

## **Lessons Learned from the On-Site Disposal Facility at Fernald Closure Project**

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### **ABSTRACT**

The On-Site Disposal Facility (OSDF) at the U.S. Department of Energy's (DOE) Fernald Closure Project near Cincinnati, Ohio is an engineered above-grade waste disposal facility being constructed to permanently store low level radioactive waste (LLRW) and treated mixed LLRW generated during Decommissioning and Demolition (D&D) and soil remediation performed in order to achieve the final land use goal at the site. The OSDF is engineered to store 2.93 million cubic yards of waste derived from the remediation activities. The OSDF is intended to isolate its LLRW from the environment for at least 200 years and for up to 1,000 years to the extent practicable and achievable. Construction of the OSDF started in 1997 and waste placement activities will complete by the middle of April 2006 with the final cover (cap) placement over the last open cell by the end of Spring 2006.

An on-site disposal alternative is considered critical to the success of many large-scale DOE remediation projects throughout the United States. However, for various reasons this cost effective alternative is not readily available in many cases. Over the last ten years Fluor Fernald Inc. has cumulated many valuable lessons learned through the complex engineering, construction, operation, and closure processes of the OSDF. Also in the last several years representatives from other DOE sites, State agencies, as well as foreign government agencies have visited the Fernald site to look for proven experiences and practices, which may be adapted for their sites.

This paper present a summary of the major issues and lessons leaned at the Fernald site related to engineering, construction, operation, and closure processes for the disposal of remediation waste. The purpose of this paper is to share lessons learned and to benefit other projects considering or operating similar on-site disposal facilities from our successful experiences.

### **INTRODUCTION**

Over the last ten years, Fluor Fernald, Inc. has cumulated many valuable lessons learned through the engineering, construction, operation, and closure processes for disposal of remediation waste. These lessons learned are cumulated from the conceptual stage of the project through the final stage of OSDF completion and post closure inspections. During these stages minor issues such as communication and coordination among various functional groups to the complex issues such as day-to-day waste placement and tracking were managed and successful solutions were developed. Lessons learned from these issues helped to: minimize the impact to the environment, increase the long term performance of the OSDF, improve efficiency in construction and operation processes, verify Waste Acceptance Criteria (WAC) at the source and at the OSDF, manage and optimize waste placement conforming to the approved placement requirements, track waste volumes at the source and in the OSDF, lower construction cost, expedite remediation schedule, gain stakeholders' and regulating agencies trust, and achieve success at the OSDF completion. .

The purpose of this paper is to share lessons learned and to benefit other projects considering or operating similar on-site disposal facilities from our successful experiences.

## **BACKGROUND**

The OSDF is an engineered above-grade waste disposal facility for LLRW consists of eight cells with a design capacity of 2.93 million cubic yards and covers approximately 70 acres (ac). Each cell in the OSDF is lined with 5-foot (ft) thick multi-layer double liner system consisted of clay liner, primary and secondary composite geosynthetic liners, leak detection system (LDS), and leachate collection system (LCS). Leachate from LCS and LDS is collected at valve houses and conveyed to the on-site wastewater treatment facility. After each cell is filled to its capacity with the waste generated from the D&D and soil remediation, it is covered with 8.75-ft thick final cover (cap) system consisted of clay liner, geosynthetic liners, drainage layer, biointrusion layer, vegetative layer, topsoil, erosion mat, and vegetation.

**Engineering** process for the OSDF was started in March 1995 and was completed by November 1996. Engineering process included: sitting study, development of functional design requirements, design criteria and waste acceptance criteria (WAC); geotechnical testing and test pad program for the on-site clay liner material; geomembrane liner (GML) leachate compatibility testing; internal and interface shear testing of geosynthetic liners; performance testing of the construction materials; engineering analysis including settlement, slope stability, seismic, flood plain and storm water, and safety analysis; engineering design of the liner and final cover systems, LDS, LCS and valve houses, haul roads, and support facilities; development of the waste placement requirements and waste tracking system; and preparation of the construction drawings, technical specifications, work plans for the construction, operation, construction quality control, and closure; and value engineering, constructability reviews, and regulatory approvals.

**Procurement** process for the support services, installation of the OSDF groundwater monitoring wells and OSDF air monitoring stations, and construction of the support facilities, haul roads, and remediation excavation in the OSDF footprint area and clay borrow area was started in winter 1996 and subcontracts were awarded in early spring 1996. Procurement process for construction of first OSDF cell liner, leachate conveyance system, waste excavation, and waste placement was started in fall 1996 and a subcontract was awarded in spring 1997.

**Construction** of the first OSDF cell liner was completed in December 1997 and waste placement started in late December 1997. From year 1997 to 2001 subcontractors performed the construction of the liners for OSDF Cells 1, 2, and 3, screening of clay material in borrow area, leachate conveyance system and valve houses 1, 2, and 3, waste excavation and placement, and final cover over Cell 1. From spring 2002, Fluor Fernald, Inc. started self-performing the OSDF construction and operation and completed remaining cell liners for cells 4 through 8, valve houses 4 through 8, final covers (caps) for cells 2 through 8, screening of clay material for remaining liners and final covers, waste excavation, concrete crushing, and waste placement.

**Operation** at OSDF started in late December 1997 with waste placement in Cell 1. Operation at OSDF includes: environmental health and safety, WAC verification at the source, waste manifestation and tracking for each waste stream by source, WAC, waste category, and location, transportation to OSDF by dedicated haul, preparation of waste placement optimization plan, tracking of waste placement volumes and schedule for each waste stream by source, WAC, waste category, and placement location, evaluating soil-debris ratio, waste placement, waste stockpiling, and winter waste placement, leachate management including collection, conveyance, treatment, maintenance, and leak detection and leachate monitoring, ground water and air monitoring, and support activities including storm water management, dust control, radiological controls, traffic control, and quality assurance and construction quality control.

Quality assurance and construction quality control included compliance with the site procedures and environmental, construction performance, and operation requirements, performance and conformance testing of the construction materials and construction performance, and periodic observation.

**Closure** process included the OSDF groundwater and leachate monitoring started in late December 1997 and periodic inspections of the completed final covers started in Spring 2000. Periodic final cover inspections are performed beginning of each quarter.

At the end of year 2005, all eight-cell liners were complete, approximately 2.77 million cubic yards of waste placed in the OSDF, and final covers (caps) has been constructed over seven and one-half of the cells. Placement of remaining 160,000 cubic yards of waste forecasted to be complete by early Spring 2006 and final cover over the last open cell is forecasted to be complete by the end of June 2006.

## LESSONS LEARNED

Lessons learned at Fernald on the OSDF project are grouped into four processes. These processes include, Engineering, Construction, Operation, and Closure. Following is the summary of major issues and lessons learned during the each process at the Fernald site:

### Engineering

*Issue # 1: Development of design criteria, design assumptions, engineering analysis, and construction documents*

Success of the OSDF project is benefited by the detail and timely reviews of the design criteria, design assumptions, engineering analysis, and construction documents by the external experts in those fields. From the conceptual stage to the final stage of the project, experienced project staff in engineering, regulatory requirements, health and safety, quality control, procurement construction, and operation of the disposal facilities were assigned to the project. Also, external experts in these areas were selected for periodic reviews from the conceptual stage to the final stage.

*Lesson learned: Assign experienced project staff and external experts from the conceptual stage to final stage of the engineering to perform the detail and timely reviews of the functional design requirements, design criteria, WAC, design assumptions, engineering analysis, and construction documents*

*Issue # 2: Development and Execution of the Waste Acceptance Criteria (WAC)*

Limits for radiological and chemical levels for waste (WAC) to be placed in the disposal facility may be developed based on two approaches. One approach based on the disposal facility-wide average acceptable concentration of constituents of concern (COCs) and other approach based on maximum acceptable concentration of COCs. WAC limits developed on average acceptable concentration may provide option to place waste with higher concentration of COCs but may be difficult to execute and track in the field and also difficult to schedule placement activities. Verifying and maintaining average concentration in the disposal facility may become most difficult and in few cases may require to place non-contaminated "clean" material to meet the average concentration. Placement of "clean" material and construction delays may add significant cost and could slow down the remediation schedule. WAC limits developed on maximum acceptable concentration may require waste volume above the maximum acceptable concentration to be shipped off-site but execution and tracking in the field is easier and will have minimum impact on the placement schedule and cost. This approach will not require placement of the "clean" material in the disposal facility and will support the faster remediation process.

At the Fernald site, a balanced approach was selected and the maximum acceptable concentration for COCs was developed for the OSDF waste acceptance criteria. Lessons learned at Fernald and other facilities will provide additional approach to solve these issues.

*Lesson Learned: In process of developing the WAC approach for the waste placement, consider how the WAC will be monitored and tracked in the field and its impact on the construction, operation, remediation schedule, and cost. Develop WAC based on both approaches and estimate the difference in waste quantity that may require shipping off-site and its cost, difference in operational costs, and impact on remediation schedules. These differences and schedule impact along with other evaluating criteria may help in selecting the WAC approach.*

*Issue #3: Engineering and construction tolerances in the engineering design and technical specification requirements.*

Engineering design and analysis were performed based on the project design criteria and best engineering practices. Based on the engineering design and analysis technical requirements were selected and indicated on the construction drawings, specified in the technical specifications, and incorporated in the construction, operation, and closure work plans. Construction tolerances for engineering requirements were included in these documents.

During the construction and operation processes it was noticed that additional tolerances are needed for few construction requirements and few construction tolerances need to be revised based on the field conditions. Difficulties were experienced in adding and revising the tolerances in the approved documents. Proposed additions and revisions to the approved tolerances created negative perception by the regulators though these proposed tolerance were within the design criteria, met or exceeded the engineering requirements, and had no impact on the safety analysis, performance of the OSDF, and environment and human health.

*Lesson learned: Provide flexibility in the engineering requirements indicated on the drawing, specified in technical specifications, and described in the work plans. Document engineering tolerances in the design documents including design criteria, design assumptions, engineering design and analysis, and other engineering documents submitted to the regulating agencies for their approval. This approach will minimize change orders and non-compliance reports (NCRs), and avoid negative perception by the regulators and stakeholders.*

*Issue #4: Compaction and related quality control performance requirements for construction of Clay liner*

In year 1997, a major difficulty was experienced to meet the compaction requirements for the construction of clay liner in OSDF Cell 1. Compaction criteria including density, upper and lower moisture content limits, and related quality control conformance requirements for the construction of the clay liner were developed and specified based on the results from geotechnical investigation of the borrow area and the clay liner test pad program. Technical specifications required compaction within the moisture content limits of the "Acceptable Permeability Zone" (APZ). A typical APZ curve was developed for the clay material from the on-site borrow area. However, available on-site clay material is from the glacial till deposits and extremely variable in clay content and specific gravity. Though the available clay material met the requirements for the clay liner material in terms of soil classification, Atterberg limits, grain size distribution, and clay content, clay material with variable clay content did not meet the moisture content limits on the typical APZ curve developed for the borrow area clay material.

To prevent the compaction difficulties from recurring, clay material from the on-site borrow area was excavated, screened, and stockpiled in smaller stockpiles (each 10,000 cubic yards or less) and tested approximately two to three months ahead of its use in the clay liner or clay cap. Soil classification, Atterberg limits, grain size distribution, hydrometer analysis, and hydraulic conductivity tests were performed for each clay material stockpile and the APZ curves were developed for each stockpile. Compaction, moisture content, and related quality control performance requirements in the technical specifications and work plans were revised accordingly.

*Lesson learned: Verify variability in the clay material, particularly in glacial till material and accordingly developed and specify the compaction and quality control performance requirements.*

## **Construction**

### *Issue# 1: Self-performance of the OSDF construction and operation*

From year 1997 to 2001, subcontractors performed the construction of the liner systems for OSDF Cells 1, 2, and 3, final cover system over Cell 1, and waste excavation.

In winter 2001, self-performance option for the OSDF construction and operation was evaluated in support of the accelerated remediation schedule. Factors such as scope, procurement schedule, available construction manpower support and needs, construction management, equipment, safety, quality control, construction schedule, construction cost, and impact cost were compared and evaluated for the subcontracting and self-performance options. This comparison and evaluation showed that the self-performance of OSDF construction and operation will be beneficial to the client, will support the accelerated construction schedule, save construction cost, minimize impact cost, and improve safety and quality.

In year 2002, Fluor Fernald, Inc. successfully self-performed OSDF liner construction, waste excavation, concrete crushing, and waste placement. After this success Fluor Fernald Inc. continued the construction of remaining five cell liners, screening of clay material (over 620,000 cubic yards), five valve houses, and seven final covers (caps), waste excavation (over 1.9 million cubic yards), concrete crushing (over 140,000 cubic yards) and waste placement (over 2.2 million cubic yards).

Self-performance of the OSDF construction and operation improved safety, quality, and schedule significantly and lowered the construction cost. During the self-performance of construction and operation construction duration for the liner and final cover was reduced by 6 to 8 weeks each and waste placement volume was increased from 227,000 cubic yards per year to 905,000 cubic yards per year. Similar increase was noted in the waste excavation. Considering the weather constrains (rain, snow, and cold temperatures) and seasonal schedule limitations, the reduction in the construction duration for cell liners and final covers and yearly increase in waste placement quantity is very significant.

*Lesson Learned: Evaluate the self-performed option for construction and operation of the disposal facility. In cases, where this option is feasible, self-performed construction will improve the safety and quality, save construction cost, minimize impact cost, and support accelerated remediation schedule. .*

### *Issue # 2: Acceleration Techniques for procurement, installation and quality control testing of the geomembrane liners (GMLs)*

To support the accelerated remediation schedule including the construction of the liner and final cover systems, the following accelerated techniques were performed during the procurement, installation, and quality control testing of the GMLs:

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1. **Procurement:** GML and geosynthetic clay liner (GCL) manufacturers were qualified during the engineering process based on the GML compatibility testing and internal and interface shear testing. GML and GCL from over five manufacturers were evaluated for the OSDF engineering performance criteria. Prequalification of the manufacturer and pretesting of the GCL and GML expedited the procurement of the vendors, approval of the GML and GCL submittals, and manufacturing and delivery of GML and GCL. Similar approach was selected for procurement of other construction material in the cell liner and final cover systems.
1. **Installation:** To further verify quality of the installed GML leak detection testing was performed on the completed primary GML in the liner system and the final cover system. This testing provided additional quality control and gain regulators and stakeholders' additional trust regarding the long-term performance of the liner and final cover system.
2. **Quality Control Testing:** To accelerate the acceptance of the completed GML and remaining layers in the final cover system, an on-site GML laboratory accredited by the Geosynthetic Accreditation Institute (GAI) was set to test the geomembrane seams (ASTM D6392 Modified). This on-site laboratory tested the time sensitive seam samples including the retests for the failed seam samples. On-site seam testing eliminated the wait for the GML seam test results particularly wait for the retest of failed seams, avoided the delays for GML installation, and reduced the duration and cost for the final cover construction.

*Lesson Learned: Pretesting of the GCL and GML liner for the engineering performance criteria and prequalification of the acceptable manufacturers for those criteria will save significant time for the procurement, approval of the submittals, and manufacturing and delivery.*

*Similar approach for procurement of other construction material in the cell liner and final cover systems will save significant time for the procurement, approval of the submittals, and manufacturing and delivery.*

*Leak detection testing of the completed GML provides additional quality control and may gain stakeholders and regulators trust.*

*Certified on-site laboratory for the GML seam testing provides cost effective alternate to support schedule acceleration.*

## **Operation**

### *Issue #1: Waste Acceptance Organization*

In addition to the routine construction quality assurance/quality control function, Fluor Fernald Inc. formed an independent oversight organization known as the Waste Acceptance Organization (WAO) that is responsible for observing excavation, implementing waste manifesting system used to track waste from excavation/D&D to the OSDF, verification of WAC, and categorizing each truck load of waste sent to OSDF.

OSDF waste placement requirements are prepared based on the waste categories described in the OSDF waste placement plan. Waste meeting the WAC for the OSDF placement purposes is grouped into five categories. These waste categories are: Category (Cat) 1 - soil or soil like material, Cat 2 - D & D debris such as broken concrete and metals smaller than 10-ft square and 18-inch thick, Cat 3 – Transite panels, mass concrete foundations meeting OSDF physical WAC, Cat 4 – organic waste such as solid waste, green waste, and Cat 5 – waste that needs special handling. Approximately 75-percent waste to be placed in OSDF is Cat 1, 15-percent Cat 2, and remaining 10-percent Cat 3, Cat 4, and Cat 5.

*Lesson learned: WAO for monitoring and tracking waste at the source and at the OSDF worked efficiently as an independent oversight organization and added value to the waste management program and helped Fernald project to gain stakeholders and regulating agencies trust regarding full compliance of the regulatory requirements.*

*Issue # 2: Optimization of waste placement, placement tracking, and compliance with waste placement requirements*

In late 1998, a waste placement optimization plan was prepared to support the year 1999 waste placement schedule. In year 1999, limited soil (Cat 1) quantity was forecasted compare to the D & D debris (Cat 2). Soil was also needed for protective and select layers over the cell 2 liner before the start of debris placement, intervening layers over the debris placement, and select layer under the cell 1 final cover. A waste placement optimization Plan was prepared to meet these soil needs and to support the construction schedule for the placement of the forecasted D & D debris volume with minimum soil-debris ratio. Waste placement optimization plan along with waste placement tracking helped to meet soil need for protective, select and intervening layers, optimize the D & D debris volume, and avoid left over of soil quantity without debris placement. For daily placement tracking, a computer model for waste placement with placement constraints (placement compliance requirements) was developed. In this computer model each grid is tracked daily by the location, waste category, source and layer/horizon thickness. Waste placement optimization plan and tracking daily placement in the computer model optimized OSDF placement capacity, minimized the soil-debris ratio, and also helped in identifying any non-compliance with the waste placement requirements.

After the success of the waste placement optimization plan in year 1999, this plan was prepared every year, ahead of the start of waste placement, to optimize the waste placement in OSDF.

In the beginning of waste placement, staging and stockpiling of waste (soil, D & D debris) outside the OSDF was not approved. When the limited soil volume was available and D & D debris was generated it was necessary to stage the debris out side the OSDF. Approval of debris and soil staging outside the OSDF helped to optimize the waste placement and improve the remediation schedule.

Similar to year 1999, shortage of soil (Cat 1) quantity was also forecasted in years 2002 and 2003. With on-site D & D operation at peak level, more D & D debris quantity was generated and limited soil was available. To optimize the placement of D & D debris in years 2002 and 2003, D & D concrete was crushed to produce the additional Cat 1 material (soil or soil like material) Approximately 140,000 cubic yards of Cat 1 material was produced by concrete crushing operation.

*Lesson learned: Prepare the waste placement optimization plan at the beginning of each year for the forecasted waste volume based on the soil needs for the protective, select, and intervening layers, placement of D & D debris and other category of waste, waste placement requirements, and waste placement schedule.*

*Develop a computer model for the waste placement based on the placement requirements (constraints). Daily track the waste placement in this computer model and identify any waste placement non-compliance.*

*Perform waste placement in accordance with the waste placement optimization plan. During placement, track the placement by location (grid), waste category, and source. Revise optimization plan when there is any change in schedule and/or waste category volume.*

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*Waste placement optimization plan and daily placement tracking optimizes the OSDF placement capacity, minimizes the soil-debris ration, and also helps to identify any non-compliance with the waste placement requirements.*

*During the shortage of soil (Cat 1) quantity consider concrete (Cat 2) crushing to produce the soil like material required to place the D & D debris or similar type of waste. This will help to accelerate the remediation schedule, optimize waste placement, and save disposal facility capacity. Staging of D & D debris will also help to optimize waste placement.*

Issue # 3: Waste volume estimate

Total volume of waste includes D & D and soil volumes to be placed in OSDF and volume of waste exceeding the OSDF WAC requirements (above WAC volume) to be shipped off-site, These volumes were first estimated based on the Remedial Investigation/Feasibility (2.45 million cubic yards).

During the OSDF engineering process the waste placement plan and WAC attainment plan were developed and waste was categorized in five categories. Based on the preliminary WAC attainment plan waste volume was re-estimated using the preliminary characterization data and revised D & D quantity (waste volume 2.80 million cubic yards). The OSDF was designed for 2.86 million cubic yards, which included 50,000 cubic yards of "buffer capacity".

By year 2002 excavation remediation plans for production area and half of the surrounding area were complete and half of the production area was excavated. At this stage remaining total waste placement volume and volume for each category of waste was re-estimated (waste volume 2.85 million cubic yards). From the re-estimate it was noted that above WAC volume has increased substantially, volumes for some of the surrounding subareas are decreased, but overall waste volume to be placed in OSDF is increased because of "additional FRL excavation" [remediation excavation beyond the design excavation limits to meet the final remediation levels (FRL)] in the production area and in few cases because of lack of excavation controls. To accommodate the growth in the waste placement volume, cell 8 was resized in year 2002 and OSDF capacity was increased to 2.93 million cubic yards with 70, 000 cubic yards "buffer capacity".

From year 2002 through year 2005 remaining characterization and excavation remediation plans for surrounding areas were complete. At the end of summer 2005 approximately 80-percent excavation was complete in production area and in the surrounding area except the "additional FRL excavation" in waste pits and part of the production area. It was noted from field surveys noted that the "additional FRL excavation" process has added over 40,000 cubic yard of the waste placement volume and reduced the "buffer capacity".

As on January 2006, based on the forecasted excavation volume approximately 20,000 cubic yard "buffer capacity" is forecasted in the OSDF.

Lessons learned: *Following is the summary of lessons learned in estimating waste volumes:*

*1. As much as possible collect the critical characterization data and establish the remedial excavation limits before the excavation remediation plans are finalized. This will help to estimate waste excavation volume more accurately.*

*2. Include "additional FRL excavation" volumes in the waste volume estimate. Based on the process knowledge and characterization data include additional volumes for the "additional FRL excavation" and above WAC excavation in the waste volume estimate for the area such as waste pits and main process area.*



*3. Establish survey field controls in excavation areas before start of the excavation. Track excavation based on weekly field surveys. Control excavation beyond the design excavation limits.*

*4. Characterize the overburden soil in the utility corridors in the surrounding areas. In most cases overburden soil excluding top 6 to 12-inch may be "clean" and can substantially reduce the waste volume.*

*5. Though the overall growth in the OSDF design capacity is less than 3-percent (from 2.85 to 2.93 million cubic yards) allow 10-percent buffer capacity in the disposal facility design. If the available characterization data is in-complete or insufficient to establish the excavation limits, increase the buffer capacity to higher percentage.*

*6. In estimating D & D volumes account for all the miscellaneous structures and temporary structures that will be to placed in the disposal facility. Allow 5 to 10-percent of D & D volume for the miscellaneous structures. If the "as-built" information is not available, increase this percentage for the "unknowns".*

## **Closure**

### Issue # 1: Periodic OSDF Inspections

To monitor the performance of the disposal facility periodic inspections of the completed OSDF cells are performed as per the OSDF Post Closure Plan. Currently representatives from DOE, Ohio Environmental Protection Agency (OEPA), U.S. Environmental Protection Agency (USEPA), and Fluor Fernald, Inc. perform these periodic inspections. To facilitate these inspections and to evaluate the performance of the OSDF a checklist was developed identifying the items needed to evaluate the performance of the OSDF and acceptance requirements for each item. Items to be evaluated are selected based on OSDF Design Criteria Package, engineering documents, and post closure plan. This checklist is developed considering the past and current information needed from these inspections to evaluate the OSDF performance and if required, to correct any non-performance at OSDF. For example, to evaluate the performance of the final cover system (cap), checklist includes items and acceptance criteria for the erosion, settlement, slopes, vegetation and other similar inspection items.

Lesson Learned: *Develop the inspection checklist for periodic inspection of the disposal facility for the items needed to evaluate performance of the disposal facility. Acceptance requirements for these items and items noted in the post closure plan should be included in the checklist for ready reference.*

## **CONCLUSION**

The issues presented in this paper are typical at most of the disposal facilities within the DOE complex. Solutions to solve these issues at every facility could be unique. Lessons learned at Fernald and other facilities will provide additional approaches to solve these issues at other sites. These lessons learned need to be shared and discussed to further improve the performance of current and future disposal facilities.

Sharing of the lessons learned will promote improving the current processes and developing the new approaches for construction and operation of similar disposal facilities which will provide additional environmental protection, support the DOE's mission of accelerated site cleanup, and save money for taxpayers.