Niagara Falls Storage Site – Balance of Plant Investigation Results - 15432

John Busse, US Army Corps of Engineers, Buffalo District, Buffalo, NY, USA
Jane Staten, Neil Miller, Shawn McCabe, William Frederick, US Army Corps of Engineers, Buffalo District, Buffalo, NY, USA

ABSTRACT

The Niagara Falls Storage Site (NFSS) is a 77.3-hectare (ha) (191-acre) property that is owned by the United States Government and located in the township of Lewiston, Niagara County, New York. The NFSS is part of the former Lake Ontario Ordnance Works (LOOW) that was used by the War Department beginning in 1942 for the production of trinitrotoluene (TNT). During the 1940s and 1950s, the Manhattan Engineer District and the Atomic Energy Commission brought various radioactive wastes and uranium processing byproducts (residues) resulting from our nation's atomic energy program to the LOOW for storage.

Site operations caused soil, sediment, and groundwater contamination that lead to several remedial actions, which culminated in the construction of the Interim Waste Containment Structure (IWCS) on the NFSS. The U. S. Army Corps of Engineers (USACE)-Buffalo District is the lead Federal agency for Formerly Utilized Sites Remedial Action Program (FUSRAP) remediation of the NFSS. As the lead agency, USACE is conducting a remedial investigation/feasibility study (RI/FS) pursuant to the protocols set forth in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). CERCLA activities at the NFSS have transitioned from the site RI activities to the FS evaluation of potential remediation alternatives. USACE recognizes the need to implement a focused CERCLA FS process and, therefore, has established three separate operable units (OUs) for NFSS: the IWCS OU, the Balance of Plant (BOP) OU [i.e., all on-site areas outside the boundary of the IWCS], and the Groundwater OU.

This paper details recent investigations into the underground utilities, groundwater/soil contamination, and past storage of contaminated material on the Balance of Plant Operable Unit of the NFSS. Recent fieldwork activities have investigated areas of elevated groundwater contamination as well as an investigation to determine/eliminate any preferential pathway that historical underground utilities may have provided on-site in these areas. Additional areas of investigation included strategic placement of groundwater wells at locations of historic residue storage piles and intersections of various underground utilities (based on aerial photography and geophysical surveys). Several hundred locations across the site were investigated with a gamma walk-over survey, boring, surveying and sampling of soil-cores to aide in the delineation of soil contamination throughout the Balance of Plant Operable Unit.

The series of investigations indicated multiple operational areas still have impacts above background conditions, risk-based concentrations, and promulgated maximum contaminant levels for multiple media in the Balance of Plant Operable Unit. The soil, groundwater, sediment, and utility sampling data show that 1) radionuclide impacts derived from ore-residue handling operations still exist, 2) impacts from other inorganic and organic compound exist in TNT manufacturing and support areas, and 3) contaminant transport from past source areas is minimal.

The full compendium of site history and recent sampling data provides a well-defined conceptual site model that provides the necessary input data to prepare volumetric soil estimates for the Balance of Plant Operable Unit Feasibility Study. The scale of the NFSS and complexity of prior operations provide many remedial challenges.

INTRODUCTION

The NFSS is located in the Town of Lewiston, NY, approximately 30.6 kilometers (km) (19 miles) north of Buffalo, NY [Figure (1)]. The NFSS is a 77 hectare (191-acre), federally-owned property that was originally part of a 3,035-hectare (7,500-acre) World War II explosives plant called the Lake Ontario Ordnance Works (LOOW). From 1944 to 1954, the Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC) (a predecessor to the U.S. Department of Energy [USDOE]) brought radioactive wastes and residues to the LOOW Site. Much of the radioactive residues sent to the NFSS originated from uranium processing activities conducted for MED and AEC at the Linde Air Products facility in Tonawanda, New York, the Mallinckrodt Chemical Works refinery in St. Louis, Missouri, and the Middlesex Sampling Plant in Middlesex, New Jersey.

Through the 1970s, the AEC gradually consolidated its operations and sold excess LOOW property to the public. In 1974, the AEC instituted the Formerly Utilized Sites Remedial Action Program (FUSRAP) to manage and remediate such sites. In the 1980s, the USDOE constructed a 4-hectare (10-acre) Interim Waste Containment Structure (IWCS) on the NFSS to contain the radioactive wastes and residues remediated throughout the LOOW and NFSS. The IWCS is an engineered landfill designed to retard radon emissions, infiltration from precipitation, and migration of contamination to groundwater.

In October 1997, Congress transferred the management of FUSRAP from the USDOE to the U.S. Army Corps of Engineers (USACE). USACE is administering and executing cleanup at eligible FUSRAP sites pursuant to the provisions of the Energy and Water Development Appropriation Act, 1998 (Title I, Public Law 105-62, 111 Stat. 1320, 1326). Under FUSRAP, an environmental surveillance program was initiated at the NFSS in 1981 by the USDOE to ensure radioactive materials buried within the IWCS are not a threat to human health and the environment. This program has evolved with time and now includes air, water, and sediment monitoring for radiological and chemical parameters.

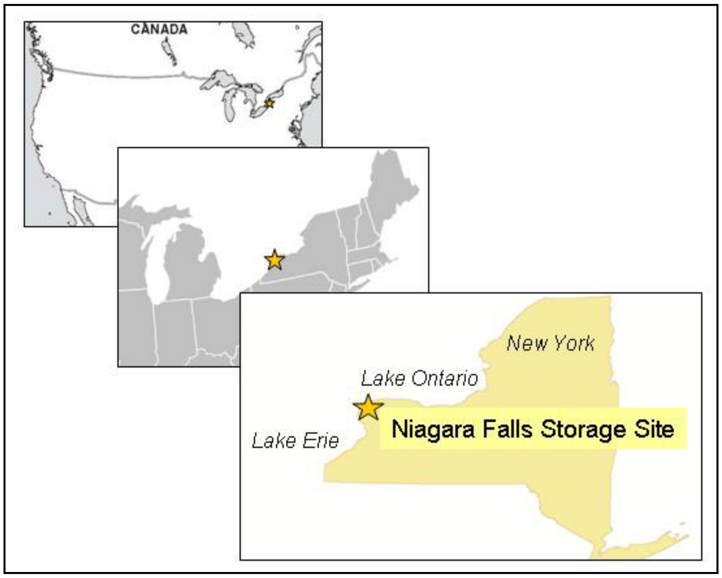

Figure 1: Location of the Niagara Falls Storage Site

Investigations at the NFSS follow the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process and are carried out by the USACE Buffalo District. To date the USACE Buffalo District has completed a Remedial Investigation Report, Remedial Investigation Report Addendum, and focused groundwater contamination studies from December 2007 to December 2013.

To manage the CERCLA activities at the NFSS, USACE has established three separate operable units (OUs). The OU approach is commonly used under CERCLA to define logical groupings of environmental issues at a single site to incrementally address site problems. By employing the OU approach at the NFSS, decisions about the primary sources of contamination at the site can be incorporated into the final site-wide groundwater approach. The OUs selected for the NFSS are as follows:

- IWCS OU – The waste material (i.e., uranium ore residues and other remedial action waste) placed in the engineered structure within the diked area at the NFSS.

- Balance of Plant OU – All material at the NFSS not placed within the IWCS, excluding groundwater.

- Groundwater OU – Groundwater remaining in both the upper water-bearing zone (UWBZ) and the lower water-bearing zone after implementation of the selected remedial actions for the IWCS and Balance of Plant OUs.

This paper will discuss investigations under the Balance of Plant OU to delineate the vertical and horizontal extent of contamination at the NFSS, to support the Balance of Plant OU Feasibility Study.

Project Objectives

During development of a previous Remedial Investigation (RI), the NFSS was divided into exposure units (EU). An EU is defined as the geographic area in which a future receptor (for purposes of the baseline risk assessment) is assumed to work or live, and where a receptor may be exposed to site-related soil contaminants. Figure 2 presents the overall site layout showing the locations of the EUs.

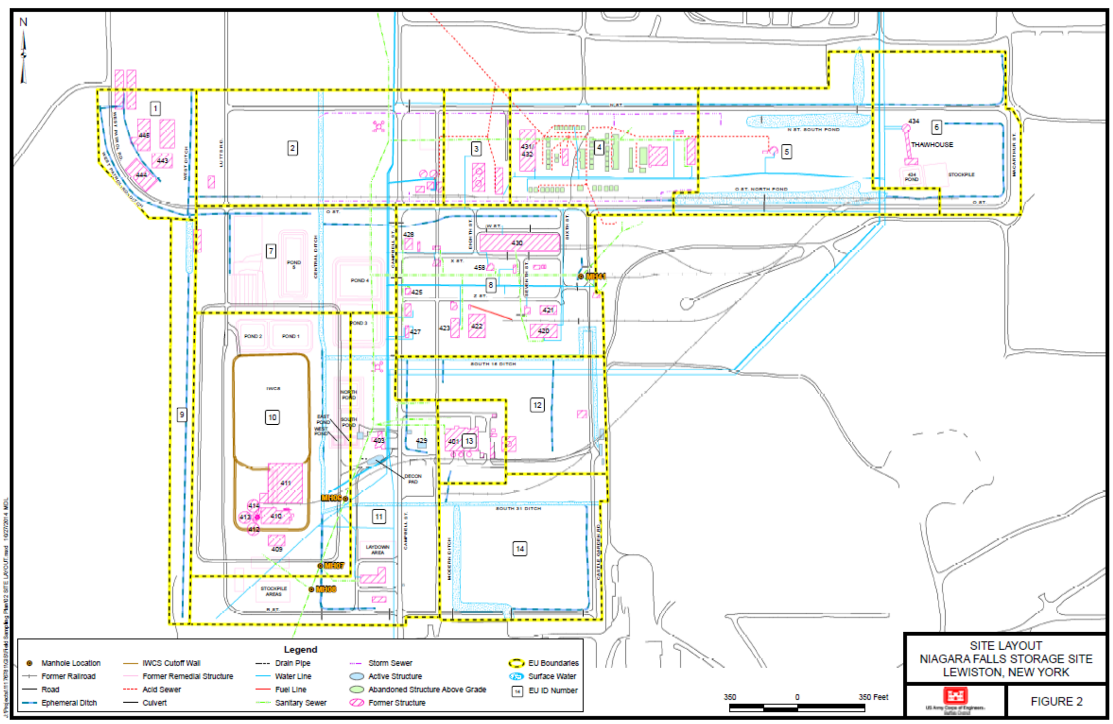

Figure 2: NFSS Exposure Unit Site Layout

To supplement the data collected during the NFSS RI the BOP field investigations were performed to delineate the vertical and horizontal extent of contamination in surface and subsurface soil, groundwater and to investigate underground utilities. The data will support the BOP OU FS effort by reducing the uncertainty of the estimated volume of soil that may require excavation, groundwater contamination delineation and further investigations of underground utilities.

The BOP fieldwork was conducted over a three year period which helped to build on site information and guide subsequent field mobilizations. The specific investigation objectives are provided below:

BOP First Fieldwork Objectives (2012):

- Delineate groundwater contamination in EUs 1, 2, 4, and 10.
- Identify the source of increasing uranium concentrations in groundwater in well OW11B.
- Eliminate potential preferential pathways for off-site migration of groundwater contaminants via subsurface pipelines located near site boundaries.
- Evaluate potential groundwater contamination along the 25-cm (10-in) diameter water line near the southeast corner of the IWCS and eliminate the water line as a potential preferential pathway.

BOP Second/Third Fieldwork Objectives (2013/2014):

- Delineate soil contamination at 478 locations across the NFSS.
- Expose and evaluate the former LOOW sanitary sewer in EU10 and EU11.
- Perform a geophysical survey in the area south of the IWCS to identify the presence of buried structures, and
- Manage/sample/dispose of existing Investigation-Derived Waste (IDW) and IDW generated during the field investigation (objective for all fieldwork).

Site Contaminants

The MED and AEC stored radioactive residues and other materials at the NFSS beginning in 1944. These residues originated from uranium-ore processing activities at the Linde Air Products facility in Tonawanda, New York (NY), the Mallinckrodt Chemical Works refinery in St. Louis, Missouri, and the Middlesex Sampling Plant in New Jersey. The original ore materials (pitchblende) contained 3.5% to 60% of tri-uranium octoxide (U_3O_8) or uranium dioxide (UO_2), along with a wide range of radium-266 (Ra-226) and thorium-230 (Th-230) concentrations. In addition to these residues, radioactive wastes from the Knolls Atomic Power Laboratory in Schenectady, NY, the University of Rochester (NY), and the Middlesex Sampling Plant in New Jersey [4, 5] were sent to NFSS for storage, transfer, or disposal.

These residues (and other containerized materials) were stored at various locations throughout the LOOW and NFSS. Materials were eventually consolidated onto the NFSS property in differing configurations, which produced localized soil and groundwater impacts. From 1981 to 1991, the USDOE systematically remediated the NFSS and vicinity properties and placed the impacted materials into the engineered IWCS on the west side of the NFSS property (Figure 2). The inventory of high-activity radioactive residues were placed in existing reinforced concrete structures that were components of a freshwater treatment plant for the LOOW. Contaminated soil and debris from the cleanup actions were then placed atop the various residues and compacted to 90% Proctor conditions to increase stability.

The IWCS is encircled by a clay dike and subsurface cutoff wall that is tied into an underlying gray clay layer. A multi-layered cap was placed over the contents and construction details are provided the Remedial Investigation Report [4] and the references cited therein. The USDOE determined the IWCS cap would have a projected service life of 25 to 50 years, while the clay dike and cutoff walls would have a 200- to 1,000-year lifespan [8].

Due to the nature of material handling at the NFSS, the area around the IWCS, localized areas of residue storage, select utility areas, and other operational areas all show groundwater impacts in the underlying silty clay glacial till (or brown clay till). The extent of this contamination reveals that uranium is the most transportive radionuclide at the site and thus the focus of the water-media sampling [2].

Given that multiple radionuclides of concern (ROCs) are identified for the BOP, the sampling strategy for the delineation investigation was designed to comply with the requirements in 10 Code of Federal Regulations (CFR) 40 Appendix A Criterion 6(6), which provides a clean-up goal for Ra-226 and a means to derive cleanup goals for radionuclides other than Ra-226.

In accordance with 10 CFR Part 40, Appendix A, Criterion 6(6), the concentration of Ra-226 is limited to 5 picocuries per gram (pCi/g) in the top 15 cm (6 in) of soil. If other radionuclides are present, their cleanup goals are the concentrations of the radionuclides that would produce the same dose as 5 pCi/g of Ra-226 in the top 15 cm (6 in). This dose for Ra-226 is called the 'benchmark' dose. The same process is used to establish a benchmark dose for subsurface soil (i.e., below the top 15 cm [6 in]), although the cleanup goals are the concentrations of the radionuclides that would produce the same dose as 15 pCi/g of Ra-226. The sum of the ratios (SOR) of the ROCs should not exceed "1" (unity); a SOR exceeding 1 indicates that at least one radionuclide is present at a concentration exceeding the benchmark dose.

Because many of the ROCs are naturally occurring, the SOR takes background radionuclide concentrations into consideration. An average SOR score is calculated for the set of data located within each 100 m^2 area, pursuant to 10 CFR 40 Appendix A Criterion 6(6). If the average SOR score within an area of 100 m^2 was greater than 1, a contaminated soil AOC was identified and Bayesian Approaches for Adaptive Spatial Sampling (BAASS) software was used to define the aerial extent of the contamination by estimating the distance between the contamination and the nearest "clean" data point (i.e., a sample location with an SOR score of less than 1).

Site Investigation Strategy

The long-term handling and storage of radioactive materials at the NFSS produced soil contamination and associated uranium impacts in the shallow groundwater. Although remedial actions throughout the 1970s and 1980s mitigated the vast majority surface contamination on the NFSS, some operational areas still exhibit residual contamination in NFSS soils. These areas pose both an exposure risk and a potential risk to groundwater due to continued leaching for surface soils [4]. These soil areas have been characterized according to exposure units (EU) and are undergoing additional sampling to bound impacted areas. Soil-based constituents of concern identified during the Baseline Risk Assessment (BRA) [3], include select radionuclides from the uranium-238 (U-238) and uranium-235 (U-235) series, arsenic, boron, cadmium, antimony metals and methylene chloride. The widest impacts to groundwater appear from U-238 (or a total uranium equivalent), thus the majority of groundwater monitoring is focused on U-238 or total uranium species. Uranium contamination at the site is typically present as U_3O_8 in soils. The following sections will further discuss the efforts during the series BOP OU investigations.

<u>Delineation of Groundwater Contamination in EUs 1, 2, 4, and 10</u>

The areas of dissolved total uranium groundwater contamination in the UWBZ in EUs 1, 2, 4, and 10 are fairly well delineated. However, additional monitoring wells were required in these areas to better define the limits of contamination. Fourteen wells (i.e., MW944 through MW946 and MW950 through MW960) were installed to provide additional delineation in these areas. Prior to invasive activities, surface gamma radiation walkover surveys were conducted at each proposed borehole and excavation location. After installing monitoring wells and restoring the excavated areas, surface gamma walkover surveys were repeated to document the final radiological condition of each area. A down-hole gamma radiation survey was performed in each borehole. The recovered soil core samples were scanned for gamma, alpha, and beta radiation to identify materials with elevated radiation readings.

Part of the UWBZ groundwater in EU 4 is contaminated with VOCs in the form of dense non-aqueous phase liquid (DNAPL) that consists of tetrachloroethene, also referred to as perchloroethene (PCE), and its degradation products. Additional monitoring wells were required in both the UWBZ and LWBZ to complete the delineation of that contamination. Three wells (i.e., MW947, MW948, and MW949) were installed to provide additional information on groundwater quality in this area.

Investigative Excavations in the Well OW11B Area

Over the past several years, groundwater analytical data for well OW11B in EU10 has shown elevated concentrations of uranium. Based on USACE's review of soil and groundwater data collected near well OW11B, the source of the uranium has not been determined. However, several areas are possible sources due to the presence of structures in the vicinity related to the site's former usage. These include a decontamination pad and associated grit chamber, a former railroad bed, and several pipelines (see Figures 4 and 5). The grit chamber and decontamination pad were constructed as part of the radiation remediation/IWCS construction. The former railroad bed and most of the buried pipelines were associated with the former LOOW.

To investigate these potential sources, eight locations (IE1 through IE8) were excavated, visually inspected, and scanned for evidence of radioactive and organic contamination. Samples of soil and groundwater, where present, were collected for laboratory analyses.

Exposing and Plugging Underground Utilities

Several underground process water, fire protection, and potable water pipelines originate in the former water supply treatment area of the LOOW (located in the southern IWCS area) and leave the NFSS to former LOOW TNT process areas to the north and east. To eliminate the possibility that the utilities provide preferential pathways for off-site migration of site contaminants, and to address stakeholder concerns, 17 pipelines at six locations (PE1 through PE6) were exposed, sampled, and plugged (see Figure 4). Pipeline diameters ranged from 10 cm (4 in) to 91 cm (36 in). Gamma radiation measurements were taken on the excavated soil during excavation. Once an excavation was complete, the sides and bottoms of the excavations were surveyed to identify any area of elevated material. In addition, to further eliminate the possibility for off-site migration of site contaminants, two manholes (MH08 and MH41) associated with the former LOOW sanitary sewer system were plugged.

Bounding Horizontal and Vertical Soil Contamination

The objective of the 2013 field investigation was to delineate the vertical and horizontal extent of contamination in surface and subsurface soils at locations across NFSS in support of the BOP OU Feasibility Study (FS). The scope of work for the investigation included:

- Delineate soil contamination at 478 locations across the NFSS,
- Expose and evaluate the former LOOW sanitary sewer in EU10 and EU11,

The delineation of areas where SOR scores exceeded 1 was done in two phases. In the first phase, proposed borings (typically four) were evenly spaced (within 5 to 10 m) around the subject borehole where the SOR score exceeded 1 to refine the extent of contamination. A total of 461 borings were completed to delineate areas of ROC contamination. Of those, 372 were completed during the first phase of the investigation. Following receipt and validation of the analytical results, the SOR scores were recalculated. The second phase of the field investigation involved advancing an additional 89 borings to complete the ROC delineation.

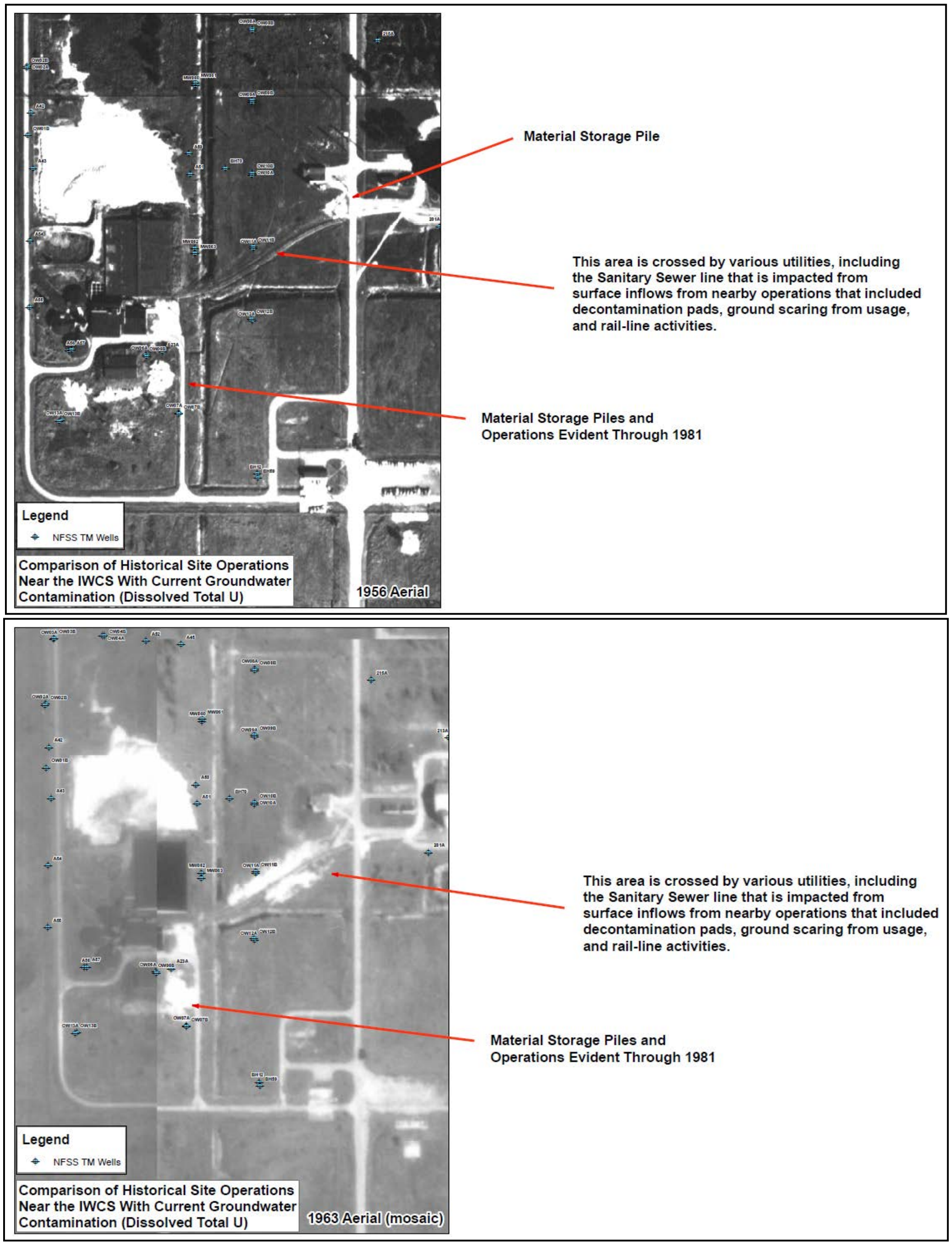

FIGURE 3: Aerial Imagery of Historical Site Operations

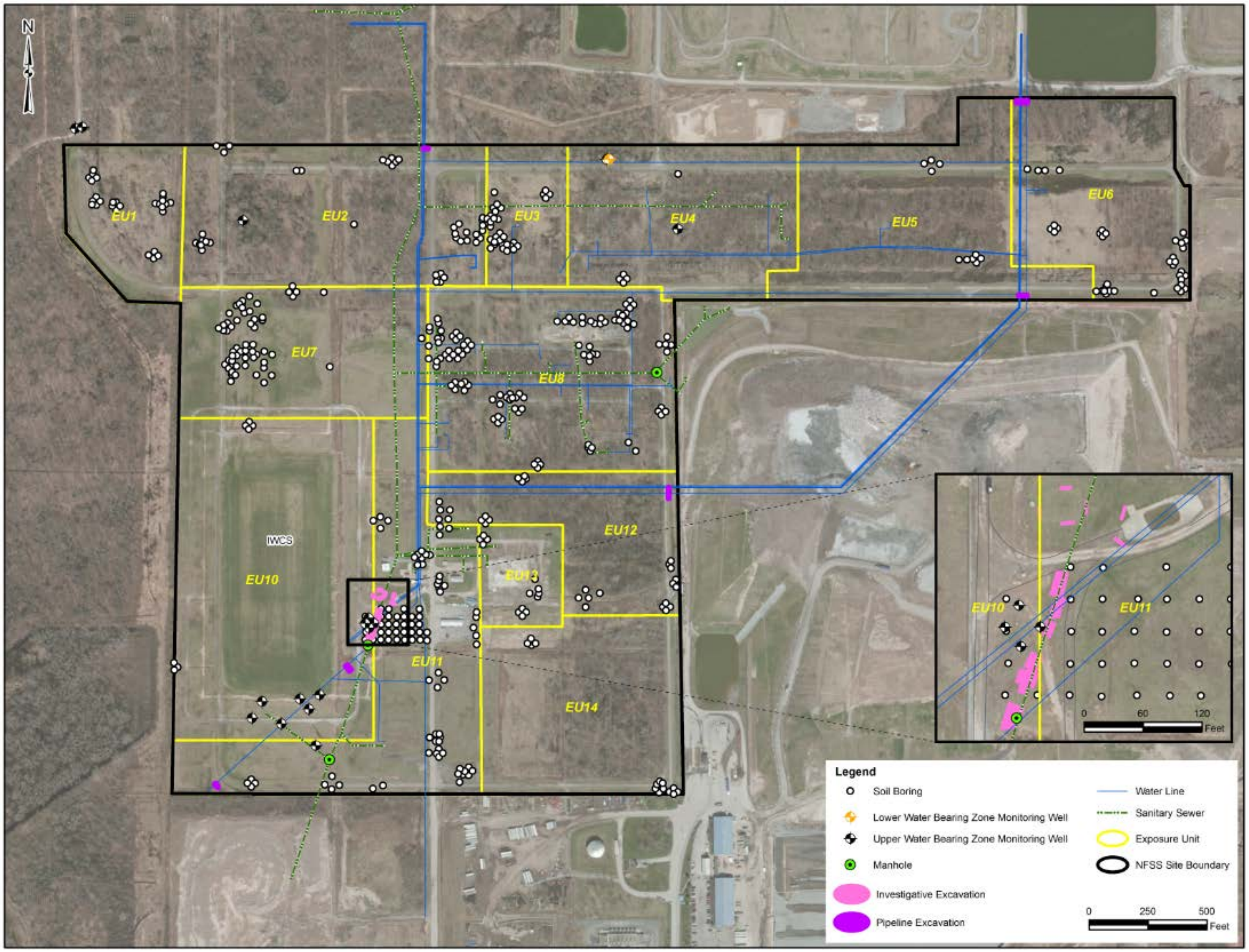

FIGURE 4: NFSS Balance of Plant Site Investigation Locations

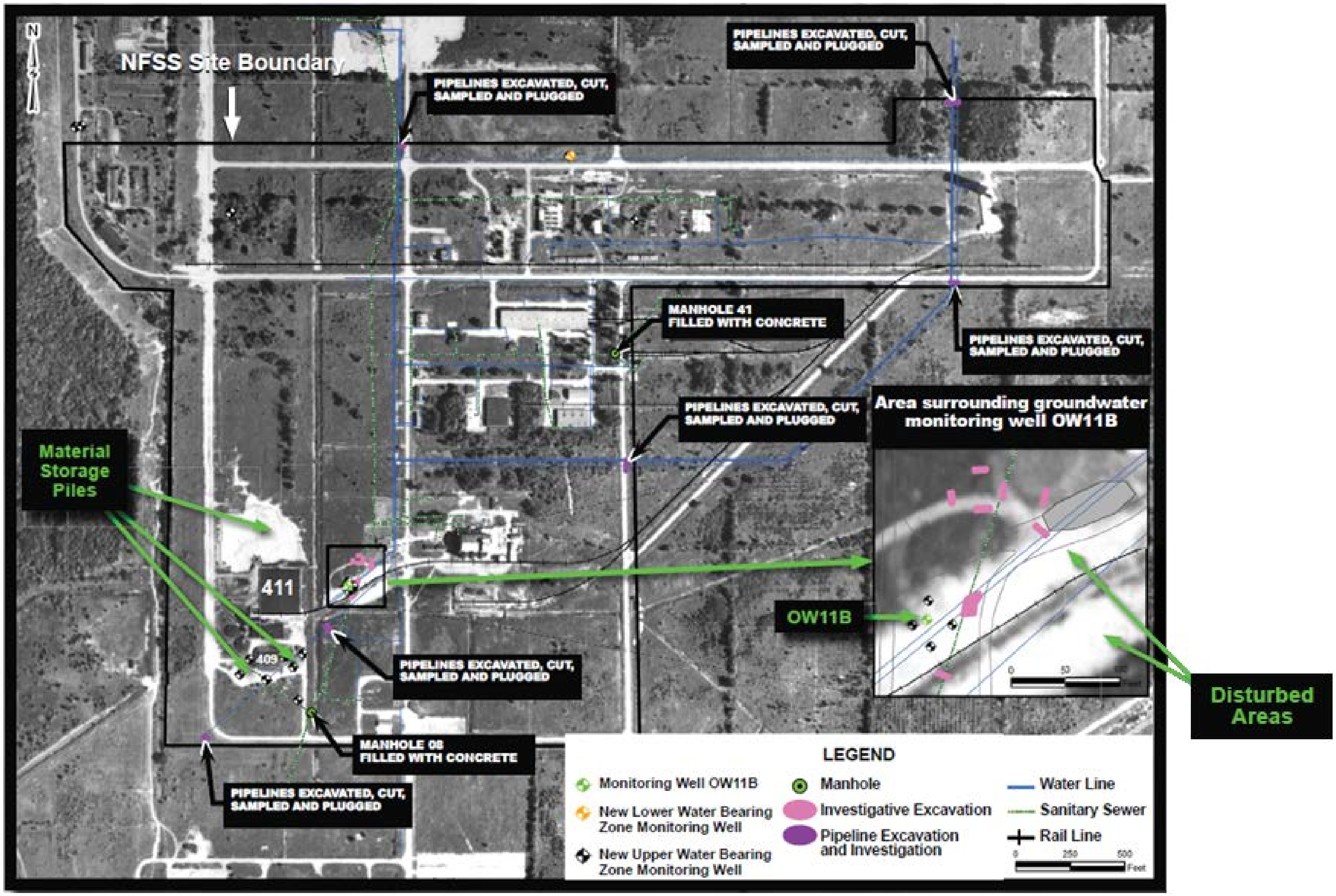

Figure 5: This is an aerial photograph of the site taken in 1958. Ground scarring (white areas) in this historic photograph show that there was a great deal of activity (earth moving, stockpiling of material, traffic) in the area surrounding groundwater monitoring well OW11B, including a railroad track. Disturbed areas (white areas) are evident along the rail line and material storage piles are seen north of Building 411, east of Building 409, and south of Building 409.

Site Investigation Results

Groundwater:
The NFSS BOP investigation confirmed the presence of uranium impacts in groundwater in the area south of the IWCS and in the area near the grit chamber, decontamination pad, and well OW11B. The impacts are likely associated with past practices at the site. In particular, the location of former material storage piles to the east and south of Building 409 (south of the IWCS) shown on historical aerial photographs (Figures 3,5 & 6) closely mirror uranium detections in groundwater in that area. Similarly, historical aerial photographs also show ground scarring along the railroad line in the vicinity of well OW11B, the decontamination pad, and the grit chamber (Figure 5).

Furthermore, decontamination activities during construction of the IWCS near the decontamination pad, grit chamber, and OW11B may have also contributed to the uranium impacts detected in soil and groundwater in that area. The soils data showed that the surface and near surface soils had uranium impacts, while the deeper soils did not. The low permeability of the soils appears to have limited migration of uranium impacts in the soil column. Impacts were generally not found along the original TNT facility water lines (e.g., 25-cm (10-in) diameter pipeline in PE1). The older TNT facility pipelines were installed without bedding material and it appears that the natural silty clay backfill inhibits groundwater migration along these older pipelines.

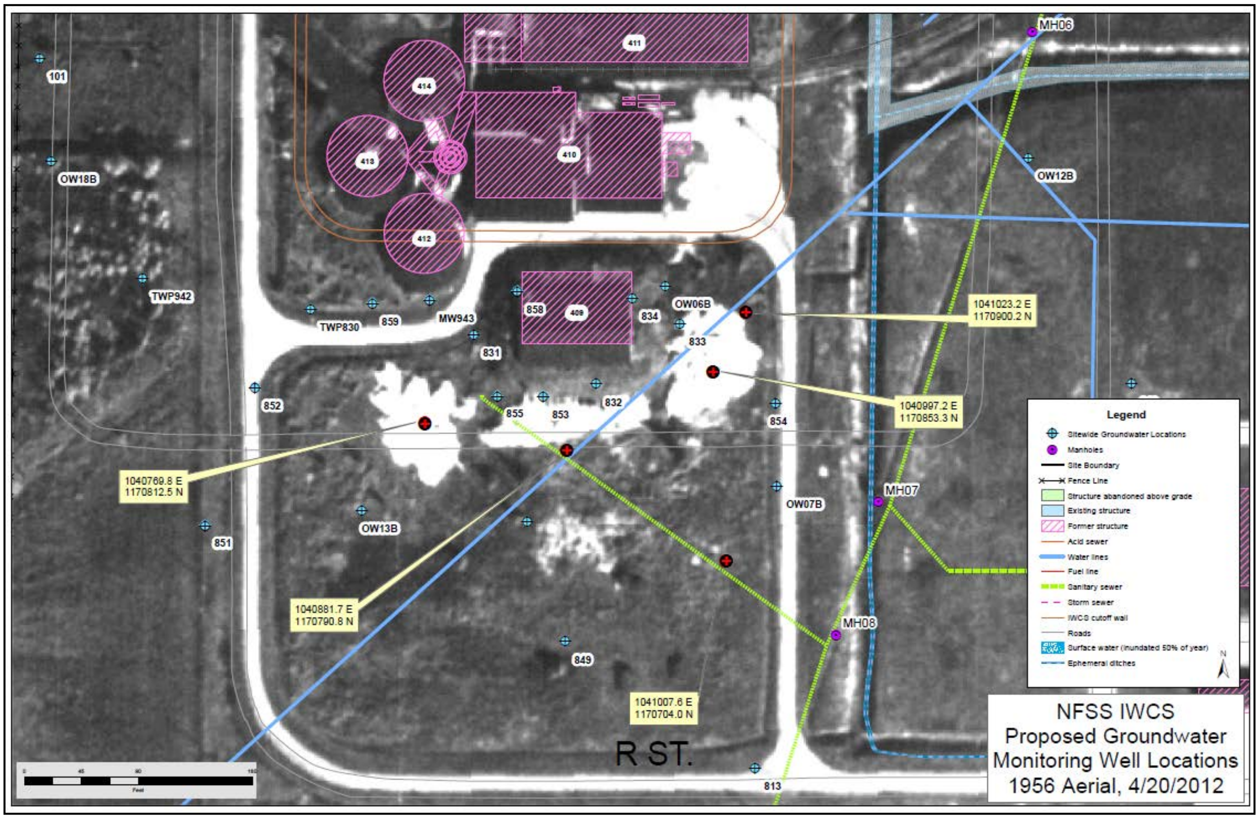

Figure 6: Historic Site Operations South of the IWCS

Investigative Excavations in the Well OW11B Area

Uranium concentrations in groundwater were detected above criteria north, south, and east of groundwater monitoring well OW11B and in Investigative Excavation (IE) 7 and IE8. The concentrations at these locations are consistent with historic operational corridors (e.g., rail line), past practices (e.g., decontamination activities during IWCS construction), and soil analytical results. Uranium soil impacts are near the surface and absent in deeper soils. The low permeability of the soils limits vertical migration of uranium impacts in the soil column. The average horizontal groundwater flow velocity at NFSS is 11 inches per year. It would take hundreds of years for a contaminant on site to reach the perimeter of the site.

Exposing and Plugging Underground Utilities

There was no pipeline bedding material noted at any of the locations associated with former LOOW activities. The natural silty clay backfill around the pipes inhibits groundwater migration along these older historic pipelines. The effect of this clay material is that there is no preferential pathway for groundwater contamination to move through the soil surrounding the pipeline.

There was no radiological contamination detected in the soil surrounding the 10-inch water line or in the pipeline.

Uranium concentrations above criteria were detected in the sediment and water samples from MH08. This manhole was subsequently backfilled with concrete during the field investigation, as planned. No radionuclides were detected at concentrations exceeding criteria in MH41 sediment or water.

There was no radiological contamination detected in soil samples taken from the ground surrounding the water pipeline or water sampled from any of the water pipelines included in this field investigation, except in Pipeline Excavation (PE) 4 and PE5. Radium-226 was detected slightly above the drinking water criterion of 3 picocuries per liter (pCi/L) in water samples from inside the pipelines at PE4 and PE5
(i.e., 5.31 pCi/L and 4.45 pCi/L, respectively).

There was no bedding material noted at any of the excavated pipeline locations associated with former LOOW activities. Known potential pathways for off-site transport of groundwater contaminants were eliminated by plugging all known former LOOW subsurface pipelines entering or exiting NFSS. The absence of bedding material surrounding the historic LOOW pipelines indicates the pipelines do not provide a preferential pathway for groundwater contamination.

Bounding Horizontal and Vertical Soil Contamination

The majority of soil boring locations were selected to delineate areas of previously identified radionuclide impacts. Therefore, it was anticipated that elevated radiation levels would be encountered during the radiation surveys in some of those areas. Gamma walkover surveys were performed prior to sampling in an area to help select bias locations, if applicable, and to assist in identifying any residual contamination. Locations with unexpected elevated radiation levels were found and an additional 13 borings were advanced to characterize those locations.

A total of 478 borings were advanced during the investigation with 461 borings advanced to better delineate radionuclide areas of concern and 34 borings to better define PAH areas of concern; some borings were used to delineate both radionuclide and PAH areas of concern. Of the 1569 samples analyzed for radionuclides, 87 samples contained Ra-226 at concentrations above the DCGLs, three samples contained Th-230 at concentrations above the DCGLs, and five samples contained U-238 at concentrations above the DCGLs. While many of the radionuclide levels decreased with depth, some locations contained elevated radionuclide concentrations at depth but not at the surface.

The delineation of the extent of soil contamination was performed in two phases. In the first phase, SOR scores were calculated for all existing surface and subsurface soil data. Sample locations that exhibited an SOR score greater than 1 were subject to further investigation, and proposed borings (typically four) were evenly spaced (within 5 to 10 m) around the subject borehole to refine the extent of contamination. Prior to drilling and sampling, all proposed boring locations were staked in the field and a gamma radiation walkover survey covering an approximate 3-m (10-ft) radius around each proposed borehole was performed to identify elevated surface radiation levels in the area. If elevated gamma radiation readings were identified, one or more of the borings was moved to the area of the higher gamma reading and/or additional borings were added, as appropriate. In either case, elevated gamma survey results outside the 100 m^2 area were generally investigated through sampling.

The second phase was initiated by overlaying a random-start 100 m^2 grid over the entire NFSS and re-calculating the average SOR scores for the set of data located within each 100 m^2 area, pursuant to 10 CFR 40 Appendix A Criterion 6(6). If the average SOR score within an area of 100 m^2 was greater than 1, a contaminated soil area of concern (AOC) was identified. The aerial extent of the contaminated soil AOC was estimated using Bayesian Approaches to Adaptive Spatial Sampling (BAASS) software, which is similar to kriging and considers the nearest “clean” data point (i.e., a sample location with an SOR score of less than 1). Following the application of BAASS, each AOC was evaluated to determine if existing data sufficiently delineated the extent of contamination. If not, additional borings were proposed and a second round of drilling and sampling was performed. Similar to the first round of sampling, all proposed boring locations were staked in the field, a gamma radiation walkover survey was performed, and BAASS software incorporated the new data to estimate the extent of the contaminated soil AOC.
A total of 461 borings were completed during this field investigation. Of those, 372 borings were completed during the first phase and 89 borings during the second phase of the investigation.

CONCLUSION

The series of investigations at the NFSS indicated multiple operational areas still have impacts above background conditions, risk-based concentrations, and promulgated maximum contaminant levels for multiple media in the Balance of Plant Operable Unit. The soil, groundwater, sediment, and utility sampling data show that:

1. Radionuclide impacts derived from ore-residue handling operations still exist,
2. Impacts from other inorganic and organic compound exist in TNT manufacturing and support areas, and
3. Contaminant transport from past source areas is minimal.

The historical placement of material storage piles appear to be the source of radionuclide and total uranium contamination in the area south of the IWCS. Previous remedial activities in and around the grit chamber, decontamination pad, and OW11B and historical material storage piles discerned from photographic analyses are likely sources of groundwater impacts in this area. Furthermore, the groundwater concentrations are consistent with the soil detections in the area south of the IWCS and near OW11B.

The vertical and horizontal extent of soil contamination has been composed using the methodology described herein and will assist in producing cost certainty to the remedial alternative evaluation that will be included in the Balance of Plant Feasibility Study. The below graphic (Figure 7) is an example of the BASS volume estimate modeling generated from results from the BOP investigations.

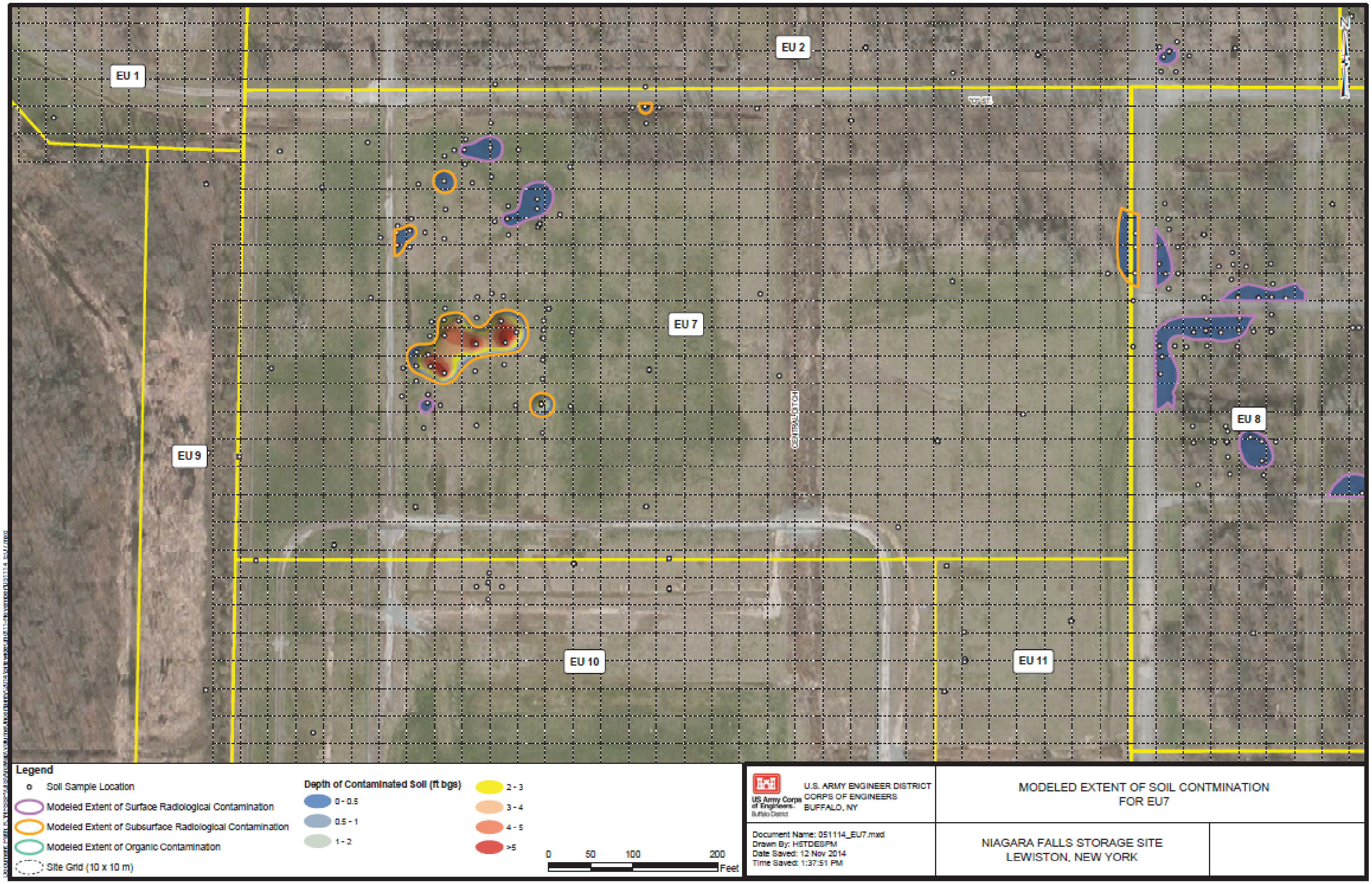

Figure 7: NFSS BOP Example Soil Contamination Modeling

REFERENCES

1. 10 CFR Part 40: Appendix A - Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material From Ores Processed Primarily for Their Source Material Content
2. Acres American, Inc., 1981. Hydrologic and Geologic Characterization of the USDOE-Niagara Falls Storage Site, Buffalo, New York (September).
3. USACE, 2007, SAIC. Baseline Risk Assessment Report. Niagara Falls Storage Site. Lewiston, New York. Revision 3, Vol. 1. December 2007.
4. USACE, 2007, Science Applications International Corporation (SAIC) and Tetra Tech. NFSS Remedial Investigation Report, (December).
5. USACE, 2011, SAIC, NFSS Remedial Investigation Report Addendum Report (April).
6. USACE, 2013, URS Group Inc, Balance of Plant Operable Unit Field Investigation (August).
7. USACE, 2015, URS Group Inc, Balance of Plant Operable Unit Investigation to Refine the Extent of Soil Contamination (February).
8. USDOE, 1994. Niagara Falls Storage Site Failure Analysis Report (unnumbered), Oak Ridge, Tenn. (December).