the locations where depth specific wells were clustered together. Table 5.1 presents the calculated vertical gradients. Between the upper portion of the Galena-Platteville aquifer and the bottom of the aquifer, there is a slight downward vertical gradient of approximately 0.01 feet/foot. This is consistent with the effects of recharge from the higher/elevated areas of the Station and discharge to the Rock River. However, at the PC-3B/DF-6 well cluster location on the former Dirk's Farm property, the downward vertical gradient is greater, at 0.443 feet/foot. The vertical gradients measured within the Galena-Platteville aquifer are in the same range as the measured horizontal hydraulic gradient.

There is only one cluster of wells in which both wells are screened within the St. Peter Sandstone aquifer: MW-20R and MW-21. The measured vertical hydraulic gradient at this well cluster is very low at 0.001 feet/foot. This suggests primarily horizontal flow within the St. Peter Sandstone aquifer, which is consistent with the high conductivity of the St. Peter Sandstone.

The groundwater elevation data confirm that the Galena-Platteville and St. Peter Sandstone aquifers are not hydraulically connected. The groundwater elevations measured in wells that are screened in the St. Peter Sandstone aquifer are typically more than 50 feet lower than those in wells screened at the bottom of the Galena-Platteville aquifer. Vertical hydraulic gradients between these two aquifers, measured at five well clusters, range between 0.622 feet/foot and 1.893 feet/foot, with the average being 1.127 feet/foot. These are much greater than the horizontal gradients measured in either of the two aquifers. These groundwater data provide evidence that the shale of the Glenwood Formation, which separates the bottom of the Galena-Platteville aquifer from the underlying St. Peter Sandstone aquifer, is acting as a local aquitard or semi-confining unit.

5.2.4 LATERAL GROUNDWATER FLOW AND VELOCITY

Across the more than two-mile distance between the generating facility and the Rock River, the water table elevation drops approximately 160 feet, creating a shallow horizontal hydraulic gradient of approximately 0.014 feet/foot. The limestones and dolomites that comprise the Galena-Platteville aquifer generally have hydraulic conductivities that can vary significantly; a study for the Byron Salvage Site immediately to the north of the west portion of the station, reported mean hydraulic conductivities ranging from 0.31 feet/day to 240 feet/day with a primary porosity of around 10 percent (Kay et al., 1997). With a gradient of 0.014 feet/foot, the average shallow horizontal groundwater flow velocity can be calculated to be 15.8 feet/year to 12,200 feet/year.

The groundwater flow direction at the bottom of the Galena-Platteville aquifer has a southwest component, under a horizontal hydraulic gradient of approximately 0.011 feet/foot (Figure 5.6). However, the wells screened at the bottom of the aquifer are only located near the blowdown line, on the Former Dirk's Farm property, not across the entire length of the Station property. In this same area for the upper Galena-Platteville aquifer, the groundwater contours also suggest a component of flow to the southwest.

In St. Peter Sandstone aquifer, the groundwater contours suggest a groundwater flow to the west toward the Rock River, under a low horizontal hydraulic gradient of approximately 0.001 feet/foot (Figure 5.7). This is consistent with expected regional groundwater flow within the lower aquifer. Using the hydraulic gradient of 0.001 feet/foot with a reported hydraulic conductivity range of 2.0 feet/day to 8.7 feet/day (Kay et al., 1997) and a reported primary porosity of 0.14 (Kay et al., 1997) yields an average horizontal groundwater velocity in the St. Peter Sandstone of 5.2 feet/year to 22.7 feet/year.

5.3 GROUNDWATER QUALITY

During the blowdown line investigation and the fleetwide assessment, both CRA and Station personnel collected numerous samples from the vacuum breaker vaults and other Station locations, from nearby residential wells, from the blowdown line itself, from the on-Station CROP, and from a subset of the monitoring wells located on the Station property. As discussed in Sections 4.1 and 4.2, the samples were analyzed for tritium, and some of the samples were also analyzed for strontium-89/90 and additional radionuclides.

Table 5.2 presents a summary of tritium analyses for water samples collected by the Station from the vacuum breaker vaults, the beginning and end of the blowdown line, and the CROP. Table 5.3 presents a summary of tritium analyses for groundwater samples collected during both the blowdown line investigation and the fleetwide investigation. Table 5.4 presents a summary of tritium analyses for groundwater samples collected from residential water supply wells. Table 5.5 presents a summary of the other radionuclide analyses (strontium-89/90 and gamma-emitting radionuclides) for groundwater samples collected during both the blowdown line investigation and the fleetwide investigation.

The analytical data presented herein has been subjected to CRA's data validation process (see Appendix E for the data validation reports). CRA has used the data with appropriate qualifiers, where necessary.

The data reported in the figures and tables does not include the results of re-analyses or 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.

5.3.1 SUMMARY OF BETA-EMITTING RADIONUCLIDES ANALYTICAL RESULTS

5.3.1.1 STATION SAMPLING POINTS

During the blowdown line investigation, Station personnel collected multiple samples on different dates from the vacuum breaker vaults, the beginning and end of the blowdown line, and the CROP. A summary of the tritium results for the water samples collected from the Station sampling locations is provided in Table 5.2. The tritium data are presented graphically on Figure 5.8.

5.3.1.2 GROUNDWATER MONITORING WELL SAMPLES

A summary of the tritium results for the groundwater samples collected during both the blowdown line investigation and the fleetwide investigation is provided in Table 5.3. Figures 5.9 through 5.11 present the tritium data graphically for the groundwater samples collected on different dates from the monitoring wells screened in the upper portions of the Galena-Platteville aquifer, the bottom of Galena-Platteville aquifer, and the St. Peter Sandstone aquifer, respectively.

All tritium concentrations were below the USEPA drinking water standard of 20,000 pCi/L. Tritium was not detected at concentrations greater than the LLD of 200 pCi/L in 35 of the 39 groundwater samples collected.

Strontium-89/90 was not detected at 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 investigations that are the subject of this HIR is provided in Table 5.5.

<u>Galena-Platteville Aquifer</u>

Groundwater samples were collected from 32 different monitoring wells screened in the upper portions of Galena-Platteville aquifer (Figure 5.9). Concentrations of tritium exceeding the LLD of 200 pCi/L for tritium were only detected in the groundwater samples collected from three of the monitoring wells: AR-2, AR-3, and AR-4. The most recent concentrations of tritium detected at each location were:

- AR-2 432 ± 140 pCi/L;
- AR-3 234 ± 128 pCi/L; and
- AR-4 3,260 ± 367 pCi/L.

The original groundwater sample collected from TW-13 had a tritium concentration less than the LLD of 200 pCi/L; however, a detection of tritium slightly greater than the LLD, 201 ± 110 pCi/L, was detected in a duplicate groundwater sample collected as part of the fleetwide sampling event at the same time on the same date. In consideration of the original sample being less than the LLD, and the duplicate sample at 201 pCi/L with an error of ± 110 pCi/L, the tritium concentration at this location is regarded as less than the LLD.

CRA collected five groundwater samples from monitoring wells installed at the bottom of Galena-Platteville aquifer (Figure 5.10), and only the samples from monitoring well AR-11 contained tritium at concentrations greater than the LLD of 200 pCi/L. The highest tritium concentration detected in a groundwater sample collected from monitoring well AR-11 was 2,340 ± 282 pCi/L. Monitoring well AR-11 is a bedrock well located in a downgradient direction from monitoring well AR-4 and VB-4 (Figure 2.3), and screened in a deeper portion of the bedrock (bottom of the Galena-Platteville aquifer) than AR-4 (upper portion of the Galena-Platteville aquifer) (Figure 5.2). The inferred vertical limits of the groundwater containing tritium exceeding the LLD of 200 pCi/L are depicted on Figures 5.2 and 5.3.

Strontium-89/90 was not detected at 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 investigations that are the subject of this HIR is provided in Table 5.5.

St. Peter Sandstone Aquifer

CRA collected groundwater samples from four monitoring wells screened in the St. Peter Sandstone aquifer (Figure 5.11). None of the groundwater samples contained detectable concentrations of tritium above the LLD of 200 pCi/L.

Strontium-89/90 was not detected at 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 investigations that are the subject of this HIR is provided in Table 5.5.

5.3.1.3 RESIDENTIAL WATER SUPPLY WELLS

Station personnel collected water samples from nine of the residences located adjacent to the Station property, along the blowdown line. In addition, a water sample was also collected from the well of a residence located approximately 2 miles east of the Station (Goral Well) to be used as a background water sample.

Tritium was not detected above the LLD of 200 pCi/L in any of the 10 residential well samples collected. A summary of the tritium results for the residential water samples is provided in Table 5.4, and the tritium data is presented graphically on Figure 5.12.

Strontium-89/90 was not detected at 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 investigations that are the subject of this HIR is provided in Table 5.5.

5.3.2 SUMMARY OF GAMMA-EMITTING RADIONUCLIDES ANALYTICAL RESULTS

Gamma-emitting target radionuclides were not detected at concentrations greater than their respective LLD. CRA collected groundwater samples from 19 monitoring wells and the samples were analyzed for gamma-emitting radionuclides. A summary of the radionuclide results is provided in Table 5.5 and presented graphically on Figure 5.13.

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

A summary of the field measurement results for the groundwater samples collected as part of the blowdown line investigation is provided in Table 4.3. A summary of the field measurement results for the groundwater samples collected as part of the fleetwide investigation is provided in Table 4.7. These field measurements included pH, Dissolved Oxygen, Conductivity, Turbidity and Temperature.

5.4 SURFACE WATER QUALITY

No samples were collected from the surface water bodies. The two surface water drainage creeks located in the area of the Station are both ephemeral streams, flowing only during times of heavy rainfall.

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 groundwater samples collected at concentrations greater than the LLD of 2.0 pCi/L. Tritium was detected in four of the 39 total sample locations. Concentrations of tritium ranged between 234 ± 128 pCi/L to 3,260 ± 367 pCi/L.

Since only tritium was detected at concentrations greater than its LLD during the fleetwide investigation, 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 (^{3}He). 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 found in groundwater beneath the Station. Tritium was only detected in groundwater at concentrations exceeding the LLD of 200 pCi/L near the vaults along the blowdown line.

The groundwater under the PA does not appear to be impacted by tritium based on the groundwater analytical results from the five monitoring wells installed in and around the PA (AR-7 through AR-10 and CAR-3) in locations that are hydraulically downgradient of Station systems. Tritium was not detected at concentrations greater than the LLD of 200 pCi/L in any of the groundwater samples collected from these five monitoring wells during the investigation.

Tritium was not detected at concentrations greater than the LLD of 200 pCi/L in the water samples collected from the residential water wells. The St. Peter Sandstone is the primary aquifer for residential potable water in the area, and the water in the St. Peter Sandstone aquifer is separated from the water in the Galena-Platteville aquifer by the shale unit of the Glenwood Formation (see Section 5.1.2).

The only tritium concentrations greater than the LLD of 200 pCi/L were detected during the blowdown line and fleetwide investigations in groundwater samples collected from four wells: AR-2, AR-3, AR-4, and AR-11. Monitoring wells AR-2, AR-3, and AR-4 screen the water table, and AR-11 is screened at the bottom of the Galena-Platteville aquifer. These four locations are adjacent to the three vacuum breaker vaults VB-2, VB-3, and VB-4, that had water within the concrete vaults exhibiting the highest concentrations of tritium (see Figure 5.8).

The tritium concentrations detected in the groundwater samples collected from monitoring wells AR-2 and AR-3, which are near VB-2 and VB-3, are not much higher than 200 pCi/L. The concentrations in these two wells fluctuate, but are all less than 600 pCi/L. The detected tritium concentrations in the groundwater samples collected during the fleetwide investigation from monitoring wells AR-4 and AR-11 were 3,260 ± 367 pCi/L and 2,340 ± 282 pCi/L, respectively. These wells are near VB-4. AR-4 screens the water table, and AR-11 is deeper and screens the bottom of the Galena-Platteville aquifer.

The original groundwater sample collected from TW-13 had a tritium concentration less than the LLD of 200 pCi/L; however, tritium was detected at a very low concentration, 201 ± 110 pCi/L, in a duplicate groundwater sample collected as part of the fleetwide sampling event at the same time on the same date. In consideration of the original sample being less than the LLD, and the duplicate sample at just 201 pCi/L with an error of ± 110, the tritium concentration at this location is regarded as less than the LLD. Monitoring well TW-13 is a shallow well (18 feet deep) located near River Road and installed within the unconsolidated alluvial sediments.

In summary, there are only three areas at the Station where tritium has been detected. They are all located near vacuum breakers along the blowdown line. These three areas are: VB-2 (well AR-2), VB-3 (well AR-3), and VB-4 (wells AR-4 and AR-11). The groundwater impacted at each of these areas is localized within the Galena-Platteville aquifer. The inferred vertical limits of the groundwater containing tritium exceeding 200 pCi/L are depicted on Figures 5.2 and 5.3. Based on the data collected, none of the other aquifers appears to have been impacted.

6.3.3 CONCEPTUAL MODEL OF TRITIUM RELEASE AND MIGRATION

This section presents CRA's conceptual model of groundwater and tritium migration at the Station.

As identified in Section 6.3.2, the groundwater under the PA does not appear to be impacted by tritium above the LLD of 200 pCi/L. Tritium was also not detected at concentrations exceeding the LLD of 200 pCi/L in the water samples collected from the residential water wells.

The highest concentrations of tritium detected in the Station sampling points were from water samples collected from within the vacuum breaker vaults along the blowdown line. The source of the tritium in the groundwater at the four wells is minor failures of the blowdown line vacuum breakers. This water originated from the blowdown line. The water encountered in the vaults was pumped out and processed in accordance with the Station's NPDES permit. As discussed in Section 3.3.2.2, Exelon performed construction upgrades on each of the six breaker vaults to ensure that there will not be any future releases of tritium to the groundwater.

Sources and Migration of Tritium

The detections of tritium exceeding 200 pCi/L in monitoring wells AR-2, AR-3, AR-4, and AR-11 appear to be localized and confined to the areas around the wells. Tritium was not detected at the LLD of 200 pCi/L in the groundwater samples collected from monitoring wells and residential wells downgradient of these locations. The source of the tritium in the groundwater at these four well locations is the blowdown line vacuum breakers (AFE-Byron-2). Once in the subsurface, the tritiated water migrated downward through the unsaturated overburden and fractured bedrock to the water table. Once at the water table, downward vertical gradients caused the tritiated water to migrate downward to the base of the Galena-Platteville aquifer, where tritium was detected in the groundwater sample from monitoring well AR-11 (Figure 5.2).

The shale of the Glenwood Formation has a low permeability and acts as a barrier to further downward migration of the tritiated water. Due to the low permeabilities of the

Galena-Platteville limestones/dolomites, combined with the shallow horizontal gradient, the tritiated water should not migrate very far laterally from the vacuum breakers. There is no indication from the HIR data that tritium-impacted groundwater in this area is migrating off the Station property.

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 focused on 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 (± 3-sigma) confidence range 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}Li (92.5 percent abundance) and ^{7}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 less than 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 damped 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 less than 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 less than 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.

Recent surface water measurements for tritium sampling locations upstream of the Quad Cities Generating Station show that concentrations in the Mississippi River are consistently less than 200 pCi/L (Exelon, 2005).

These results indicate that there is a background tritium concentration in surface water that is typically less than 100 pCi/L, but have approached 800 pCi/L in the Mississippi River.

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 less than 100 pCi/L and 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 have 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, have 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 water 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, potentially can also 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:

- potential groundwater migration to the Station's potable water supply well;
- potential groundwater migration off the Station property to private water supply wells; and
- potential groundwater migration off the Station property to a surface water body.

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 AT THE STATION PROPERTY

At the Station, the tritium detected in groundwater samples has been isolated to the Galena-Platteville aquifer, which is isolated from the deeper regional groundwater aquifer by the semi-confining Glenwood Formation. Groundwater quality data from production wells and monitoring wells at the Station located below this aquitard do not indicate concentrations of tritium greater than the LLD of 200 pCi/L. As such, the tritium impact is limited to the Galena-Platteville aquifer. There are no water supply wells located on the Station property that draw water from the Galena-Platteville aquifer. The Station receives its potable water from two cased 1,500-foot bedrock wells on the Site, which are installed in the Ironton-Galesville Sandstone. The vertical movement of tritiated water from the Galena-Platteville aquifer into deeper formations is restricted by the semi-confining Glenwood Formation. Since vertical migration of tritiated water through the Glenwood Formation to the Ironton-Galesville Aquifer is restricted but theoretically not eliminated, this is a potentially complete exposure pathway but there is no current risk for groundwater ingestion at the Station.

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

Based on the results of the investigations and the conceptual model, the only potentially complete exposure route (pathway) for tritiated water at the Station is ingestion of the groundwater at nearby private water supply wells. However, due to low permeabilities of the limestones and dolomites of the Galena-Platteville aquifer, along with the general hardness of the water, this aquifer is typically not used for potable water in the area.

The St. Peter Sandstone is the primary source for potable water in the area. The St. Peter Sandstone aquifer is separated from the Galena-Platteville aquifer by a low permeability shale of the Glenwood Formation. Residential water wells that are both off the Station property and in the direction of groundwater flow downgradient from the blowdown line typically obtain water from the St. Peter Sandstone aquifer. These water wells were sampled and were not impacted. In addition, none of the groundwater samples collected from monitoring wells near the property line contained tritium at concentrations greater than 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 off the Station property.

7.3.3 POTENTIAL GROUNDWATER MIGRATION TO SURFACE WATER USERS

Groundwater does not discharge to the local surface water drainages (ephemeral creeks) and the nearest wells located adjacent to the Rock River have not contained tritium. There is no potentially complete exposure pathway, therefore there is no current risk of exposure associated with groundwater migration to surface water at the Station.

7.4 SUMMARY OF POTENTIAL TRITIUM EXPOSURE PATHWAYS

There are three potential exposure pathways for tritium at the Station:

- potential groundwater migration to the Station's potable supply well;

- potential groundwater migration off the Station property to private water supply wells; and
- potential groundwater migration off the Station property to a surface water body.

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 the USEPA drinking water standard (20,000 pCi/L).

7.5 OTHER RADIONUCLIDES

Target radionuclides were not detected at concentrations greater than the LLDs 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 the Station, CRA concludes:

Groundwater Flow

- There are two groundwater aquifers within the first 230 feet beneath the Station: the Galena-Platteville aquifer (upper aquifer) and the St. Peter Sandstone aquifer (lower aquifer).
- The two aquifers are separated by a semi-confining shale layer of the Glenwood Formation and, therefore, not hydraulically connected under the Station.
- Groundwater (the water table) is first encountered in the upper fractured portions of the Galena-Platteville aquifer. Near the Rock River, the bedrock has been eroded, and the water table is in unconsolidated alluvial material.
- The general direction of groundwater flow in both aquifers is to the west toward the Rock River.
- The groundwater flows radially away from the facility.
- The horizontal gradient in the Galena-Platteville aquifer is shallow. There is a slight downward vertical gradient between the upper portion and bottom of the Galena-Platteville aquifer.

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 of 200 pCi/L in samples collected from the five monitoring wells located in the PA.
- Tritium was not detected at concentrations greater than the LLD of 200 pCi/L in 35 of the 39 groundwater samples collected. Concentrations of tritium in the four remaining samples, all collected near vacuum breakers, ranged between 234 ± 128 pCi/L to 3,260 ± 367 pCi/L.
- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the most recent water samples collected as part of this investigation.
- Strontium-89/90 was not detected at concentrations greater than the LLD of 2 pCi/L in any sample collected as part of this investigation.

- Tritium was not detected at concentrations greater than the LLD of 200 pCi/L in the water samples collected from the residential water wells.
- The HIR data indicate that tritium is not migrating off the Station property.

AFE-Byron-1 – Former Fiberglass Blowdown Line

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the 13 groundwater samples collected from the four monitoring wells in the vicinity of AFE-Byron-1.
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2 pCi/L in any of the 13 groundwater samples collected from the four monitoring wells in the vicinity of AFE-Byron-1.
- Tritium was not detected at concentrations greater than the LLD of 200 pCi/L in any of the groundwater samples collected from the four monitoring wells in the vicinity of AFE-Byron-1.
- There is no current impact from this AFE to groundwater.

AFE-Byron-2 – Vacuum Breaker Vaults

- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the groundwater samples most recently collected from monitoring wells near AFE-Byron-2.
- Strontium-89/90 was not detected at a concentration greater than the LLD of 2 pCi/L in any of the groundwater samples collected from monitoring wells near AFE-Byron-2.
- To the west of the generating facility, near the blowdown line, the concentrations of tritium were greater than the LLD of 200 pCi/L in four monitoring wells: AR-2, AR-3, AR-4, and AR-11. These four wells are adjacent to three vacuum breaker vaults: VB-2, VB-3, and VB-4. These vaults formerly contained water with elevated concentrations of tritium.
- Two areas where tritium was found in the groundwater near VB-2 and VB-3 are limited to the shallow portions of the Galena-Platteville aquifer.
- Near VB-4, the groundwater contains tritium down to the bottom of the Galena-Platteville aquifer.

- The source of the tritium concentrations in the groundwater was periodic leaks during re-seating of the blowdown line vacuum breaker valves.
- None of the tritium concentrations detected in the groundwater exceed the USEPA drinking water standard of 20,000 pCi/L.
- The shale unit of the Glenwood Formation has a low permeability and acts as a barrier to further downward migration of impacted water down to the St. Peter Sandstone aquifer. Due to the low permeabilities of the Galena-Platteville limestones/dolomites combined with the shallow gradient of the water table, the tritiated water in the Galena-Platteville aquifer will not migrate very far laterally from the VB-2, VB-3, and VB-4 areas.
- Tritiated groundwater at the Station is isolated in three areas, and the evidence indicates that it is not migrating off Station property. This is based upon the inferred slow groundwater flow velocities and that groundwater sampling results indicate that monitoring wells outside of these three areas are not impacted. The unimpacted wells include: monitoring wells located hydraulically downgradient, monitoring wells located at the property line, and residential water wells. The tritium detected in groundwater is not the result of large failures of the blowdown line, but of minor failures of the vacuum breaker valves to re-seat during blowdown line discharge events. No knowledge or evidence of large failures of or releases from the blowdown line have been documented or identified through the investigations.
- Therefore, additional plume delineation activities or groundwater remediation are not warranted.

AFE-Byron-3 –Protected Area

- Groundwater under the PA flows radially outward due to the topographic high on which the PA was constructed. The downgradient locations of the monitoring wells were selected based on this radial groundwater flow pattern. These monitoring wells are situated to provide for an adequate indication for future leak detection.
- Tritium was not detected at concentrations greater than the LLD of 200 pCi/L in any of the groundwater samples collected from seven monitoring wells in the vicinity of AFE-Byron-3.
- Gamma-emitting radionuclides associated with licensed plant operations were not detected at concentrations greater than their respective LLDs in any of the groundwater samples most recently collected from seven monitoring wells in the vicinity of AFE-Byron-3.

- Strontium-89/90 was not detected at a concentration greater than the LLD of 2 pCi/L in any of the groundwater samples collected from monitoring wells in the vicinity of AFE-Byron-3.
- There is no current impact from this AFE to groundwater.

Potential Receptors

- Based on the results of this investigation[1], 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 Byron 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 groundwater monitoring well locations.

10.0 REFERENCES

The materials referenced in the generation of this HIR include:

Byron Station Radiological Environmental Monitoring Program (REMP) Reports.

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Kay, Robert T., Douglas J. Yeskis, William J. Bolen, James R. Rauman, and Scott T. Prinos, 1997. Geology, Hydrology, and Ground-Water Quality at the Byron Superfund Site Near Byron, Illinois, United States Geological Survey, Water-Resources Investigations Report 95-4240, Prepared in Cooperation with the U.S. Environmental Protection Agency Ogle County, 2006, Geographical Information System (GIS) database, http://www.Oglecountygis.org.

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The main references cited in the UFSAR related to this HIR include:

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