PHASE 2 DESIGN IMPROVEMENTS FROM PHASE 1
CONSTRUCTION/OPERATIONS OF EMWMF
AT THE OAK RIDGE RESERVATION

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ABSTRACT

The Environmental Management Waste Management Facility (EMWMF) is the on-site disposal facility for most of the Oak Ridge Reservation's waste from remedial actions under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). It is authorized and designed to accept low-level radioactive waste, hazardous waste, toxic waste and mixed waste. The Record of Decision for the EMWMF was signed in November 1999. From the time that Phase 1 construction commenced in January 2001, through the ongoing operations of the 300,000 cubic-meter (m^3) [400,000 cubic-yard (yd^3)] Phase 1 facility, which started in May 2002, the project team has compiled lessons learned to apply on subsequent phases of the facility. The subcontract for the 600,000-m^3 (800,000-yd^3) Phase 2 build-out of the EMWMF was awarded in October 2003 with construction on Phase 2 beginning in May 2004. This paper describes the most significant design improvements that were incorporated in the Phase 2 build-out scope based on lessons learned during the construction and operation of Phase 1. The key design improvements made in Phase 2 were:

- Low profile intercell berms without continuous drainage media
- Burial of tracing conductors with non-metallic pipe for future locating
- New access road to eliminate conflict between construction and operations traffic
- Cast in place penetration blocks at the leachate pipe penetrations through the liner
- Bentonite-amended clay for construction of the low permeability soil liner

INTRODUCTION

The EMWMF is located on the side of Pine Ridge just west of the Y-12 National Security Complex (Figure 1). The project holds the distinction of being the first Department of Energy (DOE) privatization project to come to fruition. Construction of Phase 1 (Cells 1 and 2) of the facility started in February 2001 and concluded in April 2002, providing 300,000 m^3 (400,000 yd^3) of airspace for CERCLA waste disposal to jumpstart the cleanup of the Oak Ridge Reservation (ORR). Disposal operations then commenced in May 2002. At the end of calendar year 2004, waste disposal at the EMWMF had consumed half of the 300,000 m^3 (400,000 yd^3) of Phase 1 airspace. During construction and this initial operating period, lessons learned were assimilated for application in subsequent phases of the EMWMF project. The Phase 2 subcontract to add Cells 3 and 4 with an additional 600,000 m^3 (800,000- yd^3) of airspace was the first opportunity to apply the lessons learned to improve the design, construction, and

operation of the EMWMF. The Phase 2 subcontract, which was also privatized, was awarded in October 2003 to Washington Earth Tech Disposal Cell LLC (WEDC) and design commenced immediately. Construction of Phase 2 started in May 2004 and is scheduled to be complete by April 2005.
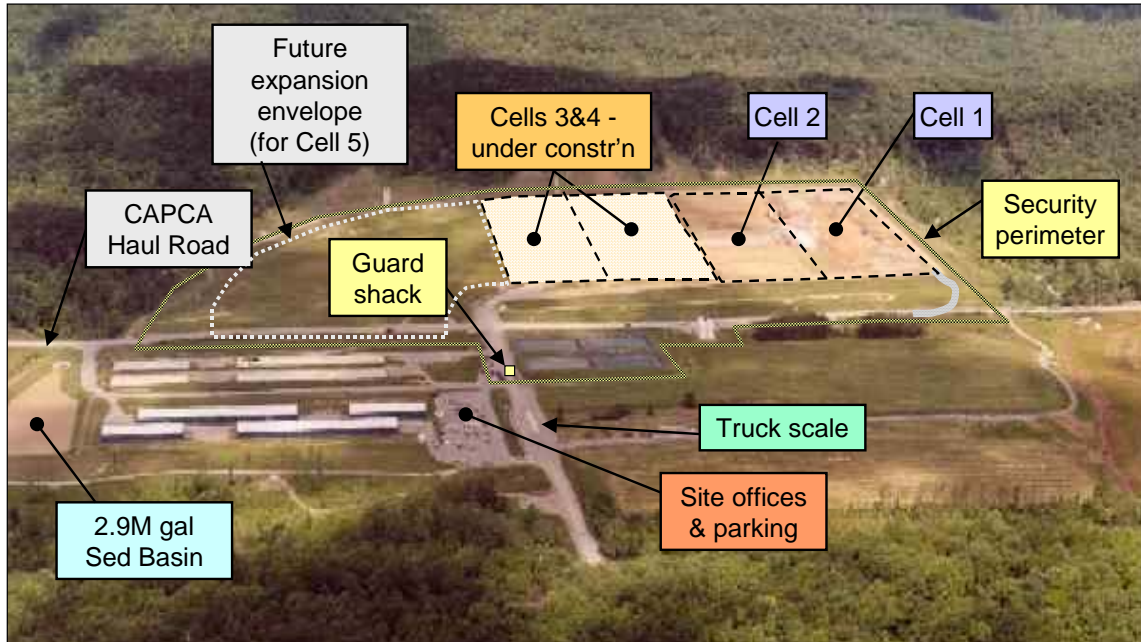

Fig. 1. EMWMF Site Plan.

DESIGN IMPROVEMENTS

Intercell Berms

The site topography on the side of Pine Ridge allowed for gravity drainage of the leachate collection system (LCS) and leak detection system (LDS) through sump-level penetrations in the south (downhill) berm into exterior manholes. To make water management more efficient, the waste containment structure is comprised of multiple cells, each having its own LCS and LDS. Phase 2 doubled the number of cells from two to four. The Phase 1 design used intercell berms [3 meters (10 feet) high, 3 meters (10 feet) wide at the top, with 3:1 sideslopes] between Cells 1 and 2 and between Cell 2 and the liner runout for then-future Cell 3. These berms functioned well as drainage breaks but presented some challenges beyond just the consumption of 5,700 m^3 (7,500 yd^3) of airspace.

During construction, several "trampolines" developed at the toes of the intercell berms. These trampolines were caused by the shrinkage of the geomembrane as it cooled at night across the abrupt grade changes presented by the intercell berms. To remedy the trampolines, the geomembranes had to be cut parallel to the intercell berm and patches up to 45 meters (m) (150 feet) long welded to the affected geomembrane.

Another drawback of the intercell berm was the quantity of clean fill required to span it with the lower access road. Protection of the liner components requires a minimum of 0.9 m (3 feet) of material above the geomembrane prior to applying loads in excess of 55 kilopascals (8 pounds per square inch), which is the pressure exerted by low ground pressure equipment. Loaded waste trucks coming into the facility on the lower access road could not accommodate a 3:1 berm slope, so several thousand cubic meters (or yards) of clean fill was required to build up the road bed sufficiently to cross both the Cell 2/3 berm and the Cell 1/2 berm at a 10:1 slope. In addition, operational experience indicated that lower profile in-cell berms could be constructed where and when needed within the facility to segregate clean stormwater from contact water, thus providing more flexibility and less consumption of airspace.

For all of these reasons, the Cell 3/4 intercell berm in Phase 2 was redesigned to be no more than a simple drainage break on the cell floor. There is a 2% cross slope in each cell to drain water to a central collection header that runs longitudinally at a 5% slope to the south. At the Cell 3/4 "berm," the grade change is simply a break from the 2% cross slope toward the center of Cell 3 to a 3:1 slope that drops 5 feet to the design elevation for the floor of Cell 4, where the 2% cross slope toward the center of Cell 4 resumes.

At the liner runout for future Cell 5, however, a more conventional intercell berm was constructed, though only 1.5m (5 feet) high, half the height of the Phase 1 berms. This was necessary to ensure adequate in-cell retention volume for contact water. The Cell 4/5 intercell berm incorporates an additional lesson learned regarding the in-cell retention of water. Experience in Cell 2 demonstrated the need to discontinue the drainage media in the LCS across the top of the berms to preclude migration of water over the berm into the uncontrolled future construction area (Figure 2). Prior to the start of waste disposal operations in Cell 2, its LCS was valved off to reduce the quantity of water entering the leachate system for treatment.
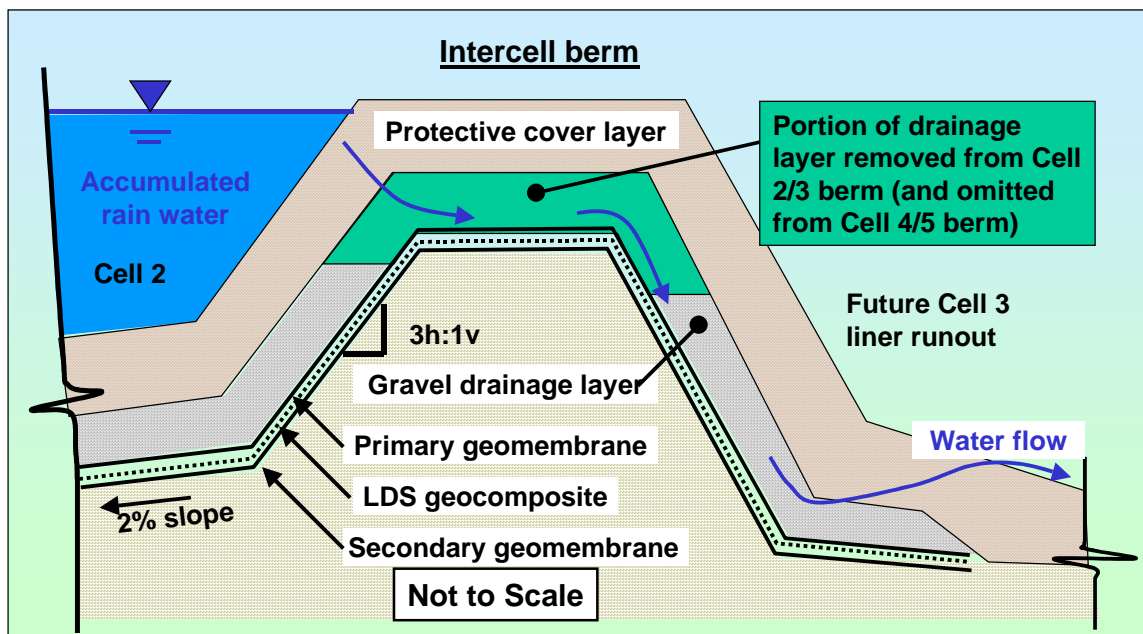
Fig. 2. Cross section of EMWMF Intercell Berm.

Consequently, accumulated water had to be pumped from the cell. After significant rains large quantities of water ponded at the south end of Cell 2 before it could be pumped out. The top 0.3 m (1 feet) of the berm was constructed of protective cover material. Beneath that was 0.3 m (1 foot) of drainage stone, and beneath that was the primary geomembrane. When the water level rose above the elevation of the drainage stone in the LCS at the top of the berm, it appeared that the protective cover material still contained the water. However, once the protective cover was saturated, the ponded water provided sufficient head to drive water through the drainage stone across the top of the berm creating a seep on the downgradient side. To remedy this, the protective cover soil and drainage stone were stripped from the top of the Cell 2/3 berm, a geosynthetic clay liner mat was inserted on top of the primary geomembrane, and the protective cover soil was backfilled. In Phase 2, the drainage stone in the LCS was discontinued 0.6 m (2 feet) from the top of the Cell 4/5 intercell berm to preclude seepage. The drainage stone was also discontinued across the Cell 3/4 intercell berm – 0.6 m (2 feet) from the top on the Cell 4 side and 7.6 m (25 feet) horizontally from the edge on the Cell 3 side.

Conductors For Locating Buried Pipe

To enhance resistance to potentially corrosive liquids, the double-walled leachate pipes and contact water pipes at EMWMF were constructed from high density polyethylene (HDPE) pipe. To facilitate the process of locating these non-metallic pipes for future maintenance or installation of additional underground utilities, the Phase 1 specifications called for 15-centimeter (cm) (6-inch) wide conductive pipe locator tape to be buried above all non-conductive underground installations. During subsequent facility maintenance and modification work, however, the pipe locating devices have frequently not been able to detect the locator tape. In more than one instance, this has resulted in damage to a pipe during an attempt to locate the tape

via exploratory excavation. Consequently, the Phase 2 requirements included a provision for a metal wire conductor to be installed in the trench above every non-conductive installation. These locating conductors are terminated above ground to allow for attachment of a pipe-locating device for vastly improved locating capabilities. Pipe locator tape is still used as well, though mostly as a visual indicator to confirm the alignment of the pipe and to serve as a warning that the pipe is just beneath.

New Access Road

The EMWMF is positioned on the south side of a ridge with no access from the north or east. To ensure the ability to expand EMWMF and make maximum use of the available site space, the Phase 1 design placed Cells 1 and 2 as far to the east as possible, against a stream and its surrounding wetlands. The plan was for new cells to be added to the west. Since the access to both the cell floor and the top of the 10.7-m (35-foot) high perimeter berms was from the west, construction of new cells on the west side of the facility would create conflicts with waste deliveries.

The schedule for Phase 2 construction included several months when construction materials (clay, geosynthetics, and drainage stone) would be delivered to the site at a rate of 100 to 200 truck loads each day. During this period, EMWMF Operations Project was forecasting 50 to 100 loads of waste per day. Thus, the Phase 2 design had to address this problem. The solution was to build a new access road at the southeast corner of the facility (at the southeast corner of Cell 1) to keep operations traffic separate from construction traffic. This access road allowed waste deliveries to use the main site access road that approached from the south while all construction materials approached the site from the west on a haul road to access the ongoing construction at the west end. Phase 2 included construction of waste disposal access from the west, but during any subsequent EMWMF expansion, waste traffic will again be confined to the southeast access road to avoid conflicts.

Liner Penetration Blocks

Leachate collected in the EMWMF cells is gravity drained through the double-layered liner to manholes outside the facility. The Phase 1 design used prefabricated penetration boxes to maintain the requirement for double-layered integrity of the liner at the points that leachate pipes passed through the liner. These boxes were constructed of 2.5-cm (1-inch) thick HDPE flatstock in a double walled configuration. The annular space was filled with bentonite grout once the boxes were set in place. This grout was also used to bed the boxes in the clay liner and a bentonite-clay mix was used to fill the incidental void spaces behind the boxes. While effective, the penetration boxes were cumbersome to handle and difficult to align to precise horizontal and vertical coordinates due their 225 kilogram (500 pound) tare weight. The placement of the grout made them heavier, even harder to nudge into final position, and created a low-traction safety hazard around the boxes.

The Phase 2 design opted for a cast-in-place concrete block at each pipe penetration to ensure stability of the pipes (Figure 3). Each dual-walled pipe (one LDS, one LCS, and one redundant LCS in each cell) was fitted with a pipe sleeve/collar constructed of 2.5-cm (1-inch) HDPE

flatstock and 30-cm (12-inch) HDPE pipe. The flatstock was shop-welded to the 30-cm (12-inch) pipe to ensure that the face of the sleeve appurtenance matched the design 3:1 slope of the face of the berm. Then the 30-cm (12-inch) pipe was field welded to the 25-cm (10-inch) HDPE outer containment leachate pipe. The penetration block was then placed and the concrete finished flush with the HDPE flatstock face and the surrounding clay liner. Fifteen-centimeter (six-inch) wide HDPE channel embeds were set in the face of each concrete block as it was being finished. The LDS penetration blocks had one ring of embeds; the LCS penetration blocks had two rings.

On the LDS blocks, the HDPE secondary geomembrane was extrusion welded to the outer edge of the channel embeds to maintain the integrity of each of the liner systems. A "picture frame" of HDPE geomembrane was welded between the inner edge of the embeds and the flatstock to provide complete coverage across the face of the penetration blocks.

Fig. 3. Leak detection system (LDS) penetration block (top) and leachate collection system (LCS) penetration block (bottom). Details typical for both blocks.

On the LCS blocks, the secondary geomembrane was welded to the outer edge of the outer ring of embeds. The primary HDPE geomembrane then covered the outer embed ring and was welded to the outer edge of the inner embed ring. Another "picture frame" of geomembrane was welded between the inner edge of the inner embed ring and the flatstock around each of the two LCS pipes.

Bentonite Amended Clay Liner Material

The final, and arguably the best, design improvement in Phase 2 was the use of native clay amended with bentonite for construction of the 0.9-m (3-foot)-thick compacted clay liner beneath Cells 3 and 4. Native clays from a local borrow source were used to construct the compacted clay liner beneath Cells 1 and 2 in Phase 1. While this approach met the regulatory standard of 1 x 10^{-7} cm/sec permeability for clay liners, it was not done without some challenges. The moisture-density window for placement was narrow and variability in the clay occasionally led to failure during laboratory permeability testing of Shelby tube samples, even though moisture-density results were within the target window. This resulted in expensive and time-consuming rework of several of the 264 grid-lifts of the clay liner.

WEDC bid the Phase 2 work with a plan to amend a local clay with 3 to 5% bentonite (by weight) to improve the consistency and performance of the clay and eliminate the risk of testing failures and costly rework. Representative clay samples from the borrow area were mixed with various amounts of bentonite to find the optimum ratio, which turned out to be 3%. Laboratory testing indicated that 3% bentonite reduced the unamended permeability by at least half an order of magnitude, while maintaining a reasonable workability. Increasing the bentonite percentage beyond 3% produced only a minimal improvement in permeability but degraded the workability of the material by making it sticky and soft at the target wet-of-optimum moisture contents.

Based on those laboratory results, a Test Pad Plan was developed using a 3% amended clay and a target moisture range of 2 to 8% wet of optimum. A two-lane test pad was specified, with a different piece of equipment constructing each lane. In the end, only one machine qualified to construct the liner. The Caterpillar 563 compactor (cleated drum in front, rubber tires in back) did not qualify. Five of the six Boutwell in-situ permeability tests on the 563 lane did not meet the 1 x 10^{-7} cm/sec standard. Forensic analysis of the test pad indicated that the combination of 13-cm (5-inch) long cleats on the drum and the machine weight were not sufficient to knead the clay into a monolith as it was placed in 20-cm (8-inch) loose lifts. The Caterpillar 815 compactor was the machine qualified to construct the compacted clay liner. The 20-cm (8-inch) long cleats on all four of the 815's wheels and its 27,000-kg (60,000-lb) weight produced in-situ permeabilities that exceeded the laboratory results and were nominally a full order of magnitude better than the 1 x 10^{-7} cm/sec standard.

A pugmill was set up at the borrow site to blend the bentonite with the native clay (Figure 4). The clay was screened through a 10-cm (4-inch) vibrating bar screen and a 2.5-cm x 2.5-cm (1-inch x 1-inch) grate prior to entering the mixing chamber where the bentonite was added. Finished product was stockpiled at the borrow site for transport to EMWMF in dump trucks. This operation produced its own set of lessons learned.

Fig. 4. Bentonite Pugmill at EMWMF Borrow Source.

Initially, the raw clay was pushed to the input stockpile by a bulldozer then dropped onto the vibrating bar grate by an excavator. Even though the pugmill operation started in May, the clay didn't dry enough between rain events to preclude large clods, which produced a high reject rate from the bar grate. Then, water was added to condition the clay to the target moisture content of 4% wet of optimum as the clay entered the mixing chamber. The mixture of wet clay and bentonite powder plugged the mixing chamber at an intolerable frequency.

The fix was two part: add a piece of equipment and relocate the moisture conditioning of the product. A tractor with a harrow was brought in to continuously disc the clay. The reduction in clod size from this pulverizing action not only improved productivity of the bar grate, it facilitated drying of the clay, which was part of the solution to the other problem. The moisture conditioning process was moved to the belt at the output of the mixing chamber because the drier input clay more readily mixed with the powdered bentonite and did not stick in the mixing chamber. The pugmill produced pellets of amended clay that ranged from pea-sized to nickel-sized. Regular testing of the moisture content of the raw clay and a little trial and error in adjusting the flow rate of the spray heads on the output belt produced a product that was reliably within a percentage or two of the target moisture content.

The workability of the amended clay product was outstanding. The pellets would flow well from the delivery dump trucks without sticking, but quickly merged into a homogenous mass when spread and compacted. A total of 33,000 m^3 (43,000 yd^3) of amended clay was used to construct the 0.9-m (3-foot)-thick compacted clay liner across Cells 3 and 4. From that effort, 43 Shelby tube samples were taken for laboratory permeability testing per ASTM 5084. The mean permeability value from those laboratory tests, with a 70 kilopascal (10-psi) confining pressure, was 1.8 x 10^{-8} cm/sec. Further, the consistency of the amended clay was such that the

permeability test results were all within approximately a quarter of an order of magnitude of this average (Table I). The quality and consistency of the amended clay gave WEDC the confidence to place subsequent grid-lifts over constructed grid-lifts as soon as the moisture-density testing was completed, without having to wait for confirmatory laboratory permeability testing. There was no rework required for any grid-lift due to permeability test failures during clay liner construction.

Table I. Summary of compacted clay liner test results

	Atterberg Limits			% < No. 200 sieve	% > No. 4 sieve	% > 1.9 cm sieve	Percent moisture	Dry density g/cm^3	Perme-ability cm/sec
	LL	PL	PI						
Minimum	59	18	35	67.6	3.3	0	20.3	1.42	8.9E-9
Maximum	82	28	58	89.3	21.5	11.9	29.2	1.64	5.3E-8
Mean	72	24	48	77	10	3	25	1.56	1.8E-8
Standard Deviation.	5.4	2.4	5.1	3.6	3.4	3.8	2.2	0.053	--
Requirements	>30	n/a	>15	>30	<20	<5	n/a	n/a	1.0E-7
Total # tests	37			37	37	37	65	45	43
Required frequency	n/a			n/a			n/a	n/a	1/0.8 ha/lift
Actual frequency	1 per 880 m^3			1 per 880 m^3			1/500 m^3	1/725 m^3	1/0.64 ha/lift

Key
LL = liquid limit   ha = hectare
PL = plastic limit   lift = 20 cm loose thickness; 15 cm compacted thickness
PI = plasticity index

CONCLUSION

Construction of Cells 3 and 4 will be complete by April 2005 and they will be available to start receiving waste by June 2005, just in time for the bow wave of waste as Bechtel Jacobs' accelerated cleanup of the Oak Ridge Reservation kicks into high gear. Preparations are currently being made for the final build-out of the EMWMF. Completion of Cell 5 in FY 2006 will bring the total capacity of EMWMF up to 1.3M m^3 (1.7M yd^3). A key facet of those preparations is the continued evaluation of EMWMF construction and operations for lessons learned that can be turned into design improvements. With the benefit of this commitment to improvement based on lessons learned, the EMWMF will fulfill its role as the key to Bechtel Jacobs' success.