CONSTRUCTION AND OPERATION OF A RCRA-TYPE SURFACE IMPOUNDMENT AT A MIXED WASTE FACILITY

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ABSTRACT

Cleanup of mixed waste contamination at the Weldon Spring Site Remedial Project (WSSRAP) necessitated the construction of three double lined RCRA type surface impoundments. The first of these was constructed in 1992 as an equalization basin for the quarry water treatment plant. Several problems were encountered during the construction of this facility resulting in extensive retrofit and testing prior to acceptance and operation. Additionally, special monitoring and data analysis programs were subsequently implemented to ensure satisfactory operation of the liners and leachate collection system. Valuable experience was gained that proved very useful in the design and construction of the other two impoundments. This paper describes the problems encountered and the solutions developed for construction, testing, and leachate monitoring techniques. The information presented regarding leachate data evaluation may also be of use to other sites with similar system requirements.

SITE HISTORY

In 1941, the U.S. Department of the Army obtained 17,000 acres of land in St. Charles County, Missouri, to construct an ordnance works facility. The Army produced trinitrotoluene (TNT) and dinitrotoluene (DNT) explosives at the facility from 1941 to 1944, and again from 1945 to 1946. In the mid 1950s, 205 acres of the former ordnance works property were transferred to the U.S. Atomic Energy Commission (AEC) for construction and operation of the Weldon Spring Uranium Feed Materials Plant, now referred to as the Chemical Plant; an additional 15 acres were later transferred for expansion of waste storage capacity. From 1957 to 1966, the U.S. Atomic Energy Commission operated the site as a uranium processing facility. In 1967, the Army reacquired control of the site to convert the facilities to produce herbicide; this project was later cancelled prior to production.

The quarry, which was excavated into a bluff that forms a valley wall at the edge of the Missouri River floodplain, was intermittently used by the U.S. Department of the Army and the U.S. Atomic Energy Commission for waste disposal from 1942 to 1969. An estimated 95,000 cubic yards of bulk waste including rubble, drummed waste, sludge, and soil contaminated with both radionuclides and chemical species, are present within the quarry. The bulk waste is currently being removed as part of the remedial activities at this site. A 0.5 acre pond occupies the lowest point in the quarry.

Within both sites, the primary contaminants of concern include uranium, thorium, radium, other metals, nitroaromatic compounds, asbestos, inorganic anions, and polychlorinated biphenyls (PCBs).

From 1981 to 1985, the DOE assumed caretaker status of the quarry and raffinate pits, and in October 1985, they assumed custody of the chemical plant. In 1986, MK-Ferguson was selected as the Project Management Contractor (PMC), and the DOE project office was established on site.

SURFACE IMPOUNDMENTS

A quarry water treatment plant (QWTP) (see Fig. 1) and a site water treatment plant (SWTP) treat contaminated waters for discharge to the Missouri River. Each facility utilizes an equalization basin to 1) control flow and contaminant levels of untreated contaminated water into the treatment process and 2) receive water from backwash and regeneration activities. A third surface impoundment, located at the chemical plant site, collects runoff from a temporary storage area (TSA) where waste materials excavated from the quarry are stored. These impoundments were generally constructed to RCRA design standards.

Application of lessons learned from installation and operation of the quarry basin minimized the problems encountered during construction of the other impoundments. These included basin configuration considerations and construction and testing requirements. Minor defects at the chemical plant site water treatment and storage basins were identified using conductivity and vacuum tests, and pinholes in the liner were repaired. Therefore, the focus of this paper is primarily on the quarry impoundment. It discusses liner construction problems and subsequent monitoring and evaluation of leachate from the equalization basin.

QUARRY EQUALIZATION BASIN CONSTRUCTION

In January 1992, the Environmental Protection Agency (EPA) finalized its double liner and leak detection standards (1). These rules amended existing regulations under the Resource Conservation and Recovery Act (RCRA) for liner and leachate collection and removal systems for hazardous waste surface impoundments, landfills, and waste piles.

The quarry equalization basin was designed in a "kidney shape" to conform to site layout and use demands. This created problems with the construction and installation of the liners, and as a lesson learned, the other surface impoundments were designed using simple geometric configurations. The quarry equalization basin was originally constructed using the following components: 1) a six-inch compacted clay layer from native soils, 2) a layer of Claymax bentonite liner, 3) a 60-mil HDPE bottom liner, 4) a geonet drainage fabric, 5) a 60-mil HDPE top liner, and 6) a leak collection sump.

Prior to start-up of the treatment facility and during installation of the quarry equalization basin leak detection sump pump, a significant volume of water was observed in the sump, indicating that one of the liners was leaking. After removal of the initial sump water, accumulations of water continued. Therefore, the PMC required the liner installation

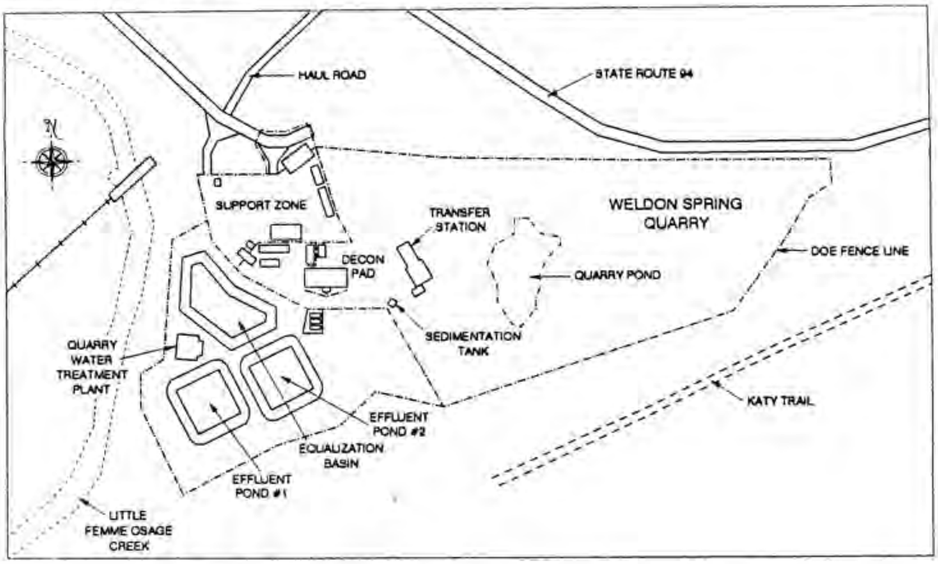

Fig. 1. Plan view of the Weldon Spring quarry area.

subcontractor to retest the upper liner. The upper liner was tested in two phases. The first included testing most of the fusion welded seams by pressure testing. The second phase involved testing the remainder of the fusion welded seams plus the extrusion welded seams. Testing during this phase included destructive testing employing both shear and peel tests, vacuum box testing of extrusion welds, pressure testing of the split shoe welds, and spark testing around metal pipe penetrations. Repair work was also accomplished during the second phase. Independent laboratory test results raised the following questions:

1. Had all the significant defects contributing to the leaks through the upper liner been located and repaired?
2. Had all the significant factors contributing to the leaks been investigated?
3. What would be the expected condition of the lower liner system based on the findings of the upper liner?

Testing of the upper liner indicated that a substantial percent of the seams were defective. Because of the problems identified in the upper liner, the integrity of the lower liner became an issue. Testing methods that would ensure that the liner was leak proof were not readily identifiable. The existence of the Claymax bentonite liner provided a level of confidence that any potential leaks through the lower liner would be minimal, but the integrity of the entire system was based on having all components meet their specified requirements. Because the same material, installation, and seam welding procedures were used for the flexible membrane lower liner component, it was possible that there were significant defects in the lower liner as in the upper liner.

ALTERNATIVE METHODS FOR TESTING AND REPAIR OF LINERS

Several approaches are available for testing and repairing flexible membrane liner systems. Approaches to testing and repairing of the equalization basin's lower liner, however, were restricted because of the presence of the upper liner and the drainage net system. Removal of these layers along with granular drain material in the leachate sump and leachate collection piping in order to allow detailed testing could damage the lower liner as could the necessary subsequent travel across the lower liner by the workers and test personnel who would reinstall the upper liner. While these risks of potential damage required evaluation, the overall system integrity had to take precedence over possible risks, given that the proper handling and storage of contaminated waste was the system's primary function.

Possible testing approaches for the quarry equalization basin's upper liner, i.e., for a single liner, can be grouped into two main categories: qualitative and quantitative. Table I summarizes these possible testing approaches. Other testing techniques requiring embedding conductor wires, electric sensors, or tubing below a liner before placement were not appropriate.

Several of the qualitative approaches, including visual inspection, probing, vacuum testing, and air pressure testing, are employed in standard Quality Assurance/Quality Control related to HDPE liner installation. Ultrasonic means, smoke testing, and geophysical techniques are usually not applied except when certain conditions warrant their use, e.g., when other more conventional techniques have not located all of the significant leak sites. Quantitative tests, such as peel and shear strength tests, are specified for installations such as the equalization basin.

Two tracer tests, one using fluorescein dye, and the other using rhodamine-WT dye, were performed to evaluate the connection between the equalization basin and the leachate collection system. Approximately 90 minutes after addition of the fluorescein dye to the basin, the dye was visually detected in the sump. A similar tracer test using rhodamine-Wt dye was performed to evaluated subcontractor repairs on the upper liner. Results were more favorable and a "ballpark" estimate of the leakage rate from the basin was calculated.

With the equalization basin's upper liner in place, there were relatively few options to determine leakage from the lower liner. Of the qualitative approaches, only the use of geophysical techniques was appropriate, considering the limited physical access to the lower liner. However, leaks from the upper liner would tend to mask leaks from the lower liner system because of the presence of water between liners. Quantitative testing, with the upper liner in place, would be similarly restricted. However, precise measurements for leak testing

TABLE I
Approaches to Liner Inspection and Testing

APPROACH	DESCRIPTION	COMMENTS
Qualitative (Nondestructive)		
Visual Inspection	Entire liner area inspected for evidence of punctures or significant flaws in liner or seams.	Can also be used to identify weld uniformity and completeness.
Mechanical Point Stressing (Probing)	Stiff probe such as a blunt screwdriver is used as an aid to inspect/stress seams.	May damage an otherwise good seam.
Vacuum Testing	Box with transparent window has vacuum applied to seam with soapy solution; soap bubbles forming indicate leak.	A commonly used nondestructive test method.
Air Lance Testing	Pipe with nozzle blows pressurized air at edge of seam, portion of seam missing causes seam to inflate or vibrate.	Tends to work better on liners thinner than 60-mil.
Ultrasonic Testing	Sound waves used to determine continuity of seam primarily by measuring intact thickness.	Very moisture sensitive.
Spark Testing	Spark established between electric device and moisture in flawed seam. Requires high-voltage current passed along seams containing a grounding wire. Moisture can be used in lieu of the grounding wire.	Grounding wire must be placed during basin construction.
Air Pressure Testing	Pressurized air blown in open channel of double seam sealed at end. Loss of air pressure in channel indicates leaky seam.	A commonly used nondestructive test method.
Smoke Testing	Smoke blown under sections of liner. Visual inspection by crew walking on liner identifies smoke discharging from leak sites.	May require installation of intake ports and division of the liner into small sections for the test to be effective. Not really applicable for single liner installation.
Geophysical Testing	Electrical conductivity, electrical resistivity, volt meter, or ground penetrating radar surveys conducted over liner area identify anomalous patterns which may be indicative of leak sites.	Not a practical method of testing for a double liner system.
Tracer Testing	A unique chemical is added to the pond water; detection of the tracer in the leak-detection sump indicates a likely connection between the pond water and water in the leak-detection sump.	Provides a "ballpark" estimate of the leakage rates.
Quantitative		
Test Seam Strength for Peel, Shear, and Flex Fatigue	Random samples of seams are cut from the liner and tested for strength and type of failure. Tested in accordance with ASTM specifications.	Tests measure the actual strength of the seams or tear patterns, which are indicative of seam strength. Flex fatigue strength tests are often not specified and probably would only be of minimal use in defining the integrity of liner seams.
Monitoring Accumulations in Leak Detection System Sump	Measurements of water collecting in leak detection sump may be indicative of leakage through upper liner.	Leakage through the bottom liner may also be a contributing factor.
Leak Test Based on Water Balance Equation (Variation with use of a tracer)	Measurements or estimates of water balance items compiled over time; hydraulic continuity equation employed to calculate leakage (tracer use helps confirm whether sump water is from the pond).	Precipitation measurements and evaporation factors must be monitored accurately.

above the upper liner and accumulations of water in the leak collection sump over a period of time could be obtained to estimate leakage through the lower liner. Use of tracers would help confirm the origin of the sump water.

LINER REPAIR ALTERNATIVES

The liner installation subcontractor took numerous steps to test and repair the upper liner. Pumping the leak detection sump, testing the water, and comparing the water quality in the sump with that in the equalization basin indicated that the basin was leaking at a rate in excess of the allowable leakage rates for this type of facility. Consequently, several alternatives to wholesale repair of the liner systems were examined. These included: 1) removal of the upper liner to access the lower liner for repair and reinstallation of the upper liner, or 2) abandonment of the lower liner and repairing and adapting the upper primary liner to function as a new lower, or secondary liner, followed by installation of a new upper, or primary liner.

SELECTED LINER REPAIR APPROACH

Cost, schedule, and reliability were all factors contributing to the decision to proceed with the following approach to repair of the equalization basin (see Fig. 2).

1. Abandon the existing lower liner in place; cut through the upper liner at locations of high tension as required to relieve stress; patch cut areas as required with new material.
2. Remove a section of the upper liner immediately above the leachate collection sump and associated section along with drainage net, and collection piping. Fabricate a new collection sump section.
3. Install the newly fabricated sump section over the existing lower liner, welding seams as appropriate (double wedge hot shoe welding for joining panels or extrusion welding in other areas, e.g., at pipe boots); replace collection piping and drain media; install new geonet and liner on top of the old primary upper liner (now serving as the lower secondary liner); anchor new liner and drainage net in existing anchor trench.

REPAIR CONSTRUCTION

Quality Assurance/Quality Control

The QA/QC procedures for the repair and installation were established by using guidelines the new material supplier developed during pre-construction testing. Third party inspection and destructive test results were evaluated against the subcontractor's destructive test reports. Third party and subcontractor laboratory random field weld samples were tested in shear and peel for compliance with the specifications that required five out of five test specimens to pass in both shear and peel for destructive test QC compliance. Field test welds, performed at least every four hours per welding machine/operator combination, required that at least four out of five test specimens pass in shear and peel. If a test weld failed, at least two consecutive test welds were then required to pass both the shear and peel. Where weld defects or problems were identified, corrective measures were taken to remove the defective seams and/or correct technical problems.

Liner Material

Numerous welding problems and failures occurred during the repair and replacement of the 60 mil HDPE liners. Liner material compatibility was suspected. However, the supplier submitted a letter prior to construction confirming that the two liners were compatible based on laboratory trial weld tests verified by a third party laboratory using different methods. It was determined that the failures were probably related to mechanical problems and/or inadequate welding techniques. Other factors contributing to the problems included ambient weather conditions, surface oxidation on the existing material, and variations in molecular weight of the liner material.

Welding

Most repair welding consisted of seam welding the existing and the new liner materials using a dual hot wedge welder; seam areas were buffed with a side grinder. For minor repairs or small patches, an extrusion welder was utilized. Approximately 80% of the seams were repaired using dual hot wedge welding and cleaning the seamed area with a cleaning product recommended by the manufacturer. The repairs and replacement operations were successful and the basin became operational.

REGULATORY REQUIREMENTS

As part of the EPA's final rules concerning liner and leachate collection and removal systems (57 FR 3462-3497), an action leakage rate must be developed. The action leakage rate must be calculated on the maximum design flow rate that the leak detection/collection system can remove without the fluid head on the bottom liner exceeding one foot. The EPA guidance document entitled *Action Leakage Rates for Leak Detection Systems* (supplement to 57 FR 3462-3497), provides

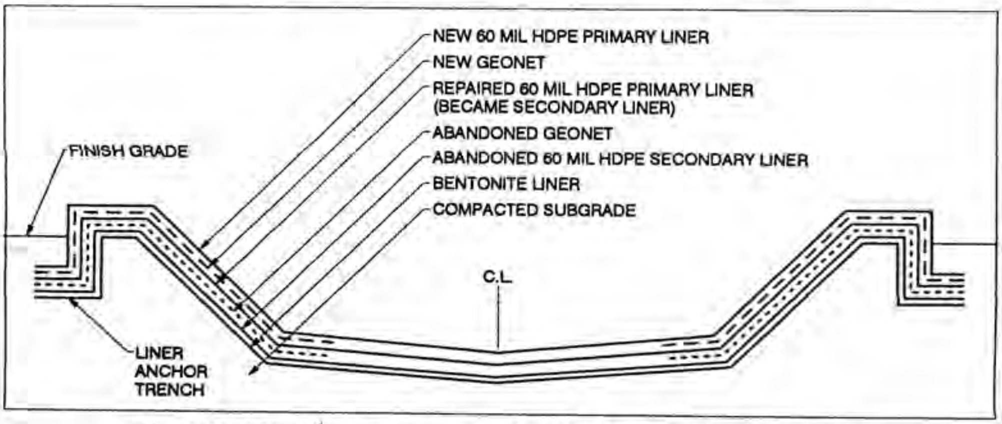

Fig. 2. Weldon Spring quarry equalization basin liner configuration.

information concerning establishment of these rates. An adequate safety margin must be included with the action leakage rate to allow for uncertainties in the design, construction, operation, and location of the leak detection system; waste and leachate characteristics; likelihood and amounts of other sources of liquids in the leak detection system; and proposed response actions (e.g., the action leakage rate must consider decreases in flow capacity over time resulting from siltation and clogging, rib layover, and creep of synthetic system components). In addition, a response action plan describing actions to be taken if the action leakage rate has been exceeded must be prepared.

The PMC was obligated to provide the Missouri Department of Natural Resources (MDNR) with an Action Response Plan defining specific action levels and subsequent actions for all double lined basins. The initial values were based on theoretical calculations of maximum leachate volume with one foot of static leachate head at any interstitial point. During operation of the facilities and basins, action leakage rates were established according to actual measured values. Additional agreements with the MDNR for the three surface impoundments include:

1. Establishment of definitive numeric action leakage rates for the basins after one year of operation to collect and evaluate sufficient leakage rate data encompassing potential seasonal affects.
2. Notification of the MDNR in the event of a substantial increase in leakage rates, excluding spikes attributed to infiltration.
3. Incorporation of definitive action leakage rate values into an Action Response Plan following the initial year of operation. The Action Response Plan will be submitted to the MDNR for review and comment.
4. Transmittal of monthly reports, including plots of the leakage rate monitoring data, to the MDNR along with a summary evaluation.

These actions are currently under way with approximately one year of operating data available to date.

OPERATIONAL MONITORING PLAN

In response to the agreement made with the MDNR, the PMC developed an operational monitoring plan for the first year (i.e., March 1993 to March 1994). The monitoring elements include precipitation, leachate flow rate, basin and leachate contaminant concentrations, and water levels.

The volume of leakage is monitored, and after one year definitive action leakage rate levels will be set. To evaluate basin performance, information on the leachate volume generated over a given 24-hr period is collected along with leachate uranium concentrations, equalization basin uranium concentrations, basin water levels, and site point precipitation totals for the same 24-hr period. Plots derived from this data include 1) leachate flow (lpd) vs. precipitation (cm), 2) leachate flow (lpd) vs. basin water levels (m), 3) leachate flow (lpd) vs. leachate [U] (pCi/l), and 4) leachate [U] (pCi/l) vs. basin [U] (pCi/l). These plots are interpreted, and monthly summaries are submitted to the MDNR.

The leachate pump for the quarry equalization basin has self start/stop on high/low levels, and the leachate flow is logged on the adjacent quarry water treatment system programmable logic controller (PLC) data logger. The leachate flow is monitored by integrating the leachate pump run time over a moving 24-hr window with the 24-hr total updated every hour. Run time is converted to gallons per day by setting a calibration constant in the PLC control system to match the leachate pump flow rate. This flow rate is calibrated twice weekly. At the chemical site equalization basin and temporary surface area impoundment, the pump is manually operated each day to collect leachate that may have accumulated over the past 24-hrs.

Total uranium measurements taken from the equalization basin and the leachate were selected as an indicator parameter because the WSSRAP has an on-site laboratory capable of these analyses. The necessity of a key indicating parameter must be stressed for this type of evaluation. The criteria for selection of an indicating parameter include 1) established background concentration and 2) on-site capabilities for quick, inexpensive analysis. Correlations between the [U] in the equalization basin and the [U] in the leachate could indicate leakage through the liner system.

Water level monitoring is used to examine a possible correlation between water levels in the equalization basin and leachate generation. If leaks were present, increased head and surface area exposed to water could result in increased leachate flow.

VOLUMETRIC MONITORING APPROACH

The volumetric monitoring approach used at the WSSRAP differs from many sites where action leakage rates are based on calculated theoretical values only, with direct measurement of interstitial fluid head. Before selecting the volumetric approach, the PMC examined potential direct measurement of head level between the liners. Potential methods of monitoring the primary liner are summarized in Table II. The study concluded that retrofitting almost any type of indicating device into an existing system would be difficult, and therefore, the volumetric determination was selected. For new systems, other options exist such as pressure transducers or bubbling level indicators. The principal problems with these types of measurements relate to the difficulty of calibrating and specifically positioning the devices between the liners. Timed and calibrated pumped flow rate measurement is much easier to maintain and calibrate, and therefore probably more reliable.

QUARRY WATER TREATMENT PLANT LEACHATE MONITORING RESULTS

Conclusions from information gathered to date indicate that in general, precipitation and resulting infiltration contribute most of the leachate generated each month (see Fig. 3). A chemical tracer test using NaCl (stock salt) was used to examine potential seepage between the liners via the liner anchor trench along the basin's southeast edge. This test confirmed that seepage from outside the basin was entering the liner system. The influent and overflow piping for the equalization basin were excavated and seepage along the pipe bedding was observed. To correct this, an interceptor trench was constructed, and the trench's sump is continually pumped to reduce seepage entering the leachate sump. However, after significant precipitation events, substantial increases in leachate volume are observed. Therefore, drainage improvements are being developed to control surface water infiltration from the area surrounding the basin.

Following a precipitation event, leachate flow increases as would be expected, and leachate [U] has been observed to decrease concurrently as illustrated in Fig. 4. In part, this relationship may be attributed to dilution from storm water inflow. Basin water levels do not appear to have correlated significantly with increased leachate flow (see Fig. 5). No apparent correlation between basin [U] and leachate [U] has been noted during ongoing observation, although it would be expected.

Groundwater levels in monitoring wells surrounding the equalization basin are measured daily and compared against the elevation of the leachate sump and the basin's bottom.

The daily leachate data is averaged weekly and reported monthly to the MDNR. Possible seasonal variations in leachate flow are trended as illustrated in Fig. 6.

CONCLUSIONS

While site space limitations may dictate the shape of a lined surface impoundment, as was the case at the quarry site, it is advisable to keep the shape as simple and regular as possible. Irregular shapes, such as the kidney shaped basin at the quarry site, result in more difficult seam configuration, and

TABLE II
Potential Monitoring Methods for the Quarry Equalization Basin

MONITORING METHOD	COMMENTS
Leak detection cables	Condensate between layers can result in false readings.
Piezoelectric or vibrating wire sensors	Can be used to detect the presence of water, but determination of actual head is difficult because of sensor placement.
Pressure transducers	Similar problems as sensors mounted between layers. Submerged pressure transducers could not be installed between existing liners. Other pressure transducers require a constant purge of air to measure the pressure at the bottom of a tube installed between layers. Air can cause problems with the primary liner.
Level sensors	Do not work well if not originally installed; do not lend themselves to retrofitting.

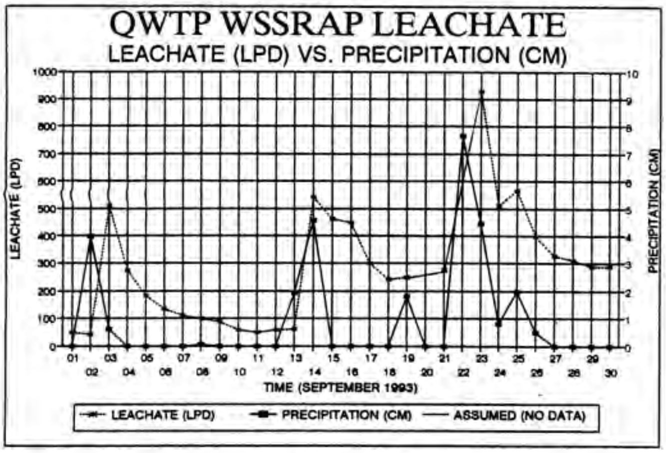

Fig. 3. Leachate flow rate vs. precipitation quarry equalization basin.

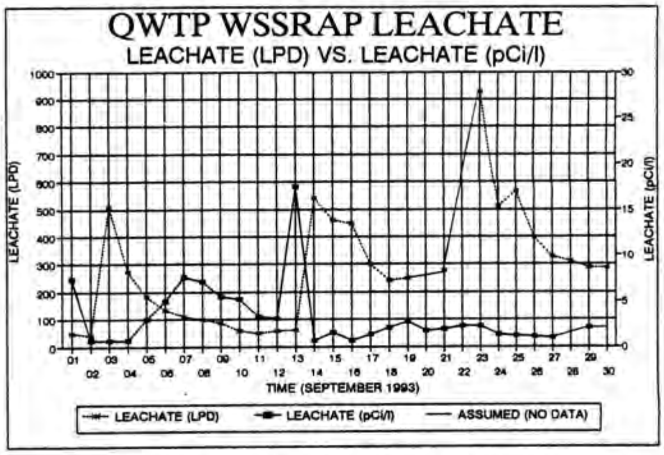

Fig. 4. Leachate flow rate vs. leachate U (total) concentration quarry equalization basin.

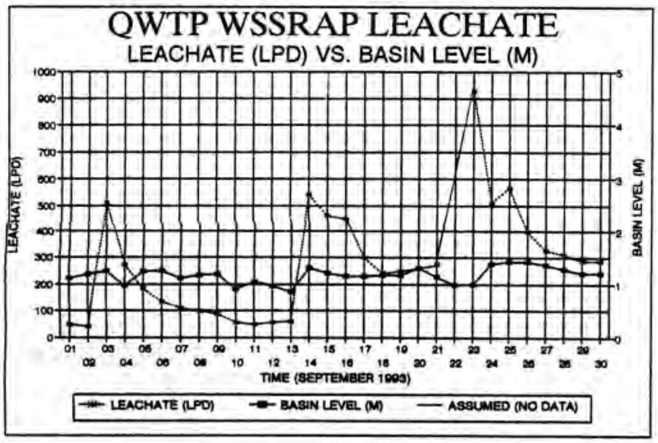

Fig. 5. Leachate flow rate vs. basin liquid level quarry equalization basin.

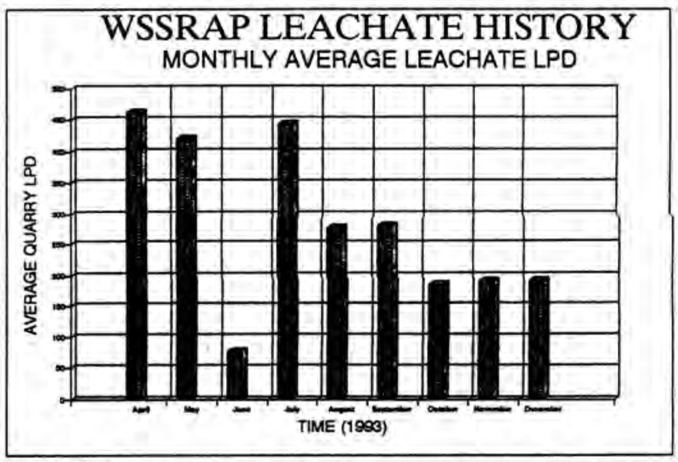

Fig. 6. Historic monthly flow rate quarry equalization basin.

consequently increase the likelihood of increased seam defects. Weather conditions (e.g., temperature and humidity) during installation and QC activities can impact the results of both, as can the use of materials supplied by different manufacturers. A variety of test methods is available, and the best selection will depend on specific site conditions and the particular skills of a given installation subcontractor. At the WSSRAP, the most successful methods involved seam pressure testing and interstice vacuum testing with the use of amplified microphones for noise or "hiss" location. Depending on the magnitudes and locations of defects discovered during testing of a double lined system, it may be appropriate to abandon the lower liner as opposed to repairing it, even though this will require complete rework of the leachate collection sump area and installation of a new upper liner.

The use of an adjacent manhole type leachate collection sump pump may provide a higher degree of reliability and accuracy than interstitial head operated surface mounted pump systems. Long pump suction lengths and difficulty in accurately placing and calibrating the head monitoring devices can result in less system accuracy, and consequently in less repeatable and reliable monitoring data. Volumetric data collected in a properly operated system can provide a high degree of certainty when compared to anticipated system responses to variables such as precipitation, basin water level, and indicator contaminant concentrations. With the selection of an appropriate indicator contaminant and regular monitoring over an adequate data collection period, system integrity can be reliably monitored.

REFERENCES

1. 57 FR 3462-3497.