DOE/RL-2005-45
Rev. 0

Surplus Reactor Final Disposition Engineering Evaluation

United States
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EXECUTIVE SUMMARY

Nine water-cooled, graphite-moderated plutonium production reactors were constructed along the Columbia River by the U.S. Government at the Hanford Site near Richland, Washington, between the years of 1943 and 1963. All of these reactors (B, C, D, DR, F, H, KW, KE, and N) are currently retired from service. The eight older reactors (B, C, D, DR, F, H, KW, and KE) were shut down by 1971. The N Reactor was placed in standby in 1987 and declared retired in 1991. All nine reactors have been declared surplus by the U.S. Department of Energy (DOE) and are available for decommissioning with the possible exception of B Reactor which is being considered for preservation as a museum.

In December 1992, the DOE issued the *Final Environmental Impact Statement: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (Final EIS) (DOE 1992). In September 1993, the DOE issued the *Record of Decision: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (58 *Federal Register* 48509), which implements the recommendation for "safe storage followed by one-piece removal" of the surplus reactors as described in the Final EIS. The Record of Decision (ROD) states the DOE will implement safe storage followed by deferred one-piece removal as the final disposition alternative for the eight surplus reactors. In August 1997, the DOE, U.S. Environmental Protection Agency, and Washington State Department of Ecology formalized agreements and commitments that resulted in milestones and target dates governing interim safe storage of the Hanford Site surplus production reactors.

In August 1996, the DOE began implementing interim safe storage (ISS) at C Reactor as a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) removal action. The ISS includes decontamination of reactor structures, reduction of the reactor footprint through decommissioning, and construction of a safe storage enclosure (SSE) over the reactor core to prevent deterioration and release of contamination for up to 75 years. The ISS of C Reactor was completed in September 1998. Interim safe storage removal actions have subsequently been completed at DR Reactor in September 2002, F Reactor in September 2003, and D Reactor in September 2004. In addition, ISS is expected to be completed at H Reactor by

September 2005. Interim safe storage of the 105-N/109-N Reactor complex was approved by the *105-N Reactor Building and 109-N Heat Exchanger Building Action Memorandum* (Ecology and DOE 2005) in February 2005. Interim safe storage of the 105-N/109-N Reactor complex is scheduled for completion by 2012 along with the KW and KE Reactors. The ISS of the KW and KE Reactors will be performed after spent nuclear fuel and sludge have been removed from the KW and KE fuel storage basins. The KW and KE basin cleanout is being performed as an interim removal action under CERCLA.

Completion of ISS is considered the first step of implementing the safe storage followed by deferred one-piece removal alternative selected by the Final EIS and ROD. The B Reactor is currently in a hazard mitigation period awaiting a final configuration determination on the facility.

This engineering evaluation is being prepared in response to *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) Milestone M-93-25, "Submit an Engineering Evaluation of the Final Surplus Reactor Disposition to EPA and Ecology" (Ecology et al. 1989). The engineering evaluation reviews the original assumptions and information contained in the Final EIS and ROD, including cost estimates and radiological inventories. A status of the DOE's progress to date implementing ISS for the surplus reactors and cost estimates for completion of ISS for all nine surplus reactors (including N Reactor) is presented.

The report also evaluates the reactor final disposition alternatives proposed in the Final EIS: one-piece removal, reactor dismantlement, and in situ decommissioning. These alternatives remain viable final disposition alternatives following ISS. No new technical innovations, environmental values, regulatory requirements, or advancements in the decommissioning process were identified that would significantly impact the original assumptions and conclusions of the Final EIS and ROD. The applicable cost estimates and dose estimates presented in the Final EIS are updated to reflect current values and estimates.

Finally, several follow-on actions are presented for continued implementation of ISS and preparing to select and implement a final disposition alternative for the nine Hanford Site surplus production reactors.

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ACRONYMS

CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
EA	environmental assessment
Ecology	Washington State Department of Ecology
EE/CA	engineering evaluation/cost analysis
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ISS	interim safe storage
ROD	record of decision
S&M	surveillance and maintenance
SNF	spent nuclear fuel
SSE	safe storage enclosure
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*

1.0 INTRODUCTION

This engineering evaluation presents an assessment of the decommissioning and final disposition options for the Hanford Site surplus production reactors. The evaluation is based on a review of the *Final Environmental Impact Statement: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (Final EIS) (DOE 1992) and the programs conducted by the U.S. Department of Energy (DOE) to implement the *Record of Decision: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (58 *Federal Register* [FR] 48509). This engineering evaluation is being prepared in response to *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) Milestone M-93-25, "Submit an Engineering Evaluation of the Final Surplus Reactor Disposition to EPA and Ecology" (Ecology et al. 1989). The evaluation will consider whether changes have occurred regarding technical innovations, environmental values, regulatory requirements, or other information documented in the Final EIS that might lead to a different decision.

Final disposition of the Hanford Site surplus production reactors is dependent on future federal funding actions, and the actual dates cannot be predicted at this time. In the interim, the DOE is implementing interim safe storage (ISS) for a period up to 75 years and is conducting a comprehensive program of surveillance and maintenance (S&M) to control the radionuclide and hazardous substances within the reactors.

2.0 SCOPE

This engineering evaluation summarizes the information and alternatives that were included in the Final EIS (DOE 1992) and updates the cost information and radionuclide inventories that were used to support the conclusions. This report also includes a summary of the activities implemented to date to support decommissioning of the Hanford Site surplus reactors and summarizes actual decommissioning costs incurred to date to place the reactors in ISS.

One of the Hanford Site production reactors, N Reactor,[1] was not included in the scope of the Final EIS (DOE 1992) because the reactor was not available for decommissioning when the document was written. The N Reactor has since been deactivated and designated for decommissioning. The action memorandum authorizing interim safe storage for N Reactor, "105-N Reactor Building and 109-N Heat Exchanger Building Action Memorandum," was approved on February 22, 2005 (Ecology and DOE 2005). This engineering evaluation supplies cost and source term information for N Reactor that brings this facility into the evaluation in order to present a comprehensive decommissioning plan for all nine of the Hanford Site surplus reactors.

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[1] Because of its unique design, N Reactor includes both the 105-N Reactor Building and the 109-N Heat Exchanger Building. The 109-N Building contains a portion of the N Reactor primary cooling water system and is considered part of the reactor complex.

Finally, this report assesses the original assumptions and conclusions of the Final EIS and evaluates if they are still relevant and applicable to the final disposition of the surplus reactors. The report also highlights issues relative to decommissioning of nine Hanford Site surplus reactors and recommends future actions that will enable the DOE to meet its regulatory commitments and obligations.

3.0 BACKGROUND

Nine water-cooled, graphite-moderated plutonium production reactors were constructed along the Columbia River by the U.S. Government at the Hanford Site near Richland, Washington, between the years of 1943 and 1963. All of these reactors (B, C, D, DR, F, H, KW, KE, and N) are currently retired from service. The eight older reactors (B, C, D, DR, F, H, KW, and KE) were shut down by 1971. The N Reactor was placed in standby in 1987 and declared retired in 1991. All reactors have been declared surplus by the DOE and are available for decommissioning.

In 1980, the DOE issued *Environmental Assessment – F-Area Decommissioning Program, Hanford Site, Richland, Benton County, Washington* (DOE 1980) that presented alternatives for final disposition of the 105-F Reactor complex. Four alternatives were considered: layaway, protective storage, entombment, and dismantlement with disposal of radioactive waste materials in burial grounds in the 200 Areas of the Hanford Site. The preferred alternative was dismantlement and onsite waste disposal. Based on the environmental assessment (EA), a finding of no significant impact for the dismantlement alternative was published in the *Federal Register* on August 22, 1980 (45 FR 56125). Subsequent to that action, the DOE concluded it would be more appropriate to consider and implement a consolidated decommissioning program for the eight surplus production reactors located at the Hanford Site rather than address them separately.

3.1 DRAFT ENVIRONMENTAL IMPACT STATEMENT

A Draft Environmental Impact Statement (Draft EIS) (DOE 1989) was developed to evaluate potential environmental impacts of decommissioning eight surplus reactors at the Hanford Site. This included the B, C, D, DR, F, H, KW, and KE Reactor complexes. The N Reactor was not included in the EIS. At the time the EIS was prepared, N Reactor was in standby mode awaiting approval for continued production of weapons-grade plutonium and steam for electrical power generation.

Facilities included within the scope of the proposed action included the surplus reactors, their associated nuclear fuel storage basins, and the buildings that housed the systems. No future long-term use of any of the surplus reactors and associated facilities had been identified by the

DOE. Because the reactors contain irradiated reactor components and the buildings that house the reactors are contaminated with low levels of radioactivity, the DOE determined there was a need for action and that some form of decommissioning/continued S&M was necessary. The purpose of the decommissioning/S&M would be to remove as much of the contaminated materials as possible and isolate any remaining radioactive or hazardous waste in a manner that would minimize future environmental impacts, especially potential health and safety impacts on the public and still allow consideration for all the final disposition alternatives in the future.

Alternatives considered in detail in the Draft EIS were no action, immediate one-piece removal, safe storage followed by deferred one-piece removal, safe storage followed by deferred dismantlement, and in situ decommissioning. Evaluation of the alternatives was carried out on the basis of several conditions and assumptions that are summarized below.

- The reactors were similar in design, construction, and radiological condition. The differences are noted but are not significant for decommissioning purposes.

- The residual radioactive materials within the surplus facilities are low-level radioactive wastes that are suitable for disposal at the Hanford Site. Waste disposal would be in the 200 West Area of the Hanford Site for the removal and dismantlement alternatives and within the current reactor locations of the Hanford Site 100 Areas for the in situ decommissioning alternative.

- Each disposal site would incorporate into the design a protective barrier, a groundwater monitoring system, and an integral marker system. The 200 West Area disposal site may be provided with a liner/leachate collection system. The protective barrier is designed to limit the infiltration of water and is assumed to limit infiltration to 0.1 cm/yr.

- Costs were estimated on the basis of efficient, overlapping work schedules and were developed in 1986 dollars.

The following bullets present brief descriptions of each of the disposition alternatives evaluated in the Draft EIS (DOE 1989).

- No Action – This alternative includes actions to continue routine surveillance, monitoring, and maintenance over a 100-year period. At the end of that period, another disposition activity would be necessary.

- Immediate One-Piece Removal – This alternative includes demolition of the reactor buildings and transport of each reactor block, intact on a tractor-transporter, from its present location in the 100 Areas to the 200 West Area burial grounds for disposal.

- Safe Storage Followed by Deferred One-Piece Removal – This alternative includes activities to place the reactors into a configuration for safe storage followed by a period of up to 75 years during which surveillance, monitoring, and maintenance are continued. Final disposition would include demolition of the reactor buildings and transport of each reactor block intact on a tractor-transporter from its present location in the 100 Areas to the 200 West Area for disposal.

- Safe Storage Followed by Deferred Dismantlement – This alternative includes activities to place the reactors into a configuration for safe storage followed by a period of up to 75 years during which surveillance, monitoring, and maintenance are continued. Final disposition would include demolition of the reactor building and piece-by-piece dismantlement of each reactor core and transport of radioactive waste to the 200 West Area for burial.

- In Situ Decommissioning – This alternative includes demolition of the reactor buildings and filling the voids beneath and around the reactor block. The reactor block, its adjacent shield walls, and the spent fuel storage basin, together with the contained radioactivity, gravel, and grout, would be covered to a depth of at least 5 m with a mound containing earth and gravel.

Table 1 presents the estimated cost for each final disposition alternative as evaluated in the Draft EIS (DOE 1989).

Table 1. Estimated Costs (in millions, 1986 dollars) for Alternatives Presented in the Draft Environmental Impact Statement (DOE 1989).

Activity	No Action (Continue Present Action)	Immediate One-Piece Removal	Safe Storage Followed by Deferred One-Piece Removal	Safe Storage Followed by Deferred Dismantlement	In Situ Decommissioning
Safe storage	$41.0	--	$33.8	$35.7	--
Decommissioning operations	--	$110.7	$110.7	$155.0	$25.4[a]
Construction of wells	--	$1.4	$1.4	$1.4	$1.9
Well monitoring	--	$35.1	$8.1	$9.6	$93.6
Waste disposal/barrier	--	$43.6	$43.6	$14.9	$58.0
Totals	**$41.0**	**$190.8**	**$197.6**	**$216.6**	**$178.9**[a]

[a] Represents corrected cost from the Draft Environmental Impact Statement (DOE 1989).

Table 2 presents the estimated radionuclide inventory as of March 1, 1985, for each reactor complex as evaluated in the Draft EIS (DOE 1989).

Table 3 presents dose information for each of the alternatives in the Draft EIS along with a summary of cost and number years of active decommissioning.

Table 2. Total Radionuclide Inventory for Each Reactor Complex as of March 1, 1985.

Radionuclide	Half-Life (years)	B Reactor (Ci)	C Reactor (Ci)	D Reactor (Ci)	DR Reactor (Ci)	F Reactor (Ci)	H Reactor (Ci)	KW Reactor (Ci)	KE Reactor (Ci)
H-3	12.3	8,300	8,900	7,700	4,900	5,800	5,500	30,000	27,000
C-14	5,730	4,500	4,500	4,300	3,200	3,700	3,500	7,000	6,700
Ca-41	1.0×10^5	192	18	152	92	142	56	16	20
Co-60	5.3	9,211	10,426	7,850	4,400	5,260	4,620	17,805	14,785
Ni-59	7.5×10^4	8.6	7.26	9.1	6.1	8.1	6.1	22	20
Ni-63	100	1,090	894	1,100	686.3	881.3	781.3	2,912	2,616
Cl-36	3.0×10^5	42	12	34	26	33	17	54	52
Sr-90	28.8	24.2	17.2	10.3	10.5	10.5	10.5	10.6	10.6
Zr-93	1.5×10^6	--	--	--	--	--	--	11	10
Mo-93	3,000	0.04	0.04	0.04	0.04	0.04	0.04	0.26	0.26
Nb-94	2.0×10^4	0.32	0.32	0.32	0.32	0.32	0.32	0.73	1.7
Tc-99	2.1×10^5	0.002	0.002	0.002	0.002	0.002	0.002	0.033	0.033
Ag-108	27	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04
Cs-137	30.2	46	36	30.12	30.8	30.8	30.8	30.8	30.8
Eu-152	13	43	45.7	43.7	41.5	41.6	41.5	42.2	42.2
Eu-154	8.5	25.4	28.3	21.2	21	21	21	21.7	21.7
U-238	4.5×10^9	0.009	0.004	--	--	--	--	--	--
Pu-238	87.7	0.075	0.075	--	--	--	--	--	--
Pu-239	2.4×10^4	2.6	2.5	1.03	1.02	1.02	1.02	1.02	1.02
Am-241	433	0.8	0.8	0.31	0.31	0.31	0.31	0.31	0.31
Totals	**--**	**23,486**	**24,888**	**21,252**	**13,416**	**15,930**	**14,586**	**57,928**	**51,312**

Table 3. Comparison of Decommissioning Alternatives and Impacts for Eight Reactors Presented in the Draft Environmental Impact Statement (DOE 1989).

Alternative	Active Decommissioning Period (years)	Total Cost (in millions, 1986 dollars)	Occupational Radiation Dose (person-rem)	10,000-year Population Dose[a] (person-rem)
No Action (Continue Present Action)	100	$41	24	50,000
Immediate One-Piece Removal	12	$191	159	1,900
Safe Storage Followed by Deferred One-Piece Removal	87	$198	51	1,900
Safe Storage Followed by Deferred Dismantlement	103	$217	532	1,900
In Situ Decommissioning	5	$179[b]	33	4,700

[a] The same population would receive 9 billion person-rem over 10,000 years from natural radiation.
[b] Represents corrected cost from the Draft Environmental Impact Statement (DOE 1989).

3.2 FINAL ENVIRONMENTAL IMPACT STATEMENT AND RECORD OF DECISION

In December 1992, the DOE issued the *Final Environmental Impact Statement: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (DOE 1992). The Final EIS included a summary of the proposed alternatives from the Draft EIS, a summary of public comments on the Draft EIS, and a final recommended alternative. The Final EIS states that the DOE selected safe storage followed by deferred one-piece removal as the preferred final disposition alternative for the eight surplus reactors. The selected final disposition alternative will be implemented within a time frame consistent with the cleanup schedule for Hanford Site remedial actions under the Tri-Party Agreement (Ecology et al. 1989) that was negotiated between the DOE, U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology) in May 1989. The Final EIS states that the safe storage period for the eight surplus reactors would be less than 30 years. The Final EIS also updated the cost figures for the alternatives to reflect 1990 dollars. Table 4 presents the decommissioning period, cost, and radiation dose from the Final EIS. Estimates of decommissioning period, occupational radiation dose, and 10,000-year population dose were unchanged from the values presented in the Draft EIS.

The *Record of Decision: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (58 FR 48509) was issued in September 1993. The Record of Decision (ROD) states that the DOE will implement safe storage followed by deferred one-piece removal as the final disposition alternative for the eight surplus reactors. The ROD also states that the DOE intends to complete the action consistent with the proposed cleanup schedule for remedial actions included in the Tri-Party Agreement (Ecology et al. 1989).

Table 4. Comparison of Decommissioning Alternatives and Impacts for Eight Reactors Presented in the Final Environmental Impact Statement (DOE 1992).

Alternative	Active Decommissioning Period (years)	Total Cost (in millions, 1990 dollars)	Occupational Radiation Dose (person-rem)	10,000-year Population Dose[a] (person-rem)
No Action (Continue Present Action)	100	$44	24	50,000
Immediate One-Piece Removal	12	$228	159	1,900
Safe Storage Followed by Deferred One-Piece Removal	87	$235	51	1,900
Safe Storage Followed by Deferred Dismantlement	103	$311	532	1,900
In Situ Decommissioning	5	$193	33	4,700

[a] The same population would receive 9 billion person-rem over 10,000 years from natural radiation.

4.0 IMPLEMENTATION OF SELECTED ALTERNATIVE

In December 1996, when the DOE, EPA, and Ecology signed an agreement in principle, the three parties agreed to enter into Tri-Party Agreement negotiations to define an effective surplus reactor disposition program. Negotiations were conducted assuming a phased approach where Phase One includes ISS and Phase Two would address final reactor disposition. In August 1997, the three parties issued Tri-Party Agreement Change Control Form M-93-97, which established a new major milestone (M-93-00) and associated interim milestones and target dates governing decommissioning/disposition of the surplus production reactors. With the exception of B Reactor, interim milestones were established to complete ISS (Phase One) of each of the 100 Area reactors (including N Reactor) by September 31, 2012. Interim milestones for B Reactor involve hazard mitigation rather than ISS because the facility has been listed on the National Register of Historic Places and is awaiting a decision on its final disposition. The three parties agreed to postpone development of Phase Two milestones until the surplus reactors were placed in a condition sufficient for ISS.

In 1999 the *Final Hanford Comprehensive Land Use Plan Environmental Impact Statement* (DOE 1999) was issued. The land-use environmental impact statement (EIS) provided a strategy for future land use on the Hanford Site. This decision helped provide a framework for cleanup standards and cleanup methodologies for the Hanford Site, including the reactor sites. The EIS based its cleanup strategy on the assumption that ". . . the reactor blocks for the eight plutonium reactors will be kept in their present sites for up to 75 years . . ." The EIS also made allowance for the B Reactor to be converted into a museum and the surrounding area made available for museum support facilities.

4.1 B REACTOR HAZARD MITIGATION

The 105-B Reactor Building has been listed on The National Register of Historic Places and was designated a National Historic Civil Engineering Landmark in 1993 by the American Society of Civil Engineers. Documentation in the form of a Historic American Engineering Record was completed as part of the *Programmatic Agreement Among the U.S. Department of Energy, Richland Operations Office, the Advisory Counsel on Historic Preservation, and the Washington State Historic Preservation Office for the Maintenance, Deactivation, Alteration, and Demolition of the Built Environment on the Hanford Site, Washington* (DOE-RL 1996b). The historical significance of B Reactor has entitled it to numerous declarations, including National Historic Mechanical Engineering Landmark by the American Society of Mechanical Engineers in 1976 and the Nuclear Historic Landmark Award.

In 2001, the *Engineering Evaluation/Cost Analysis for the 105-B Reactor Facility* (EE/CA) (DOE-RL 2001) was prepared to analyze removal actions that may be performed at the 105-B Facility to protect human health and the environment. This EE/CA was intended to support and implement the DOE's decision to preserve the 105-B Facility as a cultural resource for a period of up to 10 years. Based on this unique intended use, the interim removal action recommended in the EE/CA and selected in the associated action memorandum (EPA 2002) was hazard mitigation for a period of up to 10 years. The hazard mitigation activities included the removal of accessible hazardous substances from the 105-B Facility while performing S&M activities such as routine radiological and hazard monitoring and safety inspections.

The interim removal action EE/CA analyzed removal action alternatives for a period of up to 10 years with the expectation that a final removal action, or "final configuration," would be determined during the 10-year period. Activities and associated costs for structural upgrades to allow sustained public access were identified during this interim time period to assess the feasibility of sustained public use and the associated risks to human health and the environment due to hazardous substances that remain in the facility. The 10-year time period is consistent with the DOE's Columbia River Corridor Initiative, the goal of which is to complete many cleanup and access decisions by the year 2012 and restore the river corridor per the M-93 Tri-Party Agreement milestone series (Ecology et al. 1989).

In addition to identifying and analyzing interim removal actions for the 105-B Facility, supplemental information was provided in the interim removal action EE/CA to support decisions on the final configuration of the 105-B Facility. The supplemental information included the activities needed and estimated cost for mitigating hazards in all interior and exterior areas of the 105-B Facility to enable full public access for a 75-year period. To date, approximately 90% of the hazard mitigation removal actions stipulated in the action memorandum (EPA 2002) have been completed. No final configuration has been determined for the B Reactor. At the current time, Congress has requested the U.S. National Park Service to evaluate the feasibility of operating and maintaining the B Reactor as a museum (Public Law 180-340). Determination of the final configuration of the B Reactor is expected within the 10-year interim removal action period.

4.2 SURPLUS REACTOR INTERIM SAFE STORAGE

Interim safe storage has been implemented or is planned for seven of the eight surplus reactors included in the Final EIS and ROD. As discussed above, B Reactor is currently under a hazard mitigation program and is currently deferred from ISS.

Beginning with C Reactor in 1996, documentation to conduct a removal action under the authority of *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) has been prepared for each of the reactor facilities with the exception of the KE and KW Reactors. The 105-KE and 105-KW fuel storage basins, located respectively in the 105-KW and 105-KW Reactor Buildings, have been the storage locations for the majority of the Hanford Site's spent nuclear fuel (SNF) since the 1970s. Cleanout of the K Basins is being conducted as an interim remedial action under CERCLA.

The *Engineering Evaluation/Cost Analysis for the 100-B/C Area Ancillary Facilities at the 108-F Building* (DOE-RL 1996a) was prepared in July 1996. Among the alternatives evaluated in the EE/CA was ISS of the 105-C Reactor Building. The ISS alternative included reduction of the building footprint by demolition of the fuel storage basin and portions of the facility around the reactor core and construction of a safe storage enclosure (SSE). The SSE included sealing the facility up to the shield walls and constructing a roof over the structure with a design life of up to 75 years. The time period used for the evaluation and cost estimates was 75 years from the issuance of the Final EIS and ROD. Based on the recommendations of the EE/CA, ISS was the selected alternative as documented in the action memorandum that was issued in January 1997 (EPA 1997).

The Final EIS for the surplus reactors contemplated repair of building components and structures as needed to ensure security of the facility during the safe storage period. Implementation of the ISS alternative at C Reactor (and the following reactors) creates a robust engineered structure to achieve safe storage. The safe storage alternative presented in the Final EIS included extended S&M necessary to prevent significant deterioration of the facilities and release of contamination to the environment for a period up to 75 years. The ISS alternative employs demolition and decommissioning of major portions of the facilities, footprint reduction, and construction of a SSE. The resulting structure is more secure and less likely to release contamination, reduces the radiological inventory, and requires significantly less, and therefore less expensive, S&M over the life of the structure. The ISS alternative carries a higher initial cost than simple S&M. However, it is anticipated the increased initial cost will be recovered by a comparable reduction in cost for final disposition of each of the reactor facilities because much of the decommissioning and demolition has already been completed when the facility footprint was reduced. Figure 1 shows aerial photographs of the 105-F Reactor Building before (photograph on left) and after ISS (photograph on right). The dotted line indicates the extent of footprint reduction accomplished by ISS.

Figure 1. 105-F Reactor Building Before and After Interim Safe Storage.

Table 5 shows the initiation date, completion date, and actual or estimated cost for performing ISS of the 105-C Reactor Building and the other Hanford Site surplus reactors. The table shows that ISS of the 105-B Reactor Building has been deferred pending decisions on its status as a museum.

Table 5. Initiation Date, Completion Date, and Cost of Interim Safe Storage for Hanford Site Surplus Reactors and N Reactor. (2 Pages)

Reactor Building	Initiation Date	Completion Date	Cost[a] (Million $)
105-C	August 1996	September 1998	$31.1[b]
105-DR	March 1998	September 2002	$16.2[b]
105-F	January 1998	September 2003	$22.8[b]
105-D	January 2000	September 2004	$13.8[b]
105-H	October 2000	September 2005[c]	$26.5
105-KE	October 2008[d]	September 2012[c]	$20.4
105-KW	October 2009[d]	September 2012[c]	$20.4
105-B	Deferred	Deferred	$20.2
Total of Eight Surplus Reactors			**$171.4**
105-N/109-N	October 2006[d]	September 2009[c]	$50.0
Total of All Surplus Reactors			**$221.4**

[a] Costs reported in 2005 dollars.
[b] Actual cost reported in 2005 dollars.
[c] Proposed completion date.
[d] Proposed initiation date.

The *Engineering Evaluation/Cost Analysis for the 100-DR and 105-F Reactor Facilities and Ancillary Facilities* (DOE-RL 1998) was prepared in May 1998. In an effort to reduce cost and allow ISS of two reactor facilities to be concurrent, the EE/CA and action memorandum covered both the 105-DR and 105-F Reactor Buildings. Among the alternatives evaluated in the EE/CA was ISS of the 105-DR and 105-F Reactor Buildings. The ISS alternative included reduction of the building footprint by demolition of the fuel storage basins and portions of the facilities around the reactor cores and construction of an SSE on each structure. The SSE included sealing each facility up to the shield walls and constructing a roof over the structure with a design life of up to 75 years. Based on the recommendations of the EE/CA, ISS was the selected alternative as documented in the action memorandum that was issued in July 1998 (Ecology et al. 1998). The initiation dates, completion dates, and actual costs for ISS of the 105-DR and 105-F Reactor Buildings are shown in Table 5.

The *Engineering Evaluation/Cost Analysis for the 105-D Reactor Facility and Ancillary Facilities* (DOE-RL 2000a) was prepared in August 2000. Among the alternatives evaluated in the EE/CA was ISS of the 105-D Reactor Building. The ISS alternative included reduction of the building footprint by demolition of the fuel storage basin and portions of the facility around the reactor core and construction of an SSE with a design life of up to 75 years. Based on the recommendations of the EE/CA, ISS was the selected alternative as documented in the action memorandum that was issued in January 2001 (Ecology et al. 2001). The initiation date, completion date, and actual cost for ISS of the 105-D Reactor Building are shown in Table 5.

The *Engineering Evaluation/Cost Analysis for the 105-H Reactor Facility and Ancillary Facilities* (DOE-RL 2000b) was prepared in August 2000. Among the alternatives evaluated in the EE/CA was ISS of the 105-H Reactor Building. The ISS alternative included reduction of the building footprint by demolition of the fuel storage basin and portions of the facility around the reactor core and construction of an SSE with a design life of up to 75 years. Based on the recommendations of the EE/CA, ISS was the selected alternative as documented in the action memorandum that was issued in January 2001 (Ecology et al. 2001). The initiation date, completion date, and anticipated final actual cost for ISS of the 105-H Reactor Building are shown in Table 5.

As stated previously, removal of the SNF and cleanup of associated sludge, water, and debris is currently in progress at the 105-KE and 105-KW Reactor Buildings. Cleanup of the fuel storage basins is anticipated to be completed between 2007 and 2009. Preparation of documents to conduct a CERCLA removal action for the KE and KW Reactors is currently scheduled to be completed by July 31, 2006, as a part of Tri-Party Agreement Milestone M-93-23, "Submit Engineering Evaluation/Cost Analysis for KE/KW Reactor ISS" (Ecology et al. 1989). Preparations for ISS of the KE and KW Reactors may need to be delayed to coincide with the SNF removal and basin cleanup schedule. The proposed schedule and estimated cost for ISS of the KE and KW Reactors are shown in Table 5.

4.3 N REACTOR INTERIM SAFE STORAGE

The N Reactor was not included in the original Draft EIS, Final EIS, or ROD because at the time the documents were prepared the reactor was not available for decommissioning. Efforts to preserve the reactor were discontinued in 1991, and the reactor facilities were deactivated. Deactivation activities were completed in 1998. The reactor facilities are currently under a limited S&M program to ensure the facilities are in a stable condition and there is no impact to the public, workers, or environment.

Under the Tri-Party Agreement, N Reactor has been integrated into the ISS program implemented at the eight surplus reactors as approved by the Final EIS and ROD. In September 2004 the *Engineering Evaluation/Cost Analysis for the 105-N Reactor Facility and 109-N Heat Exchanger Building* (DOE-RL 2004a) was issued. The EE/CA was prepared to meet Tri-Party Agreement Milestone M-93-24, "Submit Engineering Evaluation/Cost Analysis for N Reactor ISS" (Ecology et al. 1989). The alternatives evaluated in the EE/CA included no action, ISS, and long-term S&M. The ISS alternative included reduction of the building footprint by demolition of the fuel storage basin and portions of the facility around the reactor core and construction of an SSE over both the 105-N and 109-N Buildings with a design life of up to 75 years. Because of its unique design, N Reactor includes both the 105-N Reactor Building and the 109-N Heat Exchanger Building. The 109-N Building contains a portion of the N Reactor primary cooling water system and is an integral part of the reactor complex. After the ISS period of up to 75 years, the 109-N Building will be dismantled in preparation for the final disposition of the 105-N reactor. The cost to dismantle the 109-N building in preparation for the final disposition of the 105-N reactor is estimated to be $32.5 million in 2005 dollars (DOE-RL 2004a).

Based on the recommendations of the EE/CA, ISS was the selected alternative as documented in the action memorandum (Ecology and DOE 2005). The ISS action is to be completed in accordance with Tri-Party Agreement Milestone M-93-20, "Complete N Reactor Interim Storage," by September 2012 (Ecology et al. 1989). The proposed schedule and estimated cost for ISS of the 105-N/109-N Buildings are shown in Table 5.

4.4 UPDATED COST ESTIMATES FOR THE FINAL EIS ALTERNATIVES

Table 6 shows the estimated costs for each of the alternatives evaluated in the Final EIS escalated to 2005 dollars. The costs were escalated at a rate of 2.86% per year. The escalation rate was determined by calculating the average rate of inflation for the years 1990 through 2005. An estimated inflation rate of 3.4% was used for 2005. In addition, costs for implementing the alternative at N Reactor have been added to each cost estimate. The costs for the N Reactor were estimated by a proportional increase in the original estimates based on the larger footprint of the N Reactor. This proportional increase includes approximately $32.5 million to dismantle the 109-N building prior to final disposition of the 105-N reactor.

The costs have been adjusted and escalated in order to compare the actual and proposed costs for ISS in Table 5 with the original estimated costs in the Final EIS. The total actual and proposed cost for ISS of the nine surplus reactors is $221.4 million.

Because ISS is more extensive than the safe storage portion of the Final EIS Alternative 3 (safe storage followed by deferred one-piece removal), the costs are not directly comparable. The ISS implementation is roughly equivalent to the safe storage activity of the Final EIS ($114.4 million) plus a portion (50%) of decommissioning operations activity (approximately $116.3 million) to account for the decontamination and decommissioning (D&D) and footprint reduction portion of ISS. By this estimation, the actual and proposed costs for ISS ($221.4 million) are roughly equal to the equivalent estimated costs presented in the Final EIS for the selected alternative, safe storage followed by deferred one-piece removal ($230.7 million).

Table 6. Estimated Costs[a,b] (in millions, 2005 dollars) for Alternatives Presented in the Final Environmental Impact Statement (DOE 1992).

Activity	No Action (Continue Present Action)	Immediate One-Piece Removal	Safe Storage Followed by Deferred One-Piece Removal	Safe Storage Followed by Deferred Dismantlement	In Situ Decommissioning
Safe Storage	$85.0	--	$114.4	$117.4	--
Decommissioning Operations	--	$249.2	$232.6	$386.4	$48.7
Construction of Wells	--	--	--	--	--
Well Monitoring	--	$66.3	$17.3	$19.9	$174.0
Waste Disposal/Barrier	--	$77.7	$77.7	$26.5	$113.5
Totals	**$85.0**	**$393.2**	**$442.0**	**$550.2**	**$336.2**

[a] Estimated costs based on 2005 dollars.
[b] Estimated costs proportionally increased to include N Reactor.

4.5 RADIONUCLIDE INVENTORY

Table 7 shows the radionuclide inventory for the surplus reactors including N Reactor. The reactor block at each of the reactor facilities accounts for approximately 96% of the total radionuclide inventory at each of the reactor facilities.

Table 7. Radionuclide Inventory for Nine Surplus Reactors During the Interim Safe Storage Period.

Reactor Facility	Total Radionuclide Inventory (Ci)					
	March 1, 1985	March 1, 2005	March 1, 2012	Percent Reduction (1985-2012)	March 1, 2068[a]	Percent Reduction (1985-2068)
105-B	23,490	9,042	7,706	67.2%	5,363	77.2%
105-C	24,890	8,977	7,536	69.7%	5,080	79.6%
105-D	21,280	8,565	7,348	65.5%	5,150	75.8%
105-DR	13,420	5,870	5,119	61.9%	3,730	72.2%
105-F	15,930	6,785	5,900	63.0%	4,290	73.1%
105-H	14,590	6,418	5,590	61.7%	4,040	72.3%
105-KE	57,930	20,703	16,626	71.3%	8,970	84.5%
105-KW	51,310	18,959	15,341	70.1%	8,480	83.5%
105/109-N	132,950	38,634	28,576	78.5%	12,440	90.5%
Total Curies	**355,790**	**123,953**	**99,742**	**72.0%**	**57,543**	**83.8%**

[a] 2068 is equivalent to 75 years from publication of the Final Environmental Impact Statement (DOE 1992) and Record of Decision (58 *Federal Register* 48509).

Approximate inventory estimates are shown for each of the reactor facilities beginning March 1, 1985, when the inventories were first calculated. Current inventory estimates for each reactor facility are shown for March 1, 2005. The anticipated inventory estimate has been calculated for each reactor facility for March 1, 2012. This date coincides with the expected completion of ISS for the reactor facilities. The percent reduction of inventory at the completion of ISS, which includes approximately 27 years of decay, is shown for each reactor. The percent reduction ranges from approximately 62% to 78% depending on the reactor facility. Several factors help account for this large range in percent reduction of inventory. The beginning inventory in each of the reactors varies depending on the size of the reactor and operating history of the reactor. For instance, the KE, KW, and N Reactors are much larger and were run at higher levels than the other older reactors. Also, the reactors were shut down at different times. The eight older reactors were shut down by 1971, allowing 14 to 15 years for short-lived radionuclides to decay before the inventory was determined in 1985. This early reduction in inventory in these reactors is not accounted for in Table 7.

The estimated radionuclide inventory is shown for each reactor facility for March 1, 2068. This date coincides with the time at which the final disposition of the reactors must be completed based on a 75-year safe storage period from the date of the 1993 *National Environmental Policy Act of 1969* ROD (58 FR 48509). At this time, approximately 93% of the residual radionuclide inventory resides in the reactor graphite blocks (primarily carbon-14). The percent reduction of inventory during the safe storage period is shown in Table 7 for each reactor facility. The percent reduction ranges from approximately 72% to 90% depending on the facility. This reduction of inventory is calculated by radionuclide decay only. Removal or dismantlement of the reactor facilities would account for further reduction of inventories.

5.0 EVALUATION OF FINAL DISPOSITION ALTERNATIVES

In December 1996, the DOE, EPA, and Ecology agreed to enter into Tri-Party Agreement negotiations to define an effective surplus reactor disposition program. As stated previously, negotiations were conducted assuming a phased approach where Phase One includes ISS and Phase Two would address final reactor disposition. Based on Tri-Party Agreement Milestone M-93-00 and associated interim milestones, the DOE began proceeding with ISS of the surplus production reactors, including N Reactor, by September 31, 2012. No Phase Two milestones were included in the original change control form or negotiated within the M-93-00 milestones or the M-16-00 milestones for final remediation of waste sites.

In October 2001, the three parties signed another agreement in principle to commence negotiations to determine the scope and establish the definition of completion of 100 Area remedial actions by 2012. The three elements of the 100 Area negotiations were remediation of waste sites, D&D of surplus facilities, and ISS of eight of the nine surplus production reactors. Remediation of waste sites and D&D of surplus facilities are captured in the M-16-00 TPA milestones. Tri-Party Agreement Change Control Form M-93-01-02 documents the agreements established for ISS of the 100 Area reactors. Additional interim milestones were developed to align the M-93-00 milestones for reactor ISS with the objective of completion of the 100 Area reactor ISS by 2012. The ISS of the 105-KE and 105-KW Reactors was established with Milestone M-93-22 (September 30, 2011). The ISS of N Reactor was established with Milestone M-93-20 (September 30, 2012). Interim Milestone M-093-25 was established requiring the DOE to submit an engineering evaluation of the final surplus reactor disposition to the EPA and Ecology by September 31, 2005. No Phase Two milestones were negotiated or described in the change control form.

For the purposes of this report, it is assumed that Phase Two Tri-Party Agreement milestones will be negotiated to complete final disposition of the reactors within a 75-year window (no later than 2068). The 75-year time period is consistent with the most recent CERCLA ISS decision documents (Action Memoranda for the reactors) and the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE 1999). The maximum safe storage period was determined as 75 years from the date of the 1993 ROD and corresponds to the year 2068[2]. The following sections evaluate each of the final disposition alternatives available to DOE based on information and assumptions in the surplus production reactors Final EIS (DOE 1992) and ROD (58 FR 48509).

[2] Although these dates and time periods were used in this engineering evaluation, the DOE and EPA will meet prior to 2024 (M-16-00 final milestone date) to negotiate a schedule for final disposition of the surplus reactors.

5.1 FINAL DISPOSITION ALTERNATIVES

The alternatives presented in the Final EIS (DOE 1992) were based on four underlying assumptions that were discussed in Section 2.1 of this document. The baseline assumptions are summarized as follows.

1. The reactors are similar in design, construction, and radiological condition. The differences are noted but are not significant for decommissioning purposes.

2. The residual radioactive materials within the surplus facilities are low-level radioactive wastes that are suitable for disposal at the Hanford Site.

3. Each disposal site would incorporate into the design a protective barrier, a groundwater monitoring system, and an integral marker system.

4. Costs were estimated on the basis of efficient, overlapping work schedules and were developed in 1990 dollars.

No new technical innovations, environmental values, regulatory requirements, or advancements in the decommissioning process were identified that would significantly impact the original assumptions and conclusions of the Final EIS and ROD. The assumptions remain valid for the eight original surplus reactors evaluated in the Final EIS (DOE-RL 1992).

These assumptions are also valid for N Reactor. The basic design, construction, and radiological condition of the N Reactor is similar to the original eight surplus reactors. In addition, the residual radioactive materials within the eight original surplus reactors and N Reactor are low-level wastes and are suitable for disposal at the Hanford Site. This assumption has been validated by the ongoing ISS and D&D work that has been occurring at the reactor sites with the waste materials being disposed at the Environmental Restoration Disposal Facility (ERDF) located in the 200 West Area of the Hanford Site.

Assumptions 3 and 4 related primarily to the cost and schedule estimates presented in the Final EIS (1992). These assumptions also remain valid. The design of the disposal site (either ERDF or a new facility) must meet the intent of assumption three. The cost estimates used in this report will be based on the original estimates presented in the Final EIS (1992) escalated to 2005 dollars using an escalation rate of 2.86%.[3]

After ISS is completed for the surplus production reactors in 2012, three of the original final disposition alternatives in the Final EIS remain that could be implemented by the DOE. The three final disposition alternatives that could be implemented include one-piece removal, dismantlement, and in situ decommissioning. No new alternatives were identified during the course of this engineering evaluation. The following sections discuss each of the three

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[3] Escalation rate is the average rate of inflation for the years 1990 through 2005. An estimated inflation rate of 3.4% was used for 2005.

alternatives and present duration, costs, and dose estimates based on implementation of the alternative for nine surplus reactors by 2068.

5.1.1 One-Piece Removal

One-piece removal involves transporting each reactor block, intact on a tractor-transporter, from its present location in the 100 Areas to the 200 West Area burial grounds for disposal, a distance of about 8 to 22 km (5 to 14 miles), depending on the reactor. The reactor block portion that will be transported includes the graphite core, the thermal and biological shields, and concrete base. Each SSE enclosing the reactor core would be removed. The weight of the reactor block would be transferred to I-beams that would be inserted through holes drilled in the concrete base and grouted in place. Then the area beneath the reactor block would be excavated through the former location of the fuel storage basin. If contaminated soil was identified during the excavation, it would be removed and transported to the 200 West Area for disposal. A tractor-transporter would then be driven under the block, and the block would be lifted from the remaining foundation by hydraulic apparatus on the transporter and carried intact on a specially constructed haul road to the 200 West Area for disposal.

The Final EIS (1992) estimated that the one-piece removal process would take about 2.5 years for each reactor. Based on a staggered schedule, one-piece removal for all nine reactors is estimated to take about 14 years. Following reactor removal, the site formerly occupied by the reactor would be backfilled, graded, seeded, and released in accordance with land-use requirements.

Based on escalation of the cost estimates presented in the Final EIS (1992), the estimated total cost for one-piece removal of all nine reactors is about $327.6 million in 2005 dollars. This cost includes $19.6 million for purchase of two tractor units and fabrication of the transporter and about $33.2 million for haul-road construction, and $77.8 million to build a disposal site for the reactor cores.

Combining the radionuclide inventory estimates in the Final EIS (1992) with the inventory of N Reactor, public radiation doses during the decommissioning period is estimated to be zero, and occupational radiation dose is estimated to be 14.1 person-rem for one-piece removal of all nine reactors. The public radiation dose of zero assumes there will be no public access to the reactor areas during decommissioning. Table 8 shows a summary of duration, cost, and estimated radiation dose for the one-piece removal alternative. All values (i.e., duration, cost, and dose) have been incrementally increased to include N Reactor. The total costs shown for each alternative includes implementation of the alternative only for the duration of the active decommissioning period. The costs do not include S&M costs incurred prior to implementation of the alternative.

Table 8. Comparison of Surplus Reactor Final Disposition Alternatives for Nine Reactors.

Alternative	Active Decommissioning Period (years)	Total Cost (millions, 2005 dollars)	Occupational Radiation Dose (person-rem)	10,000-yr Population Dose[a] (person-rem)
One-Piece Removal	14	$327.6	14.1	2,607
Reactor Dismantlement	30	$433.4	146.6	2,607
In Situ Decommissioning	7	$336.3	9.2	6,450

[a] The same population would receive 9 billion person-rem over 10,000 years from natural radiation.

5.1.2 Reactor Dismantlement

Reactor dismantlement involves piece-by-piece dismantlement of each reactor (including the graphite core) and transporting the radioactive wastes to the 200 West Area for burial. All contaminated equipment and components would be packaged and transported to the 200 West Area for disposal. Contaminated structural surfaces would also be removed, packaged, and transported to the 200 West Area for disposal. Uncontaminated material and equipment would be released for salvage, or disposed of in an approved landfill. Remaining uncontaminated structures would be demolished and the site backfilled, graded, seeded, and released for other DOE use in accordance with land use requirements.

The Final EIS (1992) estimated 6.5 years would be required for dismantlement of each reactor. Based on a staggered schedule, the entire dismantlement process for all nine reactors would take about 30 years to complete. Following reactor removal, the site formerly occupied by the reactor would be backfilled, graded, seeded, and released in accordance with land-use requirements. Based on escalation of the original cost estimates in the Final EIS (1992), the estimated total cost for dismantlement of all nine reactors is about $433.4 million in 2005 dollars.

Public radiation doses during dismantlement of all nine reactors are estimated to be zero, and occupational radiation doses are estimated to be 146.6 person-rem during deferred dismantlement for all nine reactors. The occupational radiation dose for dismantlement is higher than the occupation radiation doses for one-piece removal because of the need to work at the interior of the carbon block where dose rates are higher than in the work areas utilized for one-piece removal. Table 8 shows a summary of duration, cost, and estimated radiation dose for the one-piece removal alternative.

5.1.3 In Situ Decommissioning

In situ decommissioning involves preparing the reactor block for covering with a protective mound (barrier) and constructing the mound. Surfaces within the facility that are potentially contaminated would be painted with a fixative to ensure retention of contamination during subsequent activities. The voids beneath and around the reactor block would be filled with grout and/or gravel as a further sealant and to prevent subsidence of the final overburden. The roofs and superstructures of the SSE and concrete shield walls would be removed down to the level of the top of the reactor block. Piping and other channels of access into the reactor building would be backfilled with grout or similar material to ensure isolation of the reactor from the surrounding environment. Finally, the reactor block, its adjacent shield walls, and the spent fuel storage basin, together with the contained radioactivity, gravel, and grout, would be covered to a depth of at least 5 m with a mound containing earth and gravel. The mound would include an engineered barrier designed to limit water infiltration through the barrier to 0.1 cm/yr. Riprap on the sides of the mounds would ensure structural stability of the mounds and mitigate against the impact of any flood that might reach the reactors. The mounds may cover the existing location of inactive waste disposal sites. Necessary remedial actions for these sites would be taken prior to or in conjunction with the in situ decommissioning.

The Final EIS (1992) estimated in situ decommissioning of one reactor would take about 2 years. Based on a staggered schedule, in situ decommissioning of all nine reactors is estimated to take about 7 years. Based on escalation of the original cost estimates in the Final EIS (1992), the estimated total cost for in situ decommissioning of all nine reactors is about $336.3 million in 2005 dollars.

Public radiation doses during the in situ decommissioning period are estimated to be zero, and occupational radiation doses are estimated to be 9.2 person-rem for in situ decommissioning of all nine reactors. Table 8 shows a summary of duration, cost, and estimated radiation dose for the in situ alternative.

5.2 COMPARISON OF FINAL DISPOSITION ALTERNATIVES

Under the actions proposed in this report, each of the final disposition alternatives would be completed by no later than 2068. In order to complete the alternative by 2068, the field work would have to commence some time before 2068. This means each alternative includes a period of reduced S&M of the reactor SSE structures followed by the actual decommissioning alternative implemented over a specific period of time dependent on the alternative. Table 9 shows the implementation period, corresponding length of the reduced S&M period, estimated start date, and estimated cost of reduced S&M for each alternative. The period of reduced S&M is that time leading up to the start of the final disposition alternative when no decommissioning activities are taking place. During this time each reactor SSE structure is monitored from the outside with limited entries occurring approximately every 5 years. As shown in Table 9, the period of reduced S&M varies for each alternative. Once the disposition alternative is implemented, reduced S&M is continued only for the reactors that remain in ISS awaiting final disposition. This period of decreasing S&M scope is reflected in each cost estimate depending on the alternative.

Table 9. Implementation Periods and Cost of Reduced Surveillance and Maintenance for Each Final Disposition Alternative.

Alternative	Implementation Period of Alternative (years)	Period of Reduced Surveillance and Maintenance (years)	Estimated Start Date of Decommissioning Activities	Cost of Reduced Surveillance and Maintenance (millions, 2005 dollars)
One-Piece Removal	14	42	2054	$5.9
Reactor Dismantlement	30	26	2038	$4.5
In Situ Decommissioning	7	49	2061	$6.4

As shown in Table 8, the estimated implementation cost of each final disposition alternative is comparable. The alternative with the lowest implementation cost was one-piece removal (327.6 million), followed by in situ decommissioning ($336.3 million), followed by reactor dismantlement ($433.4 million). The costs differ by approximately 25% from lowest to highest. The cost of reduced S&M (Table 9) varies by about 30% between the final disposition alternatives. The DOE has the flexibility to reduce this portion of the total cost of the final disposition alternative by implementing the alternative at an earlier date, thereby reducing the period of reduced S&M.

Table 10 shows the total cost of implementation of each of the final disposition alternatives for nine reactors by 2068 following ISS. The costs presented for implementation of the alternatives for all nine reactors by 2068 include an appropriate estimate for reduced S&M as was shown in Table 9 and are reported in 2005 dollars. Present-worth (discounted) cost estimates have also been provided for the cost estimate for nine reactors implemented by 2068. Consistent with guidance established by the EPA and the U.S. Office of Management and Budget, present-worth analysis is used as the basis for comparing costs of cleanup alternatives under the CERCLA program (EPA 1993). The present-worth values were determined through a calculation using 30-year real interest rate on treasury notes and bonds from OMB Circular A-94, Appendix C (OMB 1992). The actual interest rate is 3.1% for a duration of 57 years.

Table 10. Final Disposition Implementation Costs (in millions, 2005 dollars) for Each Alternative.

Alternative	As Implemented for Nine Reactors by 2068 following Interim Safe Storage	Present-Worth Costs As Implemented by 2068 following Interim Safe Storage
One-Piece Removal	$333.5	$75.9
Reactor Dismantlement	$437.9	$129.0
In Situ Decommissioning	$342.7	$69.9

The total estimated costs of one-piece removal and in situ decommissioning following ISS are essentially the same. The total estimated cost of reactor dismantlement following ISS is approximately 25% higher than one-piece removal. This general trend is also reflected in the present-worth values. The relatively higher present-worth value for the reactor dismantlement alternative is directly influenced by longer duration needed to implement the alternative.

Table 11 contains estimates of occupational dose and population dose for the eight reactors evaluated in the Final EIS and for N Reactor. The table also shows the total occupational dose and population dose for all nine reactors for each final disposition alternative implemented by 2068.

Table 11. 2068 Occupational and Population Dose Estimates for the Final Disposition Alternatives.

Alternative	Dose for Eight Reactors from the Final Environmental Impact Statement (person-rem)		Dose for N Reactor (person-rem)		Total Dose for Nine Reactors (person-rem)	
	Workers	Public	Workers	Public	Workers	Public
One-Piece Removal	7.5	1,734	6.6	873	14.1	2,607
Reactor Dismantlement	78	1,734	68.6	873	146.6	2,607
In Situ Decommissioning	5	4,290	4.2	2,160	9.2	6,450

Radionuclide inventories for each of the surplus reactors were shown in Table 7. Based on this information, N Reactor has an inventory approximately four to five times greater than the average inventory for the other eight surplus reactors. This difference is primarily due to the size of the reactor, high operating power levels, and the difference in reactor cooling used at N Reactor. N Reactor had closed-loop, pressurized cooling, whereas the earlier reactors used single-pass cooling. In single-pass cooling, much of the radioactivity is discharged from the reactor in the cooling water.

As shown in Table 11, the larger inventory in N Reactor directly correlates to increased occupational and population doses. The estimated dose to workers increases by approximately 25%, while the estimated dose to the public increases by approximately a factor of 4. Carbon-14 is the principal radionuclide contributing to this increase in dose and is directly related to the relative size of the N Reactor core and larger amount of graphite in the core.

The one-piece removal and in situ alternatives each contribute similar doses to the worker. In both alternatives the reactor block is maintained in one piece and reactor shielding is intact. The estimated dose to the worker is significantly higher for the dismantlement alternative due to the intrusive work required to dismantle the highly radioactive reactor blocks. The one-piece removal and dismantlement alternatives each contribute similar population doses as both alternatives result in disposal of the reactor block in the Hanford Site 200 Areas. The significantly higher population dose estimated for the in situ alternative is related to leaving the reactor blocks along the Columbia River.

6.0 DISCUSSION

The *Final Environmental Impact Statement: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (DOE 1992) was issued by the DOE in December 1992. The *Record of Decision: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (58 FR 48509) was issued in September 1993. The ROD states the DOE will implement safe storage followed by deferred one-piece removal as the final disposition alternative for the eight surplus reactors.
In August 1997, the DOE, EPA, and Ecology issued Tri-Party Agreement Change Control Form M-93-97, which documents agreements and commitments that resulted in milestones and target dates governing decommissioning/disposition of the Hanford Site surplus production reactors.

In August 1996, the DOE began implementation of ISS at C Reactor as a CERCLA removal action. Interim safe storage includes decontamination of reactor structures, reduction of the reactor footprint through decommissioning, and construction of an SSE over the reactor core to prevent deterioration and release of contamination for up to 75 years. The ISS of C Reactor was completed in September 1998. Interim safe storage removal actions have subsequently been completed at DR Reactor in September 2002, F Reactor in September 2003, and D Reactor in September 2004. In addition, ISS is expected to be completed at H Reactor by September 2005. The ISS of the 105-N/109-N Reactor complex was approved by the *105-N Reactor Building and 109-N Heat Exchanger Building Action Memorandum* (Ecology and DOE 2005) on February 22, 2005. Interim safe storage of the 105-N/109-N Reactor complex is included in Tri-Party Agreement milestones.

To date, the actual cost of ISS compares very favorably with the estimated costs for the safe storage followed by deferred one-piece removal alternative presented in the Final EIS and selected in the ROD. The estimated cost to complete ISS of KE Reactor, KW Reactor, and the 105-N/109-N Reactor complex is approximately $90.8 million. The KE and KW estimated costs also compare favorably with the cost estimates presented in the Final EIS. The ISS of N Reactor was not estimated in the Final EIS.

The DOE is currently on schedule to complete ISS of eight of the nine Hanford Site surplus reactors by September 2012. The safe storage of B Reactor is currently deferred awaiting final determination of its status as a national historic site. If B Reactor is not preserved as a museum and the DOE decides to implement ISS for the structure, new milestones and target dates will need to be negotiated with the EPA and Ecology. Once ISS is completed, the DOE will have completed all of the Tri-Party Agreement interim milestones for M-93-00. Based on the current interpretation, commitments, and language in the implementing CERCLA documentation, it is understood that the ISS period could extend for up to 75 years from the date of the ROD. This end date is assumed to be 2068 for the purposes of this report.

Of the five alternatives evaluated in the Final EIS (DOE 1992), three remain viable alternatives for final disposition of the Hanford Site surplus reactors after completion of ISS. These alternatives include one-piece removal, total dismantlement, and in situ decommissioning. The original assumptions that formed the basis for evaluating these alternatives in the Final EIS (DOE 1992) remain valid. No new information or technologies have been identified that significantly alter the evaluations or conclusions of the Final EIS. The values for implementation duration, cost estimates, and dose estimates also are valid and consistent with current information. The values presented in the Final EIS have been used in this report and have been updated to include the 105-N/109-N Reactor complex and escalated to 2005 dollar equivalents. The actual costs to date incurred for ISS of five of the eight surplus reactors compare well to the cost estimates presented in the Final EIS (DOE 1992).

Estimated cost, duration, and dose were reviewed in Section 5.2 for each of the three final disposition alternatives. Based on the information presented in Section 5.2, one-piece removal and in situ decommissioning appear to be the most feasible of the final disposition alternatives to implement on the basis of estimated cost, duration, and dose. These two alternatives have shorter estimated durations to implement, lower estimated costs, and lower estimated occupational radiation dose. Of these two alternatives, the one-piece removal alternative contributes lower long-term radiation dose to the public due to the removal of the reactor blocks from the Columbia River shoreline to a burial ground in the Hanford Site 200 Areas.

Based on the information presented in Section 5.2, the dismantlement alternative appears to be the least feasible of the final disposition alternatives. This alternative has the longest estimated duration to implement, highest estimated cost, and highest estimated occupational radiation dose.

7.0 FUTURE ACTIONS

The current program of ISS implemented by the DOE is successfully meeting the requirements and intent of the safe storage followed by deferred one-piece removal alternative selected in the Final EIS and ROD. Public acceptance of the surplus reactor ISS program implemented to date was affirmed at the 100 Area End State Workshop held June 23 and 24, 2004 (DOE-RL 2004b). The ISS of the Hanford Site surplus reactors is being conducted on schedule and within the costs estimated in the Final EIS. It is the intention of DOE to continue the ISS program as currently implemented at a funding level that will meet the 2012 milestones to complete ISS of eight of the nine surplus reactors.

Public support for preservation of B Reactor was expressed at the 100 Area End State Workshop (DOE-RL 2004b). The DOE will continue to work with the EPA, Ecology, and other stakeholder groups to identify a sponsor interested in preserving all or part of B Reactor as early as possible. However, if no suitable sponsor and funding is identified, the DOE will prepare the documentation necessary to implement ISS of B Reactor. If a future decision is made to perform ISS on the B Reactor, the DOE will work with the EPA and Ecology to negotiate the appropriate milestones for the ISS of B Reactor.

Prior to 2024, the DOE will negotiate a schedule for final disposition of the surplus reactors. This time frame allows for further decay of radioactive inventory while supporting timely final disposition of the reactors. This decision coincides with the published notes from the 100 Areas End States Workshop (DOE-RL 2004b).

It is DOE's position that no new information or technologies have been identified that significantly change the conclusions of the Final EIS. The selected final disposition alternative, safe storage followed by deferred one-piece removal, appears to be the most feasible in terms of duration, cost, and radiological dose. In situ decommissioning may also be a viable alternative. The viability of these options should be reviewed on a regular basis.

It is the intention of DOE to prepare the necessary documents to officially include final disposition of the 105-N/109-N Reactor complex consistent with the selected alternative of the Final EIS and ROD. It may be beneficial to prepare a remedial investigation/feasibility study for final disposition of the surplus reactors. A reactor remedial investigation/feasibility study could include all of the reactors and bring all of the facilities under CERCLA. This action would also include *National Environmental Policy Act of 1969* values and accommodate waste disposal at the ERDF. An alternate pathway would be to prepare a supplemental EIS and ROD before final disposition begins to update all environmental analyses, impacts, and mitigation.

Finally, the information and conclusions of this report should be reviewed and revised as needed within a period of no more than 10 years. It would be most beneficial to review the information and conclusions of this report at or near the conclusion of ISS of the surplus production reactors.

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