REMEDIATION OF A FORMER LOW-LEVEL LANDFILL (WASTE MANAGEMENT AREA C) AT CHALK RIVER LABORATORIES

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Abstract

Waste Management Area C is a 4-hectare landfill-type facility at Chalk River Laboratories that operated for 43 years, receiving a large variety of low-level radioactive wastes and non-radioactive wastes. Since these wastes were emplaced directly into sand trenches and pits, infiltration of precipitation over time led to the development of groundwater plumes that carried primarily tritium to nearby swamps. An experimental polyethylene cover installed in 1983 over an area of filled sand trenches led to a sharp reduction in groundwater tritium downgradient of the area. In 2010, detailed design was therefore undertaken for a multi-layered low-permeability 100-year engineered cover over the entire facility. Close collaboration was needed between the owner, the designer, and the construction contractor to overcome difficulties during installation in 2013. This paper focuses on the technical challenges in mitigating hazards at the closed facility, and the collaboration that was needed to achieve this mitigation.

1. Introduction

Waste Management Area C (WMA C) is a 4-hectare near-surface landfill-type facility at Chalk River Laboratories (CRL) that operated between 1963 and 2006. WMA C received a large variety of low-level radioactive wastes (generally with hazardous lifetimes <150 years in terms of half-life and activity) from CRL operations and from medical, biological and other nuclear research activities in Canada. WMA C also received non-radioactive wastes in the form of asbestos, sewage, biological waste (e.g., animal carcasses), organic compounds (e.g., chlorinated solvents) and heavy metals. The facility consists of 28 unlined sand trenches, 2 large unlined sand pits, 12 special burials and 5 chemical pits. Figure 1 shows WMA C during the filling in 1982 of the north sand pit.

Since wastes were emplaced directly into the sand, as bulk materials or with minimal packaging, infiltration of precipitation and snow melt over time led to development of groundwater plumes that carried primarily tritium to nearby swamps (Figure 2 and Figure 3). When operations at WMA C ceased in 2006, the intent to install an impermeable cover was included in the package for license renewal. This was in large part based on the success of an experimental polyethylene cover that had been installed in 1983 over an 8000 m^2 area of filled sand trenches (shown as a green rectangle in Figure 2). This polyethylene cover led to a sharp reduction in groundwater tritium downgradient of the area.

Figure 1   Aerial view of WMA C during operation in 1982

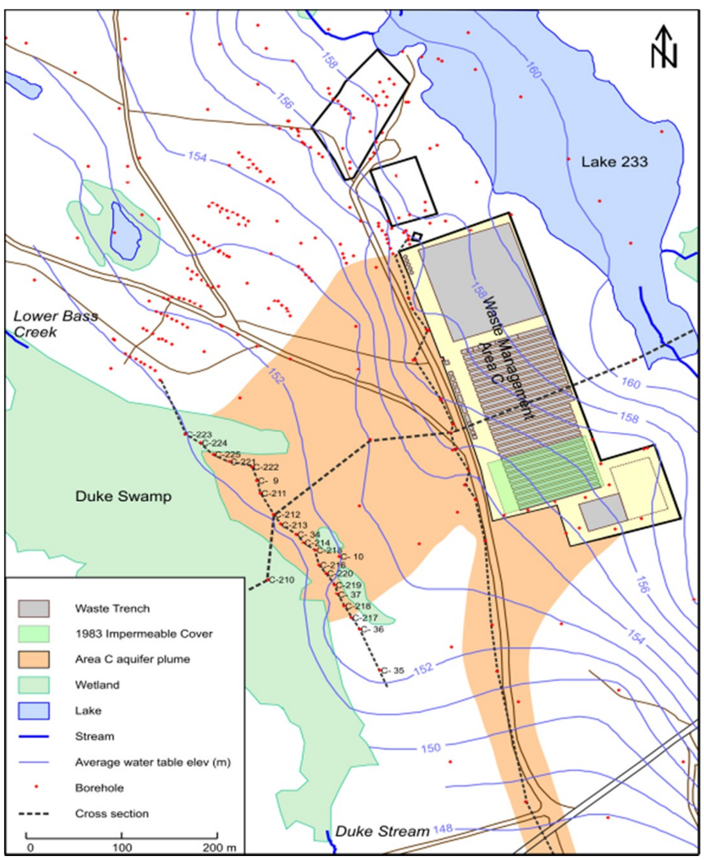

Figure 2   Map of WMA C showing contaminant plumes

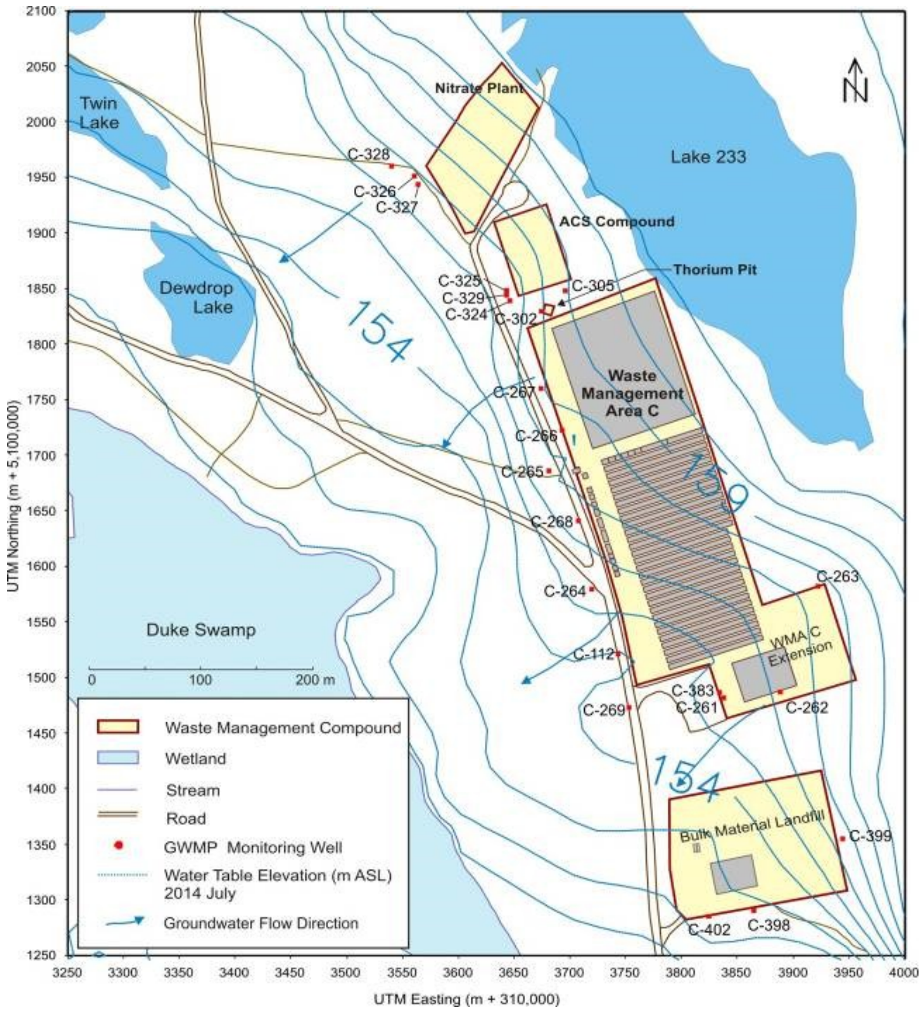

Figure 3 Map of WMA C showing groundwater monitoring wells

2. Design of engineered cover

WMA C had been under-engineered by modern standards for a near-surface radioactive waste disposal facility [1], with no groundwater protection barriers (e.g., liner or leachate collection system). Also, most wastes had been emplaced without packaging or containers that would assist retrieval. Analyses of downgradient groundwater samples showed that, while the tritium concentrations were typically less than the ecological effects concentration (1×10^7 Bq/L, the 2000 DOE benchmark for tritium in water), they were significantly greater than the current Canadian guideline maximum acceptable concentration in drinking water (7×10^3 Bq/L).

In 2010, Atomic Energy of Canada Ltd (now known as Canadian Nuclear Laboratories, CNL) launched a multi-year project to install an engineered cover at WMA C. The objectives were to limit the infiltration of surface water, reduce the subsequent transfer of contaminants into the environment, and isolate the buried waste from surface disturbances (such as erosion or burrowing animals).

A conceptual design for a 50-year engineered cover was prepared in 2003 by Jacques Whitford Environment Ltd. The proposed cover would be graded (contoured) to rise above the existing ground surface to facilitate surface drainage. The design incorporated an impermeable geomembrane layer to minimize water infiltration. A drainage system would be required to collect the surface water runoff from WMA C.

Analyses demonstrated that an engineered barrier with a lifetime of 100 years would allow a large percent of the tritium, Co-60, Cs-137, and short-lived radionuclides to decay while immobilized within the facility. Golder Associates Ltd provided the detailed design in 2011 for a multi-layered impermeable 100-year engineered cover (Figure 4). As with the preliminary design, the detailed design called for the shaping of fill to a slight mound, and drainage ditches around the perimeter to promote runoff toward two drain pits. The drainage ditches were to be excavated from the existing 1-m thick cover soil.

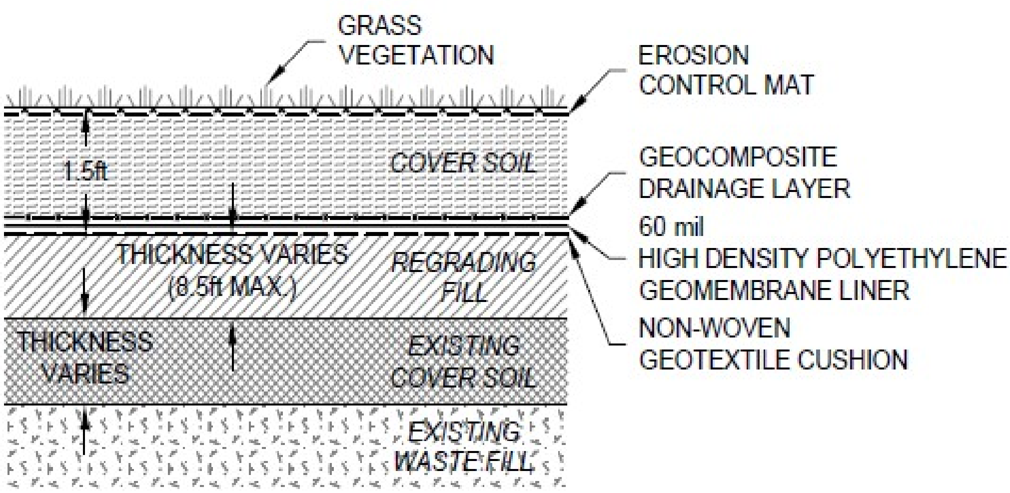

Figure 4 Engineered cover layers (design by Golder Associates, 2011)

3. Field preparations

3.1 Removal of surface-stored items

After the facility at WMA C ceased operations, temporary storage of contaminated items on the surface at WMA C (right side of Figure 5) was permitted under the facility authorization.

The first preparation for the engineered cover was the removal of surface-stored items, starting in 2009 with drums and containers (upper right in Figure 5). More than 2,000 drums needed to be dispositioned. Most drums were transferred to other CRL waste management areas for storage, with the contents of some drums repacked into compaction bins prior to transfer. An external contractor was engaged for offsite disposition of 241 empty contaminated drums and 4 contaminated sealand containers.

Figure 5 Aerial view of WMA C in 2007, after closure

WMA C had also served to store bulk soil excavated from the Controlled Area at CRL that was either suspect or had very low levels of contamination. With approval from the Canadian Nuclear Safety Commission (CNSC), this soil could be added to WMA C as fill for cover construction. The soil pile was carefully spread in 2012 following the rough fill contours called for in the design (Figure 6).

Early 2013 saw the removal of remaining rogue waste items from the surface: pieces of contaminated concrete and metal, drums of contaminated soil, and a small shed. The shed needed careful dismantling as it presented a mix of hazards: radiological (including alpha contamination), biological (rodent feces), and industrial (asbestos siding and leaded paint).

Figure 6 Preparations: spreading of suspect soil (left), relocation of NRX stack pieces (right)

Finally, 21 cut sections of the ventilation stack from the former NRX reactor (center right in Figure 5) were relocated to another waste management area. Loose contamination found falling from the stack pieces during initial attempts led to the packaging of each piece in a large custom-made overpack sack. The stack pieces were repackaged and relocated (Figure 6) shortly after the contractor arrived in 2013 June to start regrading the surface for the cover.

3.2 Surveys

Geophysics GPR International Inc was engaged in 2012 carry out a geophysical survey of WMA C using conductivity meters and ground-penetrating radar, to give information on the nature and location of the waste buried at the site. Figure 7 qualitatively indicates the waste locations. (The large soil pile and the excavated sand pit were not surveyed and show as white areas in the figure.) Some areas of thin cover soil were identified in this survey, but these areas appeared to be limited and manageable.

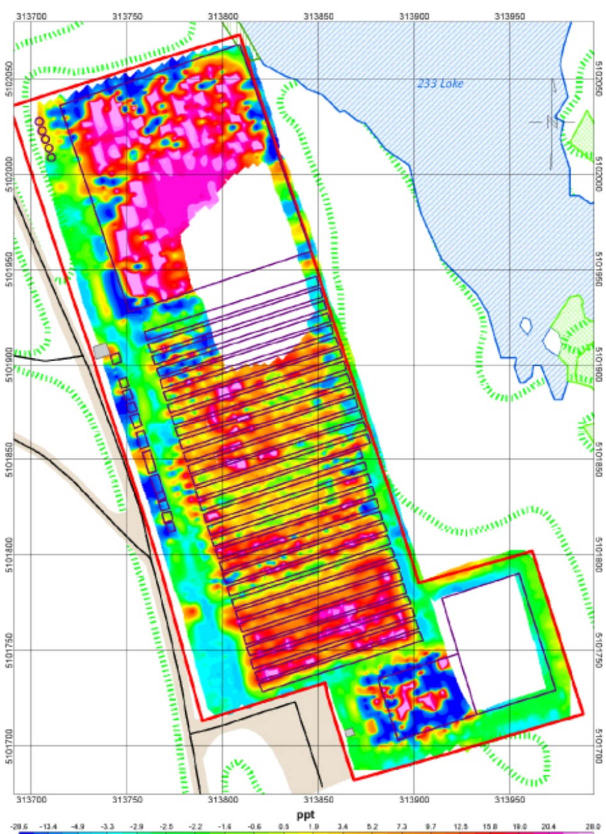

Figure 7 Results of geophysical survey (EM31 data, in-phase component)

Nuvia Ltd was engaged in early 2013 to perform radiological walk-over surveys of several waste management areas including WMA C. In the case of WMA C, the objective of this survey was to identify contaminated areas and help with planning for worker protection during the installation of the cover. The maps in Figure 8 show qualitatively the gamma radiation fields from the NRX stack pieces (center of WMA C) and beta contamination in vegetation (NW corner) prior to cover installation.

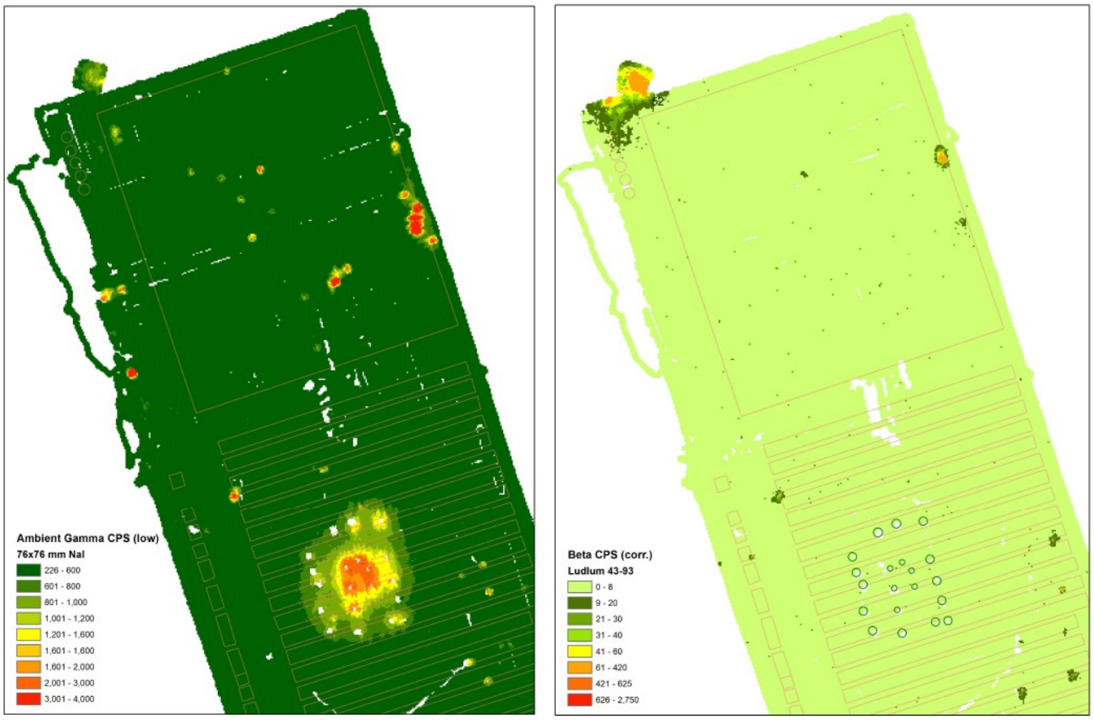

Figure 8 Results of radiological survey: ambient gamma (left), beta contamination (right)

4. Cover installation

4.1 Contracting

The contract to construct the engineered cover as per design was awarded to M. Sullivan & Son from Arnprior, Ontario. Installation of the geomembrane and associated layers was subcontracted to Terrafix, a firm specializing in such installations; hydroseeding and fence replacement were subcontracted to local firms. Golder Associates served as the Engineer of Record, performing inspections and addressing design deviations. Work started in 2013 late June and was completed 4.5 months later in November. The construction project involved $2.9 M worth of contracts.

4.2 Challenges

Close collaboration was needed with the designer (Golder Associates) and construction contractor (M. Sullivan & Son Ltd) to overcome difficulties.

The first difficulty was an underestimation in the volume of additional fill needed to achieve the design grades. This appeared in early 2013 as a discrepancy between the volume calculated based on an older topographical survey (~400 m^3) and the volume calculated based on a more recent survey (~3500 m^3); the cause was likely waste compression during spreading of the soil pile. The issue was resolved with a change order to Sullivan to import more fill.

A more disruptive surprise was the discovery that the original cover soil over the buried wastes was much less than the assumed 1 m, likely due to erosion. Within one week of starting work, a bulldozer operator regrading the surface cut into a waste package; a strong chlorine smell led to evacuation of workers from the field, and a 1-day stand-down was enforced to understand the problem. Around the same time, waste items were discovered at surface at several other locations (Figure 9).

Figure 9 Plastic waste drum near surface

It became clear that excavation of drainage ditches would breach the waste almost everywhere. A requirement for the remediation from a health and safety perspective was that no waste would be breached or removed. A major re-design of the contours was therefore needed, and quickly because the contractor had already mobilized. Golder Associates revised the design to include shallow drainage swales instead of ditches, as well as increases in elevation everywhere, to minimize cutting for the rough contours and to accommodate the slopes required for adequate water run-off.

With acceptance of this change by stakeholders and another change order to the contractor, Sullivan proceeded to import yet more soil (~11,000 m^3). Ultimately, hard work by the contractor meant that the cover installation was finished – despite the delays – in time for seeding and grass growth before frost. A vital lesson in this was that the assumption of “1 m soil everywhere” should have been verified well in advance of the design, and manually if necessary (as geophysical surveys did not have a high enough resolution to determine cover soil thickness).

Figure 10 shows the various layers of the cover during installation in 2013, and Figure 11 shows the site one year later.

Figure 10 WMA C during cover installation (2013 August)

Figure 11 WMA C one year later (2014 July)

5. Post-installation work

The area has taken several years to stabilize. The first issue presented itself in 2014 April, six months after cover installation. Heavy rains fell before ice in the ground and culverts had thawed, which led to flooding of the drain pits and erosion of areas with gravel and riprap (Figure 12). These areas were repaired in the summer, but with erosion continuing the following year, Golder Associates were engaged to inspect the cover and recommend more substantial repairs. The use of larger riprap and good compaction of repaired road appear to have addressed the erosion issues. The use of heating cables in the culverts to prevent blockage by ice was recommended but has not yet been implemented.

Figure 12 Erosion during wet spring 6 months after installation

Another issue in the first spring following installation was that grass was sparse and slow in growing. The culprit was not poor seeding or winter kill, but local wildlife such as Canada geese that could fly over or crawl under the perimeter fence. The problem resolved itself with the unpalatable white clover (originally only 10% of the seed mixture) taking over the area as shown in Figure 11.

There were difficulties as well with moisture sensors installed at five locations under the geomembrane: the sensors were found to be unreliable even after extensive trouble-shooting. The intention had been to detect water leakage through the membrane due to damage or improper installation, although with only one sensor site per hectare there is high likelihood of missing the leak. A better indicator of cover performance is the impact on groundwater contaminants (see Section 6).

Figure 13 Gate house before and after removal

A final step in the remediation was the removal of the old gate house (Figure 13) in 2015. This shack had been used as a radiological dressing station by workers entering WMA C, but was no longer needed with the cover acting as radiological shield. The planning took more than a year due to the decommissioning process being rigorous even for low-hazard structures. Also, the gate house was methodically dismantled rather than demolished, to avoid the spread of any contamination (which turned out to be minor).

6. Cover performance

Groundwater monitoring wells installed downgradient of WMA C (labelled in Figure 3) allowed the tracking of contaminant plumes, particularly for tritium. The first compelling indication of an impact by the engineered cover was in late 2014, one year after installation. As shown in Figure 14, tritium activity concentrations at some perimeter wells dropped by several orders of magnitude to background levels and well below the drinking water guideline of 7 x 10^3 Bq/L. By 2015, concentrations at the remaining perimeter wells had followed suit.

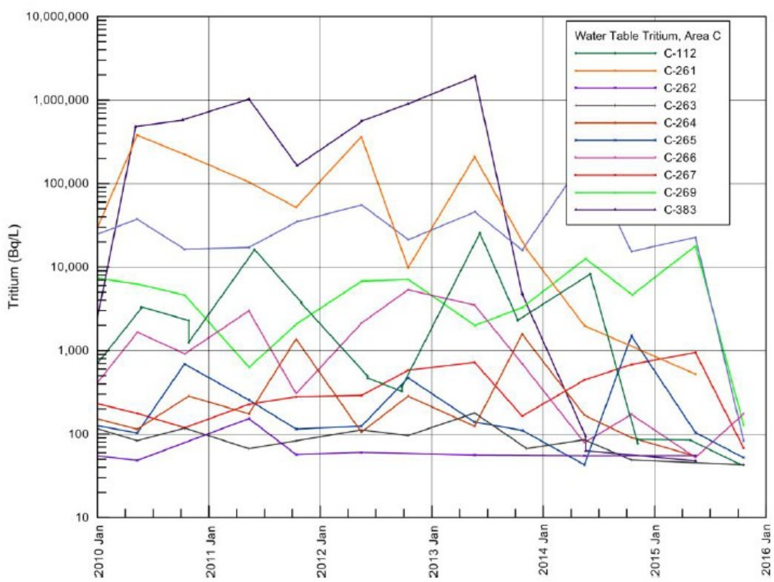

Figure 14 Trends of tritium concentrations in groundwater

A variety of volatile organic compounds (VOCs), the most significant being trichloroethane, have also been observed in groundwater samples. Reductions in VOC concentration have not yet been observed. Although the chlorinated VOCs are not thought to interact strongly with the local silts and sands in the groundwater flow system, there has likely been some retention of these compounds, and decreases will not likely be as dramatic as those of tritium.

The effect of the impermeable cover on groundwater flow direction and gradients at WMA C is not yet apparent. The effect, if any, is masked by seasonal variations of 1 to 2 m in water table elevations, with the highest elevations typically occurring after spring snowmelt and rainfall.

7. Discussion

The remedial work at WMA C is an example of a conventional approach (impermeable cover) applied to an unconventional landfill-type facility (radiological wastes). Several factors contributed to the uniqueness of this project:

1. Highly regulated environment – Besides the federal requirements from Environment Canada and the provincial standards for construction, the project needed to comply with site license requirements from the CNSC from the radiological standpoint. For example, special approvals were needed before soil with very low levels of contamination could be used as fill under the cover, as this constituted an addition of waste to a closed site.

2. Risk of exposures to workers – Strict radiation protection protocols were followed by workers during preparations and cover installation. Workers wore protective clothing while inside the WMA C fenced area, all personnel and equipment were checked for radiological contamination prior to exiting, and a crew of Radiation Protection personnel monitored all activities, especially digging.

3. No disturbance of the waste – With a high risk of contamination spread if waste were to be exposed, disturbance of the waste was to be avoided at all costs. This led to a major re-design of the cover when it was discovered that the original cover soil was much thinner than anticipated and excavation of drainage ditch would breach the waste trenches and pits.

No major health or safety effects were experienced during this project, thanks to good work control and adherence to safety principles. Without strong collaboration between owner, designer, and contractor, the project would have certainly been derailed by difficulties in the field. Other important collaborations were internal to CNL: for example, environmental monitoring experts provided groundwater data, radiation protection experts kept workers safe from exposures, and waste management experts handled the unique surface waste items.

Analyses of the long-term safety of WMA C are currently underway at CRL to support a decommissioning strategy of in-situ disposal: leaving buried wastes in their current location. This is an effort to understand the liability of the facility after the 100-year engineered cover is beyond design life, when long-lived radionuclides and non-radiological chemical species are still present. In the interim, the site is under monitoring and surveillance as part of institutional care.

8. References

[1] International Atomic Energy Agency, “Disposal of Radioactive Waste”, IAEA Safety Standards Series No. SSR-5, 2011 (formerly WS-R-1, 1999).