Design and Installation of a Permeable Treatment Wall at the West Valley Demonstration Project to Mitigate Expansion of Strontium-90 Contaminated Groundwater - 11138

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ABSTRACT

In 2008 work began at the West Valley Demonstration Project (WVDP) to first evaluate and, then if found to be appropriate, design and install a permeable in-ground treatment system [permeable treatment wall (PTW)] to contain expansion of strontium-90 (Sr-90) found in groundwater on a portion of the 68-hectare (160-acre) site. Lessons learned from a pilot PTW installed at the site in 1999 were carefully considered and factored into the planning for characterizing the leading edge of the contaminated groundwater, and the subsequent design and installation of a full-scale PTW.

Installation of a PTW, approximately 259 meters (860 feet) long was completed in the fall of 2010. The excavation was approximately 1 meter (39 inches) wide and from 5.8-9.1 meters (19- 30 feet) deep and 2,600 metric tons of zeolite were installed using a one-pass trencher. The excavated soil was placed directly into an aboveground containment structure via a conveyor specifically designed and fabricated for use in this project.

This paper follows from paper 10409 submitted to the 2010 Waste Management Symposium [1] and focuses on the application of lessons learned from the pilot PTW, measures taken to manage unknowns (risks) during design and installation, observations from full-scale PTW installation, and PTW status.

INTRODUCTION

As discussed in a 2010 Waste Management Symposium paper 10409 [1] the area of groundwater contamination was identified and initially delineated in the mid-1990s. The contamination came from piping leaks within the former irradiated (used) nuclear fuel reprocessing plant during operation (1966-1972). Contaminated liquid moved through expansion joints in the floor of the plant and into the underlying soil. Sampling beneath the plant confirmed the presence of Sr-90 and other isotopes consistent with the documented leaks.

Sr-90 is more mobile in groundwater than the other isotopes involved and has been carried with groundwater passing beneath the plant. The groundwater moves above a confining layer of glacial clay (till) which varies throughout the deposit from approximately 1.2-9.1 meter (4-30 feet) below the surface. The Sr-90 plume extends primarily northeast from the plant moving downgradient toward the edge of the WVDP site and the edge of the small plateau upon which the facility was built. At or near the edge of the plateau, the groundwater comes to the surface as springs or seeps.

The plume is approximately 430 meters (1,400 feet) long. From the reprocessing plant downgradient approximately 275 meters (900 feet), the groundwater follows a fairly narrow path 120 -152 m (400-500 feet) in width. Beyond approximately 275 meters (900 feet) the plume widens to approximately 213 meters (700 feet) and three distinct preferential pathways (lobes) occur (Fig. 1.).

The plume is almost entirely within the WVDP premises with the highest Sr-90 concentrations (350-400,000 pCi/L) occurring adjacent to the former reprocessing plant [2]. Sr-90 levels in groundwater and in groundwater surfacing at or near the edge of the WVDP ranges from several thousand pCi/L to background, dependent on location and groundwater conditions (i.e., volume).

The PTW is intended to contain further expansion of the leading edge of the Sr-90 plume until a long-term management approach is selected for this area of the WVDP site. Planning for the PTW focused on designing and installing a system that could function for up to 20 years. Current agencies' plans call for making a decision on the long-term management of the plume within the next 10 years.

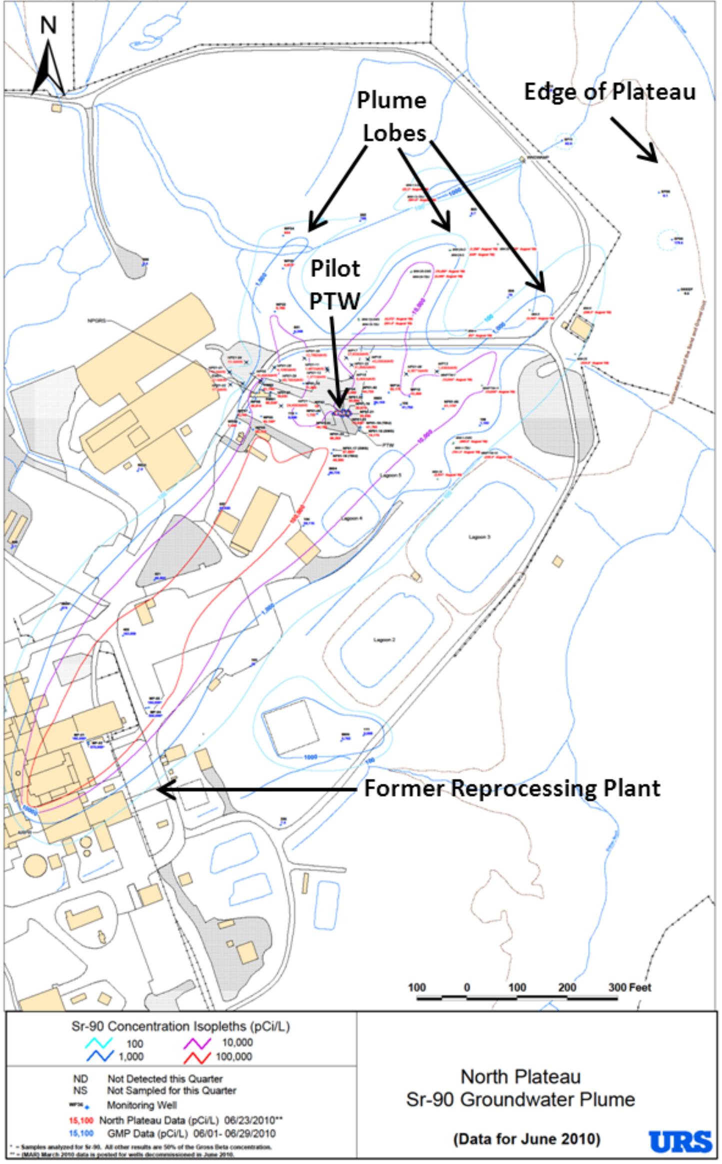

Fig. 1. Sr-90 Groundwater Plume June 2010

FULL-SCALE PTW DESIGN AND INSTALLATION – APPLYING LESSONS LEARNED AND MANAGING RISK

A pilot PTW approximately 9 meters (30 feet) long and 3 meters (10 feet) wide was installed in 1999 on one lobe of the Sr-90 plume. A natural zeolite mineral (clinoptilolite) was selected as the sorbent media based on industry knowledge and specific testing that demonstrated this zeolite removed Sr-90.

To install the zeolite, sheet piles were driven to form a cofferdam, dewatering wells within the cofferdam were pumped to dry the soil, the soil was excavated, and the zeolite was placed by emptying one-ton bags of the material into the excavation. The sheet piles were then removed.

While monitoring of the pilot PTW indicated that the zeolite was removing Sr-90 from groundwater moving through the wall, it also showed that a significant amount of groundwater was not passing through the PTW. In 2001 an evaluation of the pilot PTW was completed [3] which identified a range of factors that potentially restricted flow through the pilot PTW. The majority of the factors were related to either the zeolite or the construction technique.

- Zeolite
  - Mechanical breakdown during handling, initial placement and sheet pile removal were suspected in causing compaction and associated reduction in hydraulic conductivity.
- Construction
  - Sheet pile removal impacted zeolite on the north (downgradient) and east sides of the PTW producing a “skin” effect of fine zeolite fragments that diverted groundwater.
  - A portion of the pilot PTW was thought to not extend fully into the underlying clay (till) layer providing a pathway for groundwater movement.

An overriding conclusion was that the pilot PTW, due to its small scale, was not able to absorb the heterogeneity and complexity of the local groundwater system. Groundwater could easily be diverted by even small variations in permeability related to any of the above factors.

Planning for full-scale PTW development assumed use of zeolite as a sorptive medium and installation with a one-pass trencher. The one-pass trenching system was proposed as the technique that would have the least impact on the soil/zeolite interface thus minimizing possible affects on PTW permeability.

Investigations in three areas were required to establish that installation of a full-scale PTW was appropriate and feasible given the geohydrology of the area involved, zeolite characteristics, and one-pass trenching capabilities.

First, a field effort was conducted to collect data on the specific geology, hydrology, and Sr-90 distribution in the proposed area for PTW placement. The proposed area, approximately 300 meters (1,000 feet) long by 90 meters (300 feet) wide, was selected based on evaluation of data from past plume investigations, ongoing monitoring, and pilot PTW studies combined with the existing surface characteristics (facilities, roads, utilities, etc). Characterization results are discussed in a 2010 Waste Management Symposium paper 10409 [1] and are described in detail in WVDP-500, WVDP North Plateau Characterization to Support Design of Strontium-90 Groundwater Plume Mitigation Measure(s) [2].

The extensive field characterization confirmed that installation of a PTW was a viable approach to containing the plume allowing the project to move forward. Specifics defined by the characterization effort were also later significant in developing the detailed PTW design.

Second, more extensive testing and evaluation of zeolites were needed to: 1) address issues regarding friability that appeared to be a key factor in reducing the pilot PTW’s hydraulic conductivity and 2) better understand and model the cation exchange process by which zeolite (clinoptilolite) removes Sr-90 from groundwater to estimate the thickness of the PTW required to remove Sr-90 for up to 20 years.

Zeolite from two different deposits was tested: a clinoptilolite from the mine used in the pilot PTW and a second clinoptilolite that appeared to be less friable from a different mine. Testing not only evaluated the zeolite characteristics, but also evaluated affects that the inadvertent mixing of soil with the zeolite during installation could have on Sr-90 removal.

The initial zeolite testing is described in more detail in 2010 Waste Management Symposium paper 10409 [1] and is documented in WVDP-506, Laboratory Testing of Zeolitic Materials Submitted by Department of Civil, Structural and Environmental Engineering University of Buffalo [4].

Third, one-pass trenching (Fig. 2.) is an established, but not a wide-spread technology, that has been used effectively for installation of permeable barriers. Most referenced is its use for installation of zero valent iron to treat groundwater for chemical contaminants. Barrier permeability has not been identified as a significant issue with this technology.

Fig.2. One-pass trencher used in installation of the PTW.

However, no references were found for its use in placing a zeolite-filled permeable barrier and searches found only limited applications in radiological remediations. While one-pass trenching appeared to be the best option to address the installation issues found with the pilot PTW, significant effort was required to identify available equipment and personnel that could excavate to the depth and width required for this application and then develop methods to reduce uncertainties in the use of a new media (zeolite) and effectively manage radiological controls.

Zeolite Testing Results

Based on the laboratory testing [4] of two zeolites, the Bear River Mine zeolite selected for use had a higher cation exchange capacity (CEC), had no measureable clay content, and was less friable than the other zeolite tested. Both zeolites tested clearly removed Sr-90. The areas of uncertainty dealt with how long a zeolite PTW could be expected to contain the plume, the material’s mechanical strength, and the zeolite deposit’s natural variability relative to CEC.

Column tests, where water is pumped through the zeolite and cations in the effluent are measured, were conducted to determine the ability of the zeolite to remove Sr-90 and to investigate the impacts of co-mingled soil on Sr-90 removal over time. Columns using standardized synthetic water containing nonradioactive Sr-88 as a surrogate for Sr-90 were run for more than 180 days. Columns using site groundwater containing Sr-90 were run for 130 days. The data collected were the basis for the preliminary PTW design [4].

Over those time periods, there was no increase in Sr in the effluents from either 100 percent Bear River zeolite column. The questions remained: When would Sr-90 begin to increase in the effluent and what would be the progression over time? To reduce the uncertainty relative to PTW longevity, the column tests were extended using 100 percent Bear River zeolite for six months as design work proceeded.

At 190 days, Sr-88 began to increase in effluent from the non-radioactive column but did not reach 50 percent of influent concentrations until the 450-day mark. For the radioactive column, no significant increase in effluent Sr-90 concentrations had occurred at 320 days. The results of extended testing were summarized in an addendum to the laboratory report [5].

While the selected zeolite’s resistance to mechanical breakdown was clearly observable through handling and direct observation, how durable it was relative to shipping and installation was uncertain. With breakdown (fining) a concern in reducing PTW permeability and potential groundwater diversion, steps were taken to evaluate the zeolite’s real world durability.

A fact finding visit was made to the Bear River Mine to gather information on production, gradation testing, and transport options. Shipment in 1-metric ton sacks (Fig. 3) by truck was selected as the most viable shipping approach for the WVDP.

Fig.3. Zeolite sampling prior to test shipment.

As part of a one-pass trencher test, zeolite was sent by truck approximately 2,500 kilometers (1,500 miles) from the mine to the Michigan test site. Samples were collected from the bags pre-shipment and post-shipment, and tested for grain size. In addition, a bag was examined post-shipment for any visual signs of fining at the top, bottom and sides. No degradation was identified.

Potential for zeolite breakdown during installation was also considered and evaluated. “Stone slinger” trucks were selected to feed the zeolite to the one-pass trencher where the zeolite would pass from the back to the front of the trencher via conveyors and drop into the excavation through a trench box that held the excavation open. Tests of zeolite before and after passing through each piece of equipment were conducted to check for possible degradation; no breakdown was found.

As a naturally-occurring mineral, the zeolite selected is mined from a surface deposit and is crushed into various sizes for commercial uses. The specific use in the PTW required special attention to the zeolite’s CEC.

The original laboratory testing that was conducted used small amounts of zeolite from a 19-liter (5-gallon) sample. To ensure that the 2,460 metric tons purchased for use in the PTW was comparable in CEC value to the material tested, quality control measures were put in place.

The zeolite was produced and tracked in “lots” of 60 bags. Samples from each lot were sent to the State University of New York at Buffalo laboratory that conducted the testing program. For each lot sample, a sample from the original material that was used in the test program was also tested for comparison. Should both results be low it would indicate a potential analysis issue, not a difference in the materials. Each lot was stored at the mine until the CEC test was completed and the lot accepted and released for shipment.

One Pass Trenching Test Results

Variations in CEC were identified in the production lots and alternate CEC test procedures were run for comparison. Based on evaluations, including additional modeling, decisions on acceptance and use restrictions (location in the PTW) were made.

The pilot PTW performance emphasized the importance of the installation process on the function of the barrier. While industry experience demonstrated the value of one-pass trenching in maintaining permeability at the media soil interface, two key questions remained.
First, could a trencher excavate to the needed depth [approximately 9 meters (30 feet)] and width [approximately 1 meter (39 inches)] and place zeolite, which is less dense than the surrounding soil, to the needed thickness? Second, how could the excavated material be handled to maximize containment of potentially contaminated water and soil?

On site tests of equipment and potential approaches to the work were an obvious way to mitigate the risks (uncertainties), but there are no uncontaminated on site locations with similar geology. Therefore, arrangements were made with DeWind One-pass Trenching in Holland, Michigan, to conduct tests at the operator’s site. While the soil is very sandy (flowing sand) at the location unlike the WVDP site, it is similar in having a confining clay layer beneath and a high water table. The geology of the test site provided a very conservative (worst) case to compare to the on site location for the PTW.

Testing confirmed that the zeolite flowed well and was readily conveyed by the trencher. However, with the sandy soil conditions at the test site the walls of the excavation pushed in on the zeolite and produced a narrower zeolite barrier than desired. To address this, water lines were installed in the trench box to provide the capability to saturate the zeolite as it was placed in the excavation. The concept was to increase the density of the zeolite and thereby counteract the inward pressure of the surrounding soil and groundwater. A second test with water addition significantly improved the barrier thickness.

To address management of excavated soil and water, a conveyor (Fig.4) was fabricated that enclosed the area around the cutting bar that would collect and lift the excavated soil into an aboveground containment structure. A conveyor prototype was then tested (Fig.5) with a trencher again at the DeWind site.

Fig.4. One-pass trencher soil conveyor.

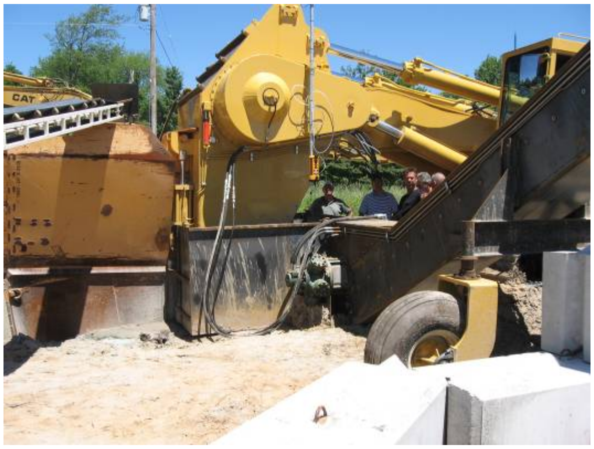

Fig.5. Testing of conveyor.

Conveyor testing was successful, with only minor modifications made to the conveyor attachment to the trencher and placement of the conveyer wheels.

It was understood that a number of situations could arise during installation due to unknown factors such as varying groundwater levels, unexpected underground obstacles, and adjustments in trencher operation etc. These and other unknowns could impact the amount and characteristics of the soil excavated, the amount of zeolite used, equipment required etc.

RISK MITIGATION

Some of the pre-installation planning for addressing potential conditions during installation included the following.

- Zeolite purchased and staged on site included a 15 percent contingency with approximately 10 percent additional zeolite prepared and staged at the mine for shipment with plans in place to produce additional zeolite on demand if required.
- The soil containment structure was designed to hold approximately 20 percent more volume than projected, and metal storage containers (roll-offs) were staged to handle excess soil if needed.
- An excavator capable of reaching to the deepest portion of the PTW trench was on site to address an underground obstruction(s) if needed.
- A second (backup) conveyor was fabricated and on site.
- Synthetic road “plates” were staged to place on the roadways (gravel) in the construction area being used to move zeolite and generally support the trenching should very wet weather conditions occur.

Trenching began on October 17, 2010, and installation was completed on November 18, 2010. The desired PTW width, depth and length were achieved and the conveyor system for collection of excavated soil worked well in collecting material. Minimal cleanup of the PTW excavation was needed before closing.

INSTALLATION CHALLENGES

During installation there were two issues that required the most effort and resources to respond to: encountering underground obstructions and groundwater volumes that were significantly more than projected.

First, underground obstructions had an impact on the trenching process (Fig. 6). Significant effort had been put forth during field characterization, design development, and site preparation to identify potential underground obstructions; historical photographs and site records were reviewed and ground-penetrating electromagnetic and radar imaging techniques were employed. Contingency planning, including having an excavator capable of reaching the deepest points in the trench, was done.

Fig.6. Trenching.

In certain areas of the excavation unknown obstructions, large cobbles, metal pipe/rebar pieces, concrete, were encountered that slowed trenching and at one point led to a delay to allow the belts in the soil conveyor to be rebuilt and strengthened. In another location, a resistant material or object too large to be pulled to the surface by the trencher had to be trenched through, slowing the process. Some sections required trenching through thick clay (till) deposits which, although clearly known and defined, again required additional trenching time.

It is worth noting that the obstructions were generally not native material OR planned man-made structures, but rather incidental remnants of past site use. The location and the size of the cobbles indicated they were probably left from placement of gravel during construction of a building in the area and the metal objects (e.g., section of chain) appeared to be left from initial site development (early 1960s) or before.

Second, in one trench section of approximately 30 meters (100 feet), an unexpected amount of groundwater was encountered. It is believed this was due to a small, confined permeable deposit in the glacial material. When this occurred, the large amount of groundwater affected the consistency of the excavated material which in turn impacted handling and storage.

Also, underground obstructions that slowed trenching were found to increase the amount of zeolite used. When changing depth or working through harder material, some zeolite would be carried with groundwater around the trench box and comingled with soil that was excavated. Although losses were estimated to be small (10 percent) and were planned for, it is another variable that needs to be understood and managed while work is in progress.

While the need to be prepared for these types of installation challenges (risks) was identified throughout the PTW design and preparation process, actually addressing process changes within the structure of a radiologically-controlled work environment is difficult. An organization/project wide understanding of the trenching process and need to react to a changeable work environment was extremely valuable. Having both the organizational flexibility and the risk mitigation strategies outline earlier in this paper enabled successful completion of this project.

The PTW was covered as the installation progressed and following completion of trenching the trencher was washed and decontaminated as needed (Fig. 7). In accordance with the Performance Monitoring Plan (WVDP-512) [6] developed for the PTW, approximately 60 monitoring wells have been placed upgradient, downgradient and within the PTW.


Fig.7. Covering the PTW.

OBSERVATIONS FROM INSTALLATION OF THE FULL-SCALE PTW

Key Criteria for PTW Performance

As described previously, significant effort was invested in testing and investigation to understand and mitigate factors that could reduce PTW thickness, led to failure to extend (key) the PTW into the underlying till, and restrict groundwater flow through the PTW.

Observations and evaluations during installation regarding actual wall placement were very positive.

1) PTW Thickness

   To gauge wall thickness during installation, zeolite was tracked by truck load installed and the surface length of PTW generated. A person was assigned to monitor and log the installed data against design volumes based on the planned trench depth [5.8-9.1 meters (19-30 feet)], and the trench width [0.91 meters (36 inches)]. In addition, the trencher operator visually monitored both zeolite feed and soil being excavated as part of machine operation.

   All indications are that throughout the length of the PTW that the planned thickness was met and in many areas exceeded. This is due to several factors.

   First, there was no indication of squeezing in of the trench walls as seen in the early trencher tests. This is attributed to the difference in the soil conditions; glacial sediments at West Valley versus a very uniformly sandy deposit at the trencher test site.

   Second, the trencher cutting bar was approximately 1 meter (39 inches) wide, with a metal chute behind it that was 0.91 meters (36 inches) wide through which the zeolite was funneled into the trench. With no discernible inward movement of the trench walls it appears that the zeolite filled out to the cutter bar width of approximately 1 meter (39 inches).

   Third, during trenching the cutting bar flexes side-to-side, especially when going through more resistant material. This flexing or turning increases the width of the excavation.

   A general PTW width of approximately 1 meter (39 inches) or approximately 10 per cent wider than planned is supported by the volume of zeolite used. Approximately 25 per cent more zeolite was required than estimated. Some zeolite did move with groundwater in the trench around the metal installation box/chute, and was picked up and removed with soil by the cutting bar. Although it is not possible to determine the exact amount of zeolite entrained with soil, estimates based on examination of excavated soil samples were in the 5 to 10 per cent range. The estimates of added PTW width and zeolite removal through entrainment with soil are consistent with the total zeolite used.

The additional PTW thickness is very positive for the PTW's longevity. The goal of the PTW is to contain the leading edge of the Sr-90 groundwater plume for up to 20 years. The additional width provides more treatment capacity, which is especially beneficial in areas with high groundwater flow and higher Sr-90 concentrations.

2) Keying Into Till

To support final PTW design, 39 borings were placed along the PTW alignment to define the depth to till. Previous characterization work provided a solid understanding of the distribution and thicknesses of soil layers along the alignment. However, it was necessary to ensure that the PTW was keyed into the till to prevent groundwater from passing under the wall untreated and to the extent practical adjust trench depth to minimize soil excavated that would require management. The trencher, equipped with a 1 meter (39 inch) wide cutting bar, had a depth range of approximately 5.8 - 9.1 meters (19 - 30 feet).

The distance between borings varied from approximately 2 meters (6 - 7 feet) to up to approximately 18 meters (60 feet) with the closest spacing done where the greatest depth to till occurred. Special attention was afforded the sections where the till was farthest below grade [approximately 8 meters (26 feet)] because these areas were near the maximum trenching depth.

During installation, tracking to ensure the trench was keyed into till proved to be straight forward. Depth markings on the trencher cutting boom were monitored against surveyed locations along the trench using a PTW installation diagram. In addition, the trencher operator could subjectively judge whether till (clay) was being excavated both through the material brought to the surface and by how the trencher performed.

Installation of monitoring wells within the PTW confirmed a well-defined zeolite–till interface at the base of the PTW.

3) Groundwater Flow

Developing an understanding of the dynamics of groundwater flow through the PTW is one of the objectives of the Performance Monitoring Program [6.] However, initial indications on the permeability of the wall are positive.

During trenching, groundwater readily flowed into the trench to the extent that excavated soils from most of the PTW were very fluid. This was reflected in drops in water levels in monitoring wells both up and down gradient of the PTW during installation.

Also, at a number of locations along the PTW groundwater level is typically very close to the surface and to date there has been no indication of groundwater surfacing in any areas along the PTW.

PTW STATUS

The PTW was covered (capped) with a layer of clay mat, followed by geotextile, and a layer of gravel to prevent surface water infiltration and to protect the in-place zeolite. Monitoring wells were installed, as previously mentioned, and vehicle access to the area was limited to small all-terrain vehicles used only for environmental monitoring purposes.

The surrounding area has also been posted and site policies implemented to prevent use of materials such as road salt/deicer in the area that could impact zeolite performance by increasing cation concentrations in groundwater. These measures are described in a PTW Protection Plan [7].

At this time, initial dye testing to gather data on groundwater dynamics in relation to the barrier is being performed and initial sample analysis for Sr-90 and other cations is in progress. Data will be collected and evaluated on an ongoing basis to evaluate PTW performance and how the zeolite is performing in relation to the patterns observed in the laboratory testing.

REFERENCES

1. M.B. BELLIS, J.D. CHAMBERLAIN, L.M. MICHALCZAK, C. DAYTON, R.H. FRAPPA, “Mitigation of the Contaminated Groundwater Plume at the West Valley Demonstration Project, New York, USA – 10409,” Waste Management Symposium, Inc., Phoenix, AZ, March 7-11 2010
2. R.H. FRAPPA, J.D. CHAMBERLAIN, “WVDP North Plateau Characterization To Support Design of Strontium-90 Groundwater Plume Mitigation Measure(s),” WVDP-500, West Valley Demonstration Project (2009)
3. “Technology Evaluation of the Pilot Permeable Treatment Wall and Recommended Path Forward,” West Valley Demonstration Project, WD:2001:0309, (2001)
4. A.J. RABIDEAU, S. SENECA, C.E. BRONNER, E. ROSS, “Laboratory Testing of Zeolitic Materials Submitted by Department of Civil, Structural and Environmental Engineering University at Buffalo,” WVDP-506, West Valley Demonstration Project (2009)
5. A.J. RABIDEAU, A. SENECA,“Update: Laboratory Testing of Zeolitic Materials,”WVDP-506 Addendum 1, West Valley Demonstration Project (2010)
6. L.M. MICHALCZAK, “North Plateau Permeable Treatment Wall Performance Monitoring Plan,” WVDP-512,West Valley Demonstration Project (2010)
7. L.M. MICHALCZAK, “North Plateau Permeable Treatment Wall Protection and Best Management Plan,” WVDP-516, West Valley Demonstration Project (2010)

ACKNOWLEDGEMENTS

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