Lessons from the Bevatron Accelerator Demolition – 12191

Joseph Harkins*, Robert Cronin**
* Lawrence Berkeley National Laboratory, Berkeley, California, 94720
**CH2M HILL, Englewood, Colorado, 80112

ABSTRACT

The Bevatron accelerator at Lawrence Berkeley National Laboratory is the first DOE accelerator to be demolished. While there are many lessons learned from its demolition, this paper focuses on the following lessons learned that may be useful for other D&D projects: bounding project scope to ensure success, hazards mapping for focused characterization and remediation, establishing radiological evaluation criteria, and forecasting activation products.

INTRODUCTION

As many of the accelerators that were constructed by the DOE in the 50's and 60's are now reaching the end of their useful lives, it is likely that the DOE will begin to shutdown, decontaminate and demolish these accelerators in the near future. The Bevatron accelerator, built at Lawrence Berkeley National Laboratory in the early 1950's, is the first major DOE accelerator to be demolished. The demolition project was started in 2006 and will complete in December 2011. While there were many lessons learned during the planning and execution of this project, four lessons learned are presented that may be useful for other D&D projects: bounding project scope to ensure success, hazards mapping for focused characterization and remediation, radiological evaluation criteria, forecasting activation products.

LESSON LEARNED #1: BOUND THE PROJECT FOR SUCCESS

On the Bevatron Project, the scope was defined very carefully to make sure that the project could successfully complete the required objectives within the budget and schedule requirements. There were significant areas of the site where the under building contamination could not be properly characterized during the planning stage since these areas were underneath the accelerator and associated shielding blocks. As such there was significant risk that additional contamination could be found and that the project would not achieve its commitments if a clean up level was set as a project requirement in these areas. Also, if the project requirements were defined too conservatively it would not be allowable to use project funds to accomplish additional clean up should contingency be available.

The DOE G 413.3-5A, U.S. Department of Energy Performance Baseline Guide [1], provided an opportunity to define the project requirements to more easily be achieved yet still allow use of contingency for additional clean up, if required. The Guide provides the following definition, "The objective value is the desired performance, scope, cost, or schedule that the completed asset should achieve, whereas the threshold value is more conservative representing the minimum acceptable performance, scope, cost, or schedule that an asset must achieve."

For the Bevatron project, the threshold value of soil clean up was defined by an anticipated quantity of contaminated soil to be abated. A clean up level was provided for an "objective value" to allow the project to proceed with additional clean up should budget and time contingency be available. These Key Performance Parameters were defined in the Project

Execution Plan and accepted by the DOE. The threshold value of soil clean up was included in the contractor's fixed price scope and a unit price was also bid should the quantities be different than assumed. This careful definition of the project scope increased the likelihood that the project would achieve its required scope.

LESSON LEARNED #2: HAZARDS MAPPING

One of the biggest risks in a D&D project is the discovery of unforeseen contamination. Some facilities that have been in operation for more than 50 years can have a significant history that can help identify areas where currently unforeseen contamination could likely be found during demolition. On the Bevatron Project a novel approach was used to document the likelihood of building contamination, it is called hazards mapping.

The activities conducted in preparing a hazards map included collection of historical documents and interviews with current and former personnel that had worked in the facility, The historical document survey includes Fire Department Run Reports, Occurrence reports, Chemical Inventories, Spill reports, Lessons Learned, Radiological Surveys, Asbestos and Lead Inspection Reports and Photographic Databases. Interviews included those involved with the construction and operation over the life of the facility. Interviews were conducted with scientists, engineers and operators that had worked at the Bevatron and craft workers that had modified and maintained the facility. In terms of the accelerator operations, it was important to understand the operating modes might have generated contamination. The interviews and document reviews helped determine if there were any accidents that might have left residual contamination.

Pertinent information was included on Hazards Maps, which are plans of the facility with areas of suspected contamination listed on a per room basis along with the source of the information. These Hazards Maps were provided to the characterization consultant to bias their investigations. The Hazards Maps were also provided to the demolition contractor to inform their own characterization demolition efforts. An example of a Hazards Map is shown in Figure 1.

Fig. 1 Example Hazards Map

LESSON LEARNED #3: RADIOLOGICAL EVALUATION CRITERIA

The Bevatron operated from 1954 to 1993. The Bevatron primarily accelerated protons (6.2 GeV) in its early years and switched to heavy ions in its later years (mid-1960s) including 238U (2.1 GeV/amu). The concrete shielding and foundations and the metals that made up the accelerator were affected. The activation of materials occurred mainly prior to 1974, thus more than 30 years had passed before demolition of the accelerator and its shielding began; only the long-lived isotopes were of concern.

Potential for surface contamination existed, primarily from depleted uranium (sputtering from beam stops), broken targets, and leaking sealed sources. However, very few items were found to have levels of surface contamination above DOE-established release limits.

Earlier work had predicted the depths of activation within concrete. Its conclusions included activation would be essentially uniform from the surface of the concrete to 16 cm (6.5 inches)and at 91 cm (36 inches) the activation would drop by a factor of 200. The conclusions showed good correlation to the results from Princeton-Pennsylvania Accelerator concrete analysis. [2]

The accelerator shielding was comprised primarily of two layers of concrete wall blocks around the outside its perimeter and two layers of concrete roof blocks above top of accelerator. Shield block removal occurred in several phases, each phase using slightly different release criteria and methods. At each phase the release criteria and process was reviewed and accepted within the LBNL radiological protection organization. The early block removal process occurred during demolition of the Bevatron external particle beam hall from 2002-2004. Over 1000 blocks from the external particle beam hall were characterized; approximately one third of the blocks were disposed of as radioactive waste.

In early 2004, about 75 of the upper-tier roof blocks were removed. The early characterization process used on the external particle beam hall blocks was found to be too long and labor intensive. An updated process was developed to survey blocks using a hand-held NaI instrument with an MDC of 1 pCi/g. DOE approved the process and block disposition became a go/no go process. If a block failed the NaI survey process, then further analysis would be made. Approximately one dozen blocks failed the go/no go survey, but were released following further analysis by in situ gamma-ray spectroscopy.

In 2006, after the above efforts, but before the removal of the remaining blocks and accelerator demolition, a reconnaissance-level characterization effort was undertaken. There were 318 in field survey measurements of concrete, plus 47 core samples collected and analyzed. Following the LBNL protocols that had been previously reviewed and approved by the DOE, the characterization effort used an MDC of 2 pCi/g to determine the bounds of concrete activation. The reconnaissance-level characterization concluded that activation products were present in few of the accelerator shield blocks and only in select areas, less than one quarter, of the accelerator foundation concrete.

It was recognized that due to the construction of the lower-tier roof blocks which included both high-density and regular concrete, the naturally occurring radioisotope concentrations were not as homogenous as in the upper tier roof blocks, so a new sensitivity level for measurements (2 pCi/g) was established and approved by DOE prior to removal of additional shield blocks. The remaining shield block removal was performed between 2009 and 2010, as part of the Bevatron Demolition Project, and included the approximately 800 remaining shield blocks. Initially the same survey protocol as upper-tier roof blocks was used, but with an MDC of 2pCi/g.

Removal of the lower-tier roof blocks began May 2009. The established protocol included use of a reference block, selected from an area that was least likely to contain activation, to establish a baseline for naturally occurring radioactive material. Under this protocol, initial surveys of roof blocks found some blocks above baseline levels and some blocks within baseline levels. The project demolition subcontractor collected core samples of the reference block to validate the absence of anthropogenic radioactive materials. In the absence of a pre-established minimum detectable concentration (MDC) for the laboratory to use, the analysis was performed to the MDC picked by the testing laboratory. The MDC achieved, 0.2pCi/g, was substantially lower than used during previous testing of shield blocks. Using this MDC, the reference block core was determined to contain laboratory-detectable radioactivity, but below what was detectable in the field. Acknowledging the presence of detectable levels of anthropogenic radioactive material at this MDC, it was deemed that all future tests of Bevatron concrete were to be performed to a similar level.

Too, recognizing that the new lower MDC established a new threshold for determining the presence of contamination, a revised protocol was required for characterization of concrete blocks and foundation materials. Because surface (removable) contamination had not been detected on any concrete shield block, slab or foundation, the LBNL revised protocol focused on volumetric contamination (activation) of the concrete.

Within the new protocol, concrete within the project was described as being either from a suspect area or a non-suspect area. Suspect areas are areas with some potential for residual contamination in excess of background. Non-suspect areas are those areas that have no reasonable potential (qualitatively assessed to be extremely low probability) to be contaminated; they are areas that would be considered acceptable as background reference areas precisely due to the virtually nonexistent potential for contamination. The determination of whether an area was a non-suspect area was based on process knowledge.

Concrete from suspect areas with potential for contamination was tested to confirm whether contamination was present. Upon receipt and validation of test results, concrete from these areas was segregated as contaminated or non-contaminated, and handled and disposed in accordance with the project Waste Management Plan. Concurrence was obtained from the DOE site office for the new measurement sensitivity included in the revised protocol. Concrete analyses were performed in accordance with industry standard methodology to the new MDC. Specifically, concrete was analyzed using gamma spectroscopy to determine the presence of project-typical activation products, i.e., Eu-152 or Co-60 using an MDC 0.2 pCi/g. Concrete that showed detectable DOE-added radioactivity did not need further testing for other radioisotopes such as H-3 because such concrete was handled and disposed as radioactive waste regardless of whether such other radioisotopes were present and the waste profile assumed their presence.

Under the revised protocol all shield blocks within direct line of sight to the accelerator would be disposed as LLW. This conclusion considered options available within the current DOE regulations that govern the unrestricted release of materials with volumetric contamination. Specifically, the cost-effectiveness of disposing the blocks under an Authorized Release was evaluated. Although obtaining an Authorized Release was deemed feasible, particularly recognizing the very low levels of radioactive materials present, it was determined that compliance with California Executive Order D-62-02, issued by California Governor Gray Davis on 30 September 2002, would likely require transportation of the shield blocks to an out-of-state receptor. Under the Executive Order D-62-02, decommissioned materials, i.e. "radioactive materials in excess of local background levels that have been released for unrestricted use as part of a decommissioning action by the appropriate state or federal agency" must not be disposed in California Class III or unclassified landfills. The cost difference between disposal as

LLW at NNSS and transportation elsewhere was determined to be minor. However the risk to the project schedule was determined to be unacceptable.

All lower-tier roof blocks and all inner wall blocks were disposed as LLW creating a waste volume significantly greater than originally anticipated. Because some inner wall blocks were oriented radially across both the inner and outer layers of the wall, the majority of the wall blocks were disposed as LLW. Only 148 outer wall blocks were not within the line of sight of the accelerator; all these outer wall blocks met the release criteria.

Implementation of the revised protocol also resulted in an increase in the volume of accelerator foundation concrete that required disposal as LLW. The initial areas deemed to require disposal as LLW are shown in Figure 2 with shading. Based on additional core sampling and analyses under the revised protocol, the areas deemed to require disposal as LLW were increased as depicted by the shaded portions of Figure 3.

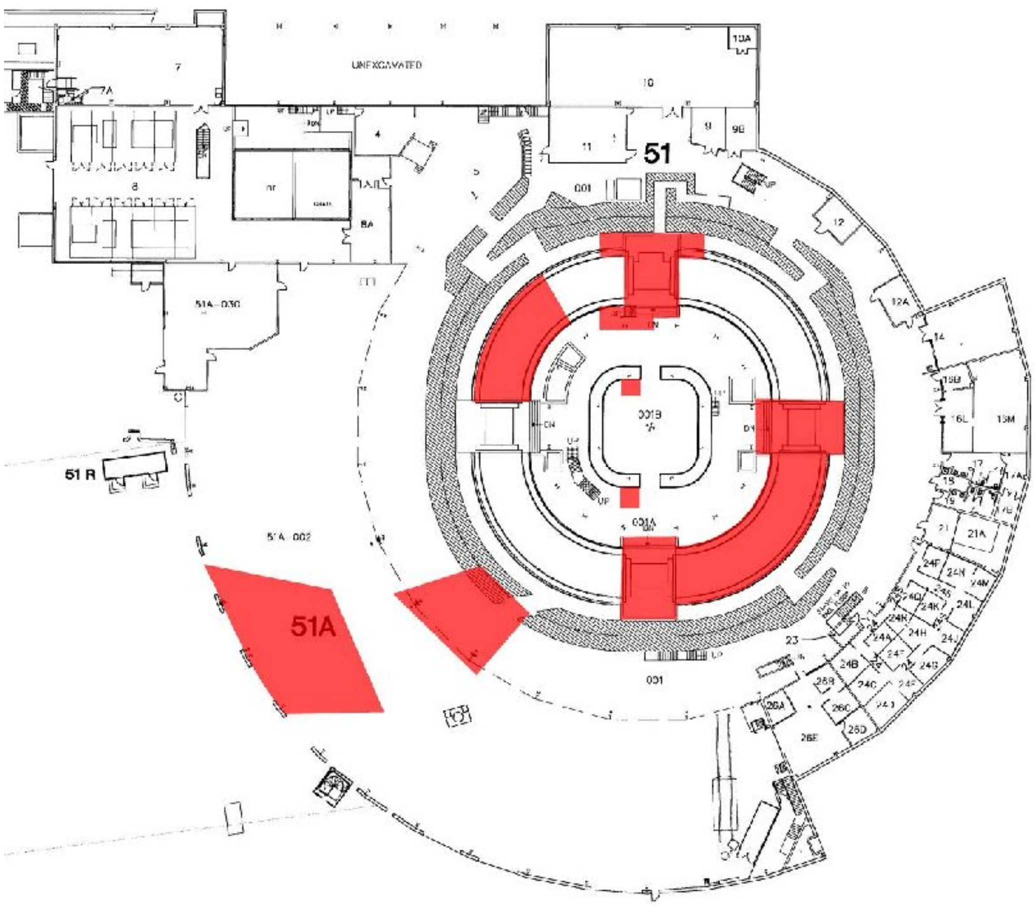

Fig. 2 Reconnaissance-Level Foundation Concrete Characterization Findings

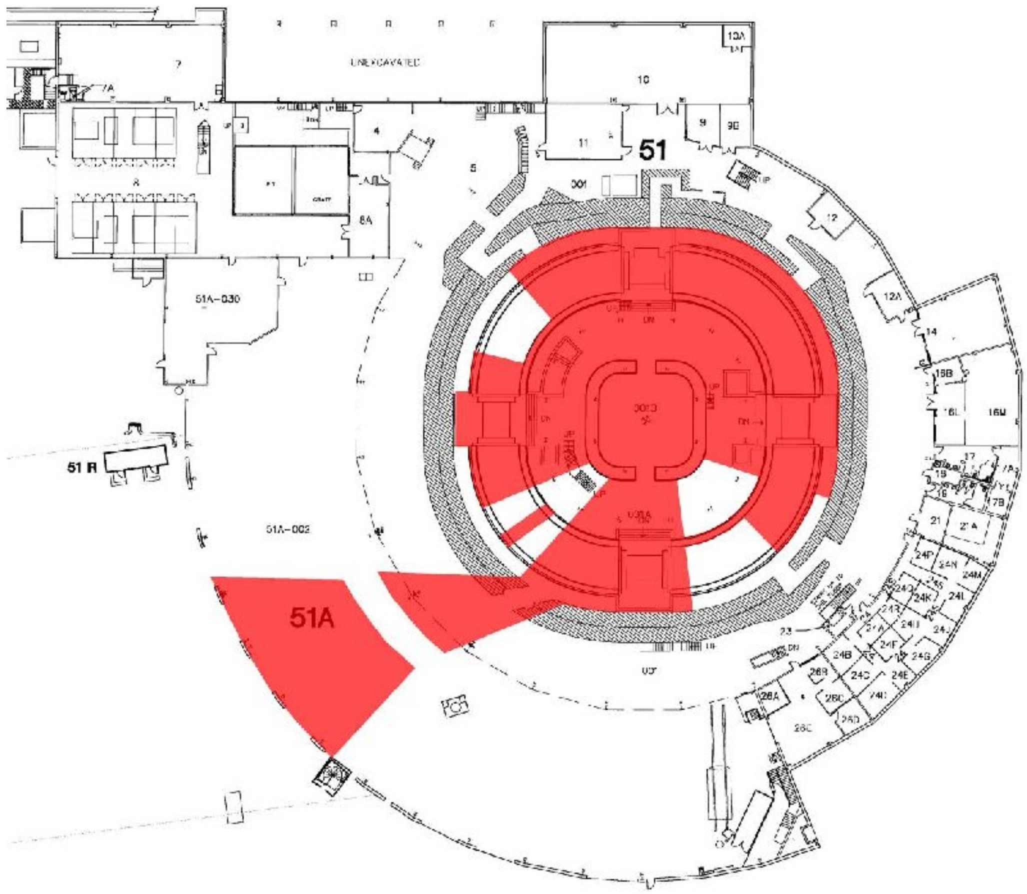

Fig. 3 Revised Protocol Foundation Concrete Characterization Findings

The lesson learned is that testing methodologies for independent laboratories should be established early and communicated to the offsite testing lab. To benefit future projects, it would be advisable to have a single point of contact who clearly understands the release criteria and who clearly communicates analysis expectations to the offsite labs. The lack of clearly defined MDCs for external laboratories to use resulted in testing to standards more rigorous than required and ultimately resulted in declaring some materials as radiological waste that may not have been necessary. The lack of established DOE-endorsed volumetric contamination release thresholds (authorized release limits) required the development of appropriate and practical criteria. Projects that are located in states where disposal or reuse pathways for materials with known volumetric contamination might be cost beneficial should pursue authorized release limits.

LESSON LEARNED #4: UNEXPECTED QUANTITY OF TRITIUM

Radiological activation products were anticipated in several accelerator areas. As noted previously, the reconnaissance level characterization determined the presence of activation products in several areas; these areas are shown in Figure 2.

Tritium, produced by the same mechanisms as other activation products, was not expected to be found in significant quantities in material compounds that did not show the presence of other activation products. However, even where activation products were not present, some level of

H-3 contamination was expected to be found in water and water vapor as a result of migration through porous materials, such as concrete.

During the demolition of the Bevatron foundation materials in 2010, the project investigated the potential migration of H-3 in concrete and through below slab soils and groundwater. Concrete foundation samples, that showed no other detectable activation products, were sampled for H-3. In a like fashion to the revised protocol for characterization of the accelerator concrete, the initial boundaries of suspect areas for tritium contamination were based on the characterization information collected for the concrete above them. The boundaries were established conservatively to include the potential migration of tritium due to water and water vapor movement. Boundaries were confirmed by testing of soil samples.

Analyses were performed in accordance with industry standard methodology and LBNL procedures. Soil samples are analyzed using gamma spectroscopy to determine the presence of typical activation products, i.e., Eu-152 and Co-60. Soil that showed detectable DOE-added radioactivity from typical activation products was not tested for H-3 because such soil was handled and disposed as radioactive waste regardless. To investigate the potential migration of H-3, samples that showed no other detectable activation products were still sampled for H-3.

Standard laboratory protocols, e.g., the sample preparation for analysis by the azeotropic distillation technique, were used to detect H-3. The MDC used for H-3 in soil was 0.2 pCi/g. This MDC was lower than the EPA Preliminary Remediation Guideline (PRG) but was selected because the MDC had been used in previous environmental soil sample analysis at the Laboratory. This very low level threshold was also selected to mitigate potential migration of H-3 into local water sources.

Soil sampling found unexpected levels of H-3 beneath the accelerator foundation. In areas where concrete foundation thicknesses were up to 130 cm (54 in), activation products in the concrete correlated closely with predicted results; activation products were not detected above the established MDCs at concrete depths greater than 60 cm (24 in). However, samples of the groundwater from beneath the foundations detected H-3 above the established MDCs. Although samples of groundwater were taken from several locations, insufficient data were collected to determine whether then source of the H-3 was only from activation, or perhaps from other accelerator processes or systems, such as an accelerator cooling water leak. Process knowledge, confirmed by groundwater samples from outside the accelerator building, supports the conclusion that the source of tritium was not from a separate facility.

The tritiated groundwater was most prevalent in locations adjacent to areas where foundation concrete was the thinnest. However, the highest concentration of H-3, more 4000 pCi/L, was found in a location separate from the greatest concrete activation. Again, insufficient data were collected to determine the reasons behind the apparent anomaly. Migration of the tritium due to natural groundwater flow is the likely reason for the difference in activation product locations; however this hypothesis could not be confirmed.

Although the activated tritium groundwater should have been considered due to the high energy operation in the early years of the Bevatron and the minimal thickness of the foundations in some areas, the distribution of the tritium found in the soil and groundwater was not anticipated. The presence of the tritiated groundwater required development and implementation of controls to mitigate potential cross-contamination as well as the evaluation of adjoining materials. Remediation levels and disposal criteria were developed in conjunction with the DOE, and state and local regulators. Due in part to the low health hazard presented by the H-3 in the groundwater, it was agreed that soil with detectable levels of tritium would not be remediated, however soil with other anthropogenic radioactive materials detected at levels above established MDCs would be removed and disposed as LLW. Approximately 600 m3 (800 yd3) of soil was disposed as LLW.

The lesson learned is to anticipate the presence of H-3 and its migration. Although the production of tritium was anticipated, the locations and quantities found were not.

CONCLUSION

With D&D of many DOE accelerators likely to occur in the near future, these lessons learned should be considered in planning those projects. These lessons learned are likely to be applicable to other D&D projects as well.

REFERENCES

1. DOE G 413.3-5A, U.S. Department of Energy Performance Baseline Guide, 9/23/11
2. Moeller, G.C., and Donahue, R.J., Induced Radioactivity in Bevatron Concrete Radiation Shielding Blocks, LBL-36072, July 1994, Lawrence Berkeley Laboratory