THE D4 PROCESS AND THE 100-N AREA D4 PROJECT AT THE HANFORD SITE, WASHINGTON, USA – 10369

Robert L. Cathel
Washington Closure Hanford, LLC
2620 Fermi Avenue, Richland, WA 99354

ABSTRACT

Washington Closure Hanford (WCH), LLC, under contract to the U.S. Department of Energy (DOE), Richland Operations Office, is currently conducting deactivation, decommissioning, decontamination, and demolition (D4) of excess facilities; placing former production reactors in an interim, safe, and stable condition – also known as Interim Safe Storage (ISS); and, remediating waste sites and burial grounds in support of the closure of the Hanford Site River Corridor. The Hanford Site River Corridor consists of approximately 210 square miles of the Hanford Site along the Columbia River, in the State of Washington.

The deactivation, decommissioning, decontamination, and demolition actions are being conducted under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA). These actions will address past operations, disposal practices and spills which have resulted in contamination of the facility structures, underlying soil, and underlying groundwater in the 100-N Area.

INTRODUCTION

Overall, the WCH D4 Project is responsible for deactivating, decommissioning, decontaminating and demolishing 486 excess facilities at the Hanford Site, totaling 2,870,000 gross square feet. This includes excess facilities in the 100 and 300 Areas and support facilities in the 400 Area not associated with the Fast Flux Test Facility. These facilities range from small mobile offices to massive highly contaminated multi-structured facilities, waste storage pads, sewage treatment structures, stacks and tanks.

The WCH contract began August 28, 2005 and work through September 2009 shows 158 buildings demolished totaling 958,000 gross square feet and 158,000 tons of debris disposed at the on-site Environmental Restoration Disposal Facility (ERDF).

This paper describes the general D4 process, the 100-N Area D4 and Interim Safe Storage/Safe Secure Enclosure (ISS/SSE) Projects, recent challenges (aka opportunities) associated with specific facilities within the 100-N Area D4 Project and the innovative measures taken to overcome these challenges.

100-N AREA

N Reactor, located along the bank of the Columbia River, was the last of nine plutonium reactors to be shut down at the U.S. Department of Energy's Hanford Site and is nearing the cocooning phase – the final stage of stabilizing and enclosing the highly radioactive reactor core for up to

75 years. The highly contaminated portion of N Reactor will be cocooned. The massive support structures at the industrial site are being decontaminated and demolished. Extensive demolition occurs after hazardous materials and equipment are isolated, stabilized and removed.

N Reactor was the only dual-purpose nuclear reactor to operate in the United States. While producing plutonium for nuclear weapons during the Cold War, steam was generated and transferred to the Hanford Generating Plant (HGP) located south of the reactor complex producing 860 megawatts of electricity – enough electricity for approximately 650,000 homes.

Figure 1. Aerial view of 100-N Area during operations

Construction of the reactor began in 1959 and was completed in 1963. It operated from 1964-87 and was officially shut down in 1989. The reactor building alone is 85,450 square feet and includes three below-grade floor area (47 feet deep), and four floors above grade level – the highest point is 80 feet tall. The reactor and heat exchanger facility share a common four-foot-thick wall. The heat exchanger facility is located south of the main reactor building.

Past operations, disposal practices, spills, and unplanned releases have resulted in contamination of the facility structures, underlying soil, and underlying groundwater in the 100-N Area. Consequently, in November 1989, the 100 Areas (which includes 100-N Area) was one of four areas of the Hanford Site that were placed on the U.S. Environmental Protection Agency's (EPA) National Priorities List under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA). The Washington State Department of Ecology (Ecology) which is the lead regulatory agency Under the Tri Party Agreement for activities at the 100-N Area and the DOE, Richland Operations Office, have determined that hazardous substances[1] in the facilities present a substantial threat of release that poses a risk to human health and the environment to the extent that a non-time-critical removal action[2] is warranted.

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[1] "Hazardous substances" means those substances defined by the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), Section 101(14), and includes both radioactive and chemical substances.

[2] "Remove" or "removal" as defined by CERCLA, Section 101(23), refers to the cleanup or removal of released hazardous substances from the environment; actions if a threat of release of hazardous substances occurs; actions to monitor, assess, and evaluate the release (or threat of release) of hazardous substances; the disposal of removed material; or other actions that may be necessary to prevent, minimize, or mitigate damage to public health or welfare or to the environment, which may otherwise result from a release or threat of release. If a planning period of at least

Alternatives for conducting a non time critical removal action were evaluated in the *Engineering Evaluation/Cost Analysis for the 100-N Area Ancillary Facilities and Integration Plan* (100-N Ancillary Facilities EE/CA) (DOE-RL 1998a) and in the *Engineering Evaluation/Cost Analysis for the 105-N Reactor Facility and 109-N Heat Exchanger Building* (105-N/109-N EE/CA) (DOE-RL 2004). These EE/CAs recommended deactivation followed by demolition for the 100-N ancillary facilities and ISS for the 105-N and 109-N facilities. The recommendations were approved in two action memorandums, *Action Memorandum for the 100-N Area Ancillary Facilities* (Ecology 1999) and *105-N Reactor Building and 109-N Heat-Exchanger Building Action Memorandum* (Ecology 2005a), signed by Ecology, the EPA, and DOE. Two Removal Action Work Plans (RAWPs) were drafted and approved which support implementation of the non-time-critical removal action. The RAWPs satisfy the requirement to submit a work plan outlining how compliance with the removal action objectives and applicable or relevant and appropriate requirements (ARARs) will be achieved.

The 100-N Area D4/ISS project includes N Reactor (105-N building), the Heat Exchanger Facility (109-N building), and their associated support (ancillary) facilities. Washington Closure Hanford, LLC, is responsible for D4 of the 105-N/109-N ancillary facilities; preparation of the 105-N/109-N buildings for ISS; and, construction of the 105-N/109-N SSE.

105-N Reactor Facility Description

The 105-N Reactor Facility (105-N) is a 4,000-megawatt (thermal) nuclear reactor designed to operate as a dual-purpose reactor. The reactor core is a graphite-moderated, light water-cooled, horizontal pressure-tube facility designed to produce plutonium. By-product steam was routed to the nearby HGP. The HGP was a privately operated electrical generation facility that produced approximately 860 megawatts of electricity for use by the public.

Construction of the 105-N Reactor began in December 1959 and was completed in October 1963. The 105-N Reactor was the last of the nine Hanford Site graphite-moderated reactors. The facility contains the reactor block, front and rear elevators, pipe galleries, exhaust fans, a receiving basin for spent fuels, offices, control rooms, electrical and instrument rooms, a shop area, ventilation supply, metal preparation and storage areas, a fuel storage basin, and a transfer area. A below-grade exhaust ventilation duct connects 105-N with the 117-N Exhaust Air Filter House. On the south side of the building is the 109-N Heat Exchanger Building, which shares a common wall with 105-N. Asbestos, radiological, and chemical contamination exists in the 105-N facility.

The footprint of the 105-N facility is approximately 7,939 m^2 (85,450 ft^2) and includes three below-grade floor areas (minus 10-ft level, minus 16-ft level, and minus 21-ft level), a main floor area (0-ft level), and four above-grade floor areas (plus 15-ft level, plus 28-ft level, plus 40-ft level, and plus 60-ft level). The roof is at the plus 70-ft level and also includes a penthouse structure that extends to 24 m (80 ft) above grade. The reactor core and other primary reactor support areas are constructed of reinforced concrete and mass shield walls. Interior walls are composed of steel frame, concrete block (concrete masonry unit), and insulated panel

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6 months exists before onsite actions must be initiated, the removal action is considered non-time-critical and an engineering evaluation/cost analysis (EE/CA) is conducted.

construction. The exterior of the building is covered with insulated corrugated-metal wall panels. The roof is covered with built-up roofing with felt strips near the edges and overcovered with urethane foam and two sealer coatings.

The reactor core is composed of interlocking graphite bars containing zirconium-alloy pressure tubes, which held the zirconium alloy-clad uranium-metal fuel elements. Reactivity and reactor power levels were controlled using horizontal control rods and a vertical ball-drop system. Boron was the primary neutron-absorbing material used in the control rods and ball-drop system.

The irradiated reactor fuel was discharged to the 105-N Fuel Storage Basin (also called the N Basin) and placed into metal canisters. The fuel was cooled and stored in the basin to provide for radioactive decay of short-lived radionuclides before it was shipped for processing. The basin is an unlined, reinforced-concrete structure measuring 46 m (150 ft) long, 15 m (50 ft) wide, and 7 m (24 ft) deep.

Deactivation of 105-N was completed in 1998, which included shutdown and isolation of operational systems, cleanup of radiological and hazardous materials, inventory of remaining hazardous materials, sealing access areas, and securing the facility. Contaminated hardware and equipment, sludge, and water were removed from the fuel storage basin. Concrete cover blocks were placed over the fuel storage basin to provide shielding and isolation. Although the deactivation has been completed, portions of the building remain as high-radiation areas and airborne radiation areas. In addition, lubricating oils and/or hydraulic fluids remain in some pieces of equipment.

109-N Heat Exchanger Building Description

Construction of the 109-N Heat Exchanger Building (109-N) was done in conjunction with the 105-N Reactor.

Reactor primary coolant from 105-N was circulated through the reactor to steam generators located in the 109-N facility and then routed back to the reactor via primary coolant pumps. Steam from the steam generators was either dumped into water-cooled dump condensers or piped to the HGP to generate electricity. Circulation of the highly radioactive reactor primary coolant through 109-N caused equipment, piping, and steam generators to be contaminated, similar to levels within the 105-N Reactor equipment and piping.

The 109-N facility is located on the south side of 105-N immediately next to the building. The footprint of the building is approximately 8,406 m^2 (90,480 ft^2) and includes a below-grade floor area (minus 16-ft level), a main floor area (0-ft level), and two above-grade floor areas (plus 15-ft level and plus 24-ft level). The roof is at the plus 38-ft level and also includes a penthouse structure that extends to 24 m (80 ft) above grade.

The facility contains an auxiliary cell and six steam generator cells in parallel. Each steam generator cell contains two steam generators; a drive turbine; a circulating pump; and associated piping, valves, and instrumentation. Each steam generator is 17 m (57 ft) long by 3 m (10 ft) in diameter and weighs approximately 154 metric tons (170 tons). The 109-N Building includes a decontamination cell and a central penthouse area that contains a 13.5-m (44.5-ft)-high by 2-m (6.5-ft)-diameter pressure vessel weighing approximately 82 metric tons (90 tons).

The building is constructed of reinforced concrete with metal siding on the exterior and polyurethane roofing material over a 10-cm (4-in.) concrete slab. Interior walls are concrete block. The reinforced-concrete walls around the steam generator cells are approximately 1.5 m (5 ft) thick. The exterior of the building has eleven 1.8-m (6-ft)-diameter roof vents and the steam distribution headers and piping that routed pressurized steam to the 185-N HGP.

Deactivation of the facility was completed in 1998 in parallel with the 105-N Reactor. The 109-N facility contains a large amount of asbestos and asbestos-containing materials (ACMs) that were used primarily for thermal insulation. In addition, lubricating oils and/or hydraulic fluids remain in some pieces of equipment.

D4 PROCESS

In general, work activities for D4 begin by developing a baseline of the facility conditions. Biological cleanup, general housekeeping, and removal of hazardous materials may also be necessary. Fluids are drained from piping and equipment. Overhead utilities and adjacent concrete and asphalt are removed, as needed, to support demolition activities. Contaminated materials are fixed in place and interior portions of the building are removed, as practical and necessary for demolition preparation. The final activity is the demolition of the structure. These activities are managed in accordance with the contractor's procedures and work packages that address removing, handling, and disposing of these materials in a manner that protects the safety of employees and the general public, minimizes spills and releases to the environment, and meets regulatory requirements.

Hazardous materials (e.g., lead bricks and sheeting, polychlorinated biphenyls [primarily in motor oils and light ballasts], mercury [primarily in lighting components and switches], etc.) are removed and disposed as hazardous or mixed waste or may be recycled. Friable and most nonfriable ACMs and presumed ACMs are removed prior to demolition of the area, as appropriate.

Most of the loose, accessible radiological contamination is either removed or fixed in place, depending on the levels, accessibility, complex shapes (e.g., grating), and type of contamination found. Some of the equipment/piping is removed, and loose contamination is wiped or vacuumed with a HEPA filter-equipped vacuum. If loose contamination remains after the initial decontamination effort the contamination is fixed in place. If required, removal of fixed contamination (radiological or chemical) is performed using nonaggressive means (e.g., wiping or using decontamination solutions). Aggressive means of decontamination (e.g., scabbling, grinding, or other abrasive/mechanical means) are used only as necessary to maintain levels as low as reasonably achievable (ALARA). Additionally, in situations where major source term still exists, but due to its location or configuration is not readily accessible, a controlled density fill material such as grout or other similar material is typically installed to stabilize the material and/or provide shielding to facilitate long term S&M of a remaining ISS, or demolition, as appropriate.

Water, fogging devices, or fixatives are used to control dust generated from demolition activities. The amount of water used is minimized to prevent ponding and runoff.

The facilities are demolished using standard demolition techniques (e.g., excavator with a hoe-ram, a hydraulic shear with steel shear jaws, concrete pulverizer jaws or breaker jaws, a crane with wrecking ball, and/or controlled explosives). Metals are segregated for salvage if economically feasible and if meeting DOE criteria for free release from radiological controls.

100-N Area D4 Project

Demolition of the large complex began in 2005. As of summer 2009, more than half of the complex's 108 structures had been demolished. Recently, several of the 100-N ancillary facilities have presented specific challenges requiring innovative solutions by 100-N Area project personnel, including: demolition of the 116-N stack and 184-N stack; preparing and demolishing the 184-N Powerhouse for demolition; removal, transportation and disposal of three highly radioactive tanks from the 107-N Basin Recirculation /Cooling Building, demolition of the 107-N building and demolition of the 1310-N Radioactive Liquid and Waste Treatment Facility (aka the Golf Ball Facility).

116-N Stack and 184-N Powerhouse

The 116-N stack was made of reinforced concrete and stood 200 feet above ground level – clearly the tallest structure at the 100-N Area. Located 100 yards from the reactor, the 116-N stack was connected by large, underground exhaust tunnels to the reactor. These tunnels were blocked off to prevent dust from pushing into the reactor building when the stack was explosively collapsed.

The 184-N Powerhouse was a steel structure with steel siding and was 70 feet tall. Inside, a turbine generator the size of two large SUVs was supported by cement pedestals. The powerhouse also includes process equipment such as a boiler, condenser, fuel heating and pumping systems, and compressors. The facility also contained an exhaust stack that stood 70 feet above the roofline of 184-N.

Demolition of the 116-N stack and 184-N stack and preparation of the 184-N Powerhouse for demolition was accomplished, in part, with the use of explosives. To begin, the facilities were decommissioned and decontaminated. Then, explosives were strategically placed within each of the two stacks and the cement support pedestals for the 184-N turbine generator. The explosives were used to fell the towers like tress facilitating safe size reduction and waste load-out by removing the stored energy hazard of these tall stacks while workers were at a safe distance. The explosives were used to fracture the robust support pedestals for the 184-N turbine generator facilitating mechanized demolition.

These components posed unacceptable safety hazards for conventional demolition practices. The use of explosives actually reduced worker exposure to industrial risks associated with demolition work and was essentially the same cost as conventional demolition techniques.

107-N Basin Recirculation/Cooling Building

The 107-N building was used to cool and filter irradiated water from the N Reactor's fuel storage basins which stored highly radioactive fuel rods. The building was designed to reduce or eliminate the need to discharge water to the crib areas associated with N Reactor operations.

Highly contaminated settling and filtering tanks had been removed from the structure located just yards off the bank of the Columbia River. A special box was used to transport the last three most contaminated tanks to a disposal site at Hanford's Environmental Restoration Disposal Facility (ERDF). The engineered steel box was constructed locally, measuring 19- by 19-foot square and 18-foot-tall box and provided shielding from the high radiation doses associated with these tanks while meeting regulatory transportation requirements.

Initially, the box was used without any additional shielding during the transportation of the two sand filter tanks from the 107-N building to the ERDF (each tank was shipped individually). This required that the tanks be prepared for removal from the building (e.g., cut/remove all piping to/from the tanks); removal of sections of the 107-N building roof over each of the tanks; utilization of a high-capacity crane to lift the tanks from the building and ultimately placing each tank into the box for shipment to the ERDF. Once at the ERDF the sand filter tanks were removed from the box and the box returned to the 100-N Area Project for re-use; once for the second sand filter tank and lastly for the backwash settling vessel (T-1). To reduce industrial safety risks and ensure radiological dose was kept ALARA, workers built a mock-up and practiced their tasks before entering contaminated work areas. The two sand filter tanks each weighed approximately 60,000 pounds and the T-1 tank was nearly 80,000 pounds; the box itself weighed in at approximately 96,000 pounds.

Figure 2. 96,000 pound box custom engineered for safe transport of contaminated filter tanks to the Environmental Restoration Disposal Facility.

Once both sand filter tanks were removed from the box and disposed at the ERDF, the box was modified to ensure radiological shielding requirements would be met to transport the last tank (T-1) to the ERDF due to the high radiological inventory in the tank. To achieve the necessary shielding and still maintain a gross weight suitable for transportation, project engineers determined that 8" – 12"of cement would be added to the bottom and sides of the box. Cement was placed into forms inside the box for the side shielding and allowed to cure for a brief period. The T-1 tank was removed from the 107-N building and placed into the box followed by an additional layer of cement into the bottom of the box for its bottom shielding and to provide bracing for the tank. The top was then placed on the box and was essentially ready for shipment to the ERDF. Once at the ERDF additional cement was added to the interior of the box through a port on the top of the container (the top of the box was not removed) to fill all void spaces in order to meet ERDF waste acceptance criteria. The box with the T-1 tank was placed in the ERDF for final disposal.

1310-N Radioactive Liquid and Waste Treatment Facility (aka 1310-N Golf Ball Facility)

The 1310-N Radioactive Liquid and Waste Facility includes a 3,200,000-L (900,000-gal) liquid waste storage and neutralization tank that is spherical in shape (referred to as the "golf ball") and a reinforced-concrete silo (12.2 m [40 ft]) that housed valve and pumping facilities. The facility is bordered on three sides by a raised earthen shielding and containment berm to reduce dose rates to workers. The berm is open to the 1301-N Crib area, which was an acceptable release area in case of an accident. The facility periodically received radioactive/hazardous decontamination effluent from the reactor's primary coolant system. These radioactive effluents contained detergents and acids used to perform decontamination; the tank was designed to hold the acidic effluent until it could be neutralized.

Because the interior of the Golf Ball facility was highly radioactively contaminated application of a fixative to the interior of the 62-foot diameter steel structure was required prior to demolition. Project personnel designed and installed a device to deliver the fixative inside the facility. A mock up of the fixative application was performed to confirm the device would provide adequate coverage of fixative. The fixative was later successfully applied and the Golf Ball facility demolished to grade. As of the writing of this paper 100-N D4 work crews are preparing to begin the below-grade demolition and removal of this facility.

100-N Area ISS/SSE Project

The highly contaminated portions of N Reactor will be cocooned (placing the reactor facility in interim safe storage and construction of the safe storage enclosure). Cocooning involves demolishing each facility down to the approximately five-foot-thick shield walls that surround the radioactive steam generators in the 109-N Heat Exchanger Building and the reactor core for N Reactor. Conduit penetrations and other openings are sealed with concrete or steel plates. A new roof, called a safe storage enclosure, is installed over the remaining structure. Finally, temperature and moisture sensors will be installed to remotely monitor conditions inside the sealed reactor building. Once every five years, workers will enter the structure to conduct inspections and make any needed repairs. During the five-year inspections the buildings are checked for structural integrity, radiological contamination and other conditions of the facility. Cocooning allows for safe long-term storage (up to 75 years) until radiation levels decay, or technology becomes available, so workers are protected from exposure risk during final demolition.

Key elements of the SSE design are as follows:

- Use existing 105-N and 109-N shield walls as the basis for establishing the SSE footprint and as prime components of the structure
- Remove exterior floors and decking to within the minimal acceptable distance of the wall for integrity of the remaining structure
- Seal all wall penetrations securely so penetration closures will not be dislodged in a seismic event or from wind loads
- Provide for limited, non-routine access into the SSE for Surveillance & Maintenance (S&M) activities
- Address closure of all subsurface tunnels and pipes that will be left in place to prevent water or pest intrusion
- Allow for decontamination of equipment and structural components to the extent reasonable for radioactive and hazardous material volume reduction, ALARA practices, and, if practical, the release of material for unrestricted use
- Provide a monitoring system for flooding and temperature monitoring

What will N Reactor look like when it's finished?

Following necessary deactivation, decontamination, and partial demolition of the 105-N Reactor Facility and the 109-N Heat Exchanger Building, the existing shield walls will be used to create a SSE, including a new or enhanced metal roof. The shield walls will support the roof, any openings/penetrations in the enclosure will be completely sealed, and remaining entrances will be welded shut. Other exposed SSE concrete surfaces will be left "as-is" upon completion of ISS work. A utility room will be used for access controls, monitoring equipment, and electrical power. Below is a graphical "before" and "after" representation of what the SSE will look like when completed.

Installation of N Reactor's cocoon roof and walls is scheduled to begin in 2009 and will be completed by 2012. The N Reactor/109-N complex represents the sixth of Hanford's nine reactors to be cocooned. C Reactor was cocooned in 1998, DR in 2002, F in 2003, D in 2004, and H in 2005. The site's K East and K West Reactors remain to be cocooned. B Reactor, the world's first full-scale nuclear reactor may not be cocooned pending a decision to make it a museum.

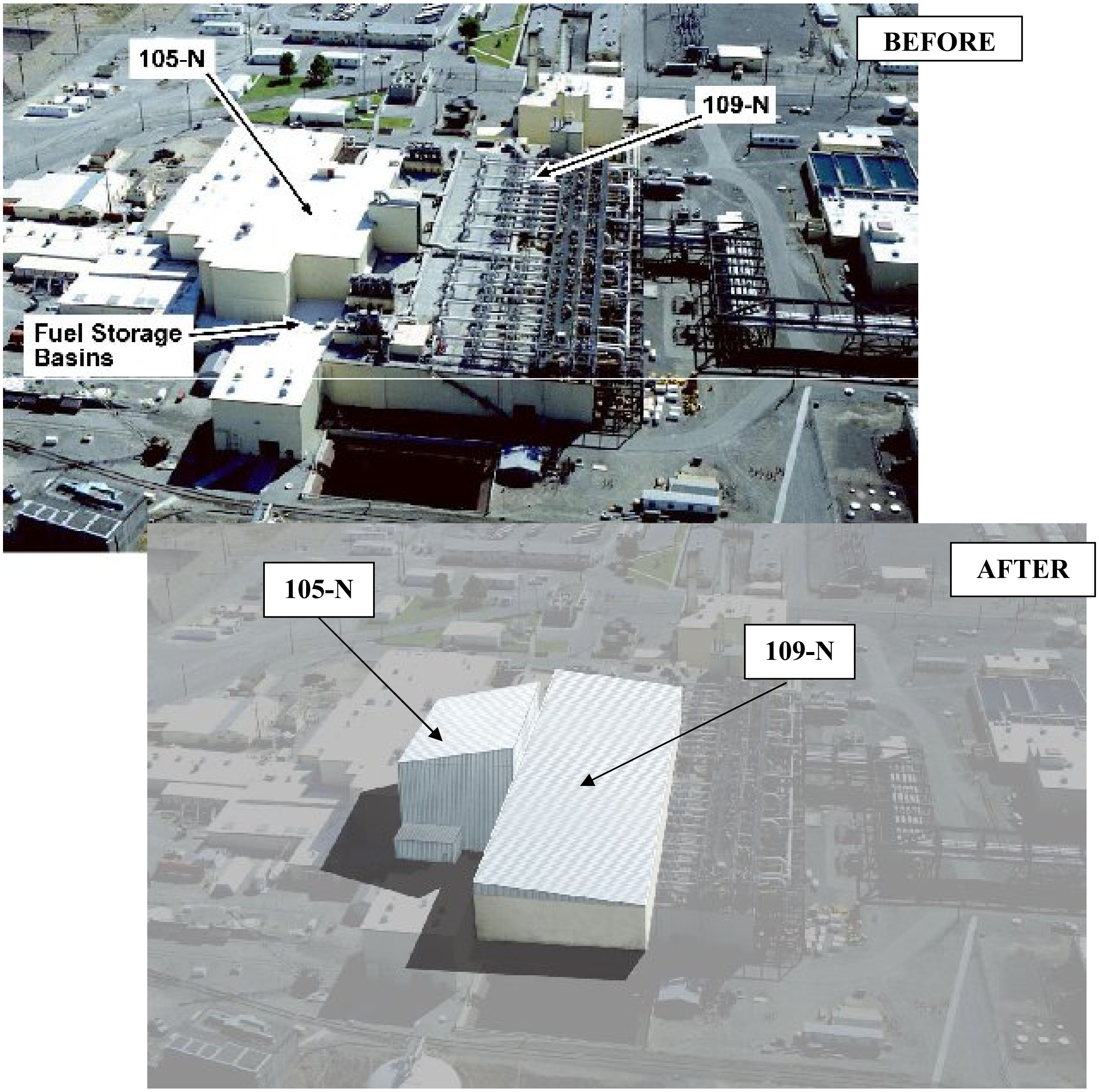

Figure 3. 105-N/109-N Safe Storage Enclosure