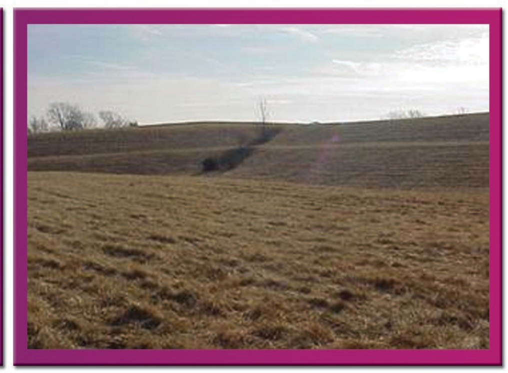
State of Illinois
Illinois Emergency Management Agency

October 2009

Site History and Environmental Monitoring Report for Sheffield Low-Level RadioactiveWaste Disposal Site





IEMA

Division of Nuclear Safety
Bureau of Environmental Safety

Foreword

This *2009 Site History and Environmental Monitoring Report for the Sheffield Low-Level Radioactive Disposal Site* was developed by the Illinois Emergency Management Agency (IEMA), Bureau of Environmental Safety (BES) to provide information to anyone interested in this closed low-level radioactive waste (LLRW) disposal site. This report provides historical background on the Sheffield LLRW site and its operation including the context of the time that it operated, design flaws, remedies, key regulatory issues, and the site's past and current performance.

IEMA published this report in an effort to communicate background information on the site, the current conditions and hopefully answer questions that residents and the general public may have about the Sheffield LLRW site. IEMA's continuing objective at the closed Sheffield LLRW site is to ensure that the radionuclides entombed there are isolated from people and the environment, in accordance with regulatory requirements, until the radionuclides become stable through radioactive decay.

Questions regarding the Sheffield LLW site or this report should be directed to:

Gary McCandless, P. E.
Chief, Bureau of Environmental Safety
Illinois Emergency Management Agency
1035 Outer Park Drive
Springfield, IL 62704

Phone: 217-785-9954 Fax: 217-524-6417

Copies of this report may be obtained from IEMA BES or by downloading it from http://www.state.il.us/iema/publications/publications.asp.

TABLE OF CONTENTS

List of Maps

Table of Contents, continued

List of Maps, continued

List of Photos & Slides

List of Drawings (DWG)

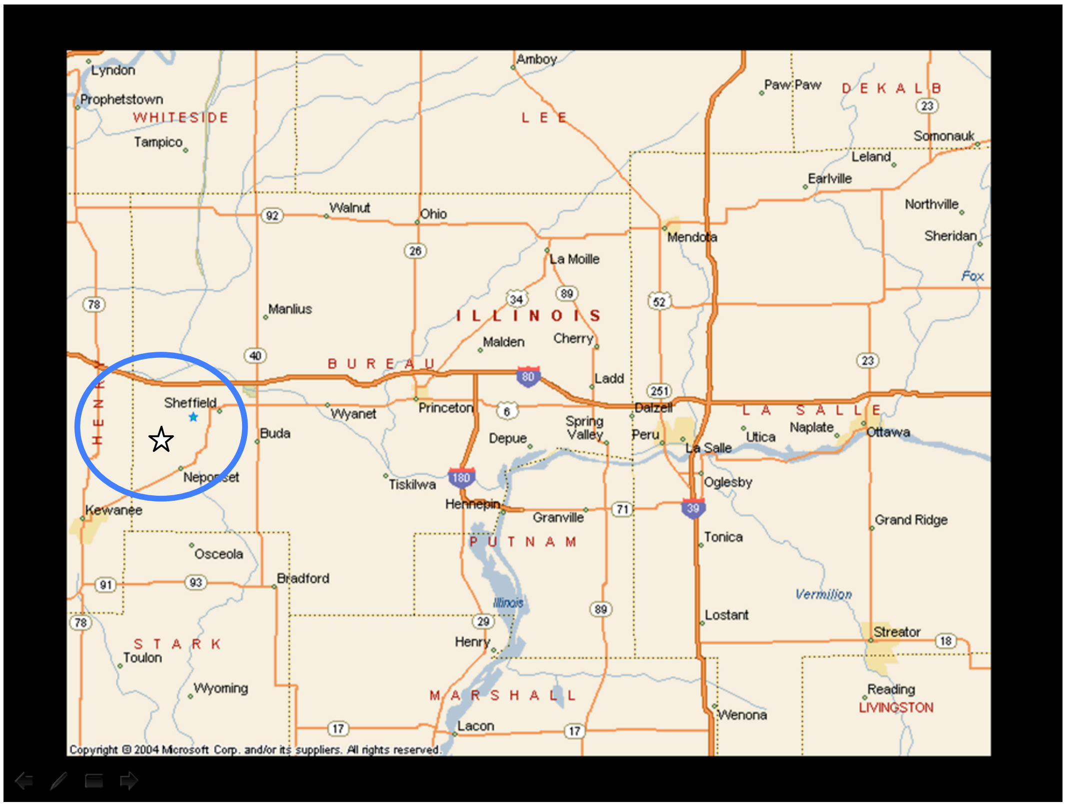
Table of Contents, continued

List of Tables

List of Data Graphs

A Brief History of the Sheffield LLRW Disposal Facility

The Sheffield Low-Level Radioactive Waste Disposal Facility (Sheffield site) is located approximately three miles southwest of the town of Sheffield in rural Bureau County, Illinois; the white star on the map below marks the approximate location.



Map 1 – Location of the Sheffield LLRW Disposal Facility (IEMA, 2005)

The Sheffield LLRW disposal facility operated from 1967 through 1978. During that time, about 3.2 million cubic feet of LLRW was buried in 21 earthen trenches. Since the 1980s, the Sheffield site has included both the “20-acre LLRW Disposal Site” and the surrounding 170-acre buffer zone shown in green on Photo 1 (p. 2). Trout Lake, a 31-acre strip mining lake that is fed by natural springs, is along the northeastern boundary of the buffer zone. Two hazardous chemical waste (HCW) disposal areas are located to the north and northwest of the 20.5-acre low-level radioactive waste disposal area and are separated from it by at least 150 feet.

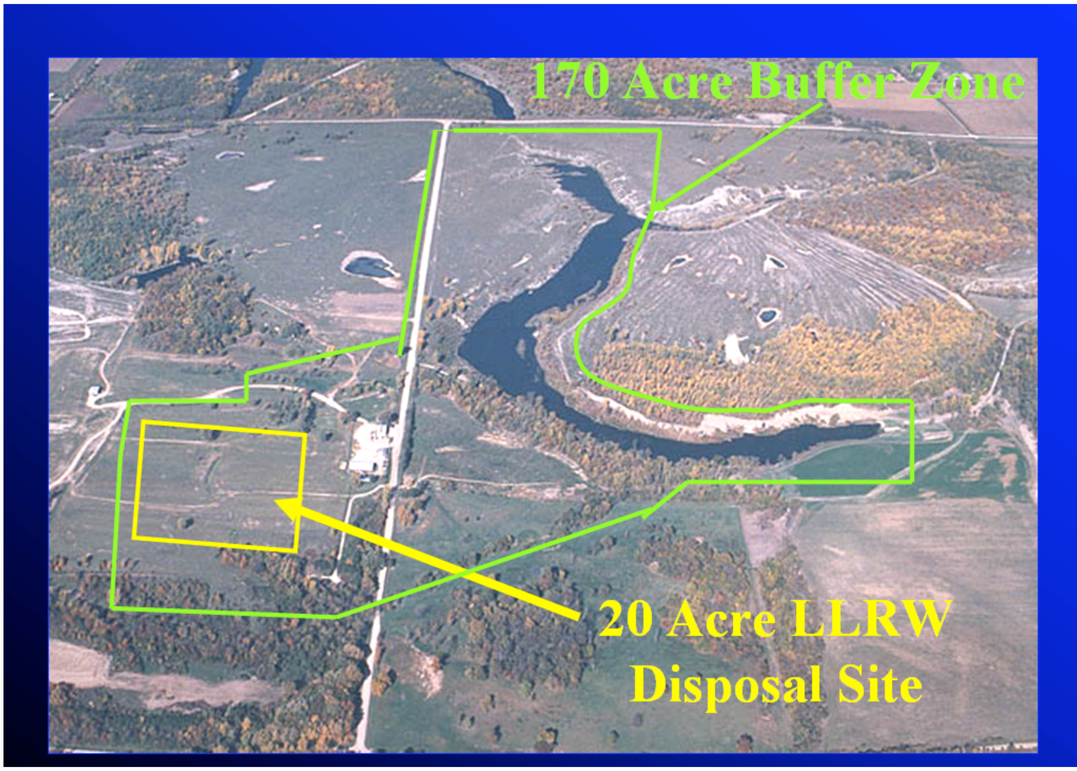


Photo 1 - Aerial view of the Sheffield LLRW Disposal Facility with feature overlays (IEMA, 1999)

These HCW areas were used for the disposal of non-radioactive waste. The first HCW site accepted waste from 1968 to 1974 and the second from 1974 to 1983.

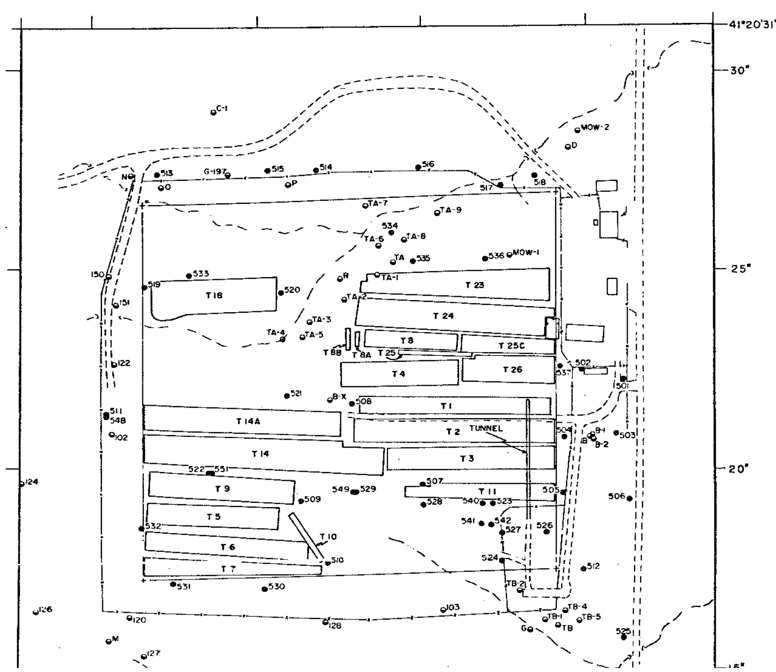
Photo 2 - Low-level radioactive waste awaits disposal at the Sheffield site (IEMA, 1970s)

In accordance with accepted practice at the time, low-level radioactive waste was packaged and placed in unlined disposal trenches. The configuration of these

Photo 3 - Burial of LLRW at the Sheffield LLRW Disposal Facility (IEMA, date unknown)

trenches is shown on Drawing 1 below (USGS, 1985).

Drawing 1



Location of wells, borings, trenches, and tunnel at Sheffield LLRW disposal site (after Foster and Erickson, 1980, in ISGS Contract/ Grant Report 1985-1)

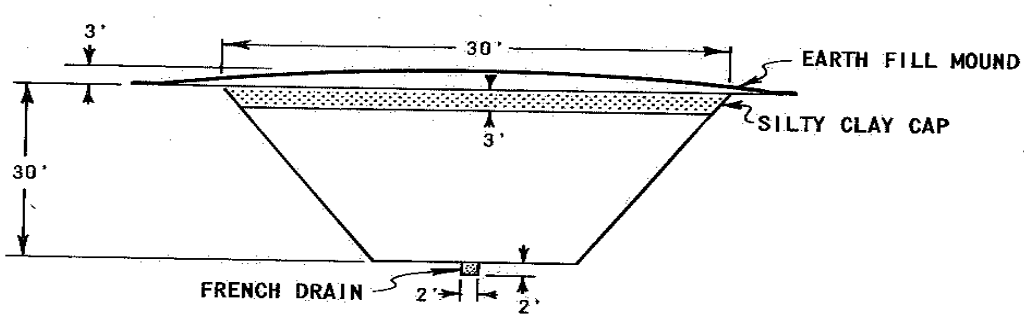
A precise ir
by the site
Dragonette et al, 1979; MacKenzie et al, 1985). The estimated inventory of important radionuclides is listed in Table 1, Maximum Values Estimated in the Sheffield Inventory.

Table 1 – Maximum Values Estimated in the Sheffield Inventory

Important Radionuclides with half-lives greater than five years, as estimated by three studies		
Radionuclide	Curies	Half-life (Years)
H-3 (Tritium)	5,990	12.35
C-14 (Carbon)	450	5,730
I-129 (Iodine)	0.01	15,700,000
Sr-90 (Strontium)	3,690	29.12
Cs-137 (Cesium)	15,500	30
Co-60 (Cobalt)	20,000	5.27
Pu-238 (Plutonium)	7.5	87.74
Pu-239, Pu-240, Pu-241	4,870	24,065; 6,550; 14.4
Am-241 (Americium)	137.5	43.2

(IEMA, 2009)

All trenches were located in the unsaturated zone on the higher ground in areas where water levels fluctuate least and are located 2 to 10 feet above the water table, except Trench 18 which was partly below the water table (USGS, 1984, p.35). However, the original trench design, depicted below in DWG 2, did not function as well as expected. See Appendix A for a chronology and timeline of regulatory events that led to improvement of the trench performance.



DWG 2 - End view of a typical trench (USGS, 1984)

A key problem with the original trench design was that water accumulated between the trench caps, as shown in Photo 4 where of the State inspector is standing in a swale. It is probable that the soil covering the waste in the trenches was not adequately compacted and that coupled with seepage into the trenches resulted in cap subsidence. Vertical collapse holes in the vicinity of

Photo 4 - State inspector standing in flooded swale at the base of a disposal trench at the Sheffield LLRW Disposal Facility (IEMA, date unknown)

the trenches occurred on the Sheffield site during spring months, as shown on the photos below. Although the site contractor filled these on a routine basis, the collapse holes provided a pathway for rapid movement of surface water into the

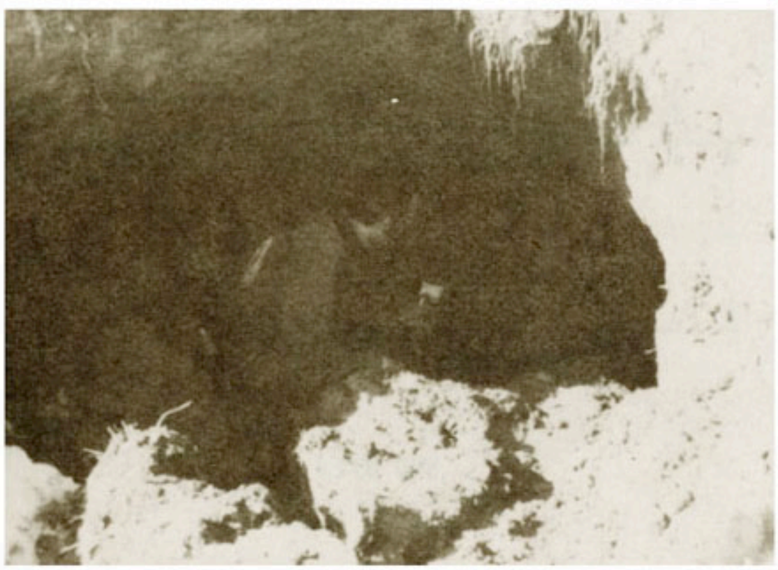


Photo 5 · **Collapse holes exposed in trench surfaces after the snow melted in March 1979.** (USGS, 1984)

shallow aquifer through waste-disposal trenches (USGS, 1986, p. 15). Precipitation falling on open trenches moistened trench walls, lowered the cohesive strength of the silt layers exposed there, and resulted in occasional slumps while the trenches were being filled with waste. Holes occasionally formed in the trench caps when voids developed below the cap, resulting in collapse of the cap material into the void. Collapse holes were repaired by filing the holes with silty-clay that was compacted by running heavy equipment over the fill (Kahle and Rowlands, 1981, in USGS 83-4125, 1984, p. 8).

Seeking improvement, Illinois sued the site operator, U S Ecology (USEC), in 1979; however, the litigation was unresolved until May 26th, 1988, when a settlement agreement was filed in the Circuit Court of the Thirteenth Judicial Circuit Bureau County, Illinois. In accordance with the Agreed Order, USEC installed new, low-permeability clay caps over the waste trenches and purchased the 170-acre buffer zone. USEC also maintains and monitors the low-level waste disposal area and the 170-acre buffer zone. Construction of the new cap began in 1987 and was completed in 1989, resulting in the site as we see it, today, in Photo 6.

Photo 6 - View towards the Old Chem Site from atop Trenches 1, 2, and 3, winter 2005 (IEMA, 2005).

In July 2003, IDNS merged with the Illinois Emergency Management Agency (IEMA) and thereby transferred its regulatory authority for the Sheffield LLRW site.[1]

[1] For interested readers, we recommend the Advisory Committee on Nuclear Waste, U. S. Nuclear Regulatory Commission's NUREG 1853, *History and Framework of Commercial Low-level Radioactive Waste Management in the United States*.

The Agreed Order aka the Sheffield Settlement Agreement

The Agreed Order also known as the Settlement Agreement included a closure plan, remediation of the site, financial support to the State of Illinois and much more. Only items of the Settlement Agreement selected for their importance in understanding the requirements applicable to the Sheffield LLRW site are described here.

One of the many important functions of the Settlement Agreement is that it stipulates regulatory limits applicable only to the Sheffield LLRW site. These limits are shown in Table 2.

Table 2 - Regulatory Limits in Water for Selected Radionuclides

Trigger/ Regulatory Limits in Water for Selected Radionuclides Per the Settlement Agreement of 1988		
Radionuclide	**Half-life**	**Limit in water(picocuries per liter)**
H-3 (Tritium)	12.35	3,000,000
C-14 (Carbon)	5,730	800,000
I-129 (Iodine)	15,700,000	60
Sr-90 (Strontium)	29.12	300
Cs-137 (Cesium)	30	20,000
Co-60 (Cobalt)	5.27	50,000
Pu-238 (Plutonium)	87.74	5,000
Pu-239	24,065	5,000
Am-241 (Americium)	43.2	4,000
From: *Title 32, Illinois Administrative Code, Chapter II, Section 340, Appendix A, Table II, Column 2*, "Concentration in Air and Water above Natural Background," January 1987, as found in the Illinois Department of Nuclear Safety, Environmental Monitoring Report Sheffield Low-Level Radioactive Waste Disposal Site 1989-1990.		

According to the terms of the Settlement Agreement, USEC installed new, low-permeability clay caps over the waste trenches (1987 – 1989); purchased the 170-acre buffer zone, and maintains and monitors the site and buffer zone. U.S. Ecology also established, as required, three financial bases: (1) an escrow account in the amount of $1.65 Million, (2) a $2.25 Million Long Term Care Fund to compensate the State for its future maintenance and monitoring obligations at the site, and (3) an irrevocable letter of credit (ILOC) in the amount of $1.9 Million – this ILOC and the requirement to maintain it expires May 25, 2038.

Along with these limits, the Settlement Agreement also defines terms that are only applicable to the Sheffield site. The first of these is “triggering limits” which are “any concentrations of radionuclides above natural background that equal or exceed the limits set forth as of the date hereof [May 26, 1988] at 32 Illinois Administrative Code, Part 340, Appendix A, Table II, Column 2 for release to unrestricted areas” (Agreed Order, May 26, 1988).

Another term important to site performance is the “signaling event” which is defined as the occurrence within the Buffer Zone of any one of several events described in detail in the Agreed Order. A signaling event within the definition in the Agreed Order does not exist unless and until [the Agency] has given written notice to USEC that the Agency has declared the event. No tritium concentration detected prior to the date of the Settlement Agreement [May 26, 1988] shall be a signaling event (Agreed Order, 1988).

Each of the parties signing the Settlement Agreement agreed to perform all of its obligations, which are affirmed as valid, legally binding and enforceable in accordance with the terms of the Settlement Agreement and the laws of Illinois.

The Sheffield Low-Level Radioactive Waste Disposal Facility is owned by the State of Illinois by Federal statute but USEC owns the 170-acre buffer zone around the site. The State may take possession of the buffer zone at any time for a nominal fee, but must take ownership when the Sheffield Settlement Agreement expires in May 2038.

Tritium Migration

With failure of the trench caps, subsidence, and water in the trenches it could be expected that leachate migration might ensue. IDPH began monitoring the Sheffield site in 1967 and when an opportunity arose in the form of a study proposed by the Illinois State Geological Survey (ISGS) to evaluate possible migration from the non-radioactive chemical waste site to the west, IDPH requested that the study ascertain whether chemical pollution from the “old” chemical site had entered State land and whether horizontal migration of radioactive waste occurred in the disposal trenches. To no one’s surprise, radioactive contamination was observed in the groundwater. Tritium (a highly mobile form of radioactive hydrogen) was migrating across the site in concentrations that were measureable but well below the levels thought to be a threat to public health. As a result of the discovery of migrating tritium, the geology and hydrology of the site was studied by both the Illinois State Geological Survey (Heigold and Larson, 1985) and the United States Geological Survey (Foster et al., 1984). Hydrogeologic studies were conducted at the LLRW site from 1976 – 1984.

In the mid-1980s, the chemical waste sites west and northwest of the radioactive waste disposal site were undergoing remediation overseen by the U.S. Environmental Protection Agency (USEPA) and the Illinois Environmental Protection Agency (IEPA). As part of the remediation effort, a single set of samples were collected during 1988 by SAIC, a USEC contractor, and analyzed for radionuclides as well as chemical contaminants. The results for this set of samples indicated tritium and chemical contamination were present in groundwater northeast of the low-level radioactive waste disposal area (SAIC, 1988, in IDNS 1989 and 1991).

Summary of the Hydrologic and Geologic Studies at the LLRW Site

In 1976, the U S Geological Survey (USGS) began a series of investigations to characterize quantitatively the hydrogeologic environments at and near the Sheffield site. This information added to the understanding of factors affecting the containment and movement of radionuclides.

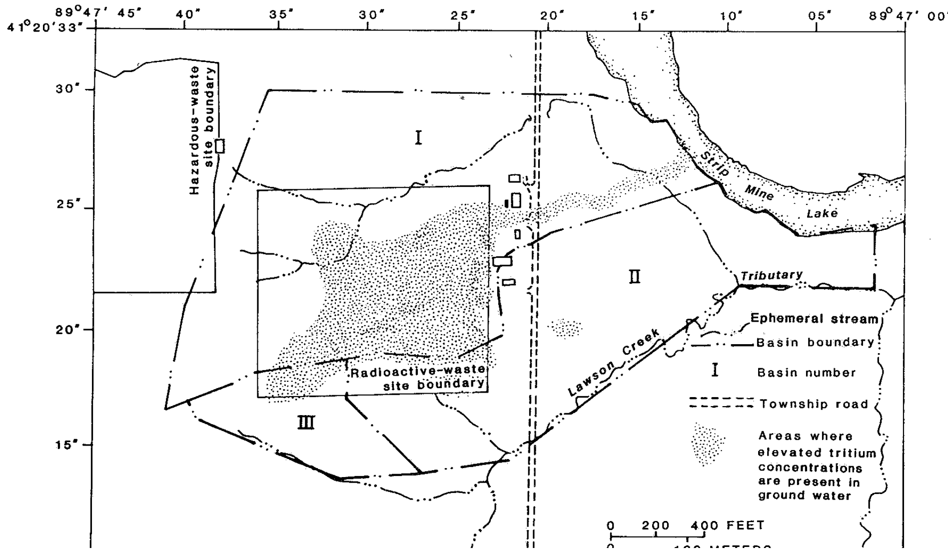
In 1980, USGS began an investigation to determine the direction and rate of ground-water flow at the Sheffield site. This study described the shallow aquifer, developed a conceptual model of ground water flow, and described the migration of tritium movement on and near the Sheffield site.

In 1984, USGS examined and described the shallow aquifer at the Sheffield site. The investigation was limited to the site and land immediately adjacent to the site bordered by the township road on the east. The shallow aquifer was defined as being composed of Quaternary sediments and marked by complex stratigraphy, in this case, the complex inter-layering of various sedimentary strata.

The sediments comprising the shallow aquifer range in thickness from 10 to 80 feet and are diverse in lithologic characteristics with complex spatial and stratigraphic configurations that are thinnest near bedrock highs and thicker in bedrock valleys. The bedrock is about 450 feet thick and is thought to be form a relatively impermeable barrier between the shallow [surficial] aquifers and the deeper bedrock aquifers in the area (USGS, 1984, p. 34).

“The only significant inflow to the shallow aquifer occurs as recharge derived from precipitation falling directly on the basins. The average annual precipitation at the Sheffield site is 35 inches (Foster, Erickson, and Healy, 1984, p.5). Recharge is seasonal (mostly in the spring months) and is estimated to be from 1 to 2 inches per year” (Foster, Erickson, and Healy, 1984, p. 20; Healy and other, 1984, p. 820, as presented in Garklavs and Healy, 1986, p. 15).
Depth from land surface to the saturated zone of the shallow aquifer averages about 25 feet but may be 5 feet in the valleys and 45 feet at topographic and bedrock highs and in the bedrock valleys within the Sheffield site (USGS, 1986, p. 15).

Basin 1 conveys groundwater from the northern three-quarters of the Sheffield site before it flows into Trout Lake along a buried channel-like depression in the Hulick Till that is filled with Toulon Member pebbly sand. A ridge-like structure just south of the channel acts as a local groundwater divide. Likewise, along the western boundary of the site a topographic high forms a groundwater divide. To the south, a tributary to Lawson Creek forms a groundwater sink that directs flow from the southern one-third of the Sheffield site (Basins II and III) toward Lawson Creek before flowing in the direction of Trout Lake (USGS, 1986, p. 34). The stippled area on Map 2 below locates tritium concentrations as reported in 1986.



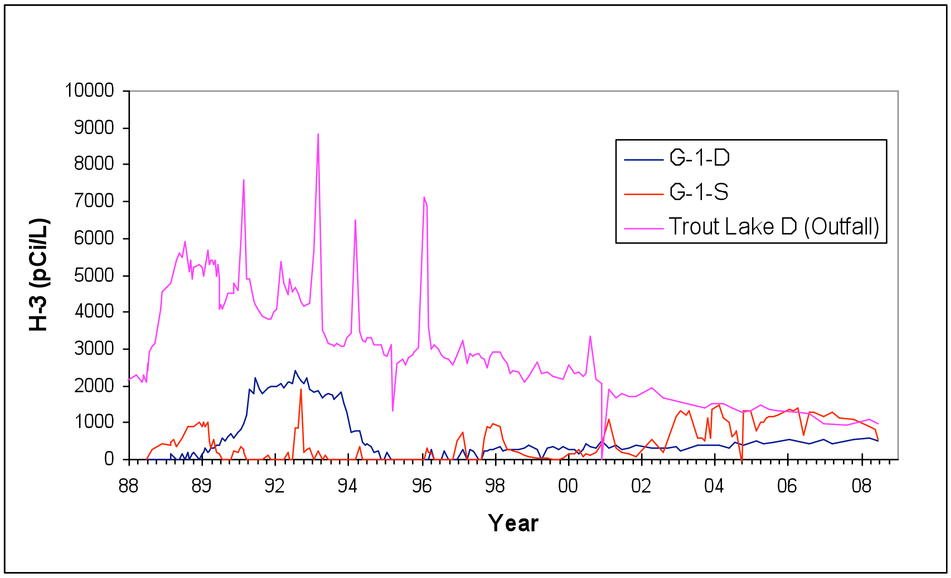
Map 2 - Areas where tritium was found at and near the Sheffield LLRW Disposal Facility site (USGS, 1986).

In November 1988, the IEPA conducted a study of a bedrock valley beneath the southeastern buffer zone. IEPA explained that prior to glaciation major rivers cut deep valleys into the bedrock. Glacial processes diverted the ancestral Mississippi River to its present position from a course that is in some places as much as 100 miles east of the modern Mississippi. The abandoned portion of the ancestral Mississippi River is called the Princeton Bedrock Valley and is filled predominantly with sand and gravel which was subsequently buried by glacial sediments. Major bedrock valleys have a system of tributary valleys similar to dendritic drainage patterns seen along modern rivers such as the Illinois (Morse & Otto, 1988, p. 1 & 2).

A small bedrock valley extending eastward from the USEC facility was mapped by Leland Harberg (Harberg, 1957). IEPA possessed a map of the USEC facility showing branches of the Harberg valley - which IEPA named the Bockel Bedrock Valley (BBV) - extending across the Sheffield site (Morse & Otto, 1988, p. 2).

In 1988, IEPA made three geologic cross-sections across this bedrock valley and reported:
The elevation at the top of the bedrock at the G-1 and G-2 locations (upper right on the map, Monitoring Wells By Unit & Monitoring Frequency, page 26) are lower than any found on the USEC property. Bedrock highs exist east and west of this buried bedrock channel, although greatly reduced by mining activity. . . .Water level data

collected over a three month period indicated flow within the sand and gravel aquifer east of Trout Lake to be down-valley, toward the northeast (Morse & Otto, 1988, p. 3).



Graph 1 - Convergence of tritium levels at G-1-D, G-1-S, and Trout Lake D (L. Haskell, IEMA email, 2009).

standpipe placed in the east end of Trout Lake and the nearest shallow monitoring well (G-1-S).

This gradient was very similar to the gradients calculated between Wells G-1-S and G-2-S (p. 26). IEPA concluded, “Simultaneous rise and fall of surface waters in Trout Lake and in these wells indicates that there may be a hydraulic connection” (Morse & Otto, 1988, p. 4).

Historic rise and fall of tritium concentrations depicted in Graph 1 above derived from IEMA monitoring data in G-1-D (71.8 feet deep in the BBV), G-1-S (35 feet deep), and in Trout Lake’s outfall suggest that a hydraulic connection may, indeed, exist.

The Environmental Monitoring Program at the Sheffield LLRW Site

Environmental sampling at the Sheffield LLRW site began in 1967. From 1967 to 1976, most of the monitoring was conducted on samples from wells installed by US Ecology. During most of this period, only gross alpha and beta analyses were conducted. Generally only background levels of naturally occurring radionuclides were found in the monitoring wells. Several anomalous readings were recorded but could not be repeated and were essentially attributed to high levels of naturally occurring dissolved solids (IDNS, p. 13, 1989).

In 1976, tritium was detected in groundwater and verified. From the summer of 1977 to the fall of 1981 the objective of the environmental monitoring program was to investigate the movement of groundwater (IDNS, p. 8, 1989).
The discovery of tritium in groundwater initiated an evaluation of potential radioactive contamination in the environment at the Sheffield site. In addition to groundwater, IDNS collected samples of fish, vegetation, soil, game and air, as well as making measurements of the ambient gamma radiation levels.

Results for air particulate samples collected at the site were consistent with the levels observed at background stations in Springfield, Illinois. Soil samples contained naturally occurring potassium-40 and radium-226 while vegetation samples contained radionuclides attributable to fallout from global nuclear weapons testing as well as from the LLW trenches. Fish samples contained only naturally occurring radionuclides as well as strontium-90 from fallout; and game (ground squirrels) contained only naturally occurring potassium-40. Results of these investigations supported the conclusion that further air, soil, fish, vegetation, and game sampling was unnecessary (IDNS, p 11 & 12, 1989).

Since 1982, the focus of environmental monitoring has been to monitor closely tritium concentrations in the northeast and southeast pathways and to determine whether there is potential exposure to the general public (IDNS, p.9, 1989).

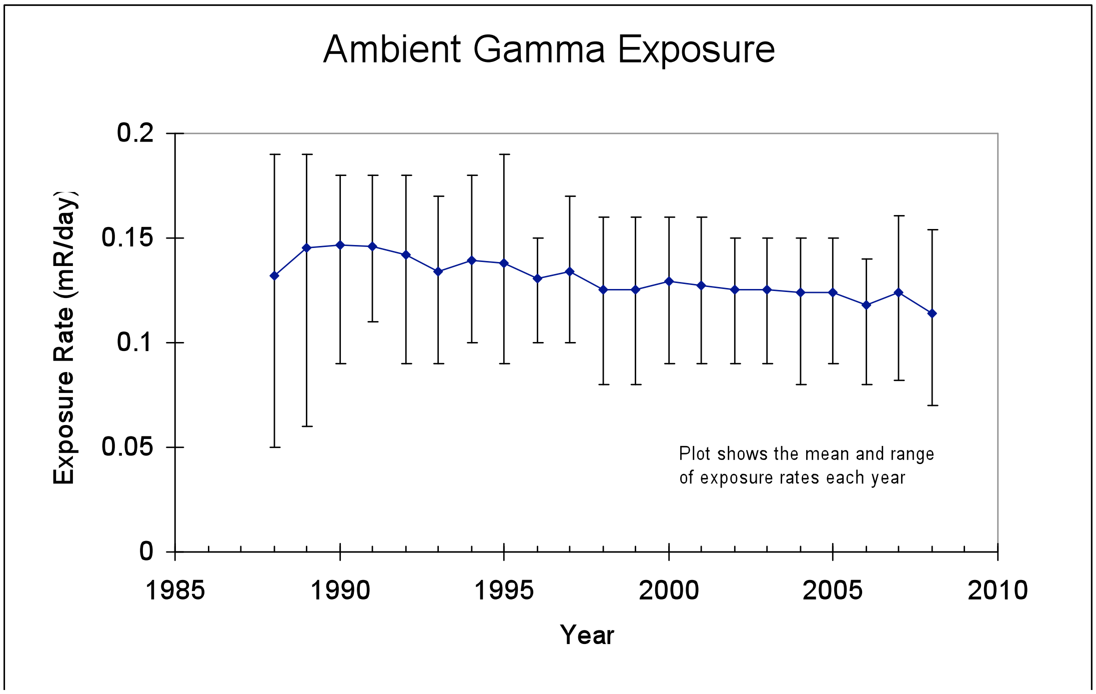
Currently, the IEMA monitoring program in and around the Sheffield LLRW site includes: ambient gamma exposure, surface waters, off-site public and private wells, and onsite groundwater wells.

Offsite, the Agency currently monitors 13 locations for gamma radiation, surface waters at Trout Lake and at sampling locations along waterways to the Mississippi River, private and public wells within 5 miles of the Sheffield site, and community water supplies at Sheffield, Mineral and Neponset. Onsite, IEMA currently monitors groundwater at 143 wells.

As in the past, the IEMA monitoring program continues to evolve over time based on need and analysis of data. Each aspect of the current monitoring program is described below along with the presentation of historical and current data.

Ambient Gamma Exposure

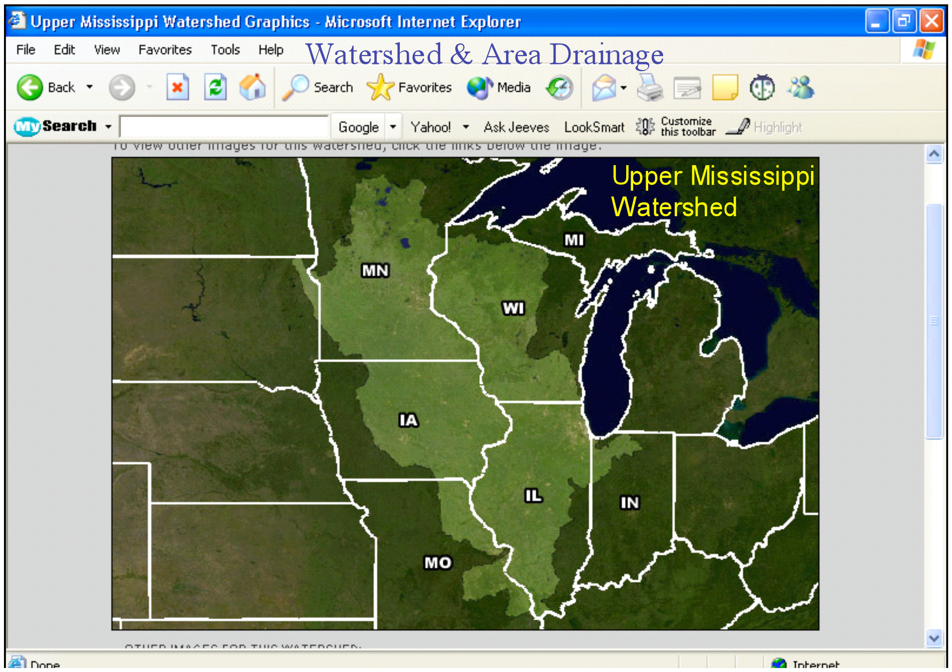
There are currently thermoluminescent dosimeters (TLDs) at 13 locations around the Sheffield site along with a control TLD. Ambient gamma exposure rate results are typical of ambient background radiation levels in Illinois.



Graph 2 – Mean of exposure rates at and near the Sheffield LLRW site (L. Haskell, IEMA email, 2009)

Surface Waters

The Sheffield site lies in the Upper Mississippi River Watershed, shown in light green on Map 3 - Watershed & Area Drainage below. These are divided into drainage subunits, as shown on Map 4.

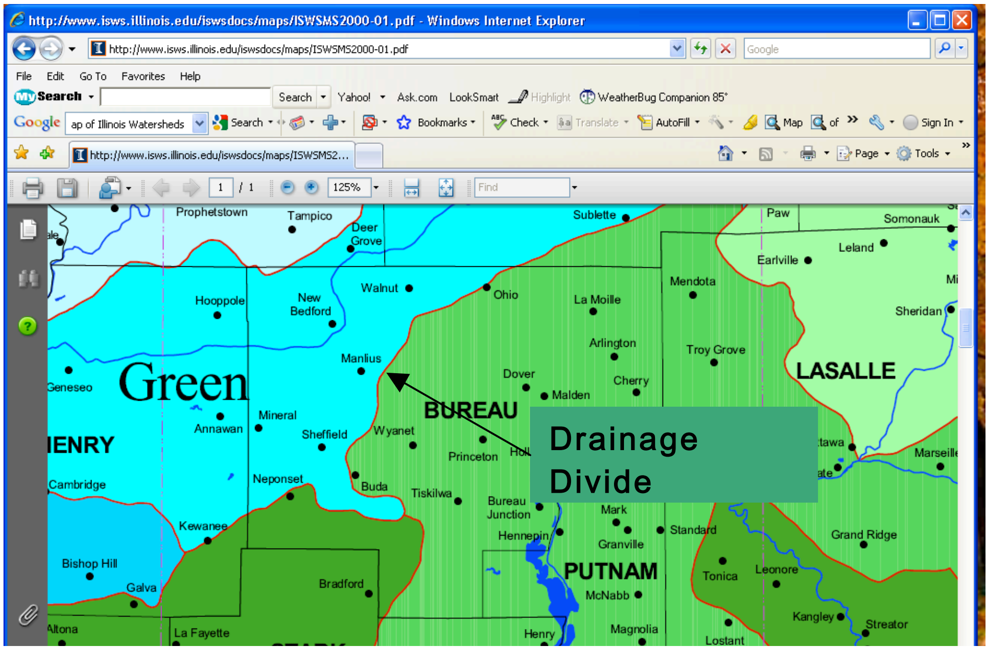


Map 3 - Upper Mississippi Watershed and Area Drainage map with states overlay (StormCenter Communications, Inc., 2002 – 2009).

The Sheffield site and the towns around it drain northwest into the Green River west of a drainage divide that runs along a line east of the town of Sheffield, as shown on the close-up of Map 4, *Major Watersheds of Illinois,* on the next page.

From the southern unnamed tributary into Lawson Creek (refer to Map 2, p. 12) and from Trout Lake further north, surface water flows into Abbott Ditch, Coal Creek, Mud Creek, and then enters the Rock River, Green River, and the Mississippi River. IEMA collects water samples from selected sites along this route, as shown in Table 3 - Surface Water Monitoring Locations (p. 19).

IEMA also collects samples from Hossetter Lake, located west of the Sheffield LLRW and HCW sites. These are used primarily background or reference checks for uncontaminated surface water. A single tritium “positive detect” occurred in Hossetter Lake in 1992. The result was right at the typical minimum detection limit (MDL) for tritium of 200 pCi/L; see Table 3 below.



Map 4 - Close-up of the Illinois State Water Survey map, *Major Watersheds of Illinois* by Sally A McConkey and Kathleen J. Brown (Map Series 2000-01)

Table 3 - Surface Water Monitoring Locations summarizes tritium sampling locations. The table shows the sampling period and the number of samples that have been collected and analyzed. "Detects" indicates the number of these

Table 3 - Surface Water Monitoring Locations

ID	LOCATION	Sampling Period		Number of Samples	Detects	Highest Conc. pCi/L
0402138	Lawson Creek	1983	present	199	74	1200 ± 110
0402177	Abbott Ditch	1988	present	130	47	750 ± 50
0402164A	Coal Creek U.S.	1983	present	63	1	500 ± 300
0402164B	Coal Creek D.S.	1988	present	67	2	560 ± 80
0402173	Hossetter Lake	1989	present	35	1	200 ± 60

samples that tested positive for tritium above the estimated detection limit of 200 pCi/L. The table also shows the highest concentration ever measured at the location.[2]

(L. Haskell, IEMA email, 2009)

The outfall of Trout Lake flows into Lawson Creek, which is sampled at a point approximately 1 mile outside the site boundary. Lawson Creek flows into Abbott

Ditch, which is sampled approximately 1.3 miles from the site boundary. In turn, Abbott Ditch drains into Coal Creek, which is sampled at two points – one just down stream of the confluence and the other two miles upstream.

Historically, tritium has been detected in Lawson Creek, although never higher than 6% of the USEPA drinking water limit. Tritium has not been detected in Lawson Creek since 2005.

---

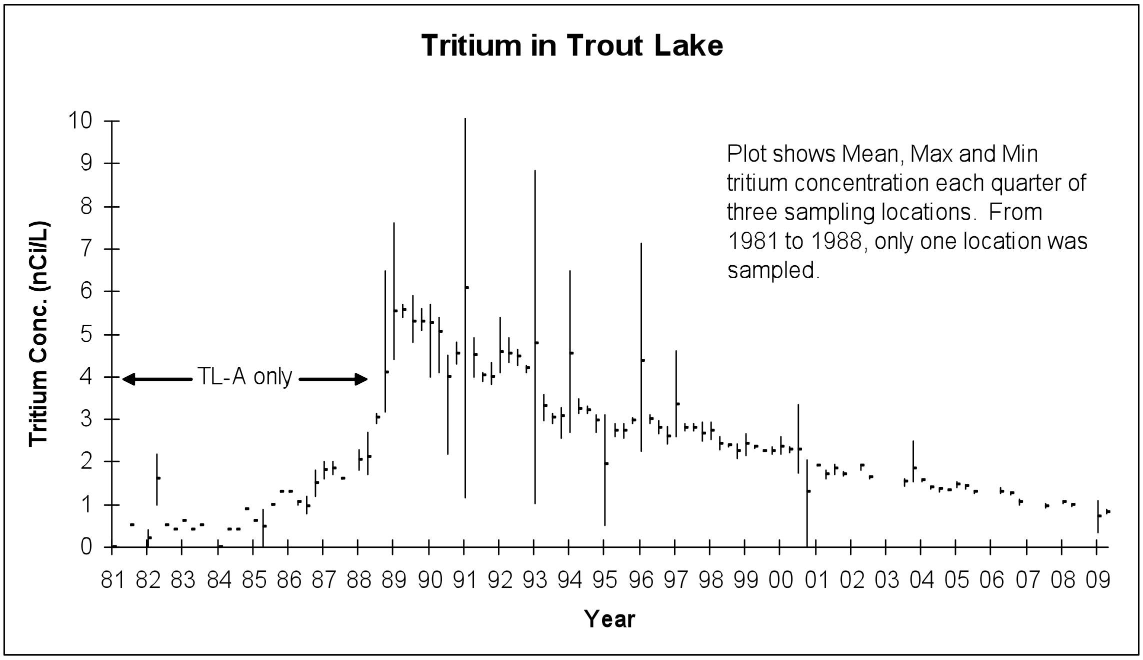
[2] The United States Environmental Protection Agency (USEPA) has established a drinking water limit for tritium at 20,000 picocuries per liter (pCi/L).

Tritium has been detected in Abbott Ditch at about the same frequency as it is detected in Lawson Creek. However, as anticipated, the results show lower concentrations. Tritium was last detected in Abbott Ditch in 2005.

Trout Lake

Trout Lake is a relatively shallow (12 to 20 feet deep), crescent-shaped lake formed by strip mining. The eastern shore of Trout Lake conforms to the northeast boundary of the Sheffield site boundary zone. At its nearest point to the disposal site, Trout Lake is approximately 700 feet from the northeast corner of the disposal site boundary (IDNS, 1989, p. 3).

The first occurrence of tritium in water leaving Trout Lake was recorded in 1990. From 1981 to 1988, only location A was sampled. Thereafter, two additional locations were sampled. Data shown in Graph 3, Tritium in Trout Lake, indicate that the tritium concentration peaked between 1989 – 1993 and then began to fall to today's levels.



Graph 3 – Tritium in Trout Lake water samples (IEMA, 2009).

Off-site Public and Private Wells

Historically public and private wells have been monitored for tritium. These include: private wells at nearby farms and Pencock Hill, and the Public Water Supplies (PWS) at Sheffield, Mineral, and Neponset.

Table 4 below summarizes tritium sampling of drinking water sources around the Sheffield LLRW site: tap water of three nearby towns, three wells located on farms bounding the site (a fourth was sampled until the well was removed in 1991), and the tap at the USEC office on-site. Currently all these taps are sampled quarterly. No tritium has ever been detected above the 200 pCi/L detection limit.

Table 4 - Drinking Water Sources Near the Sheffield LLRWDF

ID	LOCATION	Sampling Period		Number of Samples	Detects	Highest Conc. pCi/L
0402166A	US Ecology Office Tap	1985	present	104	0	< 200
0402008	Farm Well South	1974	1991	44	0	< 200
0402010	Farm Well Northeast	1974	present	114	0	< 200
0402011	Farm Well Northwest	1974	present	113	0	< 200
0402169	Private Well Southwest	1979	present	75	0	< 200
0402165	PWS Sheffield	1975	present	86	0	< 200
0402167	PWS Mineral	1976	present	86	0	< 200
0402168	PWS Neponset	1975	present	86	0	< 200

(L. Haskell, IEMA email, 2009)

Onsite Groundwater Monitoring Wells

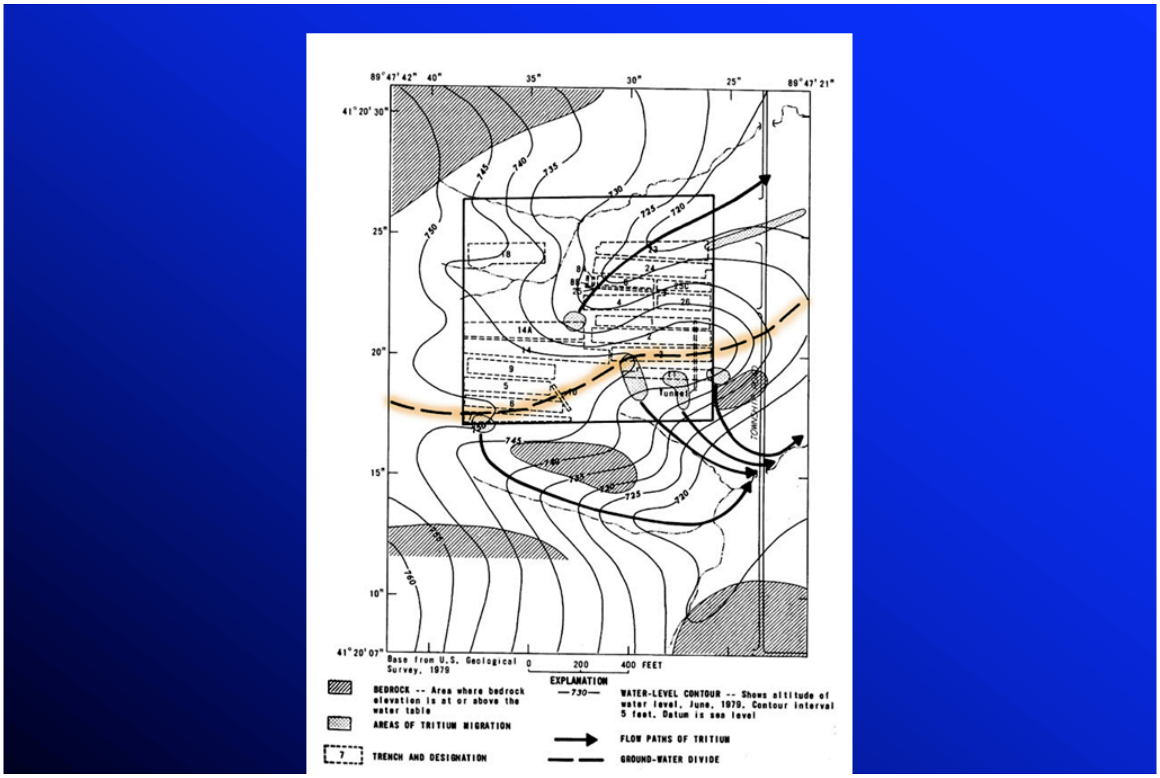
The groundwater monitoring program grew out of a need to identify the flow path of tritium from the LLRW site. Investigation by the USGS located two pathways within two buried bedrock channels that control the direction of groundwater flow away from the LLRW site. One channel directs flow towards the northeast and is known as the Northeast Pathway or NEP. The other channel directs flow southeast then turns northeast; this is known as the Southeast Pathway or SEP. A bedrock high, coincident with a topographic high near the southeastern corner of the site, forms part of the divides between basin I and II and thus separates the NEP from the SEP (USGS, 1986, p. 20).

Geohydrological studies at and near the Sheffield LLRW site discovered two aquifer systems - each with essentially opposite directions of flow - these are the shallow hydrogeologic system and the deep regional aquifer. Flow in the shallow system is eastward towards Trout Lake. Flow in the deep regional aquifer is westward towards the Quad Cities and southward into the Illinois Basin (IDNS, 1989 and 1991). Separating these two aquifers is 450-feet of relatively impermeable Pennsylvanian Carbondale shale and mudstone that serves to isolate the deeper aquifer from the shallow system. This suggests that contamination of the deep aquifer from the shallow hydrogeologic system is improbable.

The shallow hydrogeologic system extends from the glacial deposits at the land surface to the Pennsylvanian Carbondale Formation shale bedrock and may be described in two zones: the unsaturated and saturated. The unsaturated zone extends 5 feet below the surface in the valleys to 55 feet below surface on hilltops and includes the geologic units above the silt and silty clay of the Glasford Formation Duncan Mill member and the Pennsylvanian Carbondale Formation shales, both of which are completely saturated throughout the site.

Gravity flow moves water vertically downward through the soil into the saturated zone sediments, then laterally eastward through a permeable layer. Movement through the geologic units is influenced by differences in hydraulic conductivity, interfaces between soil units, soil sorption characteristics, and the degree of saturation.

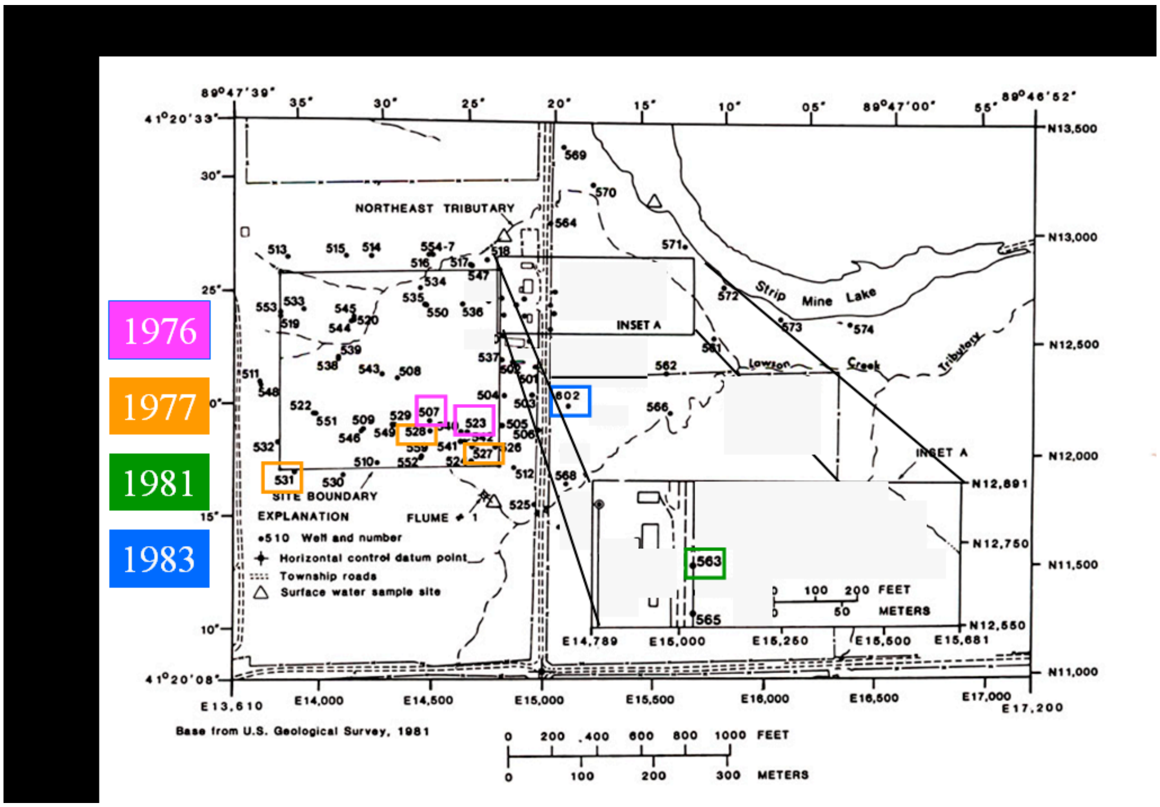
Precipitation, which annually averages 35-inches, is the source of recharge for the shallow hydrogeologic system and yields approximately 2-inches of recharge per year. Volumetrically, the 2-inches of recharge over the 20.5-acre radioactive waste disposal site yields an estimated one-million gallons of moisture penetrating the soil in that system. Runoff is estimated at 9-inches per year and evapotranspiration accounts for 24-inches per year. Ground water moves from the hill areas toward the valleys to the north and south. As it approaches the axis of the valley, flow direction changes to the east (IDNS, 1989, p. 4). A large long-dashed line shown in orange on Map 5 below identifies the groundwater divide.



Map 5 - Projected flow paths of tritium migration to ground water in relations to trenches (USGS, 1984)

<u>Discovering the migration pathways at the Sheffield LLRW site</u>

In 1976, tritium was found in monitoring well 507 and 523 either side of Trench 11, as shown on Map 6 below. The following year, tritium was found in three more wells: 527, 528, and 531. The levels were well below regulatory limits and the tritium was contained on-site or on USEC property.



Map 6 - Chronology of the early discoveries of tritium in groundwater wells at and near the Sheffield LLRW Disposal Facility (IEMA, 2005).

In 1976, a USGS study of the hydrology of the Sheffield LLRW site determined that a pebbly-sand unit (the Toulon Member of the Glasford Formation) underlies 67 per cent of the 20-acre LLRW site. The presence of this sand, and tritium in the groundwater, prompted further investigation. In 1978, USGS constructed a tunnel under Trenches 1, 2, 3 and 11 to investigate sources of migrating tritium but found it "virtually impossible to isolate individual trenches as sources of tritium in the groundwater" (USGS, 1986, p. 30). Research in monitoring wells and in the tunnel continued through 1987 when 42 wells and the tunnel were decommissioned.

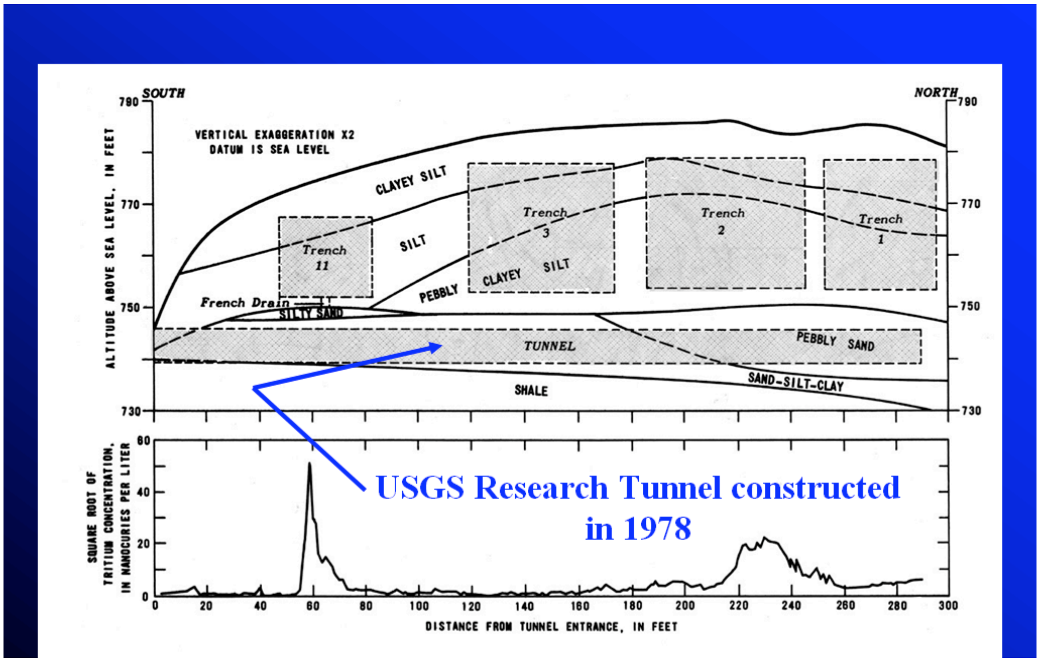
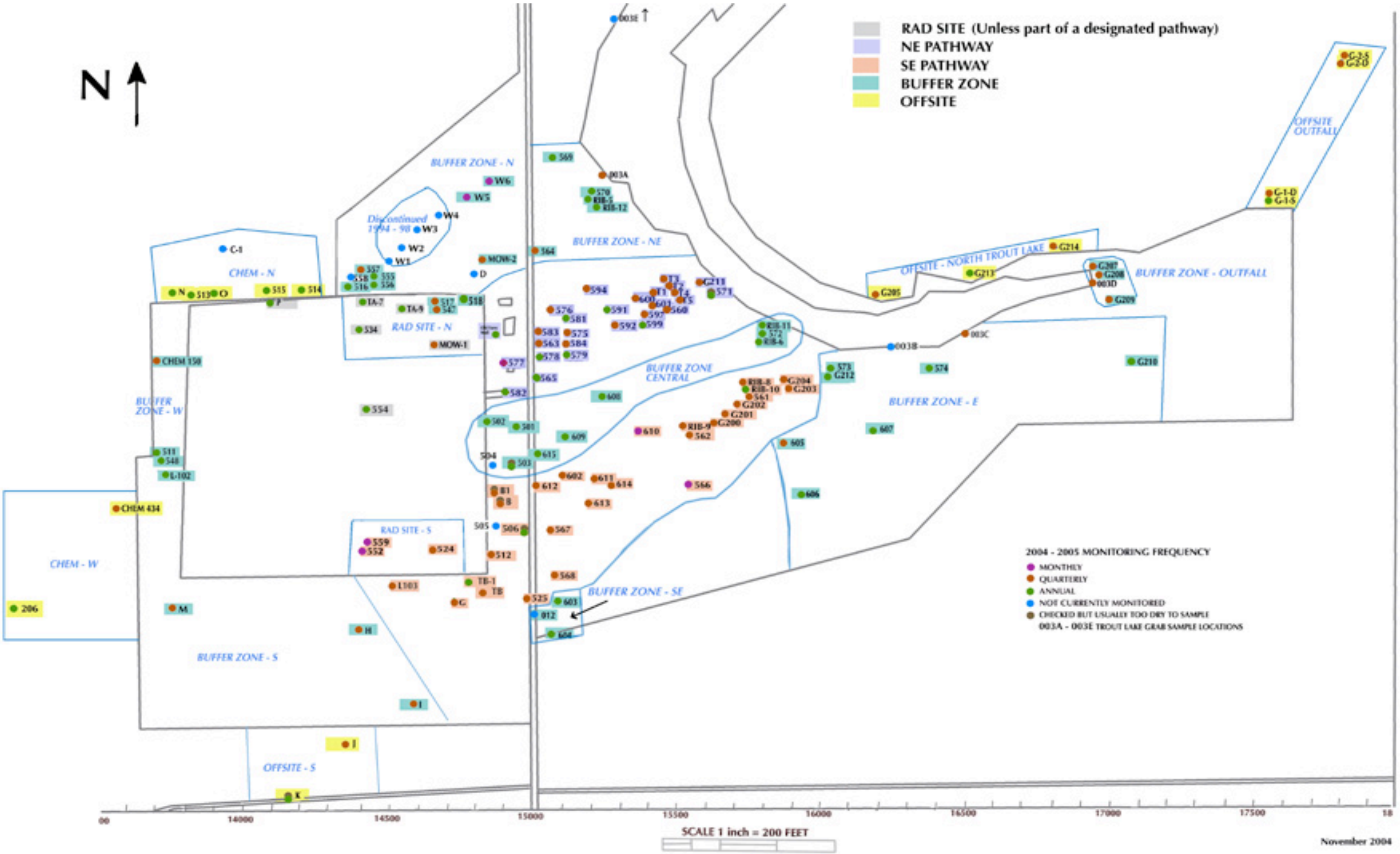


Photo 7 - Location of the tunnel constructed to facilitate USGS investigation of the Sheffield LLRW Disposal site (USGS, 1984). The graph depicts tritium concentrations in relation to the trenches.

Another USGS study begun in 1981 investigated the hydrology of the area east of the 20-acre site and extended knowledge of "the hydrogeologic system from the site to the eastern hydrologic boundaries" (USGS, 1984b, p.1). Groundwater flow boundaries were defined as Trout Lake to the east, the tributary to Lawson Creek in the south, and strip-mine spoil material to the north. The western boundary of the flow system lies to the west of the disposal site. Investigators discovered and defined the tritium migration pathways that IEMA monitors today. These pathways are shown on Map 7, Monitoring Wells by Unit and Unit Frequency - the Northeast Pathway is depicted in purple and the Southeast Pathway is depicted in orange. Both pathways are described in the following sections.

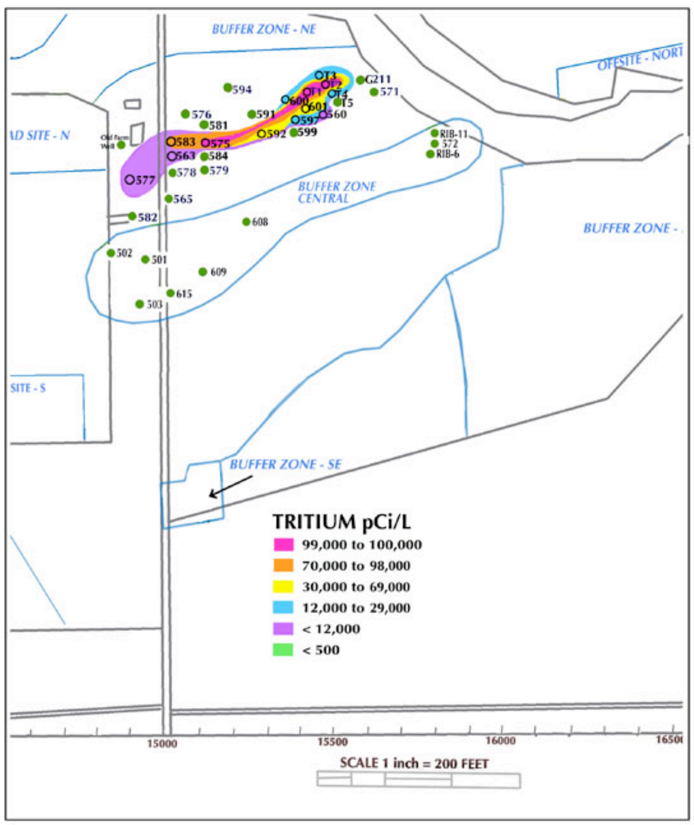


Monitoring Wells By Unit & Monitoring Frequency

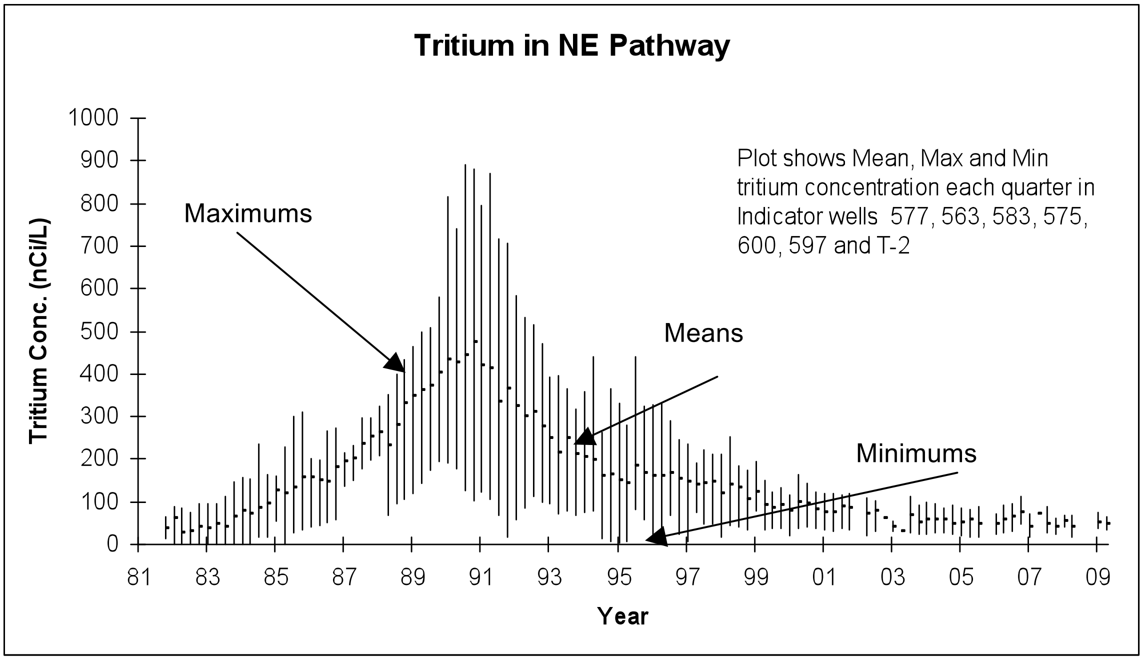
The Northeast Pathway (NEP or NE Pathway)

The Northeast Pathway (NEP) is formed and controlled by a shallow depression in the top of the Hulick Till that is filled with a gravelly, pebbly-sand of the Toulon Member (USGS, 1984b, p.19). This pathway has remained essentially unchanged since its discovery. The NEP terminates via springs that feed into Trout Lake. Tritium concentrations vary within the plume, as shown on Map 8, 2004 H^3 Concentrations in the NEP Monitoring Wells and over time, as shown in Graph 4, Tritium in the NE Pathway, on the next page.

2004 H^3 Concentrations in the NEP Monitoring Wells



Map 8 - Colorization of various tritium concentrations in the Northeast Pathway (IEMA, 2004).

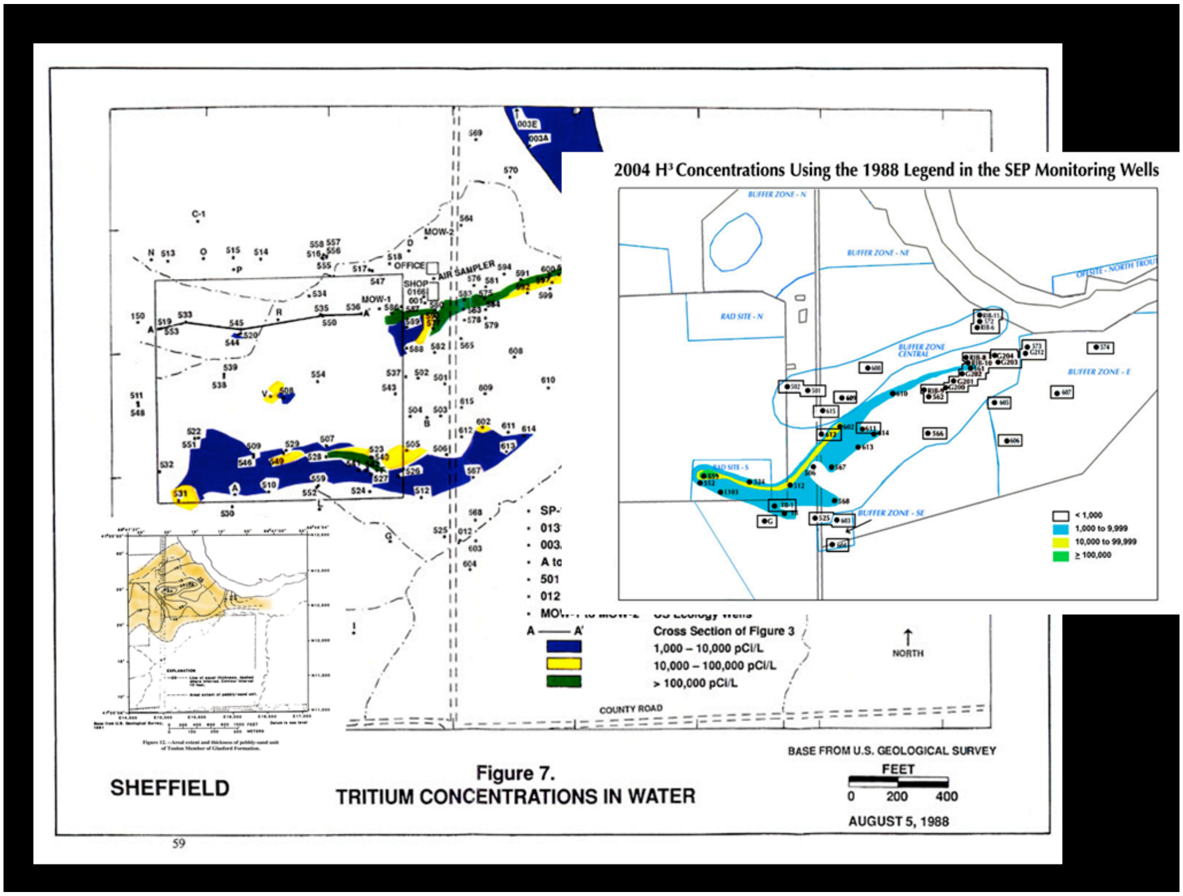


Graph 4 – Tritium in the NE Pathway monitoring wells (IEMA, 2009).

The Southeast Pathway

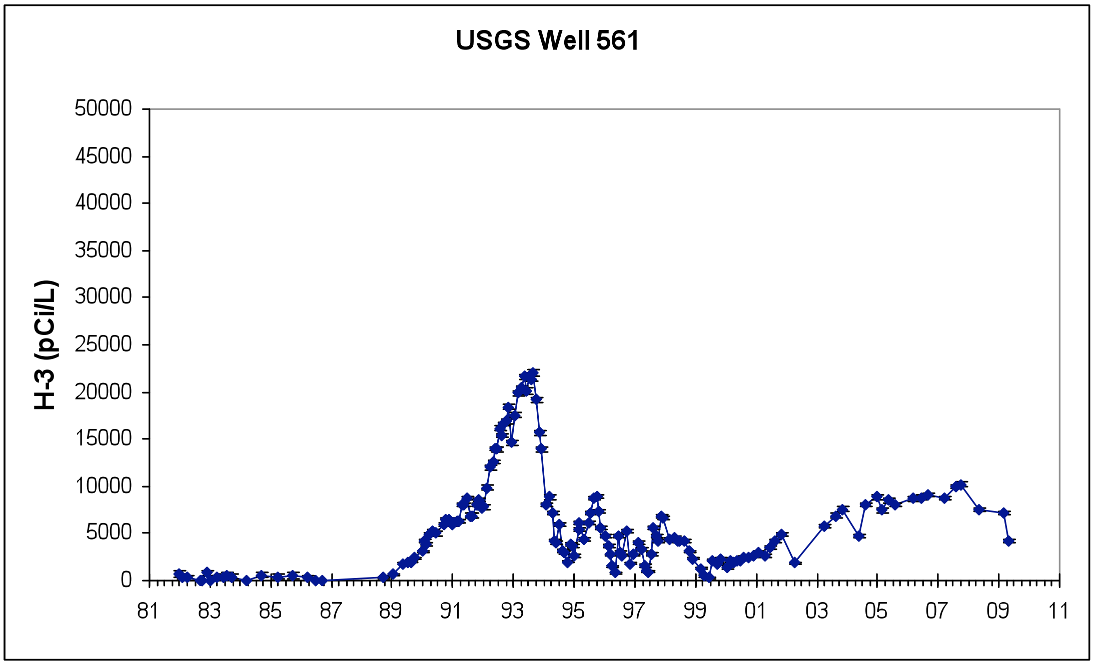
The Southeast Pathway or SEP originates beneath the lower southwest quadrant of the 20.5-acre site and flows into the basin or valley to the south through the Peoria Loess silt with lower flow volumes and velocities than those found in the NEP. The SEP is controlled by a buried bedrock channel partially filled with pebbly sand of the Henry Formation, a younger deposit than the Toulon Member sand in the NEP. Due to decreased flow velocities and groundwater volumes, compared to the NEP, the SEP possesses less potential for conveying moisture from the disposal site (IDNS, 1991, p. 6).

The SEP has become better defined with ongoing data accumulation. A comparison of the extent of tritium in groundwater known in 1967-1988 with 2004 data illustrates a thin tritium extension of the SEP northeast towards Trout Lake. Data regarding the extension ends at Well 561, which according to an IEPA geological cross-section is located at or near the center of the BBV (see discussion on pages 12 & 13) making it uniquely located to monitor tritium migrating eastward along the base of the bedrock valley. In the earlier study, tritium was not seen beyond Wells 602, 611, and 614.



Map 9 - Comparison of the 1967-1988 extension of the Southeast Pathway with data from 2004 (IEMA, 2004).

Historic data for Well 561shown on Graph 5 (next page) indicates that tritium concentrations peaked in 1992-93 well below the regulatory limit (see Table 2, p. 8).



Graph 5 – Tritium concentrations in USGS Well 561 (IEMA, 2009).

Conclusion

Data derived from the environmental monitoring program at the Sheffield LLRW site, as at other commercial LLRW disposal sites, provided valuable information on hydrologic isolation and radionuclide migration that was used to improve the design of subsequent LLW disposal facilities. Analyses of the data has helped identify pre-burial site characteristics that have corrected past design errors and operating processes. In the future, we are likely to see further improvement over current land burial techniques (Rutgers, 1996, p. 1& 2).

The primary objective of the monitoring program at Sheffield is to ensure that the radioactive waste is isolated from people and the environment until the radionuclides become stable through radioactive decay. Extensive monitoring data has shown that tritium migration from the Sheffield LLRW site does not pose a public health and safety or environmental threat. IEMA continues to monitor both the physical conditions and the radiological effluents to ensure public safety.

Dr. Keros Cartwright (ISGS), Principal Geologist and Head of the Hydrology Research Laboratory, Illinois State Geological Survey, stated in his testimony about Sheffield before the House Government Affairs Committee Subcommittee on Environment, Energy, and Natural Resources, February 23, 1978,

> "The . . . movement of tritium in itself does not constitute a threat to the people or mean that the site has failed."

His statement is as true of the Sheffield LLRW Disposal site in 2009 as it was in 1978.

Photo 8 - View from Trout Lake towards the Sheffield LLRW Disposal Facility, winter 2005 (IEMA, 2005)

References

Cartwright, Keros (1978) Testimony about the Sheffield LLW Waste Disposal Facility before the House Government Affairs Committee Subcommittee on Environment, Energy, and Natural Resources, February 23, 1978

Circuit Court of the Thirteenth Judicial Circuit, Bureau County, State of Illinois (1988) Agreed Order.

Committee on Oceanography (1971) Radioactivity in the Environment. Washington, D.C.: National Research Council [as it appears in *NUREG 1853*].

Dragonette, K., Blackburn, J., Cartwright, K. (September 1979) Interagency Task Force Report on Decommissioning of the Sheffield Nuclear Waste Disposal Site [as it appears in IDNS, 1989 and 1991)

Foster, J. D., Erickson, J. R., and Healy, R. W. (1984) Water-Resources Investigations Report 83-4125 *Hydrogeology of a Low-Level Radioactive Waste Disposal Site Near Sheffield, Illinois*. Urbana, IL: U S Department of the Interior

Foster, J.B., Garklavs, G., and Mackey, G. W. (1984b) Water-Resources Investigations Report 84-4183 *Hydrologic Setting East of A Low-Level Radioactive Waste Disposal Site Near Sheffield, Illinois.* Urbana, IL: U S Government Printing Office

Garklavs, G. and Healy, R. W. (1986) Water-Resources Investigations Report 86-4153 *Hydrogeology, Ground-Water Flow, and Tritium Movement at a Low-Level Radioactive-Waste Disposal Site Near Sheffield, Illinois*. Urbana, IL: U S Government Printing Office

Harberg, L. (1957) *Bedrock Surface of Illinois,* Second Edition [Map]. Urbana, IL: Illinois State Geologic Survey Heigold, P. C. and Larson, T. H. (1985) ISGS Contract/ Grant Report 1985-1 *Geophysical Studies at the Sheffield Low-Level Radioactive Waste Disposal Facility to Evaluate Potential Pathways for the Escape of Contaminants*. Champaign, IL: Illinois State Geological Survey

Illinois Department of Nuclear Safety (IDNS). (1989) *Environmental Monitoring Report Sheffield Low-Level Radioactive Waste Disposal Site 1967-1988.* Springfield, IL: State of Illinois.

Illinois Department of Nuclear Safety (IDNS). (1991) *Environmental Monitoring Report Sheffield Low-Level Radioactive Waste Disposal Site 1989-1990.* Springfield, IL: State of Illinois.

MacKenzie, D. R., Smalley, J. P., Kempf, C. R., and Barletta, R. E. (January 1985) Evaluation of the radioactive inventory in, and estimation of isotopic release from, the waste in eight trenches at the Sheffield Low-Level Waste Burial Site. Brookhaven National Laboratory [as it appears in IDNS, 1989 and 1991].

McConkey, S. A. and Brown, K. J. (2000) *Major Watersheds of Illinois* (Map Series 2000-01). Retrieved from http://sws.uiuc.edu/data/maps/watershed.pdf

Morse, J. & Otto, S. (1988) Summary of Hydrogeologic Study Conducted by HIEU East of U. S. Ecology Hazardous Waste Disposal Facilities near Sheffield, Illinois. Illinois Environmental Protection Agency Memo dated November 3, 1988 to Harry Chappel

NUS Corporation (October 31, 1979) Draft Environmental assessment of the Sheffield Low-Level Waste Disposal Site [as it appears in IDNS 1989 and 1991]

Science Applications International Corporation (SAIC). (October 1988) Remedial investigation report for Sheffield Hazardous Waste Disposal Sites [as it appears in IDNS 1989 and 1991]

Storm Center Communications, Inc. (2009) *The Upper Mississippi Watershed Image Selector* Retrieved from http://wtol.envirocast.net/popup-region.php?regionNum=07&thisLetter=d

The State University of New Jersey Rutgers (1996) What lessons have been learned from early low-level radioactive waste disposal facilities? [Factsheet] Retrieved from http://www.nj.gov/dep/rpp/llrw/download/fact17.pdf

United States Nuclear Regulatory Commission. NRC: Health physics questions and answers – Question 428. Retrieved from: http://www.nrc.gov/about-nrc/radiation/protect-you/hppos/qa428.html

United States Nuclear Regulatory Commission. (2009) *History and Framework of Commercial Low-Level Radioactive Waste Management in the United States*, *ACNW White Paper, NUREG-1853.* Retrieved from http://hps.org/govtrelations/documents/nrs_nureg1853.pdf

United State Nuclear Regulatory Commission (2009b) Subpart D—Radiation Dose Limits for Individual Members of the Public §20.1301 Dose Limits for individual members of the public (2) Retrieved from http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1301.html

Wayne County Emergency Management Agency. (2009) History IEMA. Retrieved from http://www.waynecountyema.com/history.html

APPENDIX A: Sheffield Low-Level Radioactive Waste Licensing Chronology

In August 1967, the Atomic Energy Commission (AEC) radioactive materials license 13-10042-01 held by California Nuclear, Inc. was amended to authorize disposal of radioactive waste on the 20.5-acre site outlined in yellow on the aerial photo on the page 2 (M. Momeni, IDNS office memorandum, March 17, 1988).

In March 1968, the AEC license was transferred to Nuclear Engineering Company, Inc. (NECO) was renamed US Ecology (USEC) as of January 1, 1981 (T. S. Baer, Illinois radioactive materials license correspondence, December 11, 1980).

In 1974, "Congress abolished the AEC. The newly created Nuclear Regulatory Commission (NRC) subsumed the AEC regulatory functions and the Energy Research and Development Administration (ERDA – which was later absorbed into the Department of Energy) took over the atomic energy promotional functions" (NUREG-1853, 2007, p. 13).

In 1976, NECO submitted a request to expand the site, along with its December license renewal application and an environmental report on the LLRW site.

In January 1977, the NRC license was amended to include the entire Sheffield operation and burial in Trenches 14 and 14 A. Notice of this application appeared in the Federal Register in February 1977.

In 1978, a Federal Register Notice established the Atomic Safety and Licensing Board (ASLB) that would play a role in future Sheffield affairs.

Radioactive wastes were buried for the last time at the Sheffield LLRW disposal facility in April 1978.

In March 1979, NECO attempted to abandon the site and unilaterally terminate the State radioactive material license and the NRC license. Both NRC and Illinois ordered NECO to resume site surveillance which NECO refused to do. Illinois then filed suit in state circuit court which issued an injunction ordering NECO back to the site. In May, ASLB allowed NECO to withdraw the expansion proposal but denied their motion to unilaterally terminate the license.

In 1980, Illinois House Bill 3614 created the Illinois Department of Nuclear Safety (IDNS) and regulatory oversight for the Sheffield LLRWDF was transferred to this first cabinet level state nuclear regulatory agency (Wayne County, 2009, p. 1).

ASLB asserted, in February 1987, that USEC had a continuing responsibility under its license for the radioactive waste buried at the Sheffield LLRW site, and that USEC could not terminate its license without affirmative action by the NRC.

In June 1987, Illinois became an NRC Agreement State. In light of that transfer of authority from the NRC to Illinois, ASLB vacated orders being appealed and terminated the proceedings. That month, Illinois assumed total regulatory authority over the Sheffield LLRW license. USEC, for their part, continued to reject both the validity of the license and the authority of Illinois to regulate the Sheffield LLRW site (Momeni, office memo, March 17, 1988).

Timeline of Selected Sheffield LLRWDF Events

1963	Illinois Radioactive Waste Act become effective
1965	Illinois Department of Public Health chooses California Nuclear, Inc. (CNI) to operate a future LLRWDF site to be developed
1966	Nuclear Engineering Company (NECO) acquires Sheffield land from CNI
1967	NECO license amendment approved by the Atomic Energy Commission
1968	**Sheffield Low-level Radioactive Waste Disposal Facility opens**
1971	Trench 1 is capped; Trench 2 in progress (Aug); Trench 3 waste placement in progress; Trench 4 excavation in progress
1975	NECO proposes three expansion scenarios; Illinois State Geologic Survey proposes study to evaluate possible migration from the non-radioactive site; IDPH requests evaluation also of radioactive waste migration; IDPH inspector notes water flowing into Trench 18; ISGS finds Trench 18 unsuitable; NECO counters with a fill and compact strategy; IDPH agrees, with stipulations; NRC approves expansion compact and fill strategy
1976	NECO applies to NRC for site expansion from 20 to 188 acres; Wells 507 and 523 have detectable levels of tritium confirmed; all available space meeting IDPH requirements is full; Trench 14 and 14A were begun using fill and compact construction; USGS drills 24 new monitoring wells to study site
1977	USGS drills 12 additional wells; Wells 528, 531, and 527 have verifiable tritium levels; NECO applies to amend NRC license for additional trenches
1978	**Sheffield LLRWDF closes;** USGS constructs tunnel under Trenches 11, 3, 2, and 1 to study tritium movement
1979	NECO attempts to terminate its license and abandon the site; Trench cap collapse; NRC, IDNS, USGS Interagency Task Force Report On the Proposed Decommissioning of the Sheffield Nuclear Waste Disposal Site (Dragonette, NRC; Blackburn, IDPH; Cartwright, ISGS) is published
1980	**Illinois Department of Nuclear Safety (IDNS) is created**
1981	NECO becomes U S Ecology (USEC); verifiable tritium found offsite and off USEC property in well 563
1987	IDNS applies for Agreement State status with NRC
1988	**Sheffield Agreed Order aka Sheffield Settlement Agreement resolves ten years of negotiation (May)**
1989	USEC completes new trench caps
1990	IDNS declares "signaling event" at Sheffield; tritium exits Trout Lake and Buffer Zone Boundary April 24, 1990
2001	**IDNS merges with Illinois Emergency Management Agency (IEMA)**
Forward	Sheffield LLRWDF Monitoring Program continues