FINAL ENVIRONMENTAL IMPACT STATEMENT ON THE DISPOSAL OF DECOMMISSIONED, DEFUELED CRUISER, OHIO CLASS, AND LOS ANGELES CLASS NAVAL REACTOR PLANTS

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ON THE
DISPOSAL OF DECOMMISSIONED, DEFUELED CRUISER,
OHIO CLASS,
AND
LOS ANGELES CLASS NAVAL REACTOR PLANTS

United States
Department of the Navy

COVER SHEET

RESPONSIBLE AGENCIES:
Lead Federal Agency: U.S. Department of the Navy
Cooperating Agency: U.S. Department of Energy

By participating as a cooperating agency in this Environmental Impact Statement, the Department of Energy expects to be able to adopt this Environmental Impact Statement, if appropriate, to fulfill its environmental review obligations under the National Environmental Policy Act.

TITLE: Final Environmental Impact Statement on the Disposal of Decommissioned, Defueled cruiser, OHIO Class, and LOS ANGELES Class Naval reactor plants.

ABSTRACT: This statement describes in detail the preferred alternative - land burial of the entire reactor compartment at the Department of Energy Low Level Waste Burial Grounds at Hanford, Washington; the "no-action" alternative - protective waterborne storage for an indefinite period; disposal and reuse of subdivided portions of the reactor plant; and indefinite storage above ground at Hanford. Other alternatives examined in limited detail are sea disposal; land disposal at other sites; and permanent above ground disposal at Hanford.

Location of U.S. Department of Navy facilities considered for implementation of the preferred alternative: Puget Sound Naval Shipyard, Bremerton, Washington.

Location of U.S. Department of Energy facilities considered for implementation of the preferred alternative: Hanford Site, Benton County, Franklin County, and Grant County, Washington.

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SUMMARY

This Environmental Impact Statement analyzes the alternate ways for disposing of decommissioned, defueled reactor compartments from U.S. Navy nuclear-powered cruisers, (BAINBRIDGE, TRUXTUN, LONG BEACH, CALIFORNIA Class, and VIRGINIA Class) and LOS ANGELES Class, and OHIO Class submarines. A disposal method for the defueled reactor compartments is needed when the cost of continued operation is not justified by the ships' military capability or when the ships are no longer needed. After a nuclear-powered ship no longer has sufficient military value to justify continuing to maintain the ship or the ship is no longer needed, the ship can be: (1) placed in protective storage for an extended period followed by permanent disposal or recycling; or (2) prepared for permanent disposal or recycling. The alternatives examined in detail are the preferred alternative of land burial of the entire defueled reactor compartment at the Department of Energy Low Level Waste Burial Grounds at Hanford, Washington; the no-action alternative - protective waterborne storage for an indefinite period; disposal and reuse of subdivided portions of the reactor compartments; and indefinite storage above ground at Hanford. No new legislation is required to implement any of these alternatives. Several other alternatives are also examined in limited detail. These alternatives include sea disposal; land disposal at other sites; and permanent above ground disposal at Hanford.

In all of the alternatives considered in this Environmental Impact Statement there would be no spent nuclear fuel left in the reactor compartments. All the spent nuclear fuel would be removed before disposal. Management of the spent nuclear fuel is addressed in a separate Department of Energy National Environmental Policy Act (NEPA) document, U. S. Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Environmental Impact Statement, (DOE, 1995) for which the Navy is a cooperating agency. Nevertheless, there would be some other radioactive materials left within the reactor compartments. Therefore, this Final Environmental Impact Statement evaluates disposal of the reactor compartments after all the spent nuclear fuel has been removed. Recycling of the non-radioactive portion of nuclear-powered ships has been evaluated in an Environmental Assessment, and the Navy concluded that there was no significant environmental impact associated with the recycling process (USN, 1993a). Types of U.S. Navy nuclear-powered ships that are not expected to be decommissioned in the next 20 years (e.g., aircraft carriers, SEAWOLF Class submarines) are not included in this Final Environmental Impact Statement.

Navy submarine reactor plants constructed prior to the USS LOS ANGELES (SSN 688) (referred to as pre-LOS ANGELES Class submarines) share many common design characteristics with reactor plants from cruisers, OHIO Class submarines, and LOS ANGELES Class submarines. Pre-LOS ANGELES Class submarine reactor compartments are currently being disposed of at the Department of Energy Hanford Site in Eastern Washington, by Puget Sound Naval Shipyard in Bremerton, Washington consistent with the Record of Decision on disposal of decommissioned, defueled Naval submarine reactor plants (USN, 1984b). Because of the commonality of design with submarine reactor compartments from pre-LOS ANGELES Class submarines, it is feasible to use the same basic disposal method for disposal of reactor compartments from cruisers, LOS ANGELES Class submarines and OHIO Class submarines. The method currently being used for disposal of pre-LOS ANGELES Class reactor compartments, has been demonstrated to be cost effective, minimizes exposure to workers and the public, and has been used to safely package and ship over 40 reactor compartments from Puget Sound Naval Shipyard to the Hanford site for

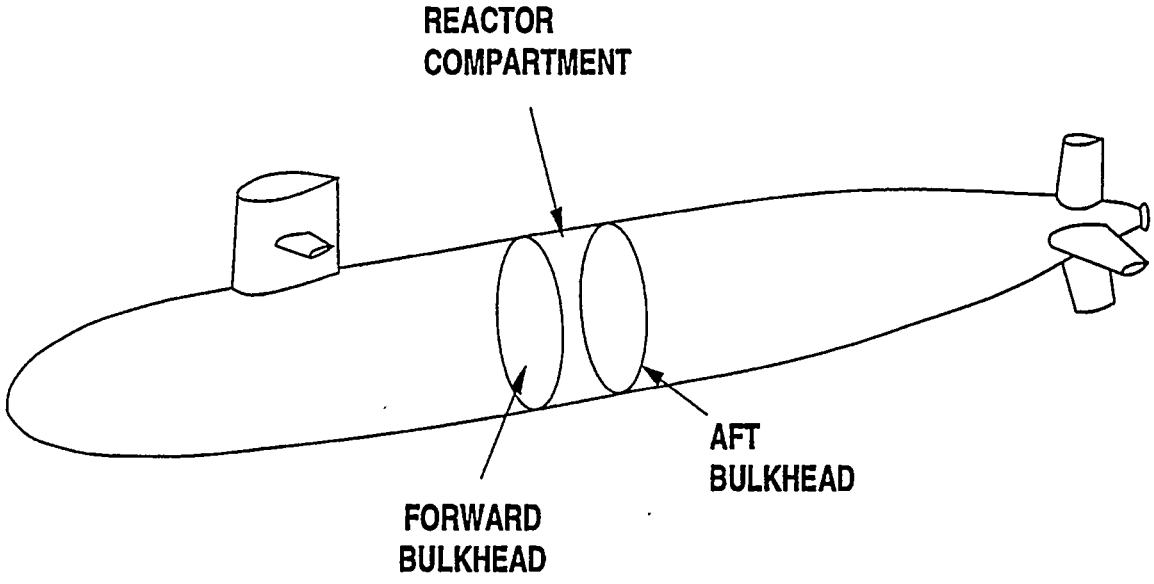

Figure S.1. Typical Submarine Reactor Compartment Location

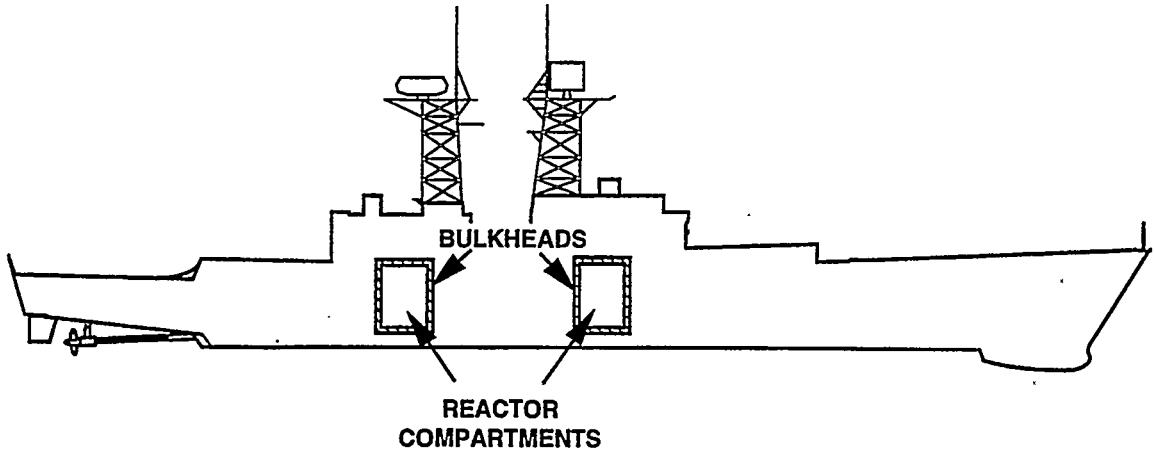

Figure S.2. Typical Cruiser Reactor Compartment Location

disposal. The Navy has determined that this same basic method is the preferred alternative for disposal of reactor compartments from cruisers, LOS ANGELES Class submarines and OHIO Class submarines when compared to the other alternatives evaluated in this EIS.

1. Background

As of the end of 1994, the U.S. Navy had 99 nuclear-powered submarines and 13 nuclear-powered surface ships in operation. Today, over 40% of the Navy's principal combatants are nuclear-powered.

A nuclear-powered ship is constructed with the nuclear power plant inside a section of the ship called the reactor compartment. Figure S.1 shows a typical submarine with the location of the reactor compartment identified. Figure S.2 shows a typical cruiser with the location of the reactor compartments identified. The components of the nuclear power plant include a high-strength steel reactor vessel, heat exchanger(s) (steam generator), and associated piping, pumps, and valves. Each reactor plant contains over 100 tons of lead shielding, part of which is made radioactive by contact with radioactive material or by neutron activation of impurities in the lead.

Before a ship is taken out of service, the spent fuel is removed from the reactor pressure vessel of the ship in a process called defueling. This defueling removes all of the fuel and most of the radioactivity from the reactor plant of the ships. The fuel removed from the decommissioned ships would be handled in the same manner as that removed from ships which are being refueled and returned to service. Unlike the low-level radioactive material in defueled reactor plants, the Nuclear Waste Policy Act of 1982, as amended, requires disposal of spent fuel in a deep geological repository. Storage and disposal of spent fuel from refuelings and defuelings of nuclear-powered ships does not affect the decision of how to dispose of the defueled reactor compartments. Further, handling of spent fuel from these ships was addressed in the Programmatic Spent Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Environmental Impact Statement, (DOE, 1995) in which the Navy is a cooperating agency. Therefore, handling and disposal of spent fuel is not the subject of this Environmental Impact Statement.

Prior to disposal, the reactor pressure vessel, radioactive piping systems, and the reactor compartment disposal package would be sealed. Thus, they act as a containment structure for the radioactive atoms and delay the time when any of the radioactive atoms inside would be available for release to the environment as the metal corrodes. This is important because radioactivity "decays" away with time; that is, as time goes on radioactive atoms change into nonradioactive atoms. Since radioactivity decays away with time, the effect of a delay is that fewer radioactive atoms would be released to the environment. Over 99.9% of these atoms are an integral part of the metal and they are chemically just like ordinary iron, nickel, or other metal atoms. These radioactive atoms are only released from the metal as a result of the slow process of corrosion. The remaining 0.1% which is corrosion and wear products, will decay away prior to penetration of the containment structures by corrosion.

The decay of radioactive atoms produces radiation, which can cause damage to tissue if there is insufficient distance or shielding between the source and the tissue. The effects on people of radiation that is emitted during decay of a radioactive substance depends on the kind of radiation (alpha and beta particles, and gamma and x-rays) and the total amount of radiation energy absorbed by the body. Within kinds of radiation, the energy of the radiation varies depending on the source isotope. The more energetic radiation of a given kind, the more energy that will be

absorbed, in general. The total energy absorbed per unit quantity of tissue is referred to as absorbed dose. The absorbed dose, when multiplied by certain quality factors and factors that take into account different sensitivities of various tissues, is referred to as effective dose equivalent, or where the context is clear, simply dose. The common unit of effective dose equivalent is the rem or mrem (0.001 or 10^{-3} rem).

An individual may be exposed to ionizing radiation externally, from a radioactive source outside the body, and/or internally, from ingesting radioactive material. The external dose is different from the internal dose. An external dose is delivered only during the actual time of exposure to the external radiation source. An internal dose, however, continues to be delivered as long as the radioactive source is in the body, although both radioactive decay and elimination of the radionuclide by ordinary metabolic process decrease the dose rate with the passage of time.

Doses are often classified into two categories: acute, which is a large dose received over a few hours or less; and chronic, which involves repeated small doses over a long time (months or years). Chronic doses are usually less harmful than acute doses because the time between exposures at low dose rates allows the body to repair damaged cells. Only chronic effects are considered here as the exposures discussed are much less than the threshold for acute effects. The most significant chronic effect from environmental and occupational radiation exposures is induction of latent cancer fatalities. This effect is referred to as latent because the cancer may take many years to develop.

Hypothetical health effects can be expressed in terms of estimated latent cancer fatalities. The health risk conversion factors used in this evaluation are taken from the International Commission on Radiological Protection which specifies 0.0005 latent cancer fatalities per person-rem of exposure to the public and 0.0004 latent cancer fatalities per person-rem for workers (ICRP, 1991).

To place exposure into perspective with normal everyday activities of the general public, a typical person in the United States receives 300 mrem of radiation exposure each year from natural background radiation, (NCRP, 1987). Natural background radiation is radiation that all people receive every day from the sun or from cosmic radiation, and from the natural radioactive materials that are present in our surroundings, including the rocks or soil we walk on.

2. Summary of Alternatives

a. Preferred Alternative - Land Burial of the Entire Reactor Compartment at the Department of Energy Low Level Waste Burial Grounds at Hanford, WA

In this alternative, the reactor compartments would be prepared for shipment at Puget Sound Naval Shipyard, shipped to and buried at the Department of Energy (DOE) Hanford Site in the state of Washington. The Hanford Site is used for disposal of radioactive waste from DOE operations. The pre-LOS ANGELES Class submarine reactor compartments are placed at the Hanford Site Low Level Burial Grounds for disposal, at the 218-E-12B burial ground in the 200 East area.

The Hanford Site is a large federal government site, occupying 1450 square kilometers (560 square miles) (365,000 acres) in southeastern Washington state. In the middle of the site on the Central Plateau, approximately 210 hectares (518 acres) have been designated as the Low Level Burial Grounds. The Low Level Burial Grounds are about seven miles from the Columbia River. The Hanford Site, and in particular the 218-E-12B low level burial ground, is well suited to the

permanent disposal of these reactor compartments due to (1) accessibility by barge via the Columbia River and proximity to barge off-loading facilities, (2) an arid climate, (3) excellent soil characteristics which inhibit the corrosion of metal and the migration of metals and radionuclides down through the soil, (4) the current designation of the area for disposal of low level radioactive waste and current placement of pre-LOS ANGELES class submarine reactor compartments at the 218-E-12B burial ground for disposal, (5) isolation of the 218-E-12B burial ground and all Hanford low level burial grounds from the general public, and (6) institutional controls for the management of radioactive and dangerous waste.

The disposal of the reactor compartments from the cruisers, LOS ANGELES, and OHIO Class submarines would be consistent with the pre-LOS ANGELES Class submarine reactor compartment disposal program. The land required for the burial of approximately 100 reactor compartments from the cruisers, LOS ANGELES, and OHIO Class submarines would be approximately 4 hectares (10 acres) which is similar to the land area needs for the pre-LOS ANGELES Class submarine reactor compartments. Besides the reactor compartments, the volume of mixed waste generated by this alternative is estimated to be about 1625 cubic meters (57,400 cubic feet). This mixed waste would be managed in accordance with the approved Shipyard Site Treatment Plan and associated implementing order pursuant to the Federal Facility Compliance Act.

Briefly, this alternative would involve draining the piping systems, tanks, vessels, and other components to the maximum extent practical, sealing the radioactive systems, removing the reactor compartment and enclosing it in a high integrity all-welded steel package. The reactor compartment packages would meet the Type B requirements of the Department of Transportation, the Nuclear Regulatory Commission, and the Department of Energy. Non radioactive metal, such as submarine hulls, could be recycled. The reactor compartment package would be transported by barge out of Puget Sound through the Strait of Juan de Fuca, down the Washington coast, and up the Columbia River to the Port of Benton where it would be loaded onto an overland transporter and hauled the short distance to the Department of Energy's Low Level Radioactive Waste Burial Grounds at the Department of Energy's Hanford Site near Richland, Washington.

Disposal of the reactor compartments would be in accordance with Department of Energy requirements for low level radioactive waste disposal. Disposal of the reactor compartments would be regulated by the State of Washington due to the lead shielding contained within the reactor compartments, and by the United States Environmental Protection Agency due to the small quantity of solid polychlorinated biphenyls within the reactor compartments in the form of industrial materials such as insulation, electrical cables, and rubber parts. The total volume of the reactor compartments is about 120,000 cubic meters (4,240,000 cubic feet).

An estimated cost for land burial of the reactor compartments is $10.2 million for each LOS ANGELES Class submarine reactor compartment, $12.8 million for each OHIO Class submarine reactor compartment, and $40 million for each cruiser reactor compartment. The estimated total Shipyard occupational exposure to prepare the reactor compartment disposal packages is 13 rem (approximately 0.005 additional latent cancer fatalities) for each LOS ANGELES Class submarine package, 14 rem (approximately 0.006 additional latent cancer fatalities) for each OHIO Class submarine package and 25 rem (approximately 0.01 additional latent cancer fatalities) for each cruiser package. The total estimated cost of this alternative is approximately $1,500 million and the total estimated Shipyard occupational exposure is 1508 rem (approximately 0.6 additional latent cancer fatalities). Occupational and public exposures, costs, and land commitments are further compared in Table S.1.

b. No Action Alternative - Protective Waterborne Storage for an Indefinite Period

A ship can be placed in floating protective storage for an indefinite period. Nuclear-powered ships can also be placed into storage for a long time without risk to the environment. The ship would be maintained in floating storage. About every 15 years each ship would have to be taken out of the water for an inspection and repainting of the hull to assure continued safe waterborne storage. However, this protective storage does not provide a permanent solution for disposal of the reactor compartments from these nuclear-powered ships. Thus, this alternative does not provide permanent disposal.

The two Naval Shipyards considered for this alternative are: Puget Sound Naval Shipyard located in Bremerton, Washington and Norfolk Naval Shipyard located in Portsmouth, Virginia. These are the two Naval Shipyards with inactive nuclear ship maintenance facilities.

An estimated cost to prepare a cruiser, LOS ANGELES, or an OHIO Class submarine for protected waterborne storage and to keep it in storage for 15 years is approximately $1.6 million each. To keep a cruiser, or a LOS ANGELES, or a OHIO Class submarine in waterborne storage for an additional 15 years is estimated to cost $1.75 million each. Occupational and public exposures, costs, and land commitments are further compared in Table S.1.

c. Disposal and Reuse of Subdivided Portions of the Reactor Plant

In general, disposal and reuse of subdivided portions of the reactor compartments would expand and build upon operations and processes in use at Naval Shipyards to overhaul ships and recycle non-radioactive portions of decommissioned ships. It would require large scale changes in terms of the numbers and size of components to be processed. Very large components, such as reactor vessels, steam generators and pressurizers, which are not removed from reactor compartments under current programs, would have to be removed, packaged and disposed of individually. In addition, the quantity of smaller components such as valves, pumps and gages to be processed would be orders of magnitude greater than under current Shipyard workloads. Compatible dismantlement processes, packaging methods, modes of transportation and disposition sites would be selected for each individual radioactive component. A massive shielded container would be needed for transport of the reactor vessel and its internal structure to the appropriate disposal site. Non-radioactive metal, such as submarine hulls, would be recycled.

The amount of waste estimated for the subdivision alternative ranged from a high of 120,000 cubic meters (4,240,000 cubic feet) to a low of 10,000 cubic meters (353,000 cubic feet) with an intermediate estimate of 24,000 cubic meters (847,000 cubic feet). The amount of mixed waste was estimated to be from 2,255 to 6,255 cubic meters (79,600 to 221,000 cubic feet).

The cost of this alternative is estimated to be between $82.2 million and $93.6 million, per reactor compartment depending upon the estimating method used (see Appendix C). The radiological dose to workers is estimated to be between 230 and 1,115 rem per reactor compartment if accomplished immediately (0.09 to 0.45 additional latent cancer fatalities) or between 60 and 338 rem per reactor compartment (0.02 to 0.14 additional latent cancer fatalities) if deferred 10 years. Deferral of subdivision operations would not result in any significant reduction in radioactive waste volume. Deferral would require placement of inactivated ships in protected waterborne storage as described in the no action alternative. Occupational and public exposures, costs, and land commitments are further compared in Table S.1.

d. Indefinite Storage Above Ground at Hanford

In this alternative, reactor compartments would be stored indefinitely at the Department of Energy Hanford Site. At the Hanford Site, Trench 94 in the 218-E-12B low Level Burial Ground of the 200 East area is currently used for disposal of pre-LOS ANGELES Class submarine reactor compartments. The area to the north of this trench is available for Navy use and could accommodate the storage of 100 reactor compartments.

Compartment packaging and transport methods would be identical to those for the preferred alternative. Estimated costs for packaging and transporting compartments to the storage site are identical to those for the preferred alternative. Corresponding radiation exposures are also identical. See Table S.1 for further comparison.

This alternative is similar to the preferred alternative through shipment of the reactor compartments to the 218-E-12B burial ground. However, as in the no-action alternative, storage is not a disposal alternative. Such storage would only defer the need to permanently disposition the radioactive, hazardous and PCB waste contained by the reactor compartments.

e. Other Alternatives

The following alternatives were eliminated from detailed evaluation as discussed below.

(1) Sea Disposal

Sea disposal would involve sinking the entire ship in the deep ocean. Ocean dumping of low level radioactive material is prohibited by the London Convention for 25 years (IMO, 1993). This alternative would require new legislation to implement.

(2) Land Disposal of Entire Reactor Compartments at Other Sites

The Low Level Radioactive Waste Policy Act Amendments of 1985 state the Federal Government shall be responsible for disposal of low-level radioactive waste owned or generated by the U.S. Navy as a result of the decommissioning of U.S. Navy vessels. In addition, the need to maintain control of the classified design information inherent in the reactor compartments and many of their components requires a site under Federal control. Federal nuclear waste disposal sites are located at Department of Energy Sites.

Department of Energy radioactive waste disposal sites, other than the preferred alternate site at Hanford, pose physical limitations. Disposal of the entire reactor compartment disposal package at any site is dependent on the ability to transport the package to the site. In general, the only feasible means of transportation over long distances for packages over 1000 tons and over 30 feet tall is by barge. Physical restrictions to overland transport of the packages include bridges, overhead obstructions, embankments, road load bearing capacity, and steep or narrow roads. Because of the lack of availability of a nearby barge transportation route and land transportation required over long distances, all other Department of Energy land disposal sites would be inaccessible.

(3) Permanent Above Ground Disposal at Hanford

In this alternative, cruiser, LOS ANGELES, and OHIO class reactor compartments would be placed above ground at the Hanford Site, and covered with soil, entombing the reactor compartments in a soil mound. A Resource Conservation and Recovery Act compliant closure cover would be placed over the compartments. The gentle slope of this cover would occupy more land space than if the compartments were placed below ground in a trench. The gentle slope would result in a minor recontouring of the original land surface into a natural looking gradual rise. For sites with groundwater aquifers that are non-existent or deep underground like Hanford, the resulting environmental impacts of this alternative are very similar to the preferred alternative.

3. Summary of Environmental Consequences

The preferred alternative of land burial of the entire reactor compartment at the DOE's Hanford site would result in a much lower potential for latent cancer fatalities among workers in addition to a much lower cost as compared to the subdivision alternative. The environmental consequences of the preferred alternative, the no action alternative and the alternative of indefinite storage above ground at Hanford would all be low, but the preferred alternative has the advantage of being a permanent solution whereas the other two alternatives are interim solutions that only defer the need for permanent disposition.

a. Preferred Alternative - Land Burial of the Entire Reactor Compartment at the Department of Energy Low Level Waste Burial Grounds at Hanford, WA

(1) Shipyard Operations

Radiation exposure to Shipyard workers associated with reactor compartment disposal packaging operations to accomplish the preferred alternative has been estimated to be 1508 rem (approximately 0.6 additional latent cancer fatalities).

In all of the alternatives, the Navy would generate radioactive waste, PCB waste, and hazardous waste for disposal. However, the Navy would minimize the amount generated and any waste generated would be disposed of in accordance with applicable state and federal regulations using licensed transportation contractors and disposal sites.

(2) Transport Route

The impacts along the transport route that would be used to move reactor compartments from Puget Sound Naval Shipyard to the Hanford Site for disposal are evaluated in Appendix E. It is estimated that the preferred alternative would involve 100 reactor compartment shipments and would result in exposure to the general population of 5.8 person-rem (0.003 latent cancer fatalities). For the transportation crew it is estimated that exposure would be 5.8 person-rem (0.002 latent cancer fatalities).

In order to use the existing land transport route, six overhead power lines may need to be modified to accommodate the larger reactor compartment disposal packages under consideration in this EIS. If necessary, these modifications would only affect the sections of the power line within the immediate vicinity of the land transport route.

(3) Land Disposal Site

Approximately 4 hectares (10 acres) of land from the 218-E-12B low level burial ground in the 200 East area of the Hanford Site would be required for land disposal of the approximately 100 reactor compartment disposal packages from the cruisers, LOS ANGELES, and OHIO Class submarines. As is the case with other areas of the Hanford Site used for radioactive waste disposal, the land area used for disposal of the reactor compartment disposal packages and the surrounding buffer zone would constitute commitment of that land area and the natural resources contained therein.

The cruiser, LOS ANGELES, and OHIO Class reactor compartment disposal packages would be regulated for their radioactivity, lead, and PCB content. The release rates for these constituents are expected to be extremely small such that applicable environmental standards are not expected to be exceeded. The volume of mixed waste generated by this alternative would be less than 120,000 cubic meters (4,240,000 cubic feet). The migration of these constituents from the reactor compartments to the groundwater aquifer and to the Columbia River is also expected to be slow. For radioactivity, no short lived radionuclides are expected to be released.

b. No-Action Alternative

Shipyard Operations

Radiation exposure to the Shipyard workers associated with preparing the ships for indefinite waterborne storage following inactivation and decommissioning to accomplish the No Action alternative is estimated to be approximately 50 rem (0.02 latent cancer fatalities). This would include the first 15 years of waterborne storage maintenance operations and inspections. Because radiation exposure to the workers is primarily due to Cobalt-60 which has a half life of 5.3 years, during each 15 years storage period nearly three half lives of radioactive decay occur. As a result, exposure during the second 15 years waterborne storage period would be only 5.3 rem (0.002 latent cancer fatalities). Existing moorage capacity is adequate until after the year 2000.

c. Disposal and Reuse of Subdivided Portions of the reactor compartment

(1) Shipyard Operations

Based on results from dismantling of the Shippingport nuclear power plant and NRC projections for decommissioning of a commercial nuclear power plant, this alternative would result in from 22,500 to 109,000 rem (9.1 to 43.7 additional latent cancer fatalities) of worker radiation dose if performed immediately after decommissioning of the ships. Worker radiation dose would be reduced by about one–half for every 5 years that operations are deferred such that after a ten year deferral, worker radiation dose would be reduced to between 6,090 and 33,100 rem. (2.4 to 13.2 additional latent cancer fatalities).

(2) Transport Routes

The impacts along transportation routes that would be used to move subdivided portions of reactor compartments to disposal sites are evaluated in Appendix E. Four origin-destination cases are evaluated (Puget Sound to Hanford, Puget Sound to Savannah River, Norfolk to Hanford and Norfolk to Savannah River). Since two of the cases are for origins and destinations on the same coast and two are for origins and destinations on opposite coasts, the evaluation is considered to bound shipment of subdivided components from either of the two origins (Puget Sound and Norfolk) to any disposal site within the 48 contiguous states. It is estimated that the subdivision alternative would involve 1571 shipments and would result in exposure to the general population

of 11 to 119 person-rem (0.006 to 0.060 latent cancer fatalities). For the transportation crew it is estimated that exposure would be from 12 to 96 person-rem (0.005 to 0.039 latent cancer fatalities).

(3) Disposal Sites

The amount of waste estimated for the subdivision alternative ranged from a high of 120,000 cubic meters (4,240,000 cubic feet), assuming no volume reduction, to a low of 10,000 cubic meters (353,000 cubic feet) assuming extensive volume reduction. An assumption of moderate volume reduction resulted in an intermediate estimate of 24,000 cubic meters (847,000 cubic feet). In all three cases the amount of mixed waste was estimated to be from 2,255 to 6,255 cubic meters (79,600 to 221,000 cubic feet).

d. Indefinite Storage Above Ground at Hanford

The impacts of this alternative would be the same as for the preferred alternative as, except for actual burial at Hanford, identical actions are performed. As in the No Action alternative, storage is not a disposal alternative. Such storage would only defer the need to permanently disposition the radioactive and hazardous material contained by the reactor compartment package.

4. Comparison of Alternatives

A comparison of the preferred alternative, the no action alternative, the subdivision alternative, and the indefinite storage above ground alternative is provided in Table S.1.

Table S.1 Comparison of Alternatives

	Preferred Alternative	No Action Alternative	Subdivision[4] Alternative		Indefinite Storage Above Ground Alternative
			Immediate	10 Year Deferral	
Number of Shipments	100	0	1571	1571	100
Additional fatalities Occupational[1] Public[2] (Radiological) Public[3] (Non-radiological)	 0.602 0.003 0.001	 0.02 0 0	 9.1 to 43.7 0.006 0.03	 2.4 to 13.2 0.002 0.03	 0.602 0.003 0.001
Land Commitment	Approximately 10 Acres	N/A	Approximately 10 Acres		Approximately 10 Acres
Estimated Cost	$1,500,000,000 (5)	$140,000,000 for first 15 years of storage plus cost of final disposition.	$9,400,000,000 (6)		$1,500,000,000 plus caretaker cost plus cost of final disposition.

[1]Occupational fatalities consist of on-site worker and transportation worker latent cancer fatalities. Occupational latent cancer fatalities are calculated by multiplying occupational exposure in rem by 0.0004 additional latent cancer fatalities per rem.

[2]Public (Radiological) fatalities consist of radiation related latent cancer fatalities for the general population, which are calculated by multiplying estimated general population exposure in rem by 0.0005 additional latent cancer fatalities per rem. The estimated number of radiological fatalities include those associated with accidents, which account for less than 15% of the total for all of the alternatives.

[3]Public (Non-radiological) fatalities consist of fatalities from non-radiological causes related to transportation accidents (which accounts for about 90% of the risk) and transportation vehicle exhaust emissions.

[4]Values shown for the subdivision alternative are based on shipment from Puget Sound Naval Shipyard to the Hanford Site.

[5]The discounted amount would be 0.7 billion dollars based on a discount rate of 4.9% over a 32 year period beginning in 1997.

[6]The discounted amount would be 4.3 billion dollars based on a discount rate of 4.9% over a 32 year period beginning in 1997.

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1. PURPOSE AND NEED

U.S. Navy nuclear ships are decommissioned and defueled at the end of their useful lifetime, when the cost of continued operation is not justified by their military capability, or when the ship is no longer needed. The Navy needs to disposition the reactor compartments from defueled and decommissioned cruisers, and OHIO Class and LOS ANGELES Class submarines. The number of reactor compartments under consideration by this Environmental Impact Statement is about 100. These reactor compartments are in addition to the pre-LOS ANGELES Class submarines already being disposed of under the Navy's 1984 Final Environmental Impact Statement (USN, 1984a). Newer types of U.S. Navy nuclear-powered ships that are not expected to be decommissioned in the next 20 years (e.g., aircraft carriers, SEAWOLF Class submarines) are not included in this Final Environmental Impact Statement.

1.1 Background

As of the end of 1994, the U.S. Navy had 99 nuclear-powered submarines and 13 nuclear-powered surface ships in operation. Today, over 40% of the Navy's major combatant warships are nuclear-powered.

In the late 1970's and early 1980's the Navy evaluated options for disposing of the pre-LOS ANGELES class nuclear-powered submarine reactor compartments as the ships were reaching the end of their design life. The Record of Decision issued by the Secretary of the Navy for the Navy's 1984 Final Environmental Impact Statement (USN, 1984b) stated that "Based on consideration of all current factors bearing on a disposal action of this kind contemplated, the Navy has decided to proceed with disposal of the reactor compartments by land burial." As of the end of 1994, the Navy has safely shipped 43 submarine reactor compartments to the Department of Energy's Low Level Burial Grounds at Hanford, Washington.

Today the Navy faces the necessity of downsizing the fleet to an extent that was not envisioned in the 1980's before the end of the Cold War. Over the next several years most of the nuclear-powered cruisers will be removed from service. The Navy has already removed from service USS TEXAS (CGN39), USS VIRGINIA (CGN38), USS TRUXTUN (CGN35) and USS LONG BEACH (CGN9). Some LOS ANGELES Class submarines are scheduled for removal from service as well. The Navy has removed from service USS BATON ROUGE (SSN 689), and is in the process of inactivating USS OMAHA (SSN 692), and USS CINCINNATI (SSN 693). Eventually, the Navy will also need to decommission OHIO Class submarines. Disposal of the reactor compartments from these classes of nuclear-powered ships was not considered in the 1984 Environmental Impact Statement, (USN, 1984a). Since the final submarines of the LOS ANGELES Class and OHIO Class are still under construction, the need to dispose of the ships of these classes will extend to the end of their service life, which could be in excess of 30 years.

US Navy nuclear-powered ships are defueled during inactivation and prior to transfer of the crew. The defueling process removes the nuclear fuel from the reactor pressure vessel and consequently removes most of the radioactivity from the reactor plant. Defueling is an operation routinely accomplished using established processes at shipyards qualified to perform reactor servicing work.

Removed spent fuel would be handled in accordance with either the Environmental Assessment (USN, 1993) and Finding of No Significant Impact (USN, 1994) or the U.S. Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Environmental Impact Statement, (DOE, 1995). A Record of Decision was issued in June 1995. Storage and disposal of spent fuel

from refuelings and defuelings of nuclear-powered ships does not affect the decision of how to dispose of the defueled reactor compartments. Therefore, spent naval nuclear fuel is not included in this Environmental Impact Statement.

1.2 General Description of Reactor Compartments

The nuclear propulsion plants in United States Navy ships, while differing in size and component arrangements, are all rugged, compact, pressurized water reactors designed, constructed, and operated to exacting criteria. The nuclear components of these plants are all housed in a section of the ship called the reactor compartment. The reactor compartments all serve the same purpose but may have different shapes depending on the type of ship. For submarines, the reactor compartment is a horizontal cylinder formed by a section of the ship's pressure hull, with shielded bulkheads on each end. Cruiser reactor compartments are shielded vertical cylinders or shielded rectangular boxes deep within the ship's structure. Figures S.1 and S.2 illustrate the general location of the reactor compartments within submarines and cruisers respectively.

The propulsion plants of nuclear-powered ships remain a source of radiation even after the vessels are shut down and the nuclear fuel is removed. Defueling removes all fission products since the fuel is designed, built and tested to ensure that fuel will contain the fission products. Figure 1.1 shows a simplified schematic of a nuclear propulsion plant. 99.9% of the radioactive material that remains is an integral part of the structural alloys forming the plant components. The radioactivity was created by neutron irradiation of the iron and alloying elements in the metal components during operation of the plant. The remaining 0.1% is radioactive corrosion and wear products that have been circulated by reactor coolant, having become radioactive from exposure to neutrons in the reactor core, and then deposited on piping system internals.

A brief description of the way this equipment is used to produce energy in a nuclear reactor will help explain how the radioactivity in a ship is generated. The fuel in a reactor contains uranium atoms sealed within metal cladding. Uranium is one of the few materials capable of producing heat in a self-sustaining chain reaction. When a neutron causes a uranium atom to fission, the uranium nucleus is split into parts producing atoms of lower atomic number called fission products (Figure 1.2). When formed, the fission products initially move apart at very high speeds, but they do not travel very far, only a few thousandths of an inch, before they are stopped within the fuel cladding. Most of the heat produced in the fission process comes from stopping these fission products within the fuel and converting their kinetic energy into heat.

Radioactivity is created during fission because some of these fission products are highly radioactive when they are formed. Most of the radioactivity produced by nuclear fuel is in the fission products. The uranium fuel in naval nuclear propulsion reactor cores uses highly corrosion-resistant and highly radiation-resistant fuel and cladding. As a result, the fuel is very strong and has very high integrity. The fuel is designed, built, and tested to ensure that the fuel construction will contain and hold the radioactive fission products. Naval fuel totally contains fission products within the fuel - there is no fission product release from the fuel in normal operation.

Fissioning of uranium also produces neutrons while the nuclear power plant is operating. Most of the neutrons produced are absorbed by the atoms within the fuel and continue the chain reaction. However, some of the neutrons travel away from the fuel, go outside the fuel, and are absorbed in the metal structure which supports the fuel or in the walls of the reactor pressure vessel (Figure 1.2). Trace amounts of corrosion and wear products are carried by reactor coolant from reactor plant metal surfaces. Some of these become radioactive from exposure to neutrons.

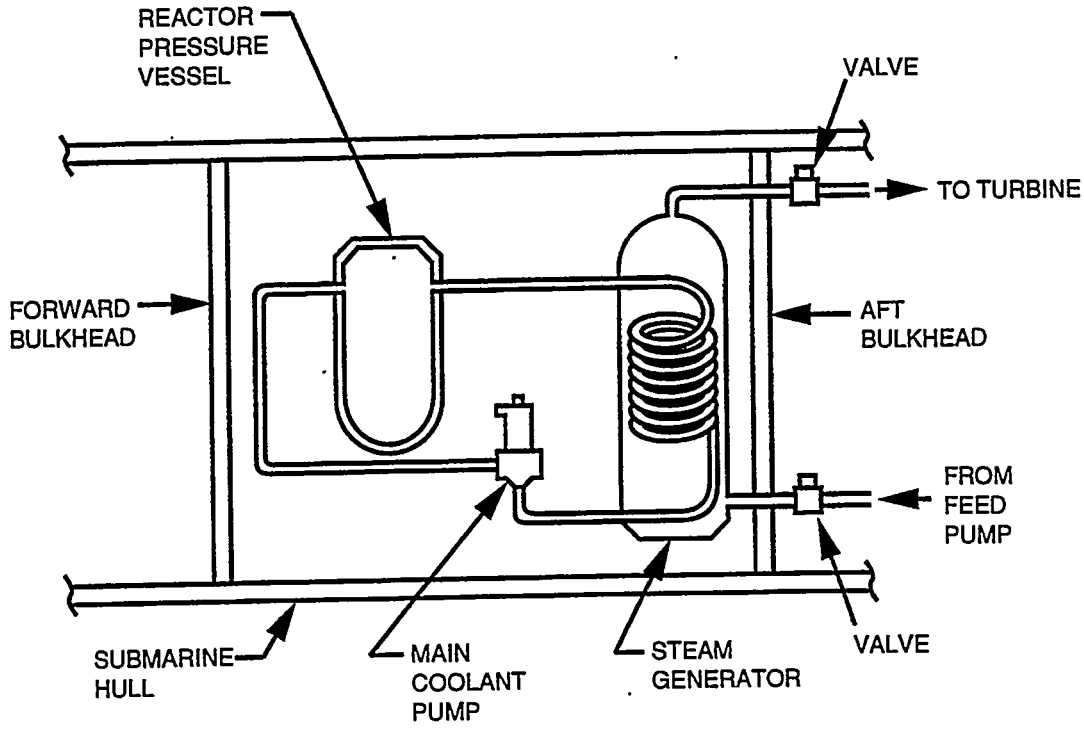


Figure 1.1. Schematic of Nuclear Propulsion Plant

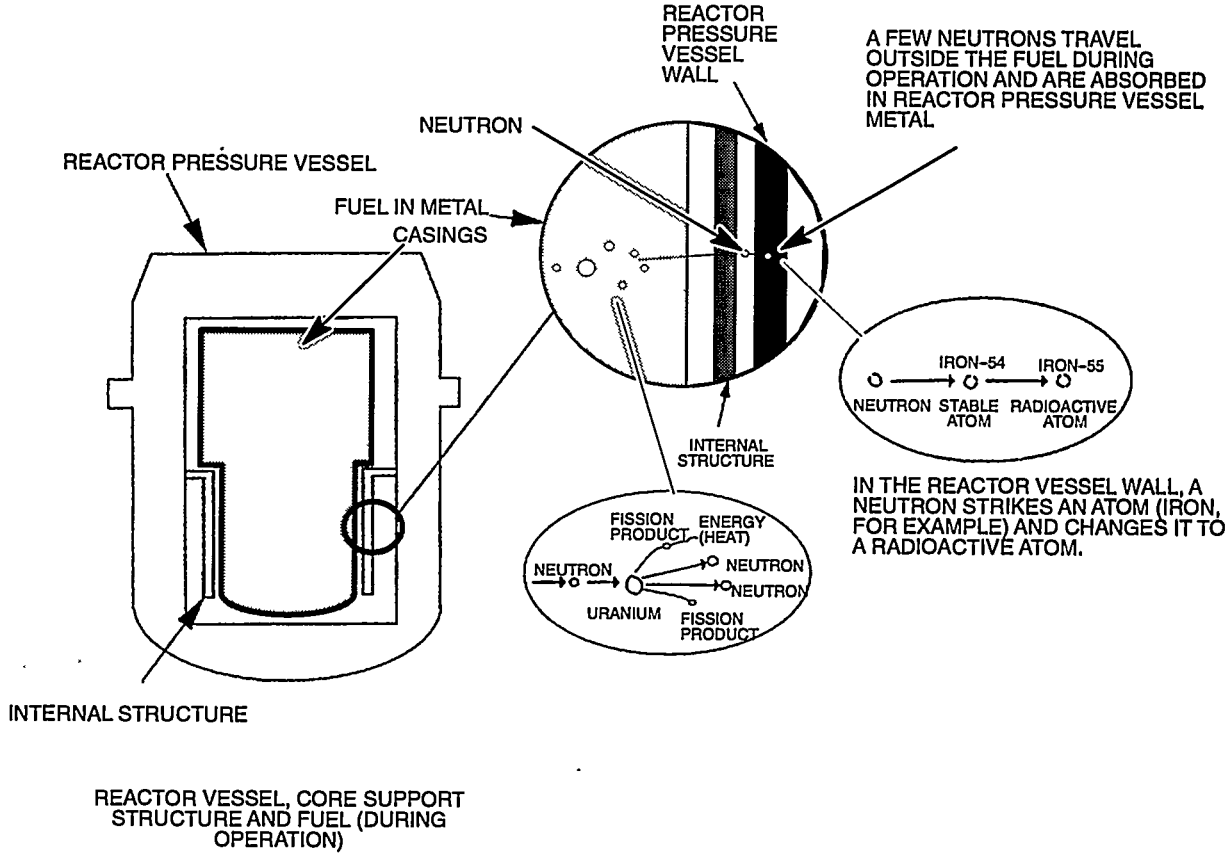


Figure 1.2. Neutron and Fission Products from Uranium Fission

Reactor coolant carries some of these radioactive products through the piping systems where a portion of the radioactivity is removed by a purification system. Most of the remaining radionuclides transported from the reactor core deposit in the piping systems. These neutrons, when absorbed in the nucleus of a nonradioactive atom like iron, can produce a radioactive atom. For example, iron-54 contains a total of 54 particles. Adding an additional neutron produces an atom containing 55 particles, called iron-55. This atom is radioactive. At some later time, it changes into a nonradioactive manganese-55 atom by releasing energy in the form of radiation (Figure 1.3). This is called radioactive decay.

Reactor design and operational life of reactor plants varies somewhat between ship classes, and consequently, radioactivity within the plants will also vary. For characterizing radioactivity, cruiser, LOS ANGELES, and OHIO Class reactor plants can be categorized into five plant types as described in Appendix D. Table 1.1 provides typical radionuclide inventories for each of these plant types and identifies radionuclides that contribute greater than 1% of the total activity in the reactor plant. These radionuclides all have half lives of 100 years or less. Of this group, cobalt-60 is the predominant radionuclide and decays by a factor of two every 5.3 years. It emits penetrating gamma radiation and is the major source of radiation in the defueled reactor plant.

Of the Table 1.1 radionuclides, after 500 years, only nickel-63 remains. This radionuclide is not a major source of radiation as it emits beta particles, which are stopped by the steel structure in the reactor vessel. Longer lived radionuclides are present in reactor plants but contribute very little to the total curie content. Carbon-14, niobium-94, nickel-59, selenium-79, and technecium-99 are essentially contained within the sealed reactor vessel, concentrated in the internal structure shown on Figure 1.2. Carbon-14, like nickel-63 is a beta emitter. Nickel-59 emits weak X-rays and electrons that do not penetrate the reactor plant structure. However, because of the quantity and long half-life of this radionuclide (decays by a factor of 2 every 75,000 years), migration of this radionuclide into groundwater is theoretically possible. Niobium-94, a gamma emitter, is present in small quantity, typically less than 1 curie per plant. Even after permanent disposal, there remains a small potential for future radiation exposure to individuals from long-lived radionuclides that may eventually be released to the environment. The only mechanism for release would be through corrosion of the metal components of the reactor plant, a very slow process under any disposal option. Most of the radionuclides would decay to stable isotopes long before they could be released, and even for the longest lived radionuclides, only a small portion of the initial curie inventory would be released. Appendix B provides a more detailed discussion of this condition and the exposure that may result from potential intruder scenarios for buried reactor plants. Appendix D provides a more detailed discussion of the amount and nature of these long lived radionuclides and the method used to calculate their quantities.

The reactor compartments also contain a large amount of elemental solid lead used as shielding. Each reactor compartment contains over 100 tons of permanently installed lead shielding which would cause the reactor compartment to be regulated as dangerous waste for disposal under Washington State Dangerous Waste Regulations, Chapter 173-303 of the Washington State Administrative Code (WAC, 1993). Some shielding lead may have impurities which have become activated due to neutron activation. Decontamination of this lead by removal of radioactive impurities would not be practicable because lead used in reactor shielding is already high purity lead which was refined an extra step to minimize impurities. Radioactive lead must be disposed of as mixed radioactive and chemically hazardous waste (hereafter referred to as mixed waste).

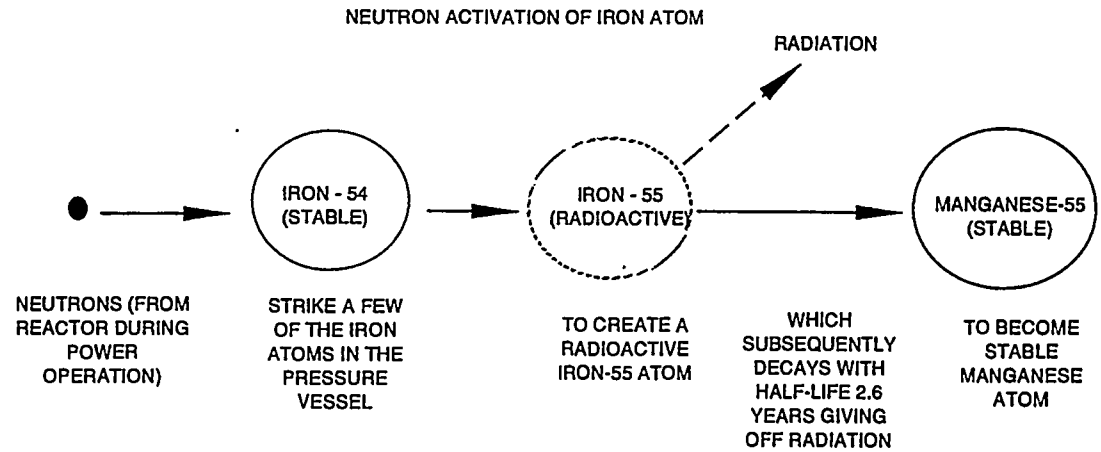


Figure 1.3. Capture Neutrons in Iron of Pressure Vessel Walls

TABLE 1.1

TYPICAL RADIOACTIVITY BY INDIVIDUAL RADIONUCLIDE PRESENT IN
CRUISER, LOS ANGELES, AND OHIO CLASS DEFUELED, DECOMMISSIONED REACTOR PLANTS
ONE YEAR AFTER FINAL REACTOR SHUTDOWN AND 500 YEARS LATER

Radionuclide[a]	tellurium-125m	zirconium-95/ niobium-95[b]	cobalt-58	tantalum-182	tin-119m	iron-55	antimony-125	cobalt-60	nickel-63	All Listed Radionuclides
Half-life (years)[c]	0.16	0.18/0.10	0.19	0.32	0.81	2.69	2.77	5.27	100	NA
Radiation Emitted[c, d]	gamma, X-rays, e^-	gamma, beta $^-$	gamma, X-rays, beta$^+$, e^-	gamma, X-rays, beta$^-$, e^-	X-rays, e^-	X-rays, e^-	gamma, X-rays, beta $^-$, e^-	gamma, beta $^-$	beta $^-$	NA
Initial Radioactivity One Year After Final Shutdown (curies)										
Reactor Plant Type #1	$(5.0 \times 10^{-10})^e$	$(1.7/5.1 \times 10^{-2})^e$	1.7×10^3	$(1.2 \times 10^2)^e$	$(4.2 \times 10^{-9})^e$	6.7×10^3	$(2.3 \times 10^{-3})^e$	1.2×10^4	2.9×10^4	5.0×10^4
Reactor Plant Type #2	$(7.8 \times 10^{-5})^e$	$(4.4/11 \times 10^{-3})^e$	4.9×10^2	$(9.6 \times 10^0)^e$	$(4.1 \times 10^{-4})^e$	1.9×10^3	$(3.6 \times 10^{-4})^e$	3.2×10^3	1.5×10^4	2.1×10^4
Reactor Plant Type #3	8.6×10^2	$2.3/4.9 \times 10^3$	8.4×10^2	1.0×10^3	6.8×10^3	8.8×10^3	4.0×10^3	1.0×10^4	1.9×10^4	5.9×10^4
Reactor Plant Type #4	8.2×10^2	$2.2/4.7 \times 10^3$	8.0×10^2	1.0×10^3	6.5×10^3	1.8×10^4	3.8×10^3	1.0×10^4	3.8×10^4	8.6×10^4
Reactor Plant Type #5	$(< 1 \times 10^{-6})^e$	$(3.8/8.2 \times 10^{-3})^e$	$(1.2 \times 10^2)^e$	$(8.20 \times 10^0)^e$	$(< 1 \times 10^{-3})^e$	4.0×10^3	$(2.0 \times 10^{-1})^e$	3.6×10^3	7.8×10^3	1.6×10^4
Radioactivity 500 Years Later (curies)[f]										
Reactor Plant Type #1	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	9.0×10^2	9.0×10^2
Reactor Plant Type #2	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	4.7×10^2	4.7×10^2
Reactor Plant Type #3	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	5.9×10^2	5.9×10^2
Reactor Plant Type #4	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	1.2×10^3	1.2×10^3
Reactor Plant Type #5	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	$(<1 \times 10^{-10})^e$	2.4×10^2	2.4×10^2

a: radionuclides listed represent 1% or greater of total curies at one year after shutdown for at least one plant type; long lived activity representing less than 1% of total curies at one year after shutdown are discussed in Appendix D.
b: both radionuclides are initially present at the curie contents provided, but are closely related in that a portion of the parent radionuclide decays to the daughter radionuclides.
c: KOCHER, 1981.
d: e^- represents (negatively charged) electrons emitted from orbital shells around the atomic nucleus.
e: less than 1% of total curies; provided for comparison.
f: decay constant=0.693/(half–life of radionuclide in years)

These regulations require that disposal of mixed waste be at an approved disposal site. There are presently no facilities authorized to treat and dispose of lead mixed waste separated from the reactor compartment. For reactor compartment disposal work, the lead shielding in the reactor compartment is not treated. The macroencapsulation treatment standard is already met as originally constructed and not as a result of packaging the reactor compartment.

Defueled reactor compartments may also contain several pounds of polychlorinated biphenyls (PCBs) (typically less than 10 pounds) tightly bound in the composition of solid materials such as thermal insulation, electrical cable coverings, and rubber items manufactured before PCBs were banned in the 1970s. Because the PCBs are present in materials in concentrations above 50 parts per million, the reactor compartment packages would be regulated as a toxic waste by the United States Environmental Protection Agency under the Toxic Substances Control Act (40CFR761).

1.3 Pollution Prevention

It is a national policy of the United States that, whenever feasible, pollution should be reduced at the source, recycled in an environmentally safe manner, or when pollution can not be prevented, disposal or other release to the environment should be employed only as a last resort (42 U.S.C. 1990).

U.S. Naval reactor compartments are constructed such that major components and structures last the lifetime of the plant. Removal and repair or replacement of system components is minimized through careful design, quality workmanship, and improvements through research and development projects. This has helped prevent pollution by reducing nuclear waste that would be generated if nuclear components had to be repaired or replaced and by reducing chemical or other hazardous materials that are regularly used in industrial operations. In addition, these nuclear components are compact by design which further reduces the volume of radioactive waste that must be disposed of.

Ship design efforts also support pollution prevention goals by minimizing the use of hazardous materials where consistent with safety and reliability. Where feasible, less hazardous materials are substituted for hazardous materials. Under the current disposal program for pre-LOS ANGELES Class submarines, portions of the submarine forward and aft of the reactor compartment are completely recycled, which greatly reduces the volume of waste to be disposed of. The same basic recycling processes would be used for recycling, where feasible, of non-radioactive, non-hazardous portions of cruisers, OHIO Class submarines and LOS ANGELES Class submarines.

The removal of lead from reactor compartment packages is planned within the constraint of keeping worker radiation exposure as low as reasonably achievable (ALARA) (e.g., removal of non-shielding lead). This work would constitute an additional pollution prevention activity.

2. ALTERNATIVES

The following sections discuss in detail the preferred alternative for disposal of cruiser, LOS ANGELES Class submarine, and OHIO Class submarine reactor compartments, the no-action alternative, disposal and reuse of subdivided portions of the reactor plant alternative, and indefinite storage above ground at Hanford. Costs for these alternatives are addressed in Appendix C. A comparison of the alternatives with regard to the key parameters that are different amoung the alternatives is provided in Table 2.1. Other alternatives that may be feasible but are not considered practical in the present case and have been eliminated from detailed evaluation are also discussed.

2.1 Preferred Alternative - Land Burial of the Entire Reactor Compartment at the Department of Energy Low Level Waste Burial Grounds at Hanford, WA

In this alternative the reactor compartments would be prepared for shipment at Puget Sound Naval Shipyard, shipped to and buried at the Department of Energy Low Level Burial Grounds located at the Hanford Site in the State of Washington.

The packaging, transportation, and disposal of the cruiser and LOS ANGELES Class and OHIO Class reactor compartments would use the same proven processes that are being successfully used for the pre-LOS ANGELES Class submarine reactor compartments. These processes are designed to minimize the potential for transportation accidents, to mitigate the consequences of potential transportation accidents, to facilitate recovery if necessary, and to mitigate the impacts on the environment at the land disposal site. The following sections describe the alternative in detail.

Non-radioactive, non-hazardous material could be recycled as outlined in the Navy's June, 1993 Environmental Assessment of the Submarine Recycling Program at Puget Sound Naval Shipyard (USN, 1993a). Under the current disposal program for pre-LOS ANGELES Class submarines, portions of the submarine forward and aft of the reactor compartment are completely recycled, which greatly reduces the volume of waste to be disposed of. The same basic recycling processes would be used for recycling, where feasible, of non-radioactive, non-hazardous portions of cruisers, OHIO Class submarines and LOS ANGELES Class submarines. The total volume of the reactor compartments is about 120,000 cubic meters (4,240,000 cubic feet). Besides the reactor compartments, the volume of mixed waste generated by this alternative is estimated to be about 1,625 cubic meters (57,400 cubic feet). This mixed waste would be managed in accordance with the approved Shipyard Site Treatment Plan developed pursuant to the Federal Facilities Compliance Act.

2.1.1 Preparations for Shipment

2.1.1.1 Liquid Removal

After defueling, the piping, tanks, and fluid system components that would remain within the reactor compartment disposal package would be drained to the maximum extent practical. The system draining processes for the current pre-LOS ANGELES Class submarine reactor compartment disposal program are effective in removing to the maximum extent practical the liquid originally present in the package (PSNS, 1990b).

Radioactive liquids from the reactor plant would be either demineralized water or a solution of demineralized water and potassium chromate (a corrosion inhibitor). The demineralized water would be collected into stainless steel tanks and processed, such as pumped through a liquid processing system which consists of particulate filters, activated carbon bed filters, mixed hydrogen hydroxyl resin and colloidal removal resin beds. This process reduces radioactivity in the liquid to about 10^{-8} microcuries of gamma radioactivity per milliliter of liquid. This processed

Table 2.1 Comparison of Alternatives

	Preferred Alternative	No Action Alternative	Subdivision[4] Alternative		Indefinite Storage Above Ground Alternative
			Immediate	10 Year Deferral	
Number of Shipments	100	0	1571	1571	100
Additional fatalities					
Occupational[1]	0.602	0.02	9.1 to 43.7	2.4 to 13.2	0.602
Public[2] (Radiological)	0.003	0	0.006	0.002	0.003
Public[3] (Non-radiological)	0.001	0	0.03	0.03	0.001
Land Commitment	Approximately 4 Hectares (10 Acres)	N/A	Approximately 4 Hectares (10 Acres)		Approximately 4 Hectares (10 Acres)
Estimated Cost	$1,500,000,000 (5)	$140,000,000 for first 15 years of storage plus cost of final disposition.	$9,400,000,000 (6)		$1,500,000,000 plus caretaker cost plus cost of final disposition.

[1]Occupational fatalities consist of on-site worker and transportation worker latent cancer fatalities. Occupational latent cancer fatalities are calculated by multiplying occupational exposure in rem by 0.0004 additional latent cancer fatalities per rem.

[2]Public (Radiological) fatalities consist of radiation related latent cancer fatalities for the general population, which are calculated by multiplying estimated general population exposure in rem by 0.0005 additional latent cancer fatalities per rem. The estimated number of radiological fatalities include those associated with accidents, which account for less than 15% of the total for all of the alternatives.

[3]Public (Non-radiological) fatalities consist of fatalities from non-radiological causes related to transportation accidents (which accounts for about 90% of the risk) and transportation vehicle exhaust emissions.

[4]Values shown for the subdivision alternative are based on shipment from Puget Sound Naval Shipyard to the Hanford Site.

[5]The discounted amount would be 0.7 billion dollars based on a discount rate of 4.9% over a 32 year period beginning in 1997.

[6]The discounted amount would be 4.3 billion dollars based on a discount rate of 4.9% over a 32 year period beginning in 1997.

liquid is then stored for reuse and the filtered radiation materials are handled, packaged, and disposed of in accordance with applicable transportation and disposal site requirements. The solution of demineralized water and potassium chromate would either be reused or managed under the approved Shipyard Site Treatment Plan developed pursuant to the Federal Facility Compliance Act.

Draining the reactor compartment to the maximum extent practicable removes about 98% of the original liquid volume. However, small amounts remain trapped in pockets of valves, pumps, tanks, vessels, and other inaccessible piping system components.

For cruiser, LOS ANGELES Class submarine, and OHIO Class submarine reactor compartments, system draining procedures would be developed based on the methodology used for the pre-LOS ANGELES Class submarine reactor compartments. Briefly, all radioactively contaminated piping systems, tanks, and vessels are drained by opening existing low point drains, or pumping and/or lancing. Non–contaminated piping systems, tanks, and voids outside of the reactor compartment are drained further by removing the system or drilling and draining. Remaining liquid in radioactively contaminated systems would not be further drained due to the large amount of radiation exposure to the Shipyard worker that would be involved without measurable benefit to the quality of the environment. Federal radiation exposure guidelines require that nuclear work be accomplished in a manner that keeps radiation exposure to workers and the public as low as reasonably achievable (ALARA) (10CFR20).

This draining methodology is effective in removing about 98% of the original liquid volume while observing the ALARA guidelines. Although equivalent liquid removal methodologies would be used, the residual liquid in the reactor vessel and piping systems would be greater than the maximum remaining in the pre–LOS ANGELES Class reactor compartments. This is due to the somewhat larger systems and components that make up the reactor plant piping, valves, tanks, and vessels. The radiological dose to the workers to remove liquid using this methodology is estimated to range between 8 rem to 20 rem (approximately 0.003 to 0.008 additional latent cancer fatalities) depending on the package type. A total dose of 1018 rem (for a total of approximately 0.4 additional latent cancer fatalities) would be received for all reactor compartments under consideration.

Removing the remaining liquid, about 2% or less, of the total volume originally present would be at a considerable cost, both in money and exposure to radiation. Any additional draining operations could only be accomplished by performing difficult draining tasks within radiation areas. Further draining of liquids from the various components would result in a considerable increase in hours that workers would be exposed to radiation.

Removal of this small quantity of residual liquid would not be warranted because the significant increase in radiation exposure to the workers would be in conflict with ALARA guidelines, and would not result in any measurable benefit to the quality of the environment.

The cost to remove the remaining liquid from the cruiser, LOS ANGELES Class and OHIO Class reactor compartments is estimated at over $5 million per reactor compartment, for a total cost of over $500 million for all reactor compartments under consideration. It is estimated that greater than 68 rem (approximately 0.03 additional latent cancer fatalities) would be required to remove the remaining liquid from each package under consideration. For all packages considered, the total radiation dose would be greater than 6,800 rem (approximately 3 additional latent cancer fatalities).

For the pre–LOS ANGELES Class submarine reactor compartment packages shipped to Hanford, a petition for exemption from land disposal restrictions for residual liquid was requested by Washington State Department of Ecology (WA, 1991). The petition was submitted in 1992 (DOE, 1992a) and will be incorporated into the Low Level Burial Grounds dangerous waste permit application documentation. The basis in the petition is the need to keep radiation exposure as low as reasonably achievable. Consistent with the pre–LOS ANGELES Class reactor compartment packages, approval from the Washington State Department of Ecology would be requested to leave the remaining liquid in the reactor compartment packages.

2.1.1.2 Radiation Exposure Reduction Practices

Access to radiation areas is controlled by posted signs and barriers. Personnel are trained in the access requirements, including the requirement to wear dosimetry devices to enter these areas. Dosimetry devices are also near the boundaries of these areas to verify that personnel outside these area do not require monitoring. Frequent radiation surveys are required using instruments which are checked before use and calibrated regularly. Areas where radiation levels are greater than 0.1 rem per hour are designated high radiation areas and are locked or guarded. Compliance with radiological control requirements is checked frequently by radiological control personnel and other personnel not affiliated with the radiological controls organization.

Maintaining personnel radiation exposures as low as reasonably achievable involves all levels of management in nuclear-powered support facilities. To evaluate the effectiveness of radiation exposure reduction programs, managers use a set of goals. Goals are set in advance to keep the dose each worker receives under certain levels and to minimize the number of workers involved. Goals are also set on the total cumulative personnel radiation dose (man–rem) for each major job, for the entire overhaul or maintenance period, and for the whole year. These goals are deliberately made hard to meet in order to encourage personnel to improve performance.

Of the various goals used, the most effective in reducing personnel radiation exposure has been the use of individual control levels which are lower than the Navy's quarterly and annual limits. Dose control levels in shipyards range from 0.5 to 2 rem for the year, depending on the amount of radioactive work scheduled, whereas 5 rem per year is the annual Navy limit. The average occupational exposure of each person monitored at all shipyards is 0.26 rem per year. The average lifetime accumulated radiation exposure from all radiation associated with naval nuclear propulsion plants for all shipyard personnel who were monitored is 1.2 rem (NNPP, 1995b).

To achieve the benefits of lower control levels in reducing total man–rem, it is essential to minimize the number of workers permitted to receive radiation exposure. Otherwise the control levels could be met merely by adding more workers. Organizations are required to conduct periodic reviews to ensure the number of workers is the minimum for the work that has to be performed.

The following is a synopsis of the checklist which has been in use for years in maintaining personnel radiation exposure as low as reasonably achievable.

Since its inception, the Naval Nuclear Propulsion Program has stressed the reduction of personnel radiation exposure. Beginning in the 1960's, a key part of the Program's effort in this area has involved minimizing radioactive corrosion products throughout the reactor plant, which in turn has significantly contributed to reducing personnel radiation exposure. Additional measures that have been taken to reduce exposure include standardization and optimization of procedures, development of new tooling, improved use of temporary shielding, and compliance with strict contamination control measures. For example, most work involving radioactive contamination is

performed in total containment. This practice minimizes the potential for spreading contamination and thus reduces work disruptions, simplifies working conditions, and minimizes the cost and exposure to clean up.

Lessons learned during radioactive work and new ways to reduce exposure developed at one organization are made available for use by other organizations in the Naval Nuclear Propulsion Program. This effort allows all of the organizations to take advantage of the experience and developments at one organization and minimizes effort.

The extensive efforts that have been taken to reduce exposure in the Naval Nuclear Propulsion Program have also had other benefits, such as reduced cost to perform radioactive work and improved reliability. Efforts such as detailed work planning, rehearsing, total containment, special tools, and standardization have resulted in increased efficiency and better access to perform maintenance with the overall result that reliability is improved and costs are reduced.

2.1.1.3 Equipment Removal and Package Containment

Piping, electrical cabling, and other components and support structure inside the ship that interfere with removal of the reactor compartment from the ship would be cut away. For the submarines, as interior structural and equipment interferences are removed, the ship's hull would be cut to remove the reactor compartment from the ship. For cruisers, the reactor compartment would be similarly separated from the ship. Cut piping would be sealed when radioactive contamination is present. The radioactive components located outside the reactor compartment package would be removed from the ship for separate disposal at licensed disposal facilities or securely placed inside the reactor compartment package.

Reusable material and equipment from the ships would be loaded onto rail cars or trucks for transport to recycling facilities. Hazardous material removed from the ships would require the necessary control for handling, shipping and disposal. Some hazardous material removed also contains radioactivity and would require control as mixed waste or radioactive–PCB waste.

Hazardous material removal for cruisers, LOS ANGELES Class and OHIO Class submarines would be similar to that accomplished for pre–LOS ANGELES Class disposal due to basic commonality in designs and materials. These materials and associated removal and disposal methods are described in the Environmental Assessment of the Submarine Recycling Program at Puget Sound Naval Shipyard (USN, 1993a). Polychlorinated biphenyl impregnated wool felt sound damping material will be removed from the reactor compartment disposal packages when present. This material could be found on the interior of the submarine hull, on bulkheads, and in other locations outside of the reactor compartment that are part of the disposal package. This material and associated PCB residue on adjacent surfaces would be removed from the reactor compartment package before disposal in accordance with EPA requirements (40CFR761). The work would be done in controlled areas by personnel wearing protective equipment. Personnel wear full body protective clothing and are supplied with breathing air. However, several pounds of PCBs (typically less than 10 pounds) might still be found tightly bound in the chemical composition of solid industrial materials widely distributed throughout the reactor compartment package such as rubber and insulation. It would not be feasible to remove these materials, and they would be left in place for disposal with the reactor compartment packages.

The removal of lead from reactor compartment packages is planned within the constraint of keeping worker radiation exposure as low as reasonably achievable (ALARA) (e.g., removal of non-shielding lead). Removed lead would be reclaimed. Lead removal work would be done in controlled areas by personnel wearing protective equipment. Permanently installed ship's shielding lead for submarine and cruiser reactor compartment disposal packages would remain.

Unlike ballast lead, lead shielding is contained by thick metal sheathing plates. Removal of all the permanent shielding lead from and structural restoration of a reactor compartment would cost between 16 to 108 million dollars depending on the ship class. Radiation exposure would be high, ranging from 585 to 1065 rem per reactor compartment (approximately 0.2 to 0.4 additional latent cancer fatalities). Retaining the lead within the reactor compartments eliminates these costs and exposures. The thick metal encapsulation meets the Resource Conservation and Recovery Act treatment standards ((40CFR268.42) Treatment Code MACRO) for disposal of radioactive lead solids, including lead shielding, as received. Work during the reactor compartment package preparation process maintains this encapsulation. No treatment of the lead shielding occurs.

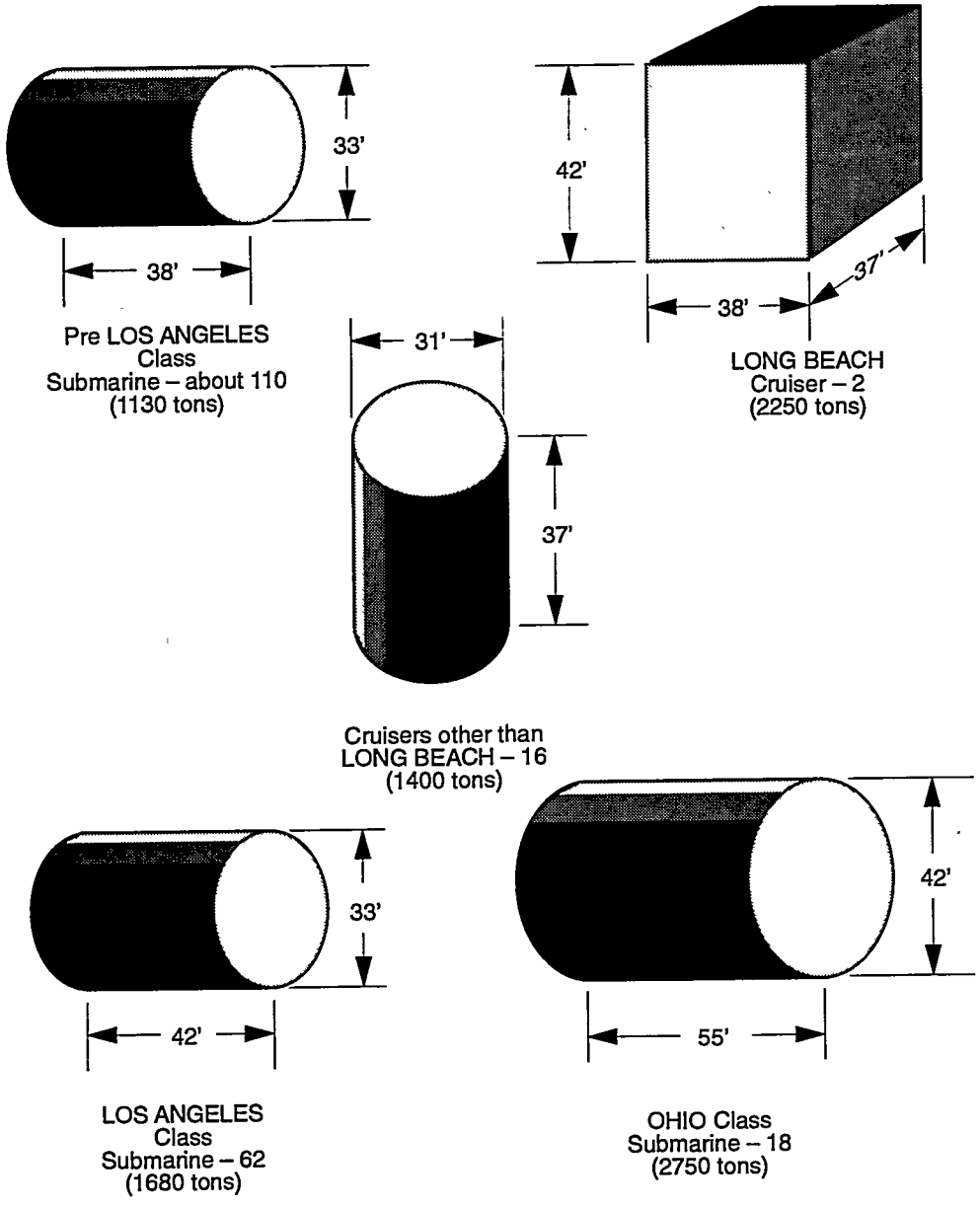
There are a variety of other hazardous materials present in small amounts in defueled reactor compartments, including silver plating on electrical contacts; silver brazing alloys; cadmium in the form of plating on fasteners and other components; chromates, amines, and ethylene glycol in small pockets of residual liquid; arsenic trioxide in glass; cyanoacrylate adhesive; and paints containing cyanide, red lead, lead napthenate, coal tar epoxy, and chromium trioxide. Preliminary investigations indicate these materials at below regulated levels for cruiser, OHIO Class submarine and LOS ANGELES Class submarine reactor compartment packages. Reactor compartments constructed before the mid-1970s also contain thousands of pounds of asbestos in the insulation on pipes and other components. This asbestos would be fully contained within the reactor compartment package, complying with the Clean Air Act regulations (40CFR61).

Containment bulkheads would be installed to the cut portions of the submarine hull to seal the reactor compartment within a disposal package. For cruisers, a containment structure would be built around the reactor compartment, enclosing it to form a disposal package. Figure 2.1 compares the size of the various reactor compartment disposal packages. While this work is occurring, the ship would be in a drydock on a combination of blocks and track mounted cradles that are designed to support and move the freed reactor compartment away from the ship. Figure 2.2 shows the conceptual sequence of these operations for submarines. Figure 2.3 shows the conceptual sequence of operations for cruisers.

The reactor compartment disposal program would be conducted and managed in accordance with all applicable federal environmental protection statutes and related Washington State and local environmental protection regulations.

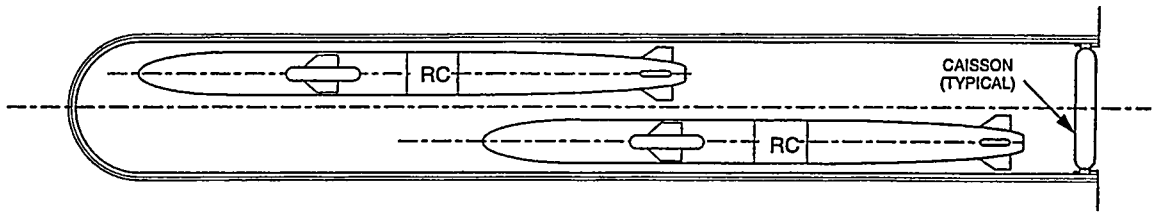
2.1.2 Transport

The Navy has transport barges that have been specially modified for transporting the pre-LOS ANGELES Class submarine reactor compartment packages. These barges are reinforced ocean-going barges. Support bulkheads have been installed to carry the reactor compartment package load in the center of the barge. Additional watertight bulkheads provide a greater number of tanks than are normally used for an ocean cargo barge. This provides added stability in the unlikely event the barge is damaged by an accident. The barges meet (a) the United States Coast Guard intact and damaged (one tank flooded) upright stability requirements (46CFR151 and 172); and (b) Navy stability requirements which require stability with two adjacent flooded tanks under storm wind and wave conditions. The barges are able to remain floating after sustaining

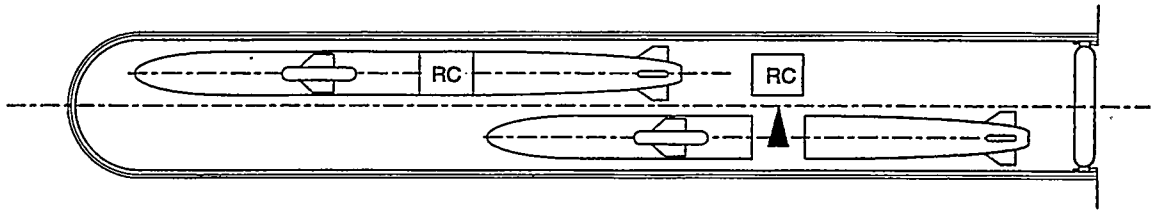


Note: Dimensions and weights are approximate. Quantities are current projections.

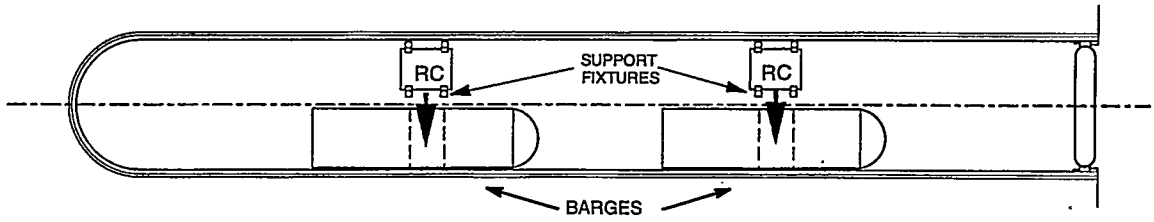
Figure 2.1. Comparison of Reactor Compartment Packages



SUBMARINES ARE PLACED IN DRYDOCK

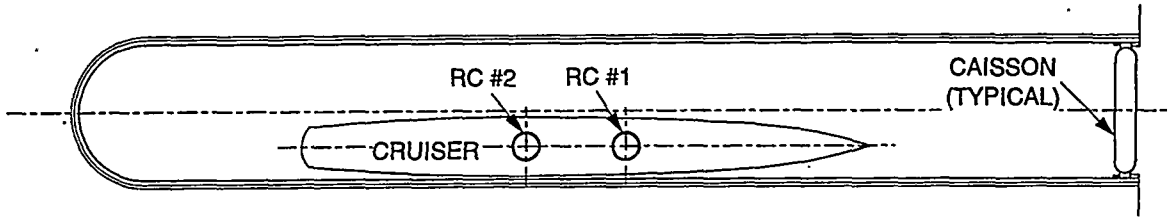


THE REACTOR COMPARTMENTS ARE CUT FROM THE SUBMARINES AND MOVED ON CRADLES AND ROLLERS TO THE SIDES OF THE DRYDOCK WHERE THEY ARE PACKAGED AND SUPPORT FIXTURES ARE INSTALLED.

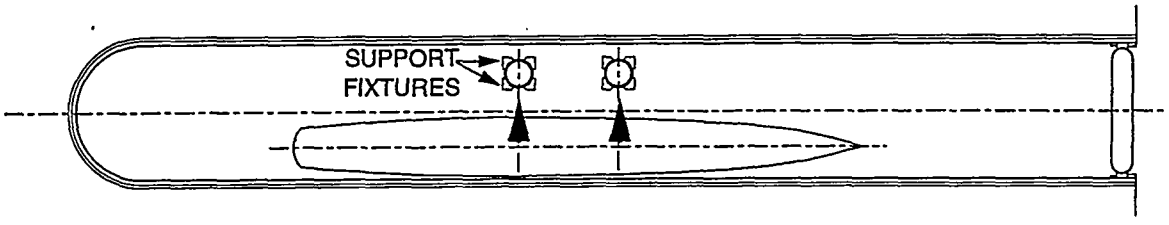


THE TWO DISPOSAL BARGES ARE PLACED IN THE DRYDOCK ALONGSIDE THE PACKAGED REACTOR COMPARTMENTS. THE BARGES ARE LOADED AND READIED FOR SHIPMENT.

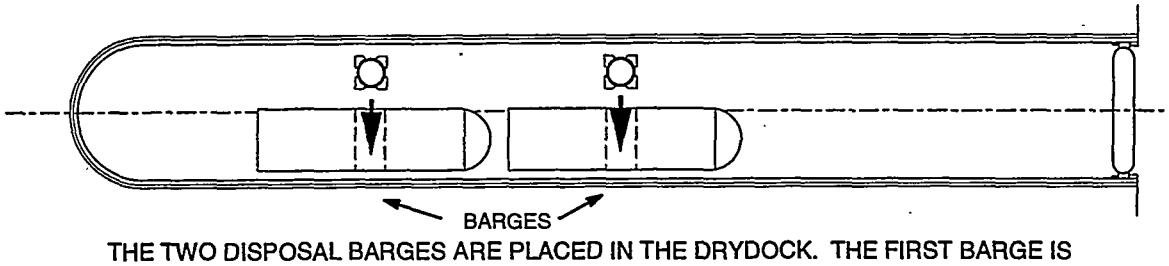
Figure 2.2. Submarine Reactor Compartment Preparation Concept



SHIP IS PLACED IN DRYDOCK AND THE REACTOR COMPARTMENTS ARE CUT FROM THE SHIP.



THE REACTOR COMPARTMENTS ARE PACKAGED AND SUPPORT FIXTURES ARE INSTALLED.



THE TWO DISPOSAL BARGES ARE PLACED IN THE DRYDOCK. THE FIRST BARGE IS LOADED, THEN THE SECOND BARGE IS MOVED INTO POSITION TO LOAD THE SECOND REACTOR COMPARTMENT PACKAGE.

Figure 2.3. Cruiser Reactor Compartment Preparation Concept

significant damage. The barges are maintained to both Navy and commercial standards and are inspected by the American Bureau of Shipping and the United States Coast Guard on a regularly scheduled basis. The same strict criteria would be used when the transport barges are used for the cruiser, LOS ANGELES Class submarine and OHIO Class submarine reactor compartment packages.

After the reactor compartment package is sealed and prepared for shipment and the remainder of the ship has been removed from the drydock, a transport barge would be placed next to the package. The package would be loaded onto the barge with hydraulic jacks to raise the package to the level of the barge deck. Support of the hydraulic jacks would be concrete keel blocks or other suitable blocking, steel plates, and timbers. These materials would also be used to provide a base for the track that would be used to move the package horizontally onto the barge deck. Jacking would be accomplished in small increments, with blocks and shims placed under the compartments as they are raised to support the compartments in case of a loss of hydraulic jacking pressure. The reactor compartments would be moved onto the barge using track mounted high capacity rollers. When in place, the reactor compartments would be welded to the steel barge deck.

The barge would be towed from Puget Sound Naval Shipyard using a large American Bureau of Shipping certified ocean-going tug. The tow would be accompanied by appropriate vessels such as a second similar backup tug and a Navy or Coast Guard escort vessel. River tugs would be used on the Columbia River. Qualified pilots would be used on all restricted waterways in Puget Sound, when crossing the Columbia River bar, and on the Columbia River. Shipments would be scheduled to avoid the less favorable Pacific Ocean winter weather. Figure 2.4 is a photograph of a pre-LOS ANGELES Class reactor compartment on a transport barge. The reactor compartments covered by this EIS would be transported in a similar manner.

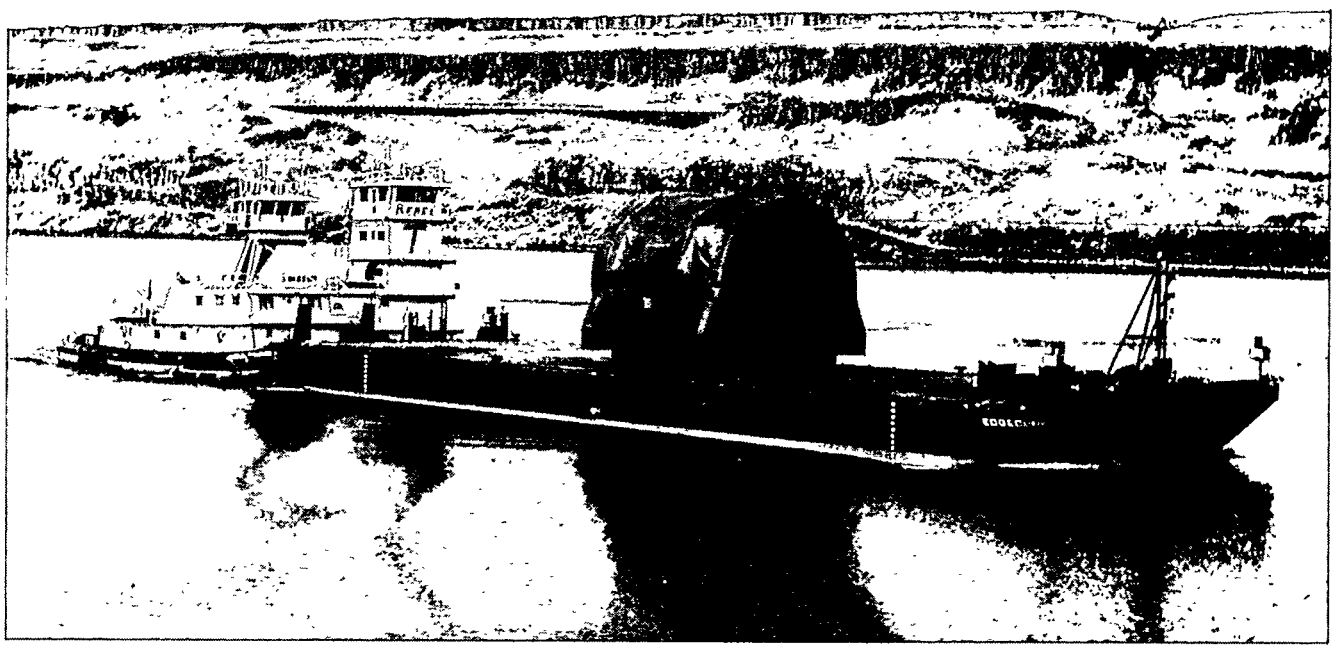


Figure 2.4. Pre-LOS ANGELES Class Reactor Compartment on a Transport Barge, Columbia River

The transport route for the cruiser, LOS ANGELES Class and OHIO Class submarine reactor compartment disposal packages would be the same as that used for the pre-LOS ANGELES Class disposal packages. The waterborne portion of the route follows the normal deep-water shipping lanes from the Shipyard, through Rich Passage, past Restoration Point, and northerly through Puget Sound. The route is then westerly through the Strait of Juan De Fuca (in U.S. territorial waters), and southerly down the Washington coast to the mouth of the Columbia River. The route is then up the Columbia River, following the shipping channel used for the regular transport of commercial cargo. The river route passes through the navigation locks at the Bonneville, The Dalles, John Day, and McNary dams to the Port of Benton at river mile 342.8. Figure 2.5 is a map showing the waterborne transport route. The time from Shipyard departure to arrival at the Port of Benton would be approximately three days.

To ensure that the reactor compartment packages cross the Columbia River bar on an incoming tide, departure times from Puget Sound Naval Shipyard would be calculated to arrive at that time. The ocean-going tugs would be replaced with river tugs at Vancouver, Washington for passing through the navigation locks at Bonneville, The Dalles, John Day, and McNary dams. The waterborne portion of the transport route ends at the Port of Benton, river mile 342.8.

The most restrictive overhead obstructions along the route are on the Columbia River in the Pasco-Kennewick area where there are two fixed bridges and one power line that cross the river between Pasco and Kennewick. Pasco's South 10th Ave. bridge (the cable bridge) at river mile 328.4 has a vertical clearance of 17 meters (56 feet) starting at the north bridge pier and extending south for 176 meters (578 feet) with the McNary pool height at 104 meters (340 feet). It is the most limiting overhead obstruction on the waterborne transport route. This would provide adequate clearance for the taller LONG BEACH packages and OHIO Class submarine packages to transit under the bridge while staying well within charted navigable waters. The Highway 395 bridge at river mile 330.1 has a vertical clearance of over 17.5 meters (58 feet) with the McNary pool height at 104 meters (340 feet) and therefore does not pose a problem.

115 kV Benton County Public Utility District (PUD) power lines cross the Columbia River approximately 180 to 275 meters (200 to 300 yards) upstream of the cable bridge. The lowest point on the power lines is 25 meters (82 feet) above the water with the McNary pool elevation at 104 meters (340 feet) above mean sea level. This would provide over 10 meters (30 feet) of clearance above the reactor compartment packages covered by this EIS.

Upon arrival at the Port of Benton the barge would be placed in the slip. Water would be added to the barge compartments in a controlled sequence to ground the barge firmly on the gravel slip bottom. Once grounded, the deck of the barge would be against and level with the top of the sill at the landward (west) end of the slip. Figure 2.6 shows a plan view of the barge slip. The slip bottom would be prepared to receive the barge under required permits such as from the Army Corps of Engineers, the Washington State Department of Fisheries, the Washington State Department of Ecology, and the City of Richland, Community Development Department. River water level would be monitored to ensure it does not affect the barge during the off-loading.

The welds holding the reactor compartment package to the barge would be cut, and the reactor compartment would be jacked up and placed upon four steel columns. Jacking would be in small increments with safety cribbing blocks and shims temporarily placed under the load to support the compartment if hydraulic jack pressure were lost. A transport vehicle would then be driven onto the barge and under the package. A multiple wheel high-capacity trailer specially designed for

heavy loads would be used. Figure 2.7 shows an off-loading arrangement concept. The package would be attached to the transport vehicle using welded attachments. The time required to off-load the package from the barge would be 24-36 hours from the time the barge is docked.

2.1.3 Land Transport Route

The transport route currently used for the pre-LOS ANGELES class packages would be used for the cruiser, LOS ANGELES Class and OHIO Class packages as well. The route begins at the Port of Benton barge slip just south of the Hanford Site on the west bank of the Columbia River.

From the barge slip the route consists of the gravel access ramp at the barge slip and a short section of C Avenue to the Hanford Site border at Horn Rapids Road. From there, a 1.6 kilometer (one mile) stretch of well compacted gravel roadway angles northwest across the desert and intersects Route 4S just south of the 300 Area. This section of the transport route could be changed to account for any currently unidentified use of that portion of the Hanford Site. The route is north and northwest for approximately 19 kilometers (12 miles) along Route 4S, a well maintained four lane paved highway, to the Wye Barricade. Only one half the width of the highway would be needed to transport the reactor compartments along Route 4S except for three areas where the entire width of the pavement would be needed to maneuver around traffic lights. From the Wye Barricade, the transport route is north for approximately 10 kilometers (six miles) to the old Hanford Town Site on Route 2S. The transport route then turns west on Route 11A for about 10 kilometers (six miles) to a short access road (Canton Avenue) which leads to the north east corner of the 200 East Area where the proposed land disposal site would be located. Figure 2.8 shows the Hanford Site map and landhaul transport route.

Because of the increased dimensions of some of the cruiser and OHIO Class submarine packages, at approximately six locations at the Hanford Site, Bonneville Power Administration electrical lines may need to be modified in order to provide the safe clearance prescribed by the utility companies for energized transmission lines. The Navy will coordinate this work with Bonneville Power Administration. The work would be confined to the immediate vicinity of the towers along the roadway and would have minimal impact on the desert environment. This route has no bridges or overpasses which would block movement of a very large and heavy package. The time in transit along the landhaul route is expected to be about 12 hours.

The time to transport a package between the Port of Benton and the Wye Barricade along the transport route would be approximately 4-6 hours. This section of the highway is open to the public. Transport arrangements would be made to afford safety to other drivers. For example, transport could be scheduled to avoid heavy use of the roadway, travel could be restricted to one side of the four lane highway, or pilot cars could be used to provide safe escort around the package. Beyond the Wye-Barricade the roadway could be closed to general traffic for the 4-6 hour transit from the Wye Barricade to the 200 East Area. Traffic could be routed around on Route 4 - South.

Transport trailers used to haul pre-LOS ANGELES Class reactor compartments are of modular construction. Each module is approximately six feet wide with two steerable dollies each with four high capacity tires. Modules are available in lengths of four, six and eight rows of wheels each. Modules are typically bolted together end to end and side to side to provide an adequate number of wheels to carry the intended load and keep the load per tire to levels the road can accept. For disposal packages considered by this EIS, trailer modules would be assembled to provide enough wheels to properly distribute the load. Figure 2.9 is a photograph of a pre-LOS ANGELES Class reactor compartment disposal package on a modular trailer.

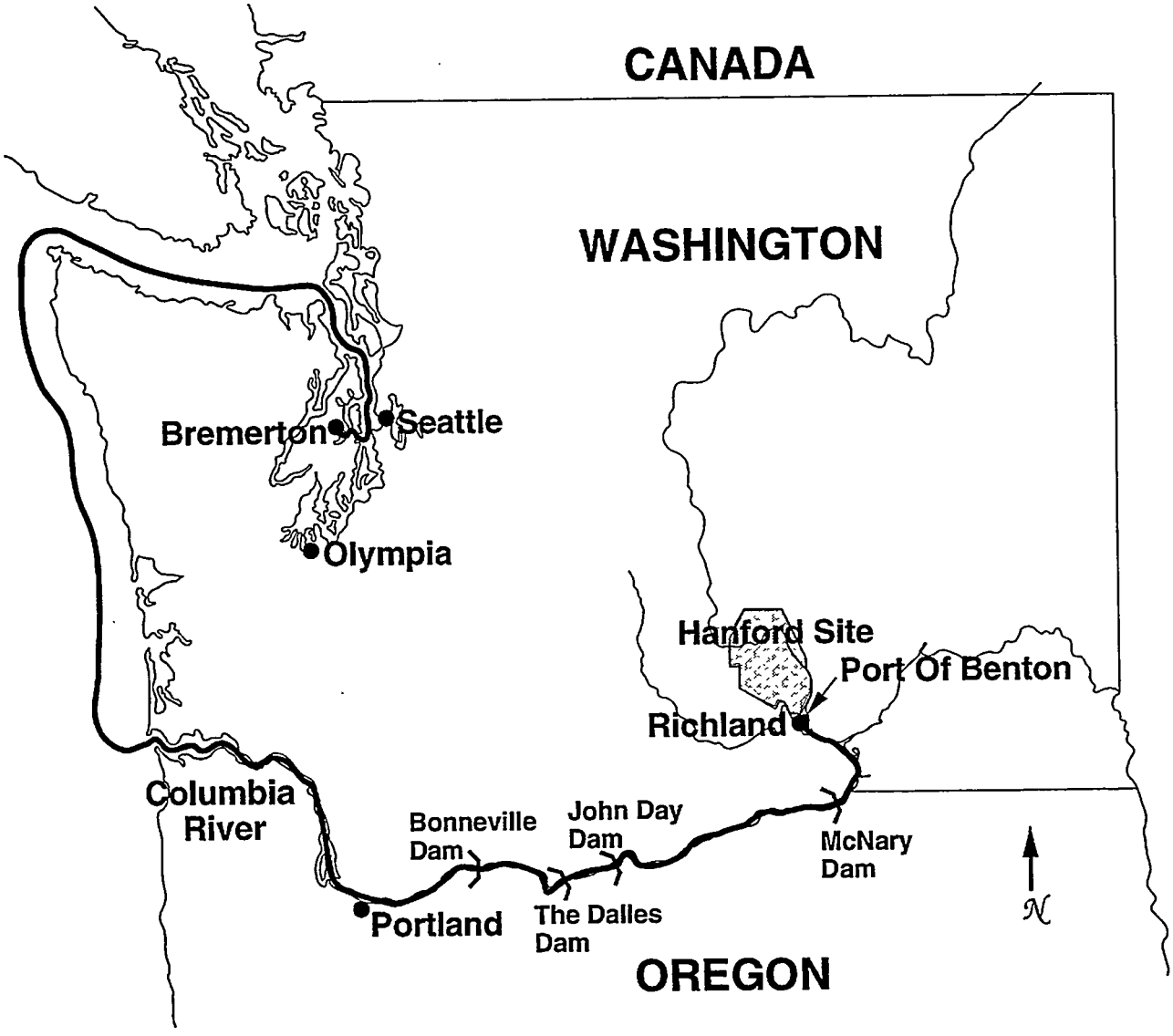


Figure 2.5. Reactor Compartment Disposal Transport Route

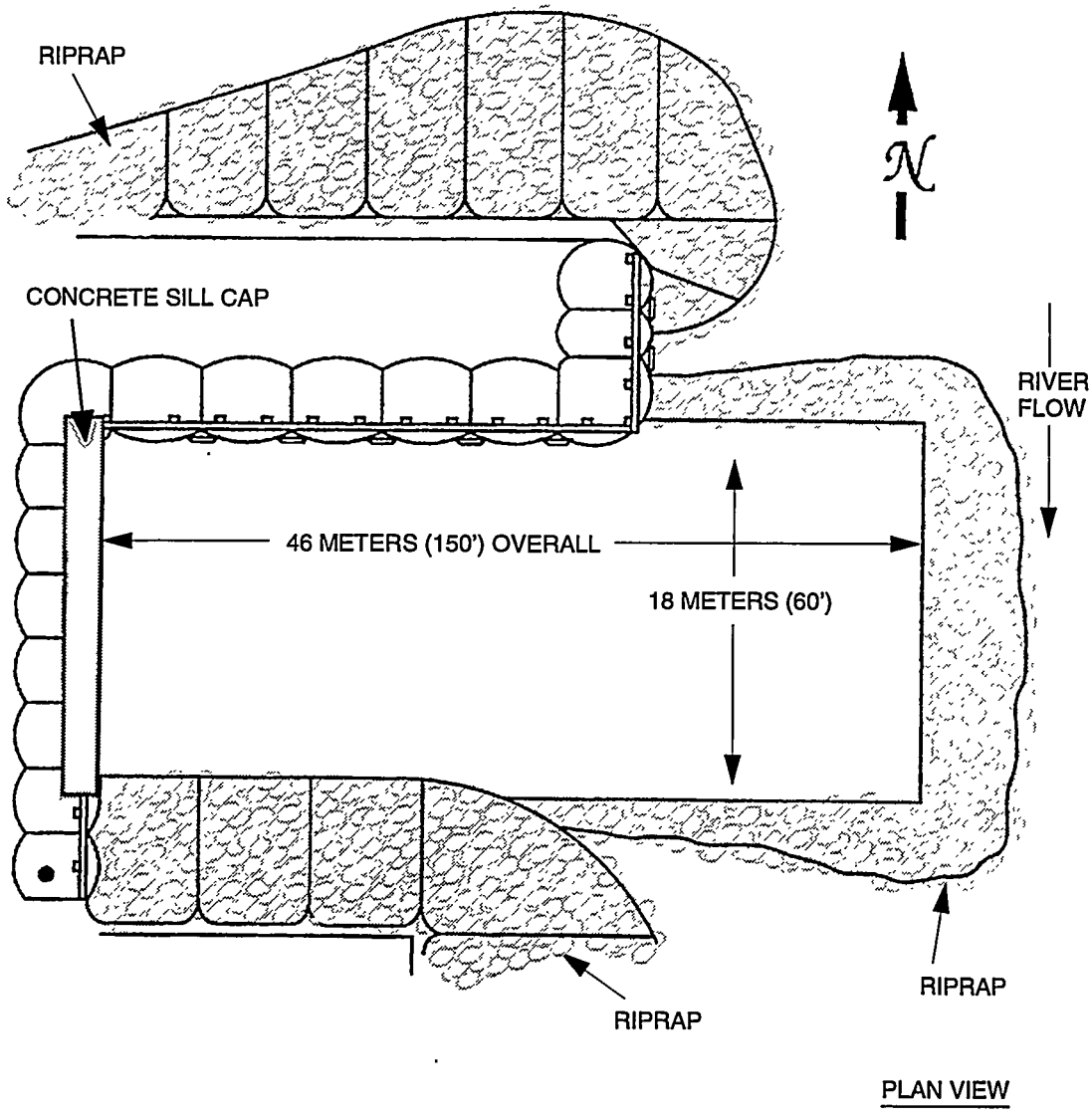


Figure 2.6. Port of Benton Barge Slip

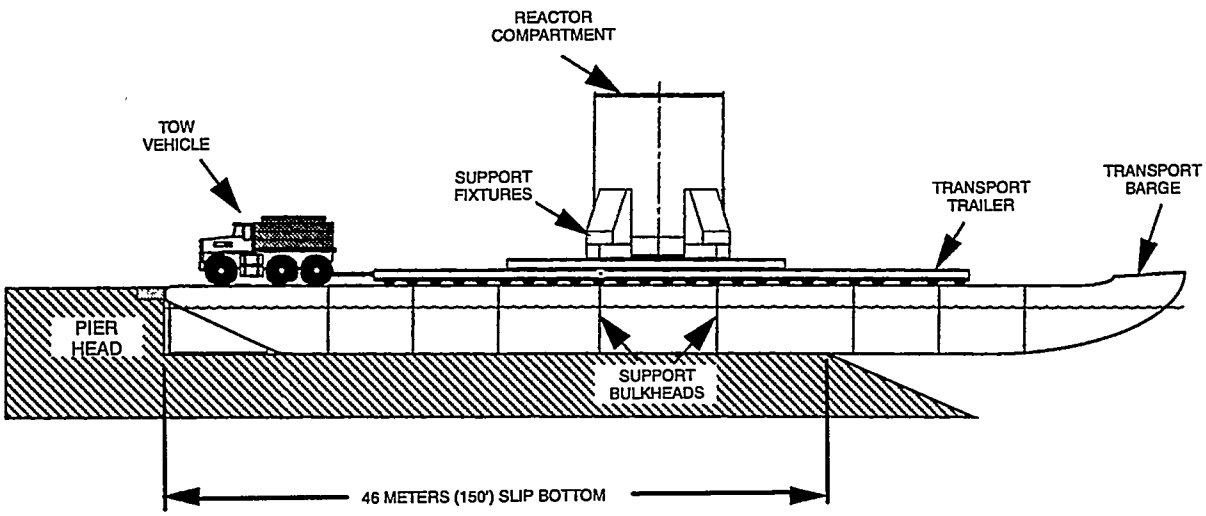


Figure 2.7. Port of Benton Cruiser Package Off-loading Concept

2.1.4 Land Disposal Site

The Hanford Site is located in the southeastern corner of the State of Washington, about 30 miles east of Yakima and immediately north of Richland. The 218-E-12B Low Level Burial Ground is situated near the center of the Hanford Site within the 200 East area.

The Low Level Burial Grounds at Hanford are currently being used for the disposal of solid radioactive wastes similar to the contents of the reactor compartments considered in this statement. The burial grounds of the 200 East and 200 West Areas are situated in an isolated area in the Central Plateau region about seven miles from the Columbia River.

The burial ground area immediately north of Trench 94 is available for Navy use. This area could accommodate expansion of Trench 94 or construction of a second reactor compartment disposal trench of adequate size to hold the approximately 100 reactor compartments considered in this EIS. Trench 94 is sufficiently deep (about 53 feet) to accommodate reactor compartment packages from cruisers and later classes of submarines.

Expanding Trench 94 approximately 60 meters (200 feet) to the north would provide adequate additional trench space for 100 reactor compartments. The existing ramp into Trench 94 could be used. Transport equipment size and configuration would also have a bearing on the final arrangement of the disposal packages in the trench. Figure 2.10 is a conceptual design of the expansion of Trench 94. Figure 2.11 shows the pre-LOS ANGELES Class reactor compartments in Trench 94 as of the end of 1994.

Likewise, a separate trench could be constructed to the north of Trench 94 which could use the existing access ramp. The ramp would have to be widened at the base to allow access to this separate trench. Since the minimum length of the ramp is restricted by the limits on the maximum allowed slope, there would be an advantage to using the existing ramp. A new ramp constructed expressly for the new trench would extend too far north and would interfere with the road and power lines along the north edge of the 200 East Area. The ramp would extend beyond the 200 East Area parameter fence and would require relocation of the power lines and closure or rerouting of the road. Construction of a new ramp would also require a new gate be constructed and would involve disturbing approximately one hectare (two acres) of land outside the existing 200 East Area boundary. If it became necessary to construct a new access ramp, the area could be restored after closure of the trench and would not constitute a commitment of irreversible resources. Figure 2.12 shows a conceptual design of a new trench which would utilize the existing ramp.

The new trench would occupy approximately 4 hectares (10 acres) of the 218-E-12B Low Level Burial Ground which is about the same size as Trench-94.

Currently the area to the north of Trench 94 is partially covered by the spoil pile from the excavation of Trench 94. Part of the spoil pile would have to be moved to allow room for either expansion of Trench 94 or construction of a separate trench. More of the spoil material would have to be moved to provide space for construction of a separate trench than for the expansion scenario. This is because a separate trench would extend approximately 140 meters (450 feet) north of the north wall of Trench-94 and expanding Trench 94 would extend only 75 meters (250 feet) north of the existing north trench wall.

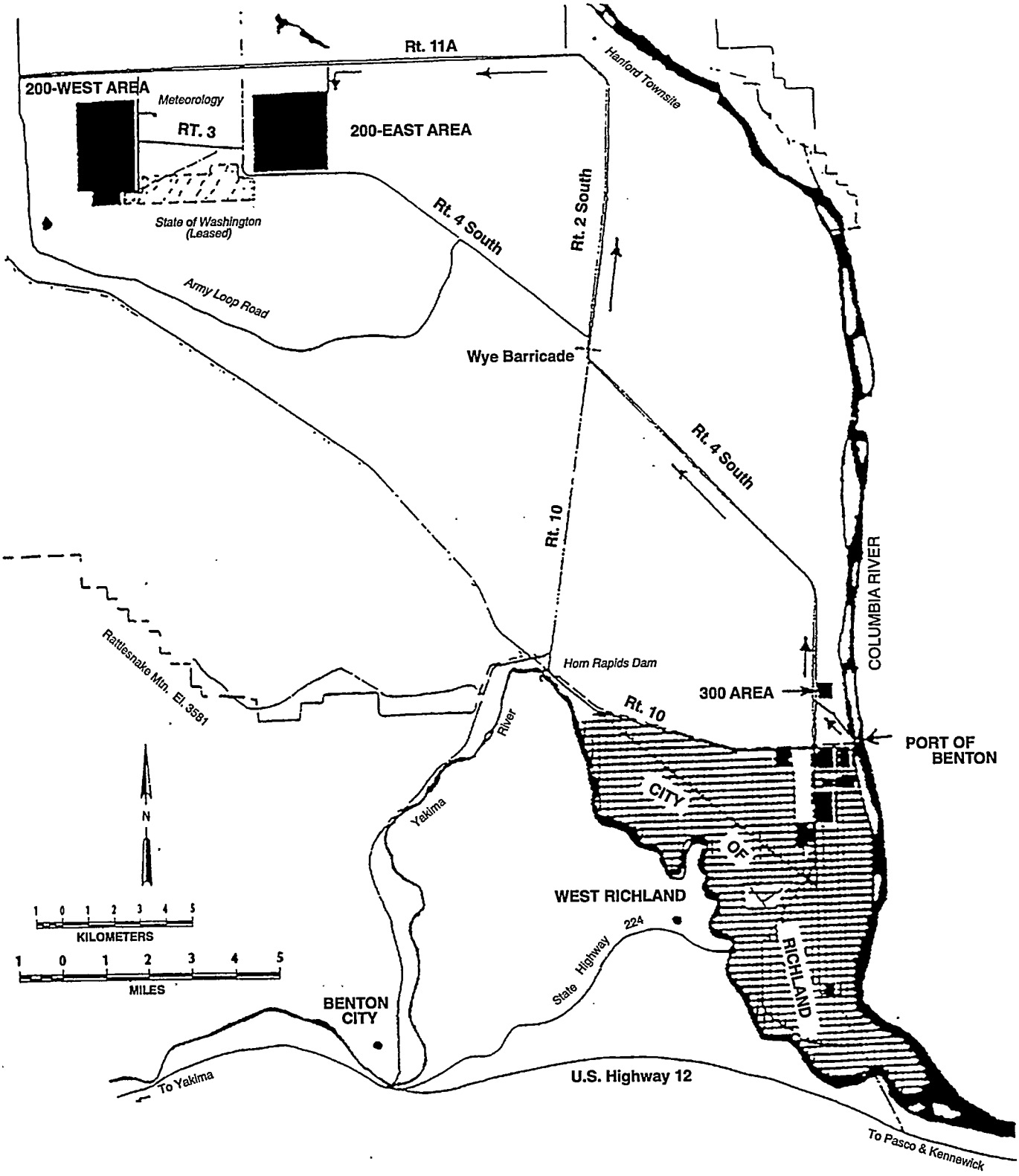


Figure 2.8. Hanford Site Transport Route

Construction operations for either of the trench options would be basically the same. Movement of material would be primarily with scrapers, bulldozers, and graders. Exhaust emissions, noise and dust normally associated with this type of work would be confined to the construction site and would not have any affect beyond the duration of the work. Watering would be used to control dust. An estimated time to accomplish the excavation would be three to six months of continuous work. Because it would be several miles distance to any area accessible to the public, there would be no affect on the general population.

The quantity of material to be excavated to expand Trench 94 would be approximately 320,000 cubic meters (415,000 cubic yards). Construction of a separate trench would involve the removal of approximately 590,000 cubic meters (770,000 cubic yards) of material. This does not include relocation of the existing spoil pile, which could require movement of roughly 50 percent more material for either option. Back-fill would be with native soils prepared (graded) to enhance corrosion performance of the reactor compartments.

It may be feasible to use the existing trench space more efficiently by placing reactor compartments closer together within Trench 94. Currently, pre-LOS ANGELES Class reactor compartments are placed roughly on 15 meter (50 foot) by 15 meter (50 foot) grids with an approximate 230 square meter (2500 square foot) area of trench floor claimed per reactor compartment. This area could be reduced substantially freeing up enough additional floor space to accommodate the cruiser, and LOS ANGELES and OHIO Class reactor compartments. It is expected that existing reactor compartments in Trench 94 would not have to be relocated. The need for trench expansion or the construction of a new trench would be eliminated under this option. However, some minor excavation at areas along the edges of Trench 94 may be required to facilitate this closer spacing of reactor compartments.

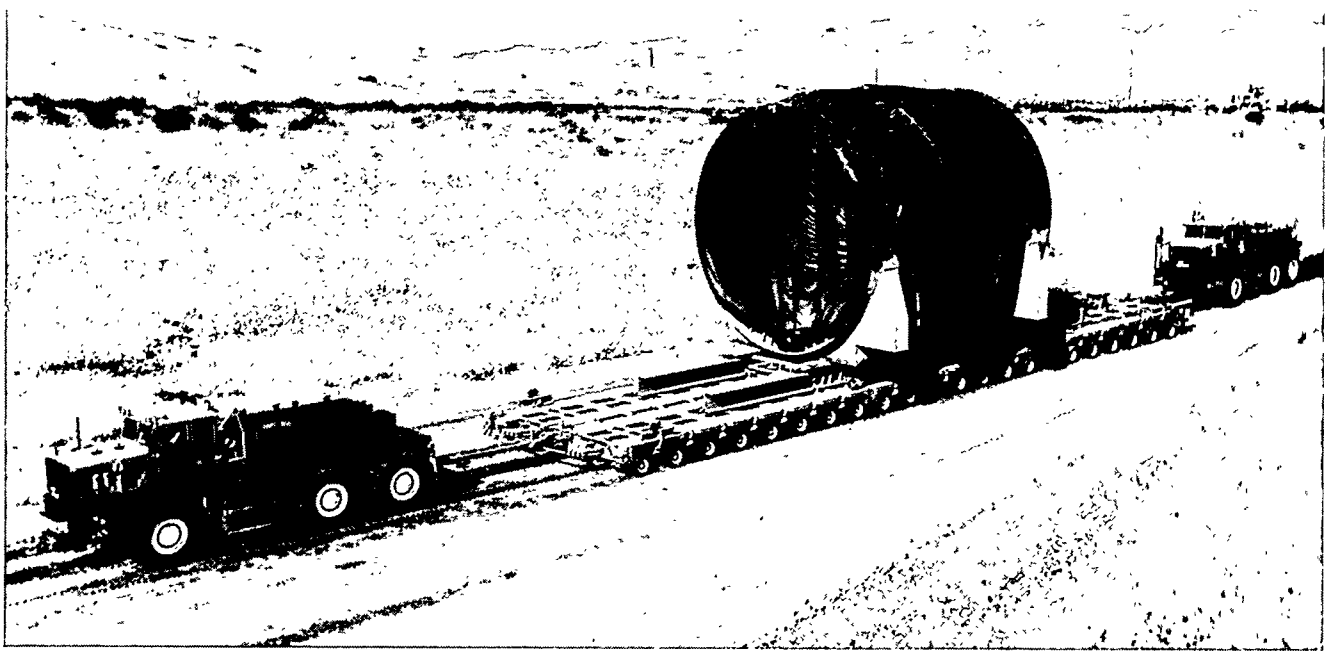


Figure 2.9. Pre-LOS ANGELES Class Reactor Compartment on a Transport Trailer, Hanford Site

2.1.5 Applicable Regulatory Considerations

The following sections discuss the applicable regulations for management, packaging, transport, and disposal of reactor compartments from cruisers, and LOS ANGELES and OHIO Class submarines.

2.1.5.1 Shipyard Preparations Prior to Transport

The applicable regulations for the reactor compartment disposal program at the Shipyard include the Clean Air Act, the Clean Water Act, Toxic Substances Control Act, and the Resource Conservation and Recovery Act (RCRA). The Puget Sound Air Pollution Control Agency has regulatory authority for the Clean Air Act. The Washington State Department of Ecology has regulatory authority over RCRA issues. The EPA has regulatory authority over PCB issues.

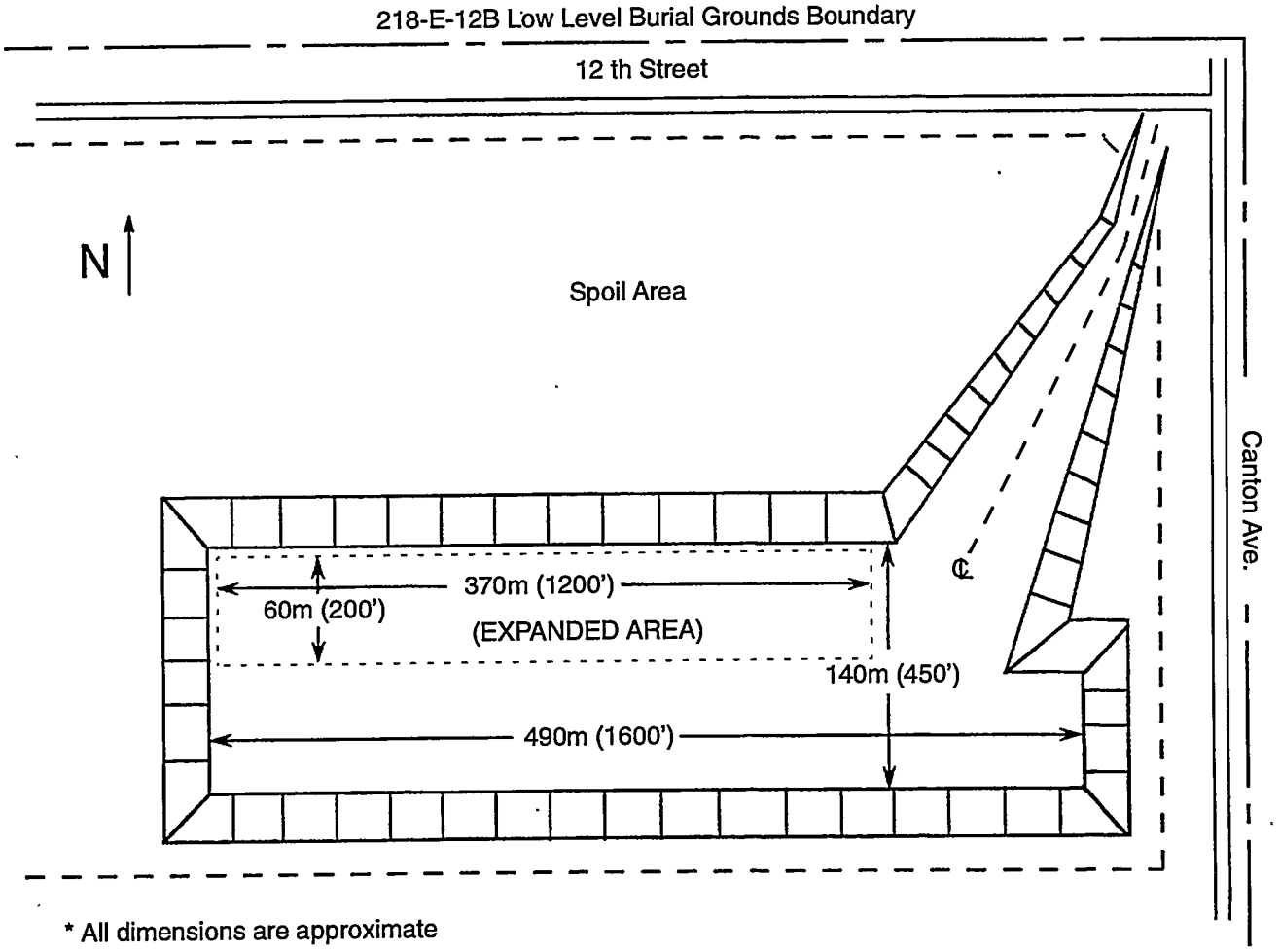


Figure 2.10. Conceptual Expansion of Trench 94

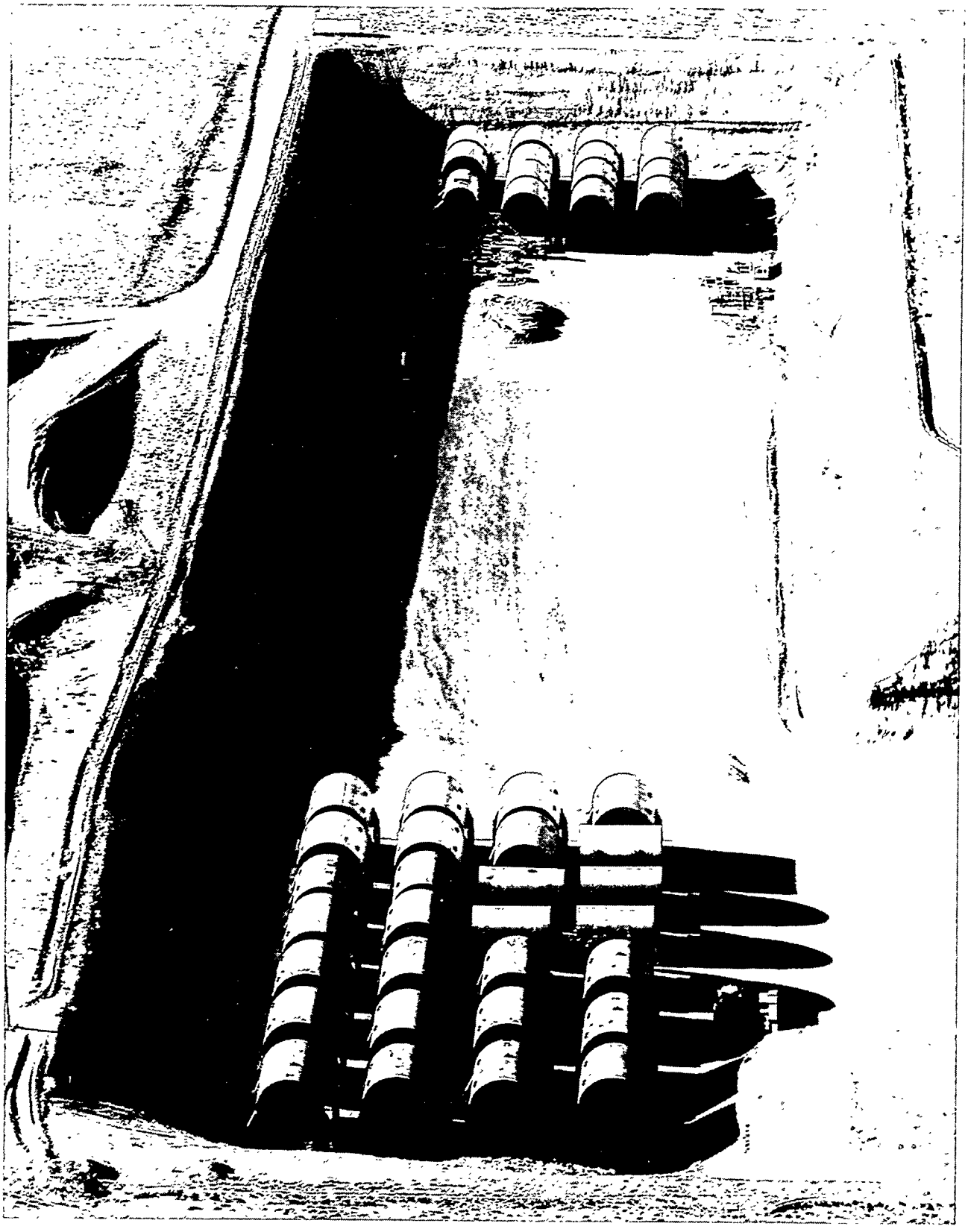
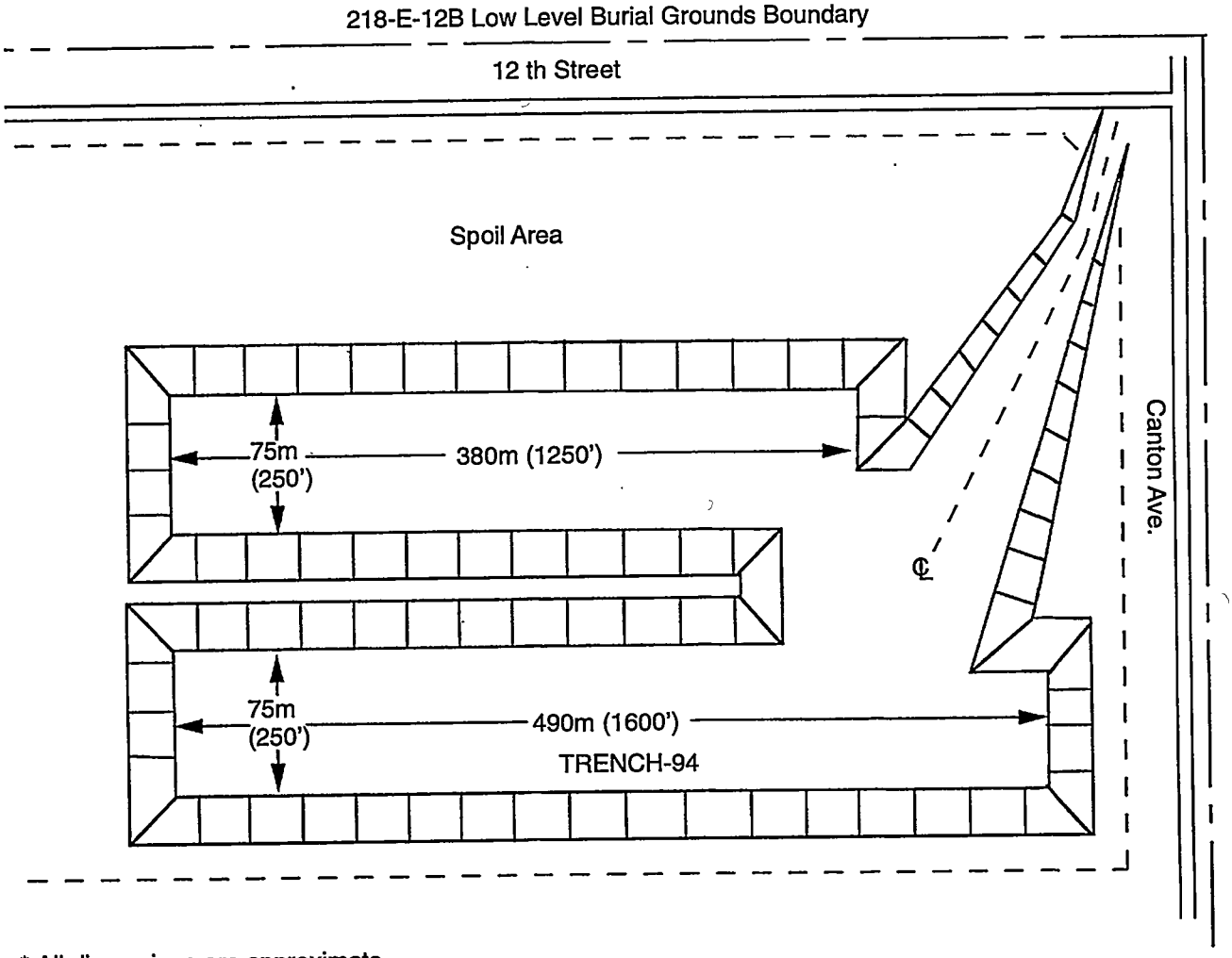


Figure 2.11. Pre-LOS ANGELES Class Reactor Compartments in Trench 94, Sept. 1994



* All dimensions are approximate

Figure 2.12. Conceptual Design of Second Disposal Trench

The Shipyard has National Pollutant Discharge Elimination System (NPDES) permit number WA-000206-2, which specifies discharge limitations for certain constituents as well as stipulates monitoring requirements. Any drydock discharges would be constrained by this permit.

2.1.5.2 Normal Conditions of Transport

Transportation would meet the requirements for normal conditions of transport as specified in 10CFR71 (Packaging and Transportation of Radioactive Materials) and 49CFR171-179 (Hazardous Material Regulations). The requirements of 10CFR71 involve evaluating the reactor compartment disposal package containment structure under: (1) free drop striking the surface in a position for which maximum damage is expected; (2) puncture; (3) temperature influences; (4) external pressure (reduced and increased); (5) water spray; and (6) vibration conditions. These requirements are more restrictive than those of 49CFR171-179.

An engineering analysis of the reactor compartment package designs will be performed to assess the performance of these designs under the hypothetical accident scenarios discussed above. The analysis results will then be compared with the specific requirements for normal transport listed in 10CFR71.51. Package designs based on this analysis will ensure that 10CFR71 requirements are met. Actual physical testing of reactor compartment packages would be impractical due to weight and size considerations and is not required by 10CFR71.

For the containment structure of the reactor compartment disposal package, the free drop scenario is considered the most limiting of all the normal conditions of transport. If the reactor compartment disposal package were to fall 0.3 meters (one foot) as specified by 10CFR71.71(c)(7), the containment structure would deform locally in the affected area of impact. This minor deformation would not affect the integrity of the containment of the reactor compartment disposal package. Additionally, during jacking operations, safety cribbing would be used that was capable of supporting the package if hydraulic jacking pressure were lost.

Package integrity is assessed by evaluating the impact condition as specified by 10CFR71.71(c)(10), which involves striking an area of the exposed surface, considered to be the most vulnerable to puncture, with a six kilogram (13-pound) steel cylinder, 3.2 cm (1 1/4 inches) in diameter, dropped from a height of one meter (40 inches). The potential impact energy from the 6 kilogram (13-pound) steel cylinder would have no effect on the exposed surface; therefore, no puncture of the exterior packaging would occur.

Temperature effects, such as subjecting packages to an ambient temperature of 38°C (100°F) in direct sunlight as specified in 10CFR71.71(c)(1), are analyzed. The maximum internal temperature has been estimated at approximately 150°C (300°F) for the internal structures of the reactor vessel. The maximum package outer surface temperature has been estimated at approximately 38°C (100°F). These elevated temperatures are considerably less than normal service temperatures of the reactor compartment; thus, there would be no damage to the reactor compartment disposal package. The associated pressure increase would be well within the design capability of the reactor compartment disposal package therefore, no damage would occur. Additionally, if a pressure were applied as specified by 10CFR71.71(c)(3) & (4), there would be no affect to the reactor compartment disposal package. This determination is based on the methods used to fabricate the reactor compartment disposal package; such as, using thick steel plates which are fully welded to form the exterior containment structure.

The method of fabricating the containment structure results in a closed and sealed package. The thick, fully welded, steel containment structure would prevent any water from entering the reactor compartment disposal package when subjected to a water spray sufficiently heavy to keep the entire exposed surface continuously wet for 30 minutes (10CFR71.71.(c)(6)). Additionally, the reactor compartment disposal package would be tested for leaks prior to shipment to confirm the integrity of the containment structure. 10CFR71.71(C)(2) specifies that the integrity of the reactor compartment disposal package containment structure be maintained when subjected to an ambient temperature of -40°C (-40°F).

During normal transport, packages are subjected to vibrations over a broad spectrum of frequencies. The vibrations incurred in transporting the reactor compartment disposal package under normal conditions of transport would occur at frequencies that are less than the natural frequencies of the reactor compartment and reactor compartment components. Therefore, it is expected that no resonance and no damage to the reactor compartment disposal package would occur due to vibration (10CFR71.71(c)(5)).

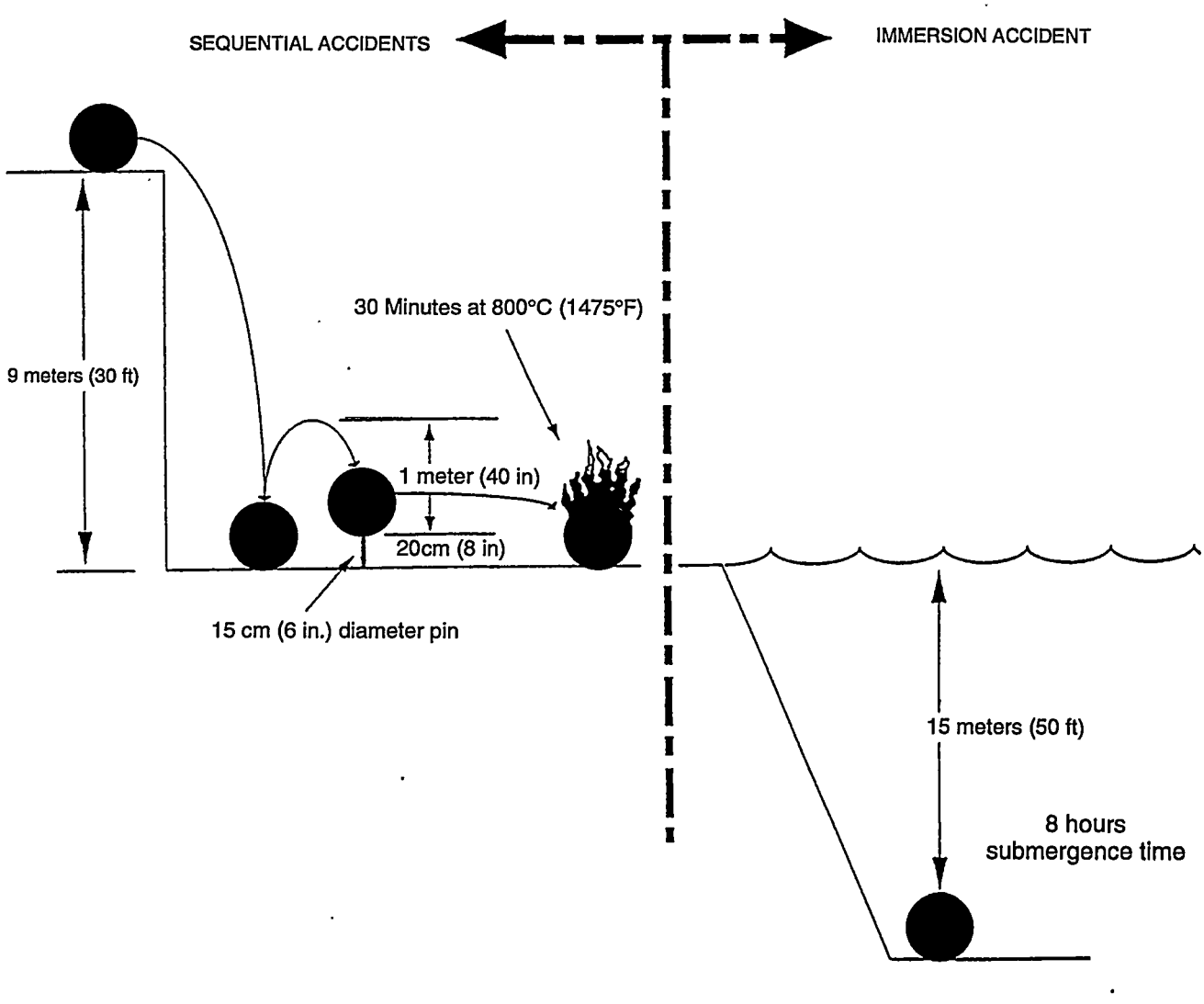
Due to the need for sailors to live on the ships during operation, reactor compartments are designed to attenuate radiation levels outside of the reactor compartment to extremely low levels. The external surface radiation levels for the normal conditions of transportation of the cruisers and LOS ANGELES Class and OHIO Class submarines are expected to be a fraction of the 200 mrem per hour on contact limit allowed under 49CFR173. For reactor compartment disposal packages, radiation levels would typically be less than one mrem per hour on contact, except for isolated spots. The reactor compartment packages would be surveyed prior to shipment to determine radiation levels. Past experience shows the highest levels for isolated spots has been 30 mrem per hour on contact. There would be no removable or fixed radioactive contamination on the outside of the package.

2.1.5.3 Hypothetical Accident Conditions

The reactor compartment disposal packages will be designed to meet the transportation requirements for hypothetical accident conditions of transport as specified by 10CFR71.73. These requirements involve evaluating the reactor compartment disposal package shipping containment structure under a 9 meter (30 feet) free drop onto an unyielding surface, puncture by a 15 cm (6 inch) bar, and 800°C (1475°F) fire for 30 minutes. Immersion in 15 meters (50 feet) of water is considered as a separate accident. The results are compared with 10CFR71.51(a)(2) requirements. Figure 2.13 depicts the sequential hypothetical accident scenario of 10CFR71.73.

The conditions of an unyielding surface and a 9 meter (30 foot) drop would not be encountered along the transport route for the package weight being considered. Also, the regulatory assumption that the 15 cm (6 inch) steel bar is mounted on an essentially unyielding surface would not be encountered. However, the containment structure of the package would be designed and constructed so the 10CFR71.51 requirements would not be exceeded by the sequential accidents.

An undamaged package is required to be analyzed for immersion under a head of water of at least 15 meters (50 feet) for a period of not less than eight hours, as specified by 10CFR71.73(c)(5). As a result of the engineering analysis work discussed previously and the design of the reactor compartment packages, the packages will not deform under this immersion and not exceed the radioactive material release requirements of 10 CFR71.51.



Note: Representative accident sequence - NOT DRAWN TO SCALE

Figure 2.13. Hypothetical Accident Scenario Specified by 10CFR71.73

The submarine hull and new containment bulkheads for the LOS ANGELES Class and OHIO Class submarines would make up the outer containment boundary for the reactor compartment disposal packages. The cruisers' reactor plants are contained within the shielded structural bulkheads of the ships' reactor compartments. Although these bulkheads are designed to accommodate normal and emergency ship's operating conditions including the ability to withstand battle shock, they do not have the larger design margins provided by a submarine's high-strength pressure hull. Therefore, the cruiser reactor compartments require a containment structure to be fabricated around the reactor compartment to meet the Type B package criteria in 10CFR71.

In both cases, the thick, fully-welded, steel containment structure would be designed, constructed, and prepared so that the packaging will prevent the release of the radioactivity in excess of the limits specified in 10CFR71 for normal transportation and hypothetical accident conditions.

It is important to note that even though the reactor compartment disposal packages would contain quantities of radioactivity, see Table 1.1, requiring the Type B level of containment for transportation, the majority of the radioactivity (approximately 99.9%) is in the form of neutron activated structural metal components contained within the reactor vessel. . Only the surface-deposited activated corrosion products, the remaining 0.1% of the radioactivity, could potentially become available for release.

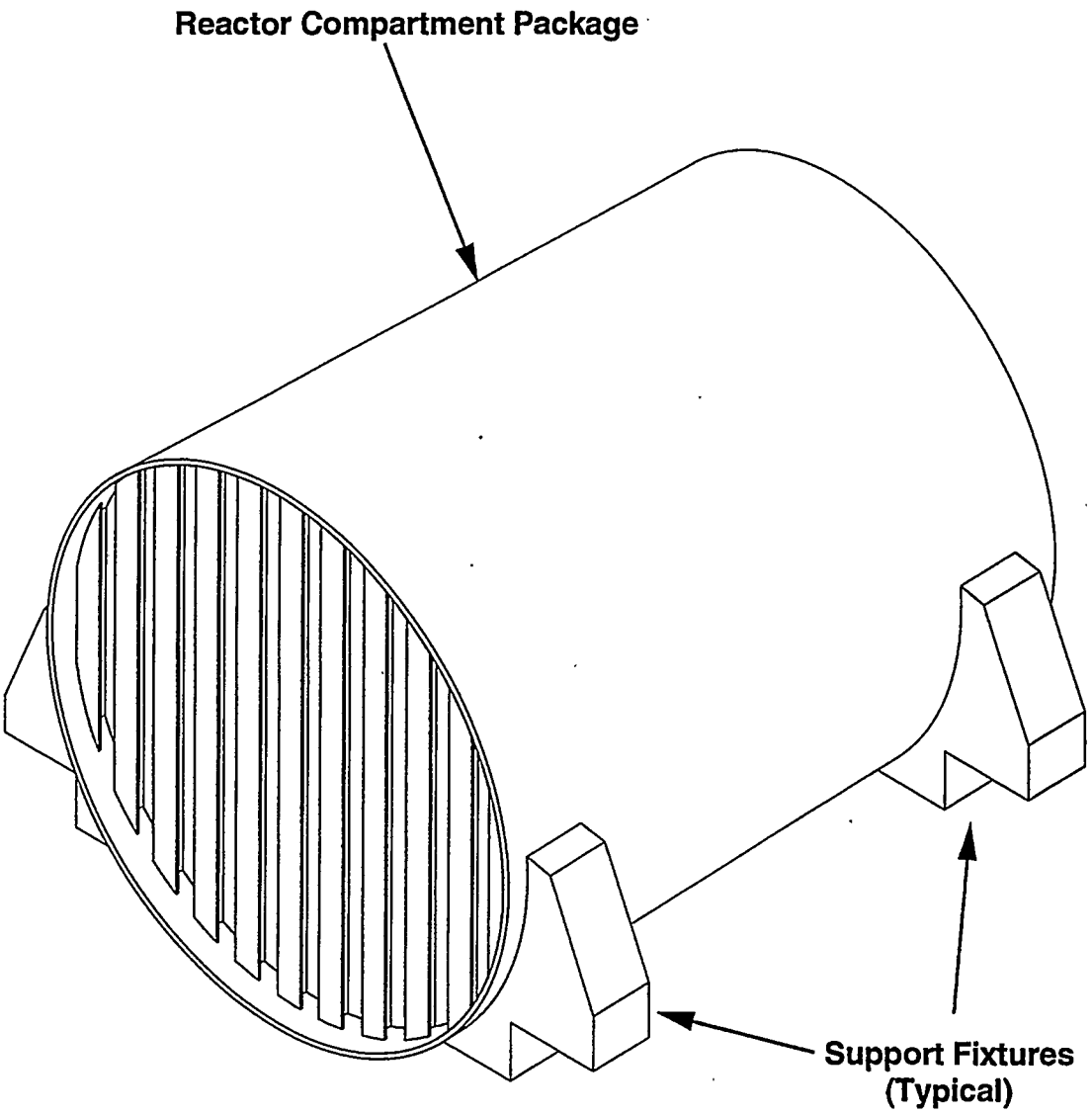
The same proven principles used to safely and successfully transport the pre-LOS ANGELES reactor compartment packages would be adapted for the cruisers and LOS ANGELES and OHIO Class reactor compartments. Figure 2.14 shows the conceptual design of a typical LOS ANGELES or OHIO Class submarine reactor compartment disposal package and Figures 2.15 and 2.16 show the conceptual design of typical cruiser reactor compartment disposal packages. As shown on the Figures, structural support fixtures would be welded to the package to facilitate moving it horizontally and vertically. In all cases, the thick, fully-welded, steel containment structure would prevent the release of the package contents in excess of the specified limits for normal transportation and hypothetical accident conditions.

2.1.5.4 Disposal

Land disposal at the Hanford Site 218-E-12B Low Level Burial Grounds would be regulated by State and Federal agencies. The United States Department of Energy would manage the disposal of the radioactive material contained in the reactor compartment packages under Department of Energy Order 5820.2A, Radioactive Waste Management (DOE, 1988). The Washington State Department of Ecology would regulate the reactor compartment disposal packages as a dangerous waste under Washington Administrative Code (WAC) 173-303, Dangerous Waste Regulations (WAC, 1993) due to the quantity of permanent lead shielding present.

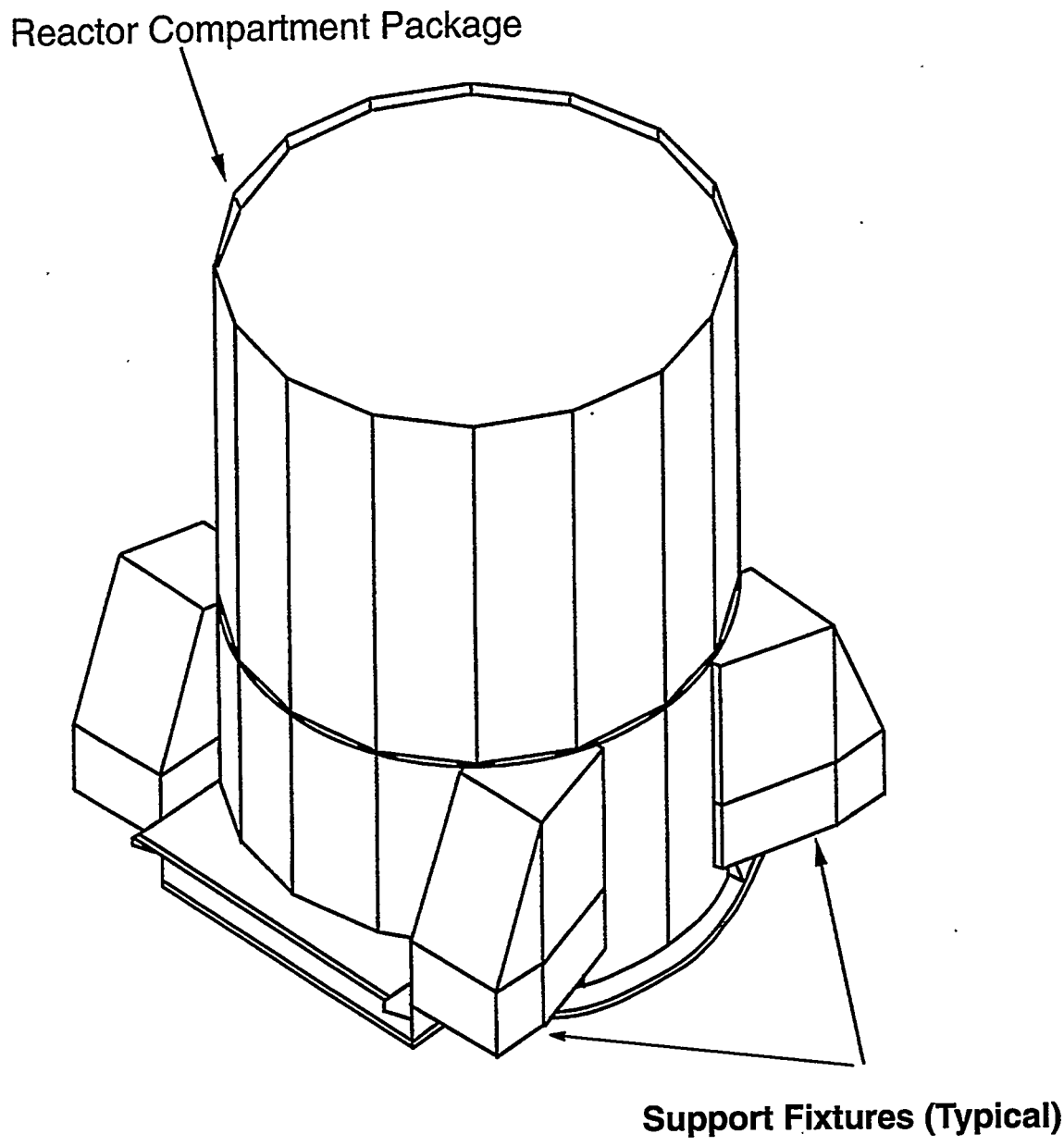
Polychlorinated biphenyls (PCB) in concentrations greater than 50 parts per million would be regulated by the United States Environmental Protection Agency (EPA) under the Toxic Substances Control Act, Title 40 of the Code Federal Regulations, Part 761.75 (40CFR761.75). Asbestos would be properly contained to meet local (Benton-Franklin Counties Air Pollution Control Authority), State (WAC 173-303), and Federal (40CFR61) requirements.

Sections 173-303-280 through 173-303-283 of the Washington Administrative Code (WAC, 1993) describe the Washington state requirements for facilities which store, treat, or dispose of dangerous wastes and which must be permitted by the State. The disposal of reactor compartments from defueled, decommissioned cruisers, LOS ANGELES Class submarines, and OHIO Class Submarines at the 218-E-12B Low Level Burial Ground would be regulated under these sections.



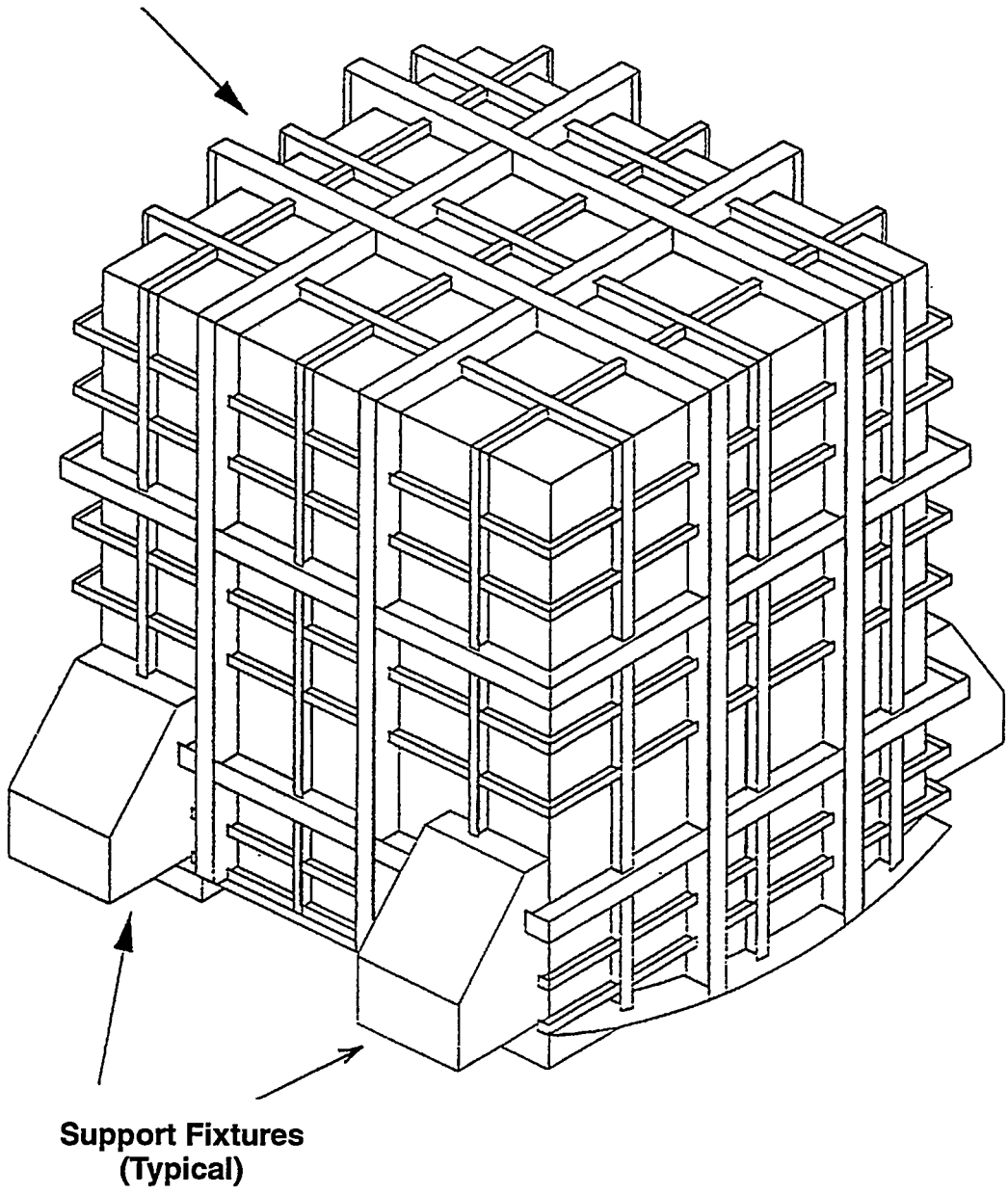
Note: Package size would be approximately 42 feet long by 33 feet diameter for the LOS ANGELES Class and approximately 55 feet long by 42 feet diameter for the OHIO Class.

Figure 2.14. Conceptual LOS ANGELES or OHIO Class Submarine Reactor Compartment Disposal Package



Note: Package size would be approximately 31 feet diameter by 37 feet high.

Figure 2.15. Conceptual Cruiser Reactor Compartment Disposal Package (Except LONG BEACH)



Note: Package size would be approximately 38 feet by 37 feet by 42 feet high.

Figure 2.16. Conceptual Cruiser Reactor Compartment Disposal Package for the Cruiser LONG BEACH

2.2 No Action Alternative - Indefinite Waterborne Storage

The closest reasonable approach to the "No Action" alternative would involve actions that would be considered prudent to provide protection of the public safety and to prevent unacceptable environmental consequences. This alternative would include work required to prepare the ships for indefinite waterborne storage in a safe and environmentally acceptable manner. After inactivation, the ship would be placed in waterborne storage. The existing facilities for waterborne storage of nuclear-powered ships are at Puget Sound Naval Shipyard and Norfolk Naval Shipyard.

The preparation for storage work would include removing fluids, removing militarily useful equipment, blanking sea connections, ensuring the preservation of containment barriers such as the hull, and installing fire and flooding alarms. Equipment and materials would be available for salvage. Periodically it would be necessary to move each ship into drydock for hull maintenance.

The alternative of taking no permanent disposal action can be selected and successfully applied. The Navy's 1984 EIS (USN, 1984a) determined that protective waterborne storage could be safely done. This determination was supported by a discussion of the measures taken in storing seven defueled, decommissioned Naval nuclear submarines to ensure that no radiological concern existed or would exist for many years as long as periodic hull maintenance is performed. Three of these seven submarines have been in waterborne storage for over 15 years. Drydocking for hull maintenance has been performed as necessary. The 1984 conclusion was that the protective waterborne storage option is considered satisfactory as an interim measure; however, maintenance will be an increasing responsibility for the Navy as the ships age and the number of inactivated ships increases. Protective storage is not a permanent solution to the disposal problem. If no permanent alternative is available, the "no action" alternative will occur by default.

The disadvantage of this option is that it only delays ultimate permanent disposal. The potential benefit would be lower radiation exposure to shipyard workers preparing the package for final disposal. A delay of 50 to 100 years would reduce the total radiation dose to shipyard workers to less than one rem per package (approximately 0.0004 additional latent cancer fatalities) in preparing the package for land disposal. At the end of protective storage, the radioactive inventory, primarily radionuclides such as nickel-63 and nickel-59, would still require permanent disposal of the reactor compartments as radioactive waste.

Although delaying disposal could potentially allow the development of some new technology to deal with the disposal of radioactivity, there is nothing presently on the horizon that would hold the promise of a more cost effective, environmentally safe disposal method for reactor compartments.

2.2.1 Moorage Facility Requirements

There are two areas designated by the Navy as inactive nuclear-powered ship moorage facilities. Norfolk Naval Shipyard maintains the designated inactive nuclear ship moorage facility on the east coast and Puget Sound Naval Shipyard maintains the facility on the west coast. These facilities have specific services and equipment to provide a safe, secure moorage for temporary storage of inactivated defueled nuclear-powered ships. The Norfolk Naval Shipyard moorage facility, with minor modifications and dredging, would be capable of handling up to twelve ships depending on the type and size. The Puget Sound Naval Shipyard morage facility has a capacity of about 35 ships depending on the classes involved.

The inactive ship nuclear mooring facilities at both Norfolk Naval Shipyard and Puget Sound Naval Shipyard would be adequate to handle the cruisers and submarines inactivated until after the year 2000.

At Norfolk Naval Shipyard, dredging would be required prior to berthing the ships considered by this EIS. Sediment buildup in the Norfolk area is about three inches per year. Periodic maintenance dredging would be required during the storage period to prevent grounding during low tides. At Puget Sound Naval Shipyard, water depths are adequate to berth the ships considered by this EIS without dredging. Since sediment buildup in the Puget Sound Naval Shipyard area is less than approximately one foot per 50 years, maintenance dredging is an insignificant factor.

2.3 Disposal and Reuse of Subdivided Portions of the Reactor Plant

2.3.1 Description of Alternative

This alternative would involve the dismantlement of the entire ship, including the reactor compartment and the reactor plant, into smaller sections. Reusable components and materials would be recycled to the extent feasible. Components and materials would be processed according to regulations applicable at the time of disposition. The amount of waste estimated for the subdivision alternative ranged from a high 120,000 cubic meters (4,240,000 cubic feet) to a low of 10,000 cubic meters (353,000 cubic feet) with an intermediate estimate of 24,000 cubic meters (847,000 cubic feet). The amount of mixed waste was estimated to be from 2,255 to 6,255 cubic meters (79,600 to 221,000 cubic feet).

Operations could begin immediately after defueling and decommissioning while the ship was still in drydock. They also could be performed after protected waterborne storage for an indefinite period following defueling and decommissioning. Periods of storage preceding operations would allow radionuclides to decay, thereby reducing radiation exposure to shipyard workers.

Puget Sound Naval Shipyard and Norfolk Naval Shipyard are the sites being considered for performing subdivision operations. One or both of these sites would be used if this alternative is selected because they are the two largest Naval Shipyards, can handle all classes of ships under consideration in this EIS, have Naval Inactive Ship Maintenance Facilities (NISMF) and would perform most of the defuelings.

The basic operations would be accomplished in drydock. The arrangement would be similar to the arrangement shown in Figure 2.17. The ship would be floated into a flooded drydock and lowered onto keel blocks as the water is drained from the drydock. Subsequent operations would take place either with the reactor compartment attached to or separated from the rest of the ship. Enclosures would be installed and openings made into the reactor compartment. Components and materials would be removed from the reactor compartment and transferred to appropriate locations within the shipyard for further disassembly or processing if necessary. When no longer needed for environmental control of radioactive and hazardous materials, the enclosures would be removed and the reactor compartment structure and hull would be dismantled.

2.3.2 Basic Facilities and Operations Required to Support Alternative

The operations required to support the subdivision alternative would require removal of the reactor plant systems, such as the fluid systems and electrical systems. Lead shielding would be removed. The reactor compartment structure and hull would be dismantled. Large components would be packaged individually for shipment and disposal while smaller items would be packaged in drums or other bulk containers. The operations and processes needed to accomplish the subdivision alternative would be expanded from those currently in use at Naval shipyards to overhaul ships. The number and size of components to be processed would be on a larger scale. Large components, such as reactor pressure vessels, steam generators and pressurizers, which are

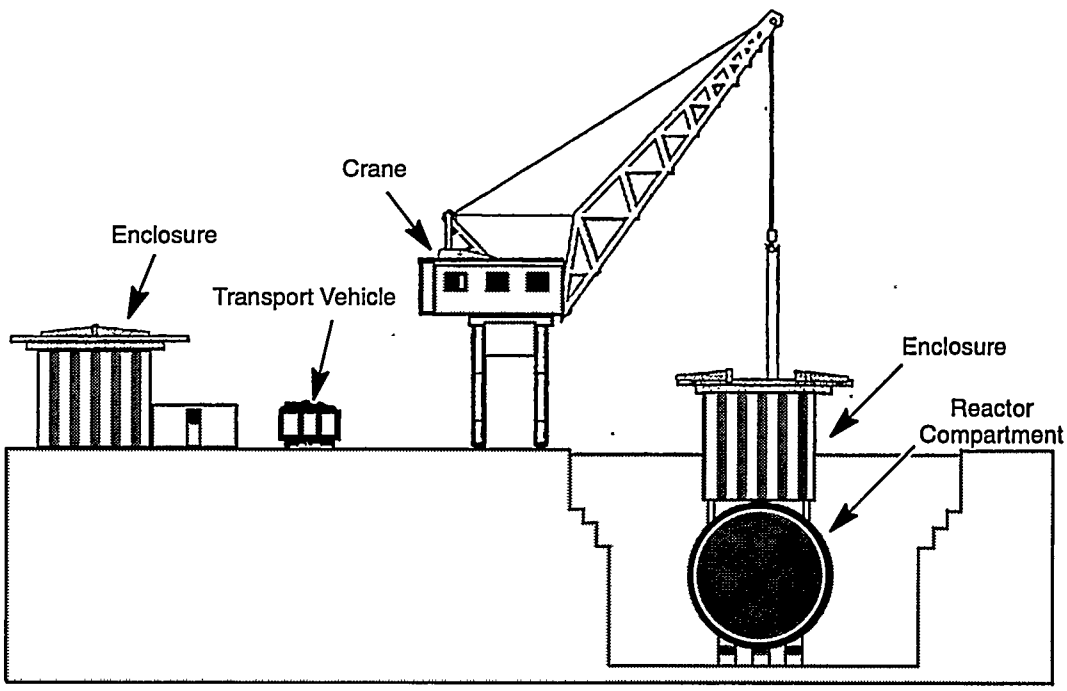
not removed from reactor compartments under current programs, would have to be removed, packaged and disposed of individually. The large quantity of smaller components, such as valves, pumps and gages would have to be removed, packaged and disposed of separately. The magnitude of this disposal effort would be at least 10 times that of current programs.

Basically, the physical operations would involve mechanical disassembly of components, machine cutting of metal, flame cutting of metal, removal of insulation, packaging of material and handling of material. Operations, in general, would be keyed to removal of the major components such as the reactor vessel, steam generators, pressurizer and main coolant pumps. Prior to removal of each major component, cables, piping, cat walks and other structures that would cause interference would be removed. Radiological considerations, together with differences in reactor compartment arrangements and component sizes and weights, would affect the specific way that each reactor plant is dismantled.

Most items to be removed would be within the capacity of existing shipyard portal cranes. However, in some cases reactor vessels, which are the heaviest components, exceed the capacity of the largest portal cranes at the Shipyards being considered for this work. Also, in the normal installed position, radiation from the reactor vessel is attenuated by lead shielding attached to the shield tank that surrounds the lower part of the reactor vessel. Therefore, it would be advantageous to remove the reactor vessel and primary shield tank as a unit to take advantage of the shielding provided by the tank and thereby reduce radiation exposure to shipyard workers. The combined weight of the reactor vessel and tank would exceed the capacity of even the largest shipyard portal cranes. Therefore, either a crane with sufficient lifting capacity would be obtained or transfer of the reactor vessel and tank for shipment would be accomplished by means of jacking and blocking. It would also be advantageous to add concrete to the primary shield tank to provide further shielding in which case the weight to be handled would be even greater.

Although some large components, such as reactor pressure vessels and steam generators, would be too large to ship by truck or by rail, none of the components would be too large to ship by barge. Department of Energy disposal sites at Hanford, Washington and Savannah River, South Carolina are accessible by truck, rail or barge. Operations would take place in a drydock or pierside. Subdividing the reactor plant and processing of the pieces would require appropriate containment to protect shipyard workers and the environment from radioactive materials and hazardous materials exposed during processing.

One or more enclosures would be placed over or around the reactor compartment for removal of components and materials. Moveable roofs, or other means of access, would be provided as necessary for transporting components and material out of the reactor compartment. The enclosure would incorporate a controlled ventilation system designed to prevent discharge of hazardous or radioactive particulates to the environment. Access would be provided from the enclosure to the reactor compartment interior. Methods would be established to ensure that hazardous materials exiting the enclosure would be properly identified for subsequent disposition. In addition to facilities for general disassembly of components and segregation of materials, special facilities would be provided for handling of radioactive material, PCB bearing material, lead and asbestos. Reusable material and equipment would be loaded onto rail cars or trucks for transport to recycling facilities. Cranes as well as trucks and rail cars would be utilized for transport of components.



Note: LOS ANGELES Class reactor compartment is shown. Approximate diameter is 33 feet.

Figure 2.17. Conceptual Arrangement for Drydock Operations

This alternative would generate (1) asbestos, toxic, hazardous, radioactive and mixed wastes, (2) equipment that could be salvaged and reused, (3) metal and other materials that could be reused or sold for reuse and (4) non-hazardous solid waste. Work involving hazardous materials would be carried out by trained people using appropriate personnel protective equipment, in accordance with occupational safety and health regulatory requirements. The method of disposition would vary according to the nature of the material. Items that were radioactive, but not otherwise toxic or hazardous, would be packaged to meet the DOT requirements at 49CFR170 through 189 and applicable DOE orders and disposal site requirements. Mixed waste, which is waste that is radioactive in addition to being hazardous, would be processed in accordance with an approved shipyard site treatment plan and Section 3021(b) of the Resource Conservation and Recovery Act, as amended. Radioactive PCB waste, which is a regulated PCB article in addition to being radioactive, would be processed for storage in accordance with 40CFR761 and applicable Navy directives.

Non-radioactive, non-hazardous materials could be recycled as outlined in the Navy's June, 1993 Environmental Assessment of the Submarine Recycling Program at Puget Sound Naval Shipyard (USN, 1993a). Under the current disposal program for pre-LOS ANGELES Class submarines, portions of the submarine forward and aft of the reactor compartment are completely recycled, which greatly reduces the volume of waste to be disposed of. The same basic recycling processes would be used for recycling, where feasible, of non-radioactive, non-hazardous portions of cruisers, OHIO Class submarines and LOS ANGELES Class submarines including non-radioactive, non-hazardous portions of the reactor compartments. There is limited disposal capacity for mixed waste and radioactive PCB waste which might result from reactor compartment disposal work. Mixed waste would require treatment in accordance with appropriate treatment standards before disposal or else would require placement in retrievable storage until a mixed waste treatment and/or disposal site became available. Similarly, radioactive PCB waste would require storage until sufficient treatment or disposal capacity became available.

The locations of radioactive items on board Naval nuclear-powered ships are clearly established through surveys conducted throughout the operational life of the ship, by surveys conducted before, during, and after maintenance work and by surveys conducted as part of the decommissioning process. In addition, surveys would be conducted before, during and after subdivision operations.

Work on radioactive items would take place in specially controlled areas with methods in effect to prevent radioactivity from being spread to uncontrolled areas. Items within such a controlled area would be considered potentially radioactive and would be subjected to radiological surveys prior to being released for unrestricted handling.

Radioactive items that would require disposal would be evaluated to determine if they were hazardous in addition to being radioactive. If so, they would be considered mixed waste or radioactive-PCB waste and would be processed accordingly.

Mixed wastes would first be collected in designated accumulation areas. Then they would be processed to segregate the radioactive, hazardous, non-recyclable, non-radioactive, non-hazardous and recyclable components to the extent practicable. The mixed waste that remained after processing would be packaged and shipped to an appropriate mixed waste treatment or disposal site. Similarly, radioactive waste, hazardous waste and non-recyclables that resulted from processing would be packaged and shipped to appropriate disposal sites.

In addition, to reduce the overall volume of waste metal from the subdivision alternative, some of the radioactive metals could be recycled using recently licensed foundry technology. The Navy has used this technology to process some Navy radioactive waste metals. In December of 1993, Norfolk Naval Shipyard awarded a contract for processing of radioactive waste, which included provisions for recycling of radioactively contaminated metals by foundry melting. The amount of metal involved was estimated to be 300,000 pounds. The contract precluded processing of mixed waste, transuranics, and Class B and Class C waste per 10CFR61.

2.3.3 Applicable Regulatory Considerations

Portions of the reactor plant which would be transported for final disposition would be packaged to meet all applicable U.S. Department of Transportation requirements for packaging of hazardous materials for transport as set forth in 49CFR173.

Items would also be packaged to meet applicable U.S. Nuclear Regulatory Commission regulations (10CFR71) for packaging and transportation of radioactive material. In addition, they would be packaged to meet applicable U.S. Environmental Protection Agency solid waste regulations of 40 CFR et seq. Any additional requirements of the disposal site operator, including those imposed by State government, would also be met.

Applicable regulations for the reactor compartment disposal program at the shipyards include the Clean Air Act, the Clean Water Act, Toxic Substances Control Act, and the Resource Conservation and Recovery Act (RCRA).

At Puget Sound Naval Shipyard, the Puget Sound Air Pollution Control Agency has regulatory authority for the Clean Air Act. At Norfolk Naval Shipyard, this function is assumed by Region 6 of the Virginia Department of Environmental Quality. The Washington State Department of Ecology has regulatory authority over RCRA issues. For Norfolk Naval Shipyard, this function is retained by the EPA. The Shipyards have national Pollutant Discharge Elimination System (NPDES) permits, which specify discharge limitations for certain constituents as well as stipulating monitoring requirements. Any drydock discharges would be constrained by these permits.

The EPA has regulatory authority over PCB issues at the shipyards. Toxic or hazardous wastes and wastes that contain asbestos or PCBs would be disposed of at sites authorized to accept those wastes in accordance with 40CFR240 et seq. and 40CFR700 et seq. as applicable.

The shipyard has an occupational health/preventive medicine unit and a branch clinic (industrial dispensary) which are run by Naval Hospital Bremerton. Personnel may also be taken to Harrison Memorial Hospital as needed.

The shipyard maintains two fire stations with approximately 50 personnel. The shipyard has a fire department that is fully equipped for structural and industrial firefighting and hazardous material spill response.

The shipyard has a security force of approximately 177 personnel providing law enforcement services, emergency services, security clearances, and parking and traffic control for the Bremerton Naval Complex.

In the non-radiological Occupational Safety, Health, and Occupational Medicine area, the Navy complies with the Occupational Safety and Health Administration regulations. The Navy policy is to maintain a safe and healthful work environment at all naval facilities. Due to the varied nature

of work at these facilities, there is a potential for certain employees to be exposed to physical and chemical hazards. These employees are routinely monitored during work and receive medical surveillance for physical hazards such as exposure to high noise levels or heat stress. In addition, employees are monitored for their exposure to chemical hazards such as organic solvents, lead, asbestos, etc., and where appropriate are placed into medical surveillance programs for these chemical hazards.

2.3.4 As Low as Reasonably Achievable (ALARA) Considerations

Radiation exposure to both shipyard workers and the public would be reduced by approximately one-half for every five years that operations are deferred because cobalt-60, which would be the primary source of exposure from 1 to 100 years after reactor shutdown, has a relatively short half-life of 5.3 years. After about 100 years, niobium-94 dominates the radiation dose to workers or personnel in the vicinity (NRC, 1991). In its evaluation of radiation exposure to personnel performing disposal of large commercial pressurized water power plants, the Nuclear Regulatory Commission estimated that, after 10 years worker exposure would be reduced to 55% of the exposure for immediate decommissioning, (NRC, 1988, Table 4.3-2). For Naval reactor compartments, however, the proportion of exposure to prepare for storage (which is constant regardless of how far in the future subdivision takes place) relative to the overall exposure for disposal is lower than for commercial reactors. Therefore, the overall exposure for disposal using the subdivision alternative could be reduced, after ten years to about 27% of the exposure for immediate subdivision.

The reason that deferral reduces exposure is straightforward. Radioactive isotopes that are mainly beta emitters or have very short half-lives do not contribute significantly to the personnel radiation dose associated with the subdivision alternative. Because beta radiation is weakly penetrating, it can be easily shielded and mainly presents a hazard if ingested or inhaled. Precautions to preclude ingestion or inhalation are implemented during all stages of work.

Radiation dose to workers would be kept as low as reasonably achievable through detailed planning, use of work processes that result in reduced personnel exposure, and installation of temporary shielding.

2.4 Indefinite Storage Above Ground at Hanford

In this alternative, reactor compartment packages would be stored above ground indefinitely at the Department of Energy Hanford Site. Compartment packaging and transport methods would be the same as those for the preferred alternative. The reactor compartments would be placed on foundations, similar to the current placement of pre-LOS ANGELES Class reactor compartments in Trench 94. However, for storage, there would be no intent to landfill the compartments for disposal as is planned for Trench 94. For storage, the surface coatings (paint) on the exterior of the compartments and the compartment foundations would be maintained as needed.

As in the no action alternative, storage is not a disposal alternative. Such storage would only defer the need to permanently disposition the radioactive and hazardous material contained by the reactor compartment.

The total volume of the reactor compartments is about 120,000 cubic meters (4,240,000 cubic feet). Besides the reactor compartments, the volume of mixed waste generated by this alternative is estimated to be about 1,625 cubic meters (57,400 cubic feet).

2.4.1 Storage Land Area Requirements

Storage of 100 reactor compartments would require an area of about 4 hectares (10 acres). The area within the 218-E-12B burial ground, immediately north of Trench 94 is considered in this EIS for the Hanford Site above ground storage alternative. Trench 94 is currently used for disposal of pre-LOS ANGELES Class submarine reactor compartments with 43 such compartments having been placed in the trench as of the end of 1994, Figure 2.11. The area to the north of this trench is available for Navy use and could accommodate the storage of 100 reactor compartments. Use of other areas on the Central Plateau of the Hanford site would entail extending the current landhaul route by up to 30%. Figure 2.18 shows conceptually how 100 reactor compartments could be arranged for storage at 218-E-12B.

Sites outside of Hanford were not considered for this alternative. Among the other radioactive material management and storage sites owned by the Federal Government, only the Hanford site would be accessible by barge shipments of reactor compartments. The physical access limitations of the other potential sites are discussed in previous sections.

Figure 2.19 is a sketch of a typical submarine reactor compartment placed on foundations for above ground storage.

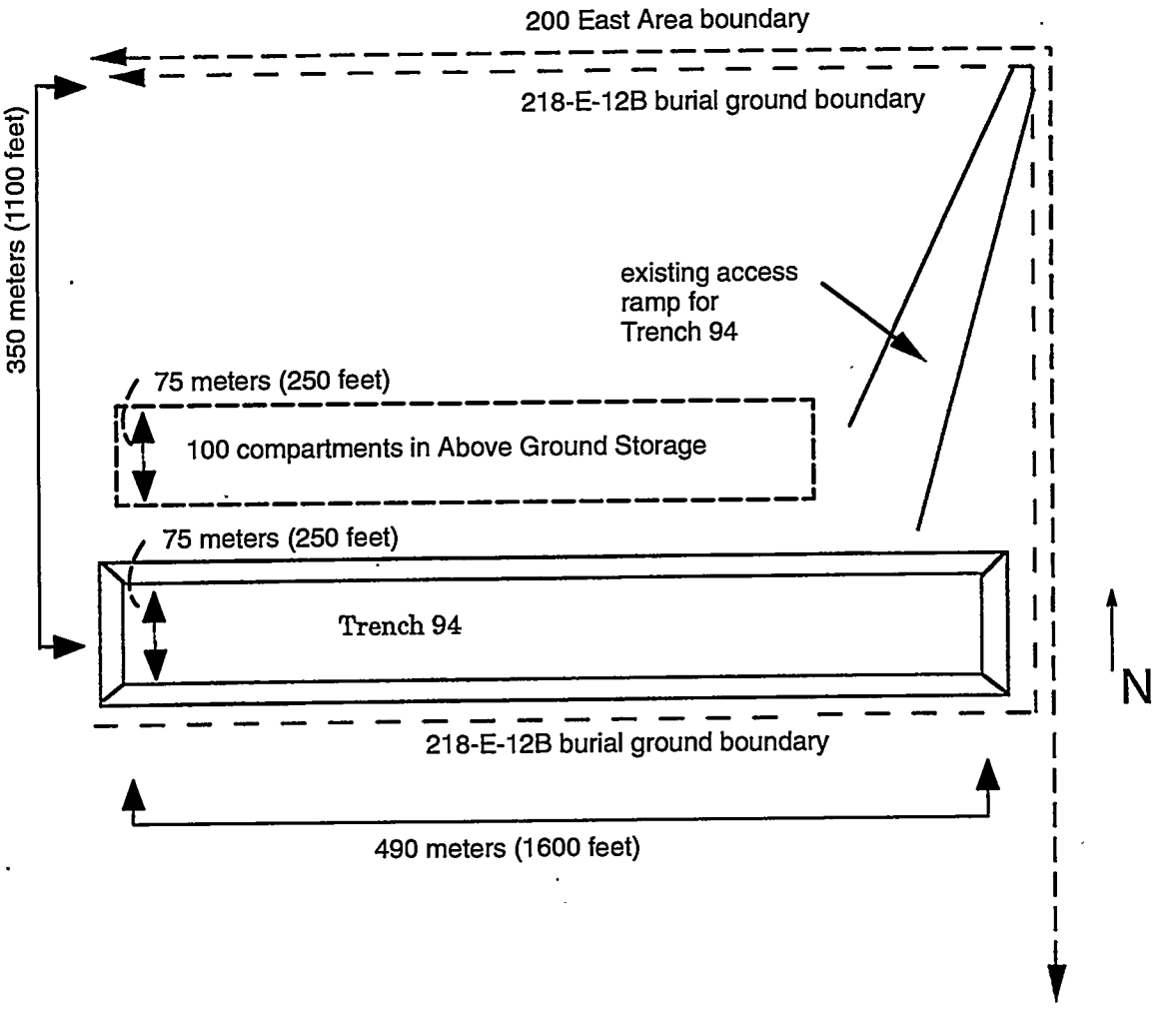
2.4.2 Applicable Regulatory Considerations

Packaging and shipping requirements for storage would be the same as for the preferred alternative (Section 2.1.5.1). Requirements provided by Title 49 "Transportation" of the Code of Federal Regulations do not differentiate between the transportation of hazardous and radioactive waste for storage or disposal. The same transport route through the Hanford Site used for the preferred alternative would be utilized to transport reactor compartments to an above ground storage site.

2.4.2.1 Federal Resource Conservation and Recovery Act and Washington State Dangerous Waste Regulations

The State of Washington has been delegated authority to implement a portion of the Federal Resource Conservation and Recovery Act. This is accomplished pursuant to the federal program by regulations promulgated in chapter 173-303 Dangerous Waste Regulations of the Washington Administrative Code (WAC), WAC 173-303. These regulations provide dangerous waste storage facility requirements. Because of the quantity of lead shielding present in the reactor compartment disposal packages, the Washington State Department of Ecology would regulate the reactor compartment disposal packages as a dangerous waste under the Washington State Administrative Code (WAC) 173-303, Dangerous Waste Regulations (WAC, 1993).

The area north of Trench 94 meets the facility siting criteria of the WAC 173-303 part 282. Hydrogeological characteristics for this area have been defined by Pacific Northwest Laboratory (PNL, 1992, PNL, 1994a). The thick and strong structure of the cruiser, LOS ANGELES, and OHIO Class reactor compartments would serve the same function as a dangerous waste storage facility described in WAC 173-303. Shielding lead in the compartments is in a solid elemental form and thus is not readily soluble in water. The lead is jacketed in steel canning. The reactor compartment packages provide their own containment. In the arid climate of the Hanford Site, with periodic maintenance of surface coatings (paint) and foundation structures, the compartments in storage would retain their structural integrity indefinitely with no migration of lead or radioactivity occurring.



* All Dimensions are Approximate

Figure 2.18. Conceptual Arrangement of 100 Reactor Compartments in Above Ground Storage at 218-E-12B Burial Ground.

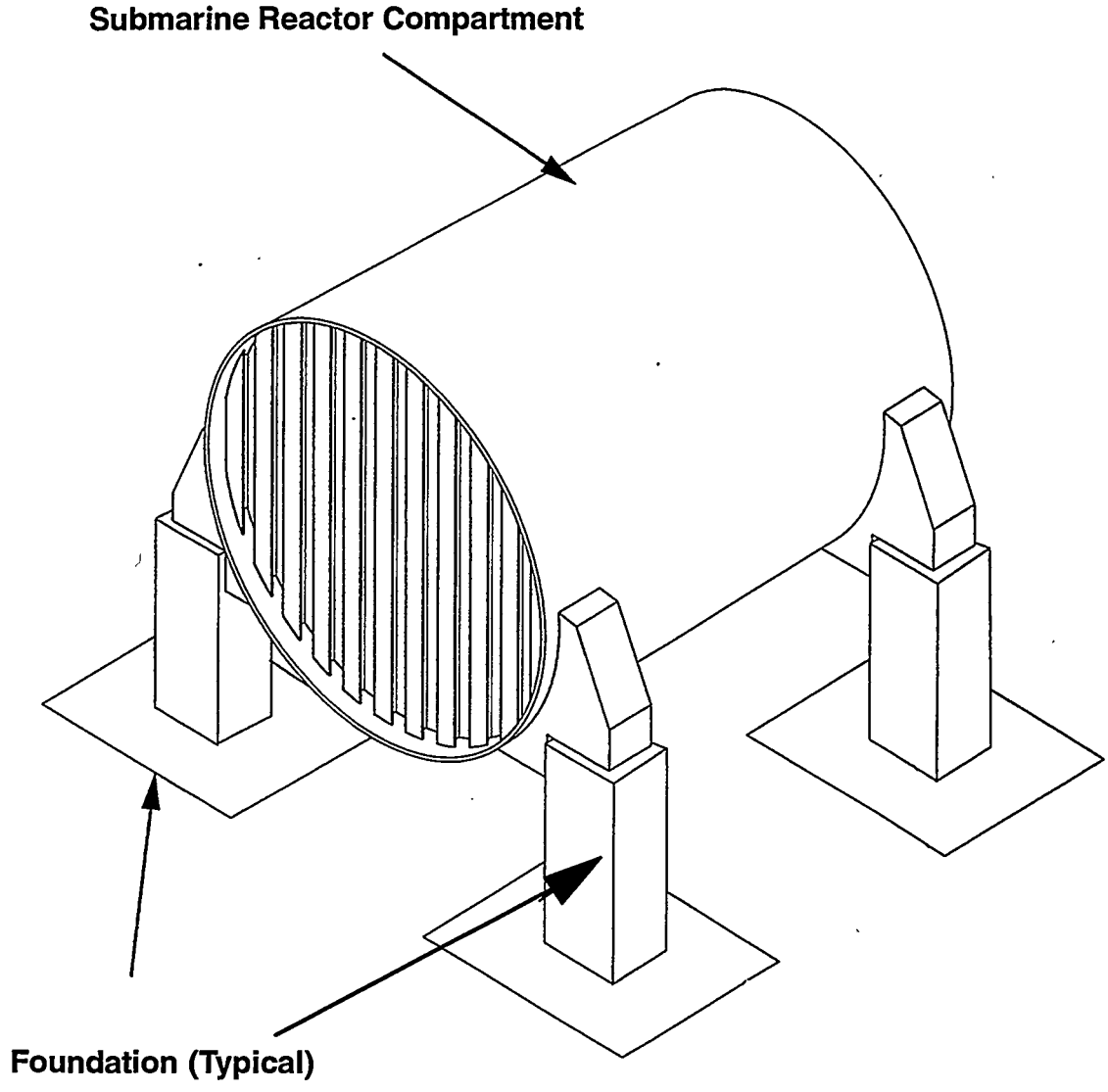


Figure 2.19. Typical Submarine Reactor Compartment Placed on Foundations for Above Ground Storage

Part 72 of WAC 173-303 provides a mechanism for Ecology to approve alternate means of meeting storage facility requirements. Such approval would be necessary in order to store cruiser, LOS ANGELES Class and OHIO Class reactor compartments above ground at 218-E-12B. This approval would involve demonstrating reactor compartment packages provide functional equivalence to hazardous waste storage requirements (e.g., a storage facility with a sloped floor and leak detection/containment system) as well as requirements for a fire protection system. The 218-E-12B burial ground already has a groundwater monitoring system around its perimeter that complies with the Resource Conservation and Recovery Act.

2.4.2.2 Toxic Substances Control Act

Cruiser, LOS ANGELES, and OHIO Class submarine reactor compartments may contain solid polychlorinated biphenyls in industrial materials at levels equal to or greater than 50 ppm, causing these compartments to be regulated by the Environmental Protection Agency under the Toxic Substances Control Act (TSCA) at 40CFR761. Requirements for chemical waste storage facilities under TSCA are similar to those provided by WAC 173-303 and generally can be satisfied by meeting or showing equivalence to the requirements provided by WAC 173-303.

A justification for indefinite storage under TSCA storage requirements could be based on the functional equivalence of the compartments to the storage facility required.

2.4.2.3 Asbestos

Asbestos is regulated in the workplace, in removal operations, and in the air, land, and water environments. There shall be no discharge of visible emission to the outside air during the collection, processing, packaging, or transportation of any asbestos containing material (40CFR61.150(a)).

2.5 Other Alternatives

The preferred, no action, disposal and reuse of subdivided portions of the reactor plant, and indefinite storage above ground at Hanford alternatives are considered to cover all reasonable implementable alternatives at the present time. Other approaches that may be feasible for certain waste disposal operations but are not considered practical in the present case or different from other alteratives have been eliminated from detailed evaluation as discussed in the following sections.

2.5.1 Sea Disposal

A detailed evaluation of sea disposal is contained in the Navy's 1984 Final Environmental Impact Statement (FEIS) for Disposal of Decommissioned Defueled Naval Submarine Reactor Compartments (USN, 1984a). The 1984 FEIS concluded that sea disposal could be performed in an environmentally safe manner with no significant adverse effect. However, the 1984 Record of Decision (USN, 1984b) noted that Congress passed an amendment which restricted the issuance of permits for sea disposal of radioactive material and required Congressional approval before such a permit could be issued. Furthermore, the Environmental Protection Agency stated that additional regulations may be required before a permit request could be reviewed. Also, in November 1993, the U.S. voted along with the majority of other signatories to the London Convention (IMO, 1972) to ban sea disposal of low level radioactive waste subject to a scientific review in 25 years (IMO, 1993). Therefore, the sea disposal alternative is currently precluded by the London Convention.

Sea disposal would not be a viable alternative until after 2018 (1993 plus 25 years), and then only pending favorable results from the scientific reviews resulting from the London Convention. An interim storage method such as described in the no-action alternative would be a necessary part of this alternative. If this alternative were employed, preparations for ocean disposal would be made at one of the shipyards normally servicing nuclear-powered naval ships. The reactor vessel would be sealed by welding following defueling. The ship would be towed to the disposal location and sunk in a controlled flooding operation. The reactor compartment would be allowed to flood as the ship descended to the ocean bottom. This would preclude crushing the reactor compartment bulkheads by the extreme pressure at the depths considered for disposal. When the ship came to rest on the ocean bottom, it would be intact. The additional containment of radioactive material provided by the intact reactor compartment is not crucial to the safety of the sea disposal alternative. This is because almost all of the radioactive material is also contained within the thick pressure vessel and is an integral part of the metal components.

Although there is no technical basis for expecting that retrieval or further containment of an ocean-disposed ship would ever become necessary, methods for doing so have been examined and found to be technically feasible. They are described in Appendix M of the 1984 FEIS (USN, 1984a).

Over a period of time, radioactive material would be released as the ship and nuclear plant system components slowly corrode away. Since the radioactive atoms would be inside the sealed reactor vessel, many years would elapse before corrosion could free radioactive material from the metal. During this time most of the radioactivity would decay to stable isotopes.

In the evaluation of sea disposal presented in the 1984 FEIS (USN, 1984a), it was assumed that 100 submarines were sunk at a single location at a rate of three ships per year. These ships were then assumed to corrode and release radioactive materials to the ocean. The transport of radioactive material through the oceans included the effects of ocean currents, eddies, and water temperature and density variations, mixing in the water layers nearest the bottom, settling out of particles through the water column, etc. The same assumptions are made for purposes of this EIS. Possible radiological doses to members of the general public were extrapolated from doses calculated for the 1984 FEIS.

Doses were extrapolated for realistic assumptions and for very conservative assumptions; for example, that all the rusted particles were carried off by the water and none of them settled to the bottom.

Baseline radionuclide content was taken from Table 1-1 of the 1984 FEIS, which gives radionuclide quantities for one typical pre-LOS ANGELES class submarine at six months after final reactor shutdown. For purposes of extrapolation, the Table 1-1 values were adjusted for a total of 100 submarines at 365 days after final shutdown. Baseline values for dose commitments corresponding to disposal of 100 pre-LOS ANGELES were taken from Tables J-2, J-16 and J-17 of the 1984 FEIS, which provide estimated radiation exposures due to various radionuclides under various conditions for disposal of 100 submarines at a rate of three submarines per year. The exposures listed in the tables vary linearly with the number of curies of a given radionuclide.

Comparative radionuclide content for about 100 reactor compartments from cruiser, OHIO Class and LOS ANGELES Class submarines was developed from data generated by government laboratory computer models. Then linear extrapolations were made for each of the three conditions evaluated by first calculating the dose commitment for each radionuclide expected to be present in the cruisers, OHIO Class and LOS ANGELES Class submarines. The dose commitment

for each radionuclide listed in Table J-12, Table J-16 and Table J-17 was multiplied by the ratio of the comparative value to the baseline value. Then the dose commitments for each radionuclide were summed to arrive at an overall dose commitment.

Extrapolation yields a dose of $2x10^{-11}$ mrem per year to the typical affected person. For example, this person is assumed to eat all of his seafood from ocean fish caught at the fishing ground nearest the disposal site. This radiological dose is less than one ten-trillionth of the average annual dose received from background radiation. Extrapolation for the very conservative assumptions gives a result of less than 0.0005 mrem per year of exposure, or less than 2 millionths of normal dose from background radiation.

To provide a "worst case" estimate for this environmental impact statement, possible radiological dose was extrapolated from the "worst case" estimate provided in the Navy's 1984 Final Environmental Impact Statement (USN, 1984a). That value was calculated assuming that at some time in the future a person might eat a very large amount of seafood (145 pounds a year) all of which had somehow been caught at the deep ocean disposal site. Even with such a hypothetical shortcut of the food chain, extrapolation indicates that this person would receive a whole body dose of less than 20 mrem per year. This is not considered to be an actual consequence of sea disposal but has been included to show that even a hypothetical short cut in the food chain would not result in significant exposure to any individual.

The sea disposal analysis for the pre-LOS ANGELES Class submarines did not consider removal or disposal of PCBs from the ship hulls and components. The Environmental Protection Agency regulates the handling and disposal of PCBs and PCB waste (40CFR761). Some of the ships covered by this EIS may contain PCB bearing material in concentrations above the 50 ppm limit requiring controlled disposal specified by 40CFR761.60. This material would have to be dealt with per 40CFR761 and 40CFR229 (EPA's ocean disposal regulations) before the ship could be disposed of by sinking at sea. To gain access to the PCB bearing material, equipment and structural material would have to be removed from the ships. If a ship were to be disposed of at sea, the structure of the ship would have to be restored to a degree that would allow the ship to be towed to the disposal site and sunk.

2.5.2 Land Disposal of Entire Reactor Compartments at Other Sites

Disposal sites other than the DOE Hanford Site have been considered for land disposal of the entire reactor compartment. The Low Level Radioactive Waste Policy Act Amendments of 1985 state the Federal Government shall be responsible for disposal of low-level radioactive waste owned or generated by the U.S. Navy as a result of the decommissioning of U.S. Navy vessels. In addition, the need to maintain control of the classified design information inherent in the reactor compartments requires a site under Federal control. Federal nuclear waste disposal sites are located at Department of Energy Sites. In the Navy's 1984 EIS (USN, 1984a), DOE radioactive waste disposal sites other than Hanford were evaluated. The Savannah River DOE Site was the only other site which was considered practicable.

The physical limitations imposed by the size and weight of the reactor compartment packages considered by this EIS would require that the disposal sites be accessible by barge shipment with an unobstructed land transportation route to the final disposal area the same as with the pre-LOS ANGELES Class submarine reactor compartment disposal program.

The Savannah River Site was evaluated in the Navy's 1984 EIS and it was concluded that the site was barely accessible by a barge loaded with a pre-LOS ANGELES Class reactor compartment. The limiting factors were shallow areas of the river that would require dredging and two bridges across the river that would require that the barge be ballasted down to transit under them.

The reactor compartments considered in this EIS are one and one half to two and one half times heavier and physically larger than the pre-LOS ANGELES Class submarine packages. The National Oceanic and Atmospheric Administration nautical charts numbers 11514 and 11515, Savannah River, show areas where the river depth is seven feet at low water. The chart also shows a fixed bridge at river mile 61.3 which has a vertical clearance of 38 feet at low water. The draft of a barge loaded with a LOS ANGELES Class reactor compartment package is expected to be greater than seven feet and the height above the water line would be approximately 41 feet. Cruiser and OHIO Class reactor compartments are taller than LOS ANGELES Class reactor compartments. The physical constraints up the Savannah River transit route would be insurmountable for the larger reactor compartment disposal packages covered by this EIS which would make the Savannah River Site inaccessible as a disposal site. As a result, the Hanford Site is the only site available for land disposal of the entire defueled reactor compartment.

2.5.3 Permanent Above Ground Disposal at the Hanford Site

In this alternative, cruiser, LOS ANGELES Class, and OHIO Class submarine reactor compartments would be placed above ground at the Hanford Site, covered with soil, and entombed in a soil mound.

The State of Washington has been delegated authority to implement a portion of the Federal Resource Conservation and Recovery Act. This is accomplished pursuant to the federal program by regulations promulgated in chapter 173-303 Dangerous Waste Regulations of the Washington Administrative Code (WAC), WAC 173-303. Because of the quantity of lead shielding present in the reactor compartment disposal packages, the Washington State Department of Ecology would regulate the reactor compartment disposal packages as a dangerous waste under the Washington State Administrative Code (WAC) 173-303, Dangerous Waste Regulations (WAC, 1993). The cruiser, LOS ANGELES Class, and OHIO Class submarine reactor compartments may also contain solid polychlorinated biphenyls in industrial materials at levels equal to or greater than 50 ppm, and thus be regulated as a toxic waste by the Environmental Protection Agency under the Toxic Substances Control Act. The implementing regulations for polychlorinated biphenyls are codified at Title 40 Code of Federal Regulations Part 761 (40CFR761). Permanent disposal of these reactor compartments must comply with requirements for land disposal of hazardous waste specified by the above regulations.

Part 665 of WAC 173-303 provides requirements for the disposal of dangerous waste by landfill. Disposal by landfill as defined in section 040 of the WAC 173-303 includes disposal in or on land. The regulations for disposal of polychlorinated biphenyls (40CFR761) specify the requirements for chemical waste landfills. Compliance with the WAC 173-303 requirements generally satisfies TSCA requirements. The alternative of permanent above ground disposal at Hanford, with entombment in a soil mound, would be subject to these requirements as well. The applicable regulations require that upon closure, an engineered cover be placed over the disposal site to divert surface precipitation away from the buried waste.

The EPA technical guidance document for Resource Conservation and Recovery Act compliant closure covers recommends a multilayer cover design with a uniform surface slope of between 3 and 5 percent (after allowance for settlement) (Golder, 1992). This gentle slope reduces the potential for cover erosion. Figure 2.20 shows a conceptual arrangement of a Resource Conservation Recovery Act compliant engineered cover over an above ground disposal site for the reactor compartments.

In order to maintain the minimum 5 meter (16 feet) burial depth specified in 10CFR61 for near surface disposal of radioactive waste, the peak of this cover would be at least 18 meters (60 feet) above ground surface. Maintaining the gentle 5% slope along the entire slope of the cover from peak to original land grade, for erosion control, would result in a the cover extending almost 400 meters (1/4 mile) in each direction from the reactor compartments. Total area occupied by the cover would be around 100 hectares (240-250 acres). This area could potentially encompass less disturbed shrub-steppe environment at Hanford. Large quantities of soil would also be required to create this structure (on the order of 6E6 cubic meters). The end result would be a recontouring of the land surface into a gradual rise that would be natural looking but represent a new feature on the landscape. Disposal facility closure requirements in WAC 173-303 discuss returning the facility to the natural appearance of the surrounding land. For sites with groundwater aquifers that are deep or partially non-existent, like Hanford, this alternative is essentially the same as the preferred alternative except that more land space would be occupied by the above ground cover due to the increased height of this cover over the existing grade of the land.

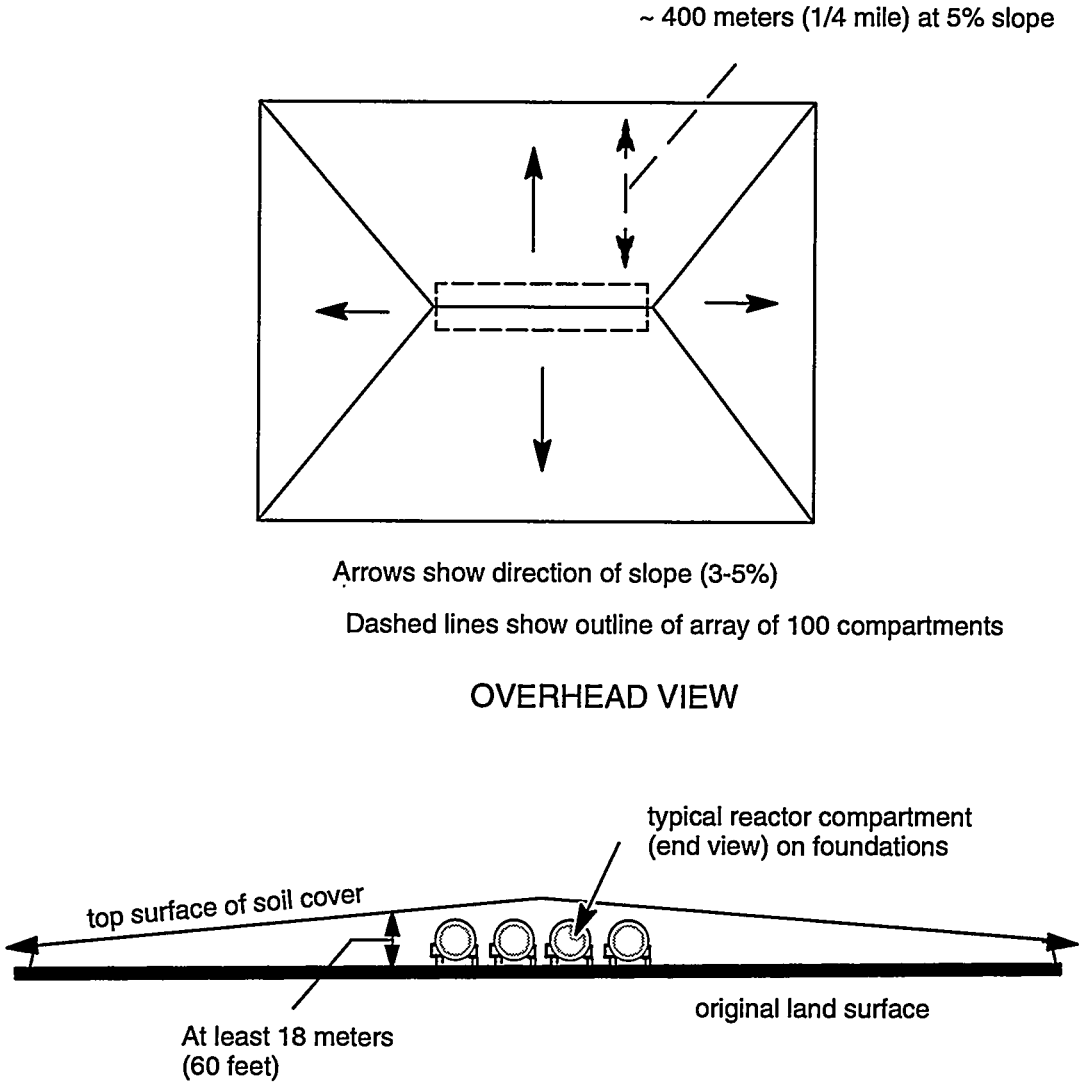


Figure 2.20. Conceptual Arrangement of Resource Conservation Recovery Act Compliant Engineered Cover over Above Ground Disposal Site

3. AFFECTED ENVIRONMENT

3.1 Preferred Alternative

The existing environment of the preferred alternative includes the Puget Sound Naval Shipyard where the reactor compartment disposal packages would be prepared for shipment, the waterborne transport route between the Shipyard and the barge off-load site at the Port of Benton, Richland, Washington, the landhaul transport route on the Hanford Site, and the proposed Hanford land disposal site.

3.1.1 Shipyard

The Puget Sound region lies in the northwest corner of Washington State as shown on Figure 3.1. The region is defined by the Olympic Mountain Range to the west and the Cascade Mountain Range to the east. The lowlands contrast dramatically with the mountains, with numerous channels, bays, and inlets on the inland sea that is Puget Sound. The Puget Sound Naval Shipyard is located inside the city limits of Bremerton, Washington at 47° 33′ 30″ north latitude and 122° 38′ 8″ west longitude. Bremerton is located in Kitsap County on the Sinclair Inlet 22 kilometers (14 miles) across Puget Sound west of Seattle and about 32 kilometers (20 miles) straight line distance northwest of Tacoma. Topography in the Bremerton area is characterized by rolling hills with an elevation range from sea level to +60 meters (+200 feet) above mean sea level (msl) in West Bremerton and ranging up to +90 meters (+300 feet) above msl in East Bremerton (area east of Port Washington Narrows). The predominant native vegetation in the area are douglas fir, cedar, and hemlock. Within a distance of 40 to 65 kilometers (25 to 40 miles) in a westerly direction from Bremerton, the Olympic Mountains rise to elevations of 1200 to 2100 meters (4,000 to 7,000 feet). The higher peaks are covered with snow most of the year and there are several glaciers on Mount Olympus (elevation 2,425 meters (7,954 feet)). In an easterly direction and within a distance of 96 kilometers (60 miles), the Cascade Range rises to average elevations of 1,200 to 2,100 meters (5,000 to 7,000 feet) with snowcapped peaks in excess of 3,050 meters (10,000 feet).

Puget Sound Naval Shipyard is the largest activity of the Bremerton Naval Complex, which also includes the Fleet and Industrial Supply Center, Puget Sound and Naval Sea Systems Command Detachment, and Planning and Engineering for Repair/Alteration of Aircraft Carriers. Tenant activities include Naval Inactive Ship Maintenance Facility, Naval Reserve Center, and the Defense Printing Service.

Bremerton Naval Complex includes a total of approximately 539 hectares (1,347 acres) consisting of uplands and submerged lands. Puget Sound Naval Shipyard has 130 hectares (327 acres) of upland and is highly developed. Puget Sound Naval Shipyard also owns about 135 hectares (338 acres) of submerged tidelands. The waterfront dry dock area is the high–security portion of the shipyard where most production takes place. It includes production shops, administration, and some public works and supply functions. The upland area of the Shipyard is the military support area which provides services to military personnel, including housing, retail goods and services, recreation, counseling, dental care, and other support services. The industrial support area in the southwestern portion of the shipyard includes several piers for homeported ships and inactive fleet, the power plant, warehouses, steel yard, public works shops, and parking.

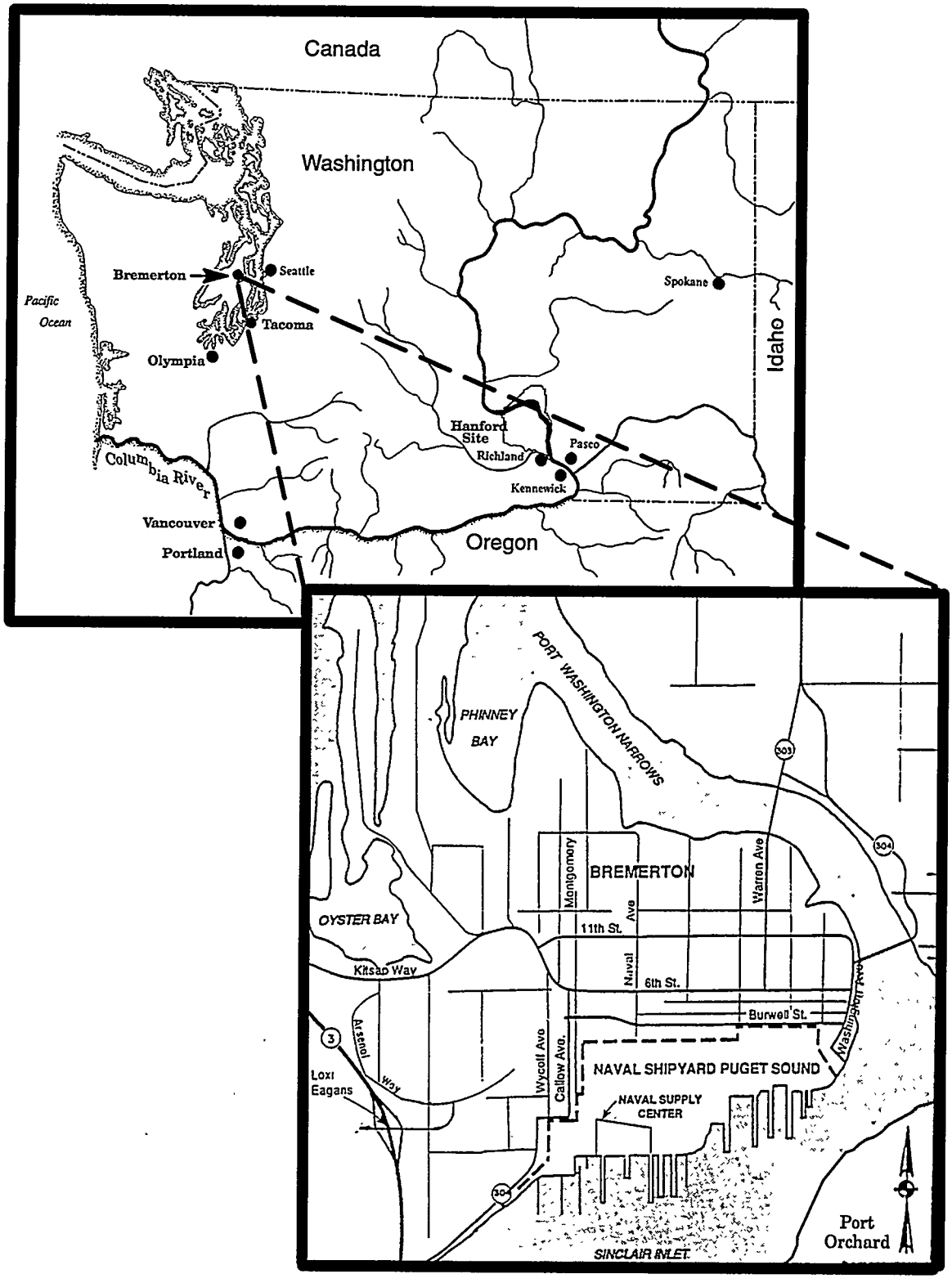


Figure 3.1. General Site Location, Puget Sound Naval Shipyard

The operations to prepare the reactor plants for shipment would be accomplished within the controlled industrial area of the Shipyard. This area consists of the facilities involved in ship overhaul, repair, dry docking, and conversions. The area is bounded by Decatur Avenue on the north, the waterfront on the south, the Fleet Industrial Supply Center on the west, and the main gate on the east. The area is industrialized with the land area typically covered with structures or paving. There would be no significant changes in the uses of this area of the Shipyard from the industrial operations that have been conducted there for several decades.

The general meteorological conditions of the Puget Sound area are typical of a marine climate, since the prevailing air currents at all elevations are from the Pacific Ocean. The relatively cool summers, mild winters, and wetness characteristic of a marine climate are enhanced by the presence of Puget Sound. The area tends toward damp, cloudy conditions much of the year. The Cascade Range to the east serves as a partial barrier to the temperature extremes of the continental climate of eastern Washington. Extreme weather conditions, such as thunderstorms, tornados, etc., rarely occur in the Puget Sound area.

The shipyard has an occupational health/preventive medicine unit and a branch clinic (industrial dispensary) which are run by Naval Hospital Bremerton. Personnel may also be taken to Harrison Memorial Hospital as needed.

The shipyard maintains two fire stations with approximately 50 personnel. The shipyard has a fire department that is fully equipped for structural and industrial firefighting and hazardous material spill response.

The shipyard has a security force of approximately 177 personnel providing law enforcement services, emergency services, security clearances, and parking and traffic control for the Bremerton Naval Complex.

In the non-radiological Occupational Safety, Health, and Occupational Medicine area, the Navy complies with the Occupational Safety and Health Administration regulations. The Navy policy is to maintain a safe and healthful work environment at all naval facilities. Due to the varied nature of work at these facilities, there is a potential for certain employees to be exposed to physical and chemical hazards. These employees are routinely monitored during work and receive medical surveillance for physical hazards such as exposure to high noise levels or heat stress. In addition, employees are monitored for their exposure to chemical hazards such as organic solvents, lead, asbestos, etc., and where appropriate are placed into medical surveillance programs for these chemical hazards.

In accordance with the Clean Air Act and the required State Implementation Plan for achieving nationwide air quality goals, air pollution control in the State of Washington is a coordinated effort by the Department of Ecology and various single or multi–county local air pollution control authorities. The State is divided into intrastate Air Quality Control Regions (AQCRs). Each AQCR has the responsibility for developing its point and area source emissions inventory and for analyzing and reporting on air quality monitoring data within its jurisdiction. The Puget Sound Air Pollution Control Agency has the delegated authority for enforcement of the Clean Air Act in the area encompassing the Shipyard (Kitsap County). The Code of Federal Regulations, Title 40, part 81, designates this area as being in attainment of national standards for suspended particulate matter and sulfur dioxide. Air quality with respect to ozone, carbon–monoxide, and nitrogen dioxide has not been classified but is considered to be in attainment. Puget Sound Naval Shipyard is not located in an area where degradation of air quality is severely restricted under the prevention of significant deterioration (PSD) regulations of Title 40, part 52.

Seismic risk related to structural damage may be represented in the United States by a relative scale of 0 through 4, with Zone 0 not expected to encounter damage and Zone 4 expected to encounter the greatest seismic risk as defined by the Uniform Building Code (UBC, 1991). Puget Sound Naval Shipyard is located in a Zone 3 as defined by the Uniform Building Code (UBC,1991). The largest probable earthquake which could be expected in the Central Puget Sound area could have a magnitude of up to 7.5 on the Richter scale. There have been approximately 200 earthquakes since 1840, most of which caused little or no damage. The most recent earthquakes of high magnitude in the region near Olympia (approximately 65 kilometers (40 miles) from Bremerton) in 1949 (7.1 on the Richter scale) and near Seattle in 1965 (6.5 on the Richter scale).

There is no known fault line within 915 meters (3000 feet) of the Bremerton Naval Complex; however, two known fault traces have been identified in Kitsap County. The Kingston-Bothell trace, in the northern portion of the county, and the Seattle-Bremerton trace, located a few miles north of Bremerton. There has been no known surface faulting in conjunction with earthquakes in the Shipyard vicinity. Recently published studies have noted that a large earthquake is believed to have occurred less than 1100 years ago on a fault line referred to as the "Seattle Fault", (SCIENCE, 1992a), which stretches from east of Seattle and terminates near Bainbridge Island on the western shores of Puget Sound. The magnitude of this large earthquake was estimated at 7 or larger on the Richter scale. The magnitude and occurrence of the earthquake are based on carbon dating of trees believed to have slid into Lake Washington from landslides, sediments deposited at two sites north of Seattle on the Puget Sound believed to be from a tsunami, and a sudden 7-meter uplift of Restoration Point on Bainbridge Island, located approximately 3 to 5 kilometers (2 to 3 miles) east, north-east of the Shipyard. All of these phenomena are believed to have been induced by the earthquake, (SCIENCE, 1992a; SCIENCE, 1992b). The studies also noted that a repeat of a similar earthquake would cause extremely strong shaking, tsunamis in the Puget Sound, and ground uplift and subsidence over large populated areas, particularly in the Seattle metropolitan area.

As noted in the studies, a wide variety of effects were attributed to the earthquake in far reaching areas of the Puget Sound Lowlands, from the Olympic Mountains to Lake Washington east of Seattle. These studies however, did not note any effect in Sinclair Inlet or in the vicinity of the shipyard. Additionally, the Shipyard has had the seismic design work for the Water Pit Facility reevaluated. This reevaluation considered the shallow fault referred to in the recently published studies and concluded that the fault was not close enough or well established enough to constitute any significant hazard to the facility. Additional details are provided in the Seismic Design Study for the Water Pit Facility at Puget Sound Naval Shipyard, (STUDY, 1978).

Puget Sound Naval Shipyard and Sinclair Inlet lie within the usual and accustomed fishing area of the Suquamish Tribe. The Tribe is entitled to take up to one-half of the fish passing through the Sinclair Inlet, including hatchery produced fish. Historically the area has been of cultural significance to the Tribe, who depend on the quantity and quality of its resources for a livelihood (USN, 1994a).

3.1.1.1 Socioeconomic Background Information for the Puget Sound Region

This region is defined as encompassing Kitsap County (which contains Puget Sound Naval Shipyard) and adjacent countries (mainly Clallam, Mason, Pierce and Jefferson Counties). Although population growth in the State of Washington was increasing at 5.5% in 1992, population growth in Kitsap County averaged 12% between 1990 and 1994 making it the eighth fastest growing in the state. This growth has largely been due to the development of a retail center in

Silverdale. Growth in the City of Bremerton during the same period averaged 3%. Projected growth for the next 20 years is 91,000 (or 43%); 19,000 of which is projected to occur in the City of Bremerton.

Based on U.S. Bureau of the Census, Statistical Abstract of the United States (1993, 113th edition, Washington D.C.), the ethnic makeup of the county was 87.4% (183,951) White, 2.8% (5,971) Black, 1.7% (3,545) American Indian/Eskimo/Aleut, 4.7% ((9,948) Asian/Pacific Islander and 3.4% (7,115) Hispanic. Unemployment rate for last 5 years averaged 5.6% - 1 percent less than the state as a whole. In January 1994, unemployment was 5.9% vs 6.8% statewide.

Due to lengthy experience with the Shipyard, City of Bremerton planning allows for plus or minus ten percent shift in total Shipyard (military and civilian), due to Shipyard workload changes and the types of ships traditionally in overhaul or in port. Beyond this expected shift, a change of one worker at the Shipyard results in a 6 person population change in the City and surrounding region. (Source: a report prepared by the Office of Economic Adjustment, ODS, in February 1976 titled The Trident Impact on Kitsap County. The forecast in this report for 1985 (166,000) was close to actuals for that year (168,000).

Regional infrastructure is generally adequate for current projected growth. This includes transportation, health care, schools, fire protection, water supply, power supply, solid waste collection and treatment, wastewater treatment, storm water collection, and recreational facilities.

It is postulated that a change of one worker in the Shipyard (greater than the ±10% threshold) will result in a change in need for 2.6 housing units. (Source: this multiplier was extrapolated from a report prepared by the Office of Economic Adjustment, ODS, in February 1976 titled The Trident Impact on Kitsap County.) The current supply of single-family and mobile home lots is falling short of consumption. Over the past four years, 1.33 lots were used to every lot created. According to the 1990 U.S. Census, projected housing demand in the County is 3,100 units average per year for the next three years. In order to meet a critical Government housing shortage, the Navy is building 400 housing units for local Navy families.

3.1.1.2 Socioeconomic Background Information for the Norfolk Virginia Region

Based on U.S. Bureau of the Census, Statistical Abstract of the United States (1993, 113th edition, Washington D.C.), population increased from 1990 to 1993 by 1.5%. The ethnic makeup of this population was 58.3% (841,269) White, 33.6% (484,848) Black, 3% (43,290) American Indian/Eskimo/Aleut, 2.3% (33,189) Asian/Pacific Islander and 2.8% (40,404) Hispanic. This contrasts with population growth of 3.1% in the State of Virginia.

3.1.1.3 Ecological Resources

Vegetation and wildlife on Puget Sound Naval Shipyard are limited to "open spaces", noncontiguous, undeveloped areas. Most of these areas have been disturbed and are currently landscaped with native and ornamental trees and shrubs. Due to the extensive industrial nature of the shipyard, its resident bird community is characterized by "urban species" with numerous glaucous–winged gulls (Laurus glaucescens) inhabiting the waterfront area. Current populations of mammals at the shipyard are extremely limited. The lack of suitable habitat restricts the population of reptiles and amphibians. The majority of the shipyard is developed and covered with an impervious surface.

The shoreside of the shipyard consists primarily of riprap, concrete bulkheads, and old wooden piers. Marine vegetation along the shipyard shoreline consists primarily of sea lettuce (Ulva lactuca), rockweed (Fuchus distichus), and debris of algae that has been carried inshore. Juvenile Pacific Salmon (Oncorhvnchus spp.) migrate near–shore from mid March to mid June. Pacific herring (Clupea harengus) also mill in the vicinity of the Shipyard from mid January to mid April.

The bald eagle (Haliaeetus leucocephalus), a listed species under the Endangered Species Act may be found in the Bremerton Area from about the end of October to the end of March. Trees suitable for perching and roosting are found in the non–industrialized area at the shipyard, but not near the waterfront. No eagles have been reported nesting on the shipyard. Several marine mammal species may be found in Puget Sound waters including the gray whale (Eschrichtius robustus) and humpbacked whale (Megaptera novaeangliae), both endangered, and the killer whale (Ordinus orca), a protected marine mammal.

Additional discussion of the Ecological Resources of the Shipyard and surroundings can be found in Volume 1, Appendix D, Section 4.1.1.9 of the Final Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Environmental Impact Statement (DOE, 1995).

3.1.2 Waterborne Transport Route

The waterborne transport route follows the normal shipping lanes from Puget Sound Naval Shipyard, through Rich Passage, past Restoration Point, and northerly through the Puget Sound. The route is then westerly through the Strait of Juan De Fuca (in U.S. territorial waters), past Cape Flattery, and down the Washington coast to the mouth of the Columbia River. The route is then up the Columbia River, following the shipping channel used for the regular transport of commercial cargo. The river route passes through the navigation locks at the Bonneville, The Dalles, John Day, and McNary dams to the Port of Benton at river mile 342.8. Figure 2.5 is a map showing waterborne transport route.

A Final Environmental Impact Statement (FEIS) prepared by the National Oceanic and Atmospheric Administration (NOAA) evaluated establishment of the Olympic National Marine Sanctuary off the Northern Washington State coast (NOAA, 1993). NOAA has requested the U.S. Coast Guard to submit a request to establish an Area To Be Avoided (ATBA) which would limit vessel traffic from the shoreline to 25 nautical miles off the Olympic Peninsula.

The Columbia River is the fourth largest river in North America. Several large hydroelectric dams and navigation locks have been constructed on the Columbia River and Snake River, one of the major tributaries of the Columbia River, between the 1930s and 1970s. This system of dams and locks allows movement of large commercial tug and barge shipments on the Columbia and Snake Rivers. The Columbia-Snake River system provides a variety of resources for public and private use. Major economic activities include transportation, agriculture, electric power generation, fisheries, and recreation. The 465-mile (748-km) Columbia-Snake inland waterway represents a key part of the economics of the Pacific Northwest region. In 1990, over 26.5 million tons (23.9 million metric tons) of goods were exported from Columbia River deep water ports.

The Army Corps of Engineers has issued a Draft Environmental Impact Statement (ACoE, 1994) which accomplished a System Operation Review that evaluates various options for operating the Columbia River system. The formal listings in November 1991 and April 1992 of the Snake River Sockeye salmon as endangered and the spring/summer, and fall chinook salmon as threatened under the Endangered Species Act (ESA) have significant implication on the future operation of

the Columbia River system. The ESA requires development of plans to help threatened and endangered species to recover. The ESA makes survival and restoration of the three salmon stocks an overriding issue in the preparation of the Columbia River system operation plan, and places significant restraints on system operation. No changes to the operations of the river system have been identified to date that would affect shipments of reactor compartments via the normal shipping channel and navigation locks.

The identified System Operation Review actions for control of the Columbia River System would not have a direct impact on prime or unique agricultural lands; direct impact would be confined to the reservoirs. Since reactor compartment shipments on the Columbia River would observe all controls imposed to control the river, there would be no direct impacts to prime or unique agricultural lands from the reactor compartment shipments as well. Shipments along the saltwater portion of the transportation route would not have an impact on prime or unique agricultural lands since by the location of the shipping route no farm lands would be encountered.

Reactor compartment shipments would not have a direct impact on wetlands or floodplains along the transportation route. Shipments would be along normal ocean shipping lanes and river channels, and be a small part of the normal ocean and Columbia River traffic. Shipments would observe all controls imposed to control the river and river traffic. Shipments would use the same off-loading facilities at the Port of Benton already in use for the current pre-LOS ANGELES Class reactor compartment disposal program. At this facility, river banks slope steeply into the water with little riparian vegetation. Water levels at the Port of Benton fluctuate daily and seasonally. This fluctuation tends to inhibit the formation of stable wetland environments.

Overhead clearances were evaluated along the waterborne transport route from Puget Sound Naval Shipyard to the Port of Benton at Richland, Washington. This evaluation determined that there were no overhead obstructions on the Columbia River that would pose an interferrence problem for the shipments covered by this EIS.

The drafts of the shipping barges for the cruiser, LOS ANGELES and OHIO Class reactor compartment disposal packages would not pose a problem for shipping. The shallowest river depths encountered are about 5 meters (15 feet) near the barge slip at the Port of Benton. The depth in the barge slip can be adjusted through the control of river flow at the up stream dam (Priest Rapids Dam) and the pool height at the down stream dam (McNary Dam) for docking barges of different drafts. This is routinely done for docking barges for the pre-LOS ANGELES Class disposal program.

The Hanford Reach, approximately 82 kilometers (51 miles) of the Columbia River that flows past or through the Hanford Site, has been the subject of a Comprehensive River Study and Environmental Impact Statement under Public Law 100-605, The Hanford Reach Act. The study and Final EIS (DOI, 1994) identified as the preferred alternative the designation of a National Wildlife Refuge and a National Wild and Scenic River. Area to be designated would be between river mile 346.5 and upstream 80 kilometers (49.5 miles) to river mile 396. The Port of Benton is located below the lower end of the study area at river mile 342.8. Therefore reactor compartment shipment and off-loading operations would be downstream of and not within the proposed National Wildlife Refuge and National Wild and Scenic River area of the Hanford Reach.

3.1.3 Land Disposal Site

The preferred land disposal site is the 218-E-12B Burial Ground located in the northeast corner of the 200 East Area of the U.S. Department of Energy's Hanford Site in southeastern Washington State. Figures 3.2 and 3.3 depict the Hanford Site and the location of the 218-E-12B Burial Ground.

3.1.3.1 Background

The Hanford Site is a 1450 square kilometer (560 square mile), mostly undisturbed area of relatively flat shrub-steppe desert lying within the Pasco Basin of the Columbia Plateau, a semi-arid region in the rain shadow of the Cascade Mountain Range. The Saddle Mountains form the northern boundary of the site. The Columbia River flows through the northern part of the site and forms part of its eastern boundary. The Yakima River forms part of the southern boundary. The City of Richland bounds the site on the southeast. The site contains numerous plant and animal species adapted to the region's semi-arid environment. More information on site ecology can be found in the Hanford Site National Environmental Policy Act (NEPA) Characterization (PNL, 1994b). This document does not identify any endangered species indigenous to the 200 East Area. Areas on the northern and southwestern edge of the site, totaling 665 square kilometers (257 square miles), have been designated as ecology and wildlife reserves/refuges and game management areas. Adjoining lands to the west, north, and east of the site are principally range and agricultural land. The Tri-Cities of Richland, Kennewick, and Pasco to the southeast constitute the nearest population center with a combined incorporated population of 100,600 as of 1993 (PNL, 1994b). About 376,000 people live within an 80-kilometer (50 mile) radius of the center of the Hanford Site according to the 1990 census (DOE, 1992b).

In prehistoric and historic times, the Hanford Reach of the Columbia River was heavily populated by Native Americans of various tribal affiliations. The Chamnapum band of the Yakama tribe dwelt along the Columbia River from south of Richland upstream to Vantage. Palus people, who lived on the lower Snake River, joined the Wanapum and Chamnapum bands to fish the Hanford Reach and some inhabited the east bank of the Columbia River. Walla Walla and Umatilla people also made periodic visits to the area to fish (PNL, 1994b).

The Hanford Site, is located on lands ceded to the U.S. Government by the Yakama and Umatilla Indians and near lands ceded to the U.S. Government by the Nez Perce Indians. The Yakama Indian Nation and the Confederated Tribes of the Umatilla have large reservations to the west and southeast of the Site, respectively, and the Nez Perce reservation is in Idaho. Treaties in 1855 established the reservations and provided the basis and compensation under which the remainder of the lands were ceded to the United States. Figure 3.4 is a map of the ceded lands and reservations of the nearby Indian tribes. As part of the 1855 treaties, the tribes, in common with citizens of the Territory, may fish in their usual and accustomed places. The treaty also provides, for hunting, gathering of roots and berries, and pasturing stock on open and unclaimed lands. The land occupied by the Hanford Site has not been considered open and unclaimed (DOE, 1987). Descendants of the Chamnapum band still live near the Hanford Reach at Priest Rapids, and others have been incorporated into the Yakama and Umatilla Reservations. The Washane, or Seven Drums religion, which has ancient roots and had its start at the Hanford Site, is still practiced by many people on the Yakama, Umatilla, Warm Springs (central Oregon), and Nez Perce reservations. Native plant and animal foods, some of which can be found on the Hanford Site, are used in ceremonies performed by tribe members (PNL, 1994b). There are other Indian

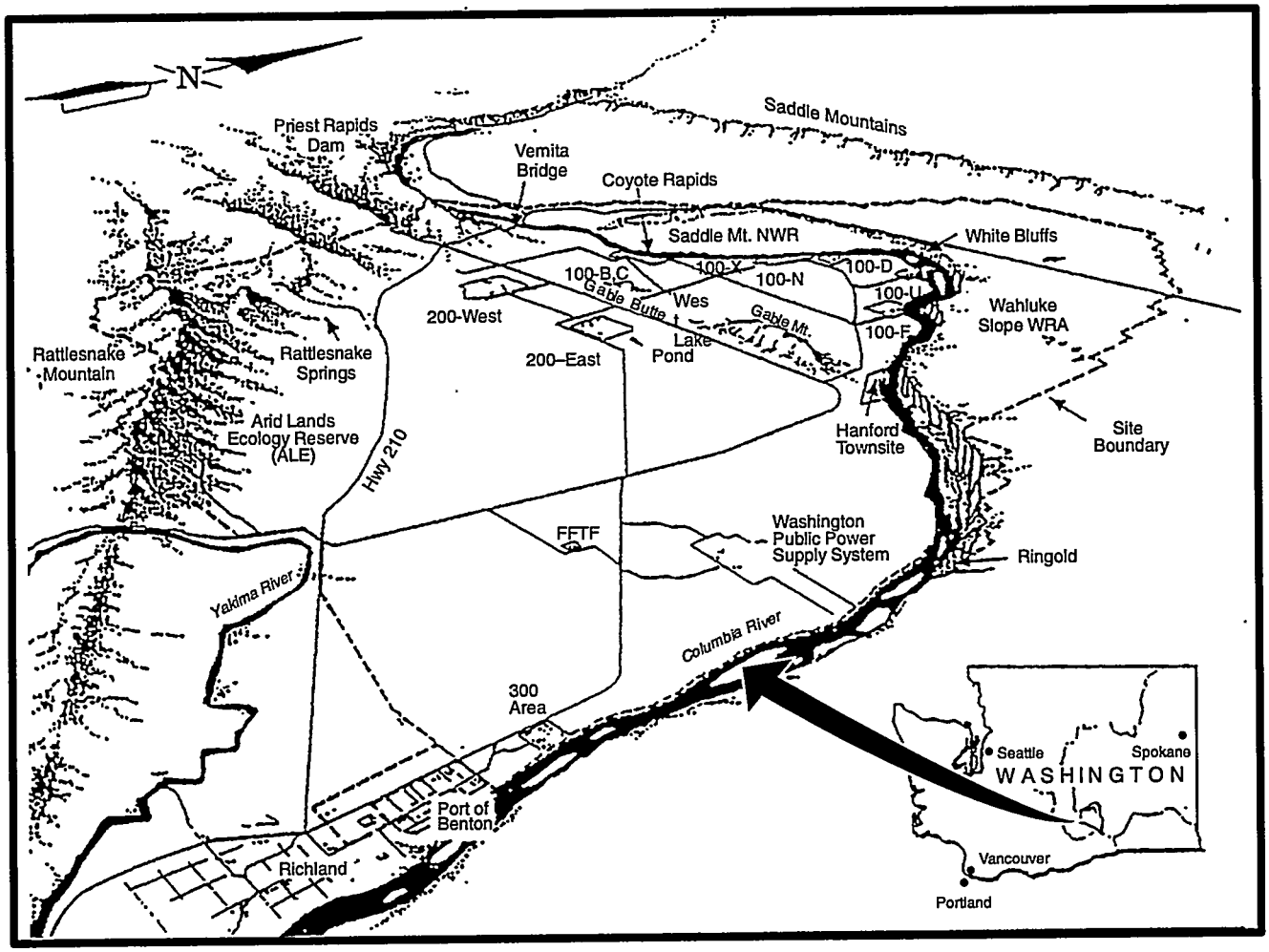


Figure 3.2. Overview of the Hanford Site

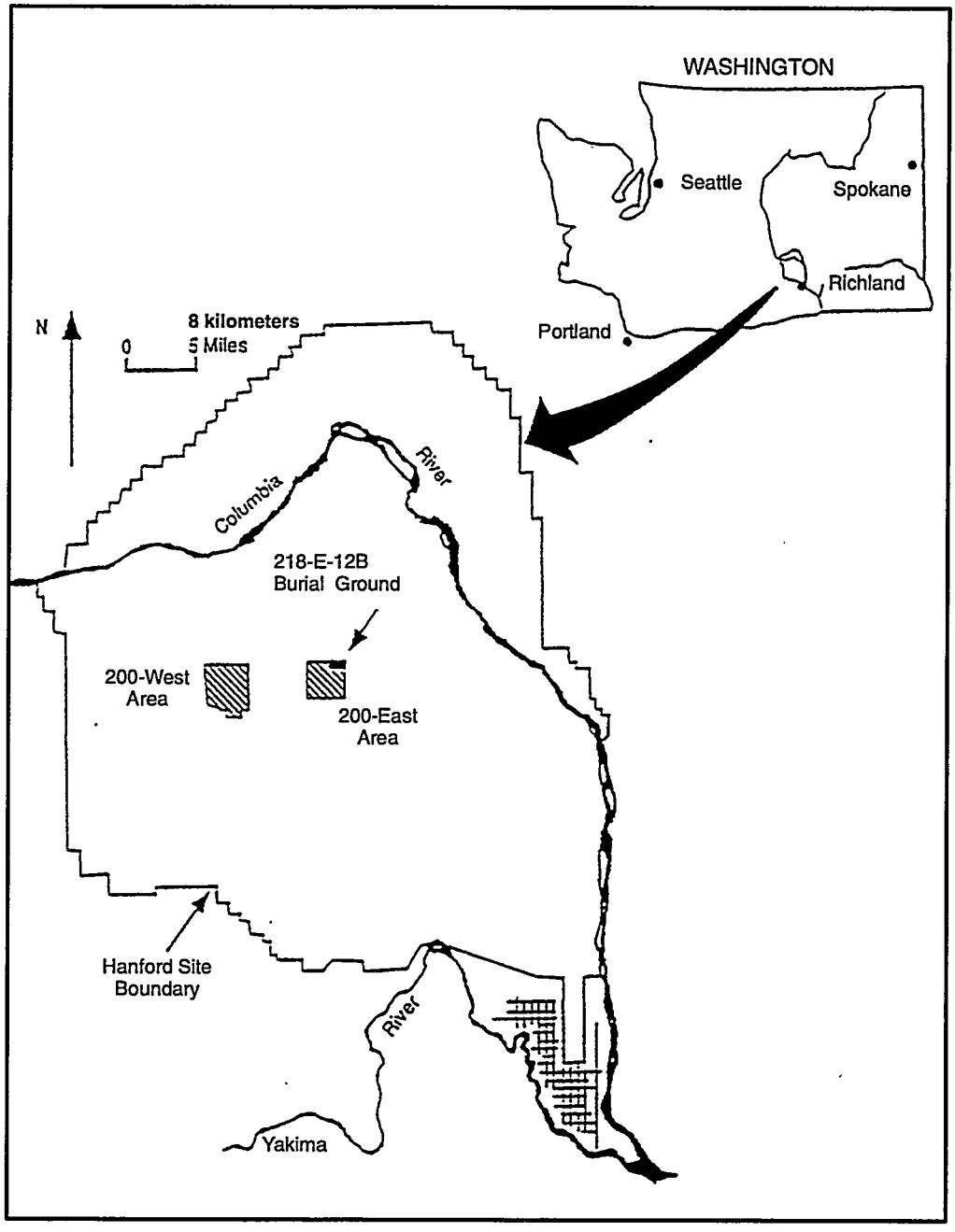


Figure 3.3. Location of the 218-E-12B Burial Ground

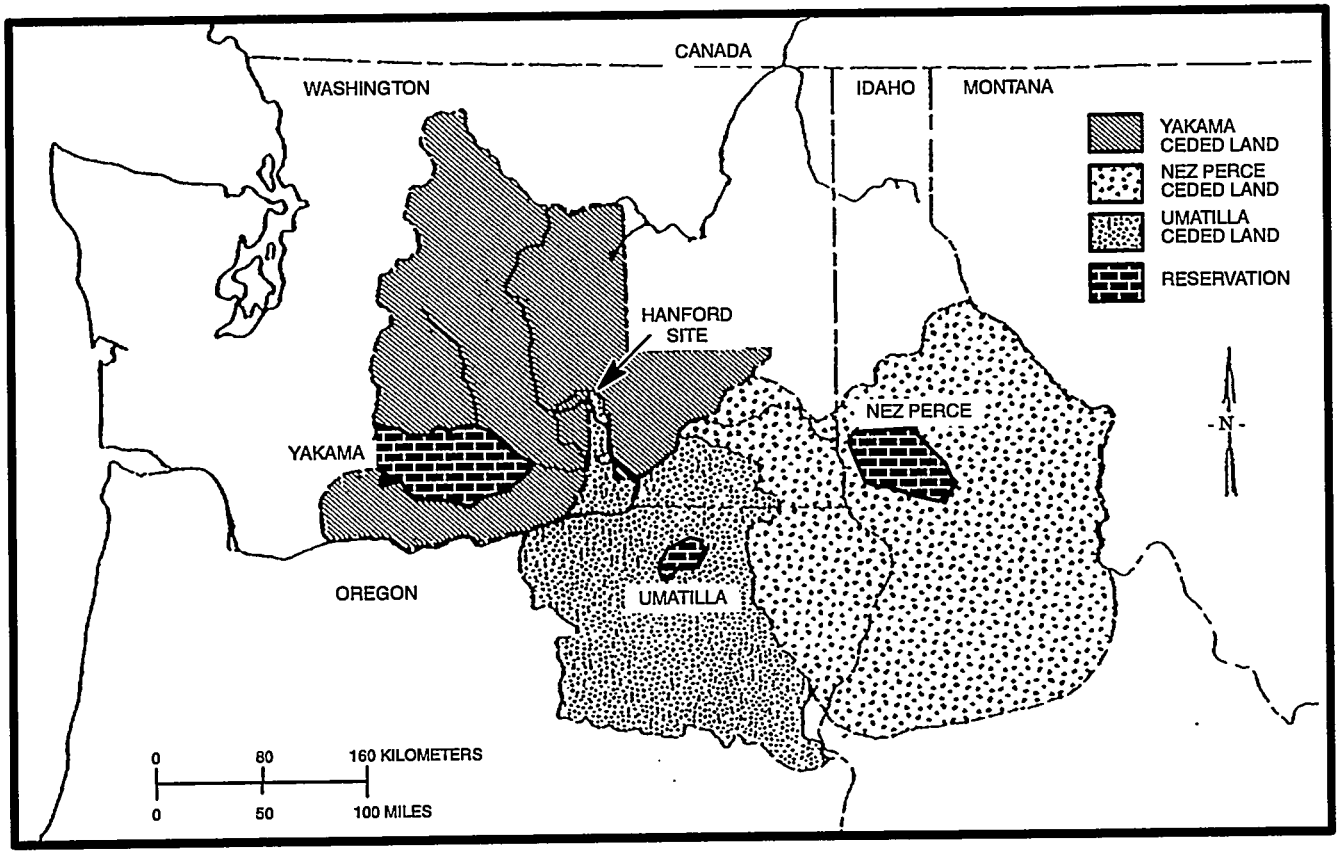


Figure 3.4. Ceded Lands and Reservations of Nearby Indian Tribes

tribes in the area whose ceded lands did not include any portion of the Hanford Site but who may make use of the Columbia River downstream of the Hanford Site for fishing (e.g., Warm Springs) (DOE, 1987). Additionally, the Wanapum band, a non federally recognized tribe living adjacent to the Hanford Site, has cultural and religious interests protected by the American Religious Act and is regularly consulted by the Department of Energy.

The Hanford Site contains numerous, well-preserved archaeological sites representing both the prehistoric and historic periods. Gable Butte and Gable Mountain, located about 3 to 5 miles to the north and east of the 218-E-12B burial ground, are some of the sites considered sacred to the Native Americans who originally inhabited the Hanford Site. However, no archaeological sites or areas of Native American interest are identified within the 200 East Area in the 1994 Hanford Site NEPA Characterization Document (PNL, 1994b). Archaeological surveys have been conducted of all undeveloped portions of this area. Historic resources from the Manhattan Project and Cold War eras include buildings and structures located in the 200 East Area. These buildings have been evaluated for National Register of Historic Places eligibility, however, these buildings are not located within or adjacent to the 218-E-12B burial ground. For additional discussion of the Hanford Site with respect to the 1855 treaties and Native American use, refer to the Environmental Impact Statement, Hanford Reach of the Columbia River, Final - June 1994 (DOI, 1994).

The Department of Energy's Native American Policy commits the Department of Energy to consult with tribal governments to assure the tribal rights and concerns are considered prior to the Department of Energy taking actions, making decisions, or implementing programs that may affect tribes. The Department of Energy has cooperative agreements with the Yakama Indian Nation, Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce, which provide financial assistance to the tribes for providing comment for, and participating in Hanford related decisions.

In accordance with the Clean Air Act and the required State Implementation Plan for achieving nationwide air quality goals, air pollution control in the State of Washington is a coordinated effort by the Department of Ecology and various single or multi–county local air pollution control authorities. The State is divided into intrastate Air Quality Control Regions (AQCRs). Each AQCR has the responsibility for developing its point and area source emissions inventory and for analyzing and reporting on air quality monitoring data within its jurisdiction. Authority for enforcement of the Clean Air Act in the Area of the Hanford Site is shared by the Washington State Department of Ecology and the Benton County Clean Air Authority. The Code of Federal Regulations, Title 40, part 81 designates this area as being in attainment of national standards for suspended particulate matter and sulfur dioxide, however, suspended particulate in diameters of 10 micrometers or less occasionally exceeds national standards due in large part to natural events in the arid climate/ecology of the Pasco Basin. Air quality with respect to ozone, carbon–monoxide, and nitrogen dioxide has not been classified but is considered to be in attainment. The Hanford Site is not located in an area where degradation of air quality is severely restricted under the prevention of significant deterioration (PSD) regulations of Title 40, part 52.

3.1.3.2 Existing Land Use

In early 1943, the U.S. Army Corps of Engineers selected the Hanford Site as the location for reactor and chemical separation facilities for the production of plutonium for use in nuclear weapons. The site was used for this purpose until the recent decision to cease plutonium production. The work at Hanford is now primarily directed toward decommissioning the

production facilities, disposal of the wastes, and environmental remediation actions. Environmental remediation actions are being accomplished under the Federal Facility Agreement and Consent Order signed by the Washington State Department of Ecology, the U.S. Environmental Protection Agency, and the U.S. Department of Energy (ECOLOGY, EPA, and DOE, 1989).

Land at the Hanford Site has not been used for farming since the site was established. Abandoned fields are found in areas along the Columbia River and highland areas along the western edge of the site (PNL, 1994b). About 6% of the Hanford Site is occupied by widely spaced clusters of Department of Energy processing facilities, nuclear reactors, and other industrial buildings located along the shoreline of the Columbia River and at several locations in the interior of the site. The industrial buildings are interconnected by roads, railroads, and utilities such as electrical transmission lines.

The Hanford Site also contains waste storage and waste disposal facilities. These facilities include buried tanks containing high-level radioactive defense wastes and burial grounds containing solid and radioactive wastes. Planning and preparations are underway for the disposal of mixed wastes (both hazardous and radioactive). The Washington Public Power Supply System operates a power generating reactor, WNP-2, near the Columbia River on the southeast portion of the site. Industrial and scientific activity at Hanford has a dominant role in the socioeconomics of the Tri-Cities.

Environmental impact statements and planning documents have been issued over the last decade which characterize site ecology, waste storage and disposal practices, site contamination, proposed corrective actions, and related environmental, historical, archeological, endangered species, and cumulative impacts (e.g., DOE, 1987, DOE, 1991, DOE, 1992a, DOE, 1992b PNL, 1994b). The results of ongoing environmental compliance monitoring at onsite and off-site locations are published yearly (PNL, 1994c). Because of these studies, the Hanford Site's characteristics are well documented.

3.1.3.3 Low Level Burial Grounds

The Low-Level Burial Grounds is a section of the Hanford Site used for land disposal of wastes. The Low-Level Burial Grounds cover a total area of approximately 210 hectares (518 acres), divided into eight burial grounds located in the Site's 200 East and 200 West areas. The 200 East Area is located near the center of the Hanford Site about 11 kilometers (seven miles) from the Columbia River, on a plateau about 183 meters (600 feet) above mean sea level. The 200 East area also contains reactor fuel chemical separation processing facilities that are currently inactive. Located in the northeast corner of the 200 East area is burial ground 218-E-12B. The 218-E-12B burial ground began receiving waste in 1967 and currently consists of over 80 existing or planned trenches covering 70 hectares (173 acres). These trenches contain mixed waste, low-level waste, and transuranic waste. A system of Resource Conservation and Recovery Act compliant ground water monitoring wells is in place around the 218-E-12B burial ground.

Trench 94 of the 218-E-12B burial ground is used for the disposal of decommissioned, defueled pre-LOS ANGELES class submarine reactor compartments. Trench 94, which has been in operation since 1986, contained 43 submarine reactor compartment disposal packages by October, 1994, and has a capacity for approximately 120 packages. The reactor compartment packages currently in Trench 94 are regulated as a mixed waste because they contain radioactivity, essentially as activated metal, and solid lead shielding (regulated by the State of Washington).

They are also regulated for small quantities of solid polychlorinated biphenyls (PCBs) bound within industrial materials at a concentration greater than 50 parts per million (regulated by the EPA under the Toxic Substances Control Act). The reactor compartment packages may also contain asbestos in the form of component insulation and parts. The asbestos would be fully contained within the welded reactor compartment which meets local (Benton-Franklin countries Air Pollution Control Authority), State, and Federal disposal requirements.

A portion of the 218-E-12B burial ground to the north of Trench 94 is available for use by the Navy. This area is classified as "disturbed/facilities" on vegetation/land use maps for the Hanford Site provided by the 1994 Hanford Site NEPA Characterization (PNL, 1994b). The area is not in a native condition, having been covered with excavation spoils from Trench 94 for a number of years. Grasses have recently established themselves on limited areas of the spoils. Surrounding areas to the south and west are also disturbed with backfilled trenches and spoil piles. Pockets of shrub-steppe are present to the south but not adjacent to the burial ground. Less disturbed shrub-steppe lands border the burial ground to the north and east. The shrub-steppe lands are typically vegetated with a sagebrush/cheatgrass cover. A further detailed discussion of 200 East area ecology can be found in PNL, 1994b.

3.1.3.4 Endangered Species

The U.S. Fish and Wildlife Service lists the American peregrine falcon (Falco peregrinus) as endangered; and the bald eagle (Haliaeetus leucocephalus) as a threatened animal species on the Hanford Site (PNL, 1994c). The American peregrine falcon is not known to nest on the Hanford Site and its presence is as casual migrant. The bald eagle also has not been known to nest on the Hanford Site; however, it is a regular winter resident mainly foraging for dead salmon and preying upon waterfowl along the Columbia River, with occasional foraging flights onto the Hanford Site and in the last few years there have been several nesting attempts. The Washington State Wildlife Department also lists animal species in three categories: sensitive, threatened, and endangered. Listed species that are known to occur or thought to have a potential to occur on the Hanford Site are discussed in depth in Volume 1, Appendix A of the Department of Energy Programmatic Spent Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Environmental Impact Statement (DOE, 1995).

None of the plants occurring at Hanford are included on the federal list of endangered and threatened species, but there are four plant species which are candidates for consideration for future listing; Columbia milk-vetch (Astragalus columbianus), Hoover's desert parsley (Lomatium tuberosum) Columbia yellowcress (Rorippa columbiae) and Northern wormwood (Artemisisa campestris ssp. borealis var. wormskioldii), (WA, 1994). However, none of these species are indigenous to the 200 East area. The total number of insect species known to exist on the Hanford Site probably exceeds 600 with grasshoppers and darkling beetles among the most conspicuous groups (PNL, 1994b).

Washington State has listed several plant species as "sensitive" which probably could occur on the dryland areas of the Hanford Site; Dense sedge (Carex), Gray cryptantha (Cryptantha leucophea), Shining flatsedge (Cyperus rivularis), Piper's daisy (Erigeron piperianus), Southern mudwort (Limosella acaulis), and False-pimpernel (Lindernia anagallidea), (DOE, 1995). It is unlikely that these plant species could be impacted since the 218-E-12B Low Level Burial Ground is not in a native state. Spoils from any additional excavation that might be conducted at the 218-E-12B burial ground would also likely be placed in already disturbed areas within the Low Level Burial Grounds.

3.1.3.5 Floodplains/Wetlands

Floodplain and wetland environmental review requirements are provided in Section 404 of the Clean Water Act and Executive Orders 11990 and 11988. The Department of Energy has published regulations in 10CFR1022 on compliance with these requirements. Definitions of floodplains and wetlands from 10CFR1022 and an analysis of the flood potential of the Columbia River can be found in DOE 1992b. Based on the subject discussion in DOE 1992b, the 218-E-12B burial ground does not meet the definition of wetlands or floodplains of 10CFR1022. In addition, the land transport route for the reactor compartments would not impact floodplains or wetlands. This route traverses dry, upland areas of the Hanford Site and would not impact floodplains or wetlands. This route traverses dry, upland areas of the Hanford Site and would be the same route currently used for the pre-LOS ANGELES Class reactor compartment disposal program.

3.1.3.6 Seismicity

The 218-E-12B burial ground, and the Hanford Site in general, are located on the Central Columbia Plateau, a region of low to moderate seismicity. For purposes of structural design, the Hanford Site is rated seismic Zone 2B by the Uniform Building Code. Estimates for the earthquake potential of structures and zones in the Central Columbia Plateau have been developed during licensing of nuclear power plants at the Hanford Site. The largest estimated maximum magnitude was 6.5 on the Richter Scale for a seismic event originating along the Rattlesnake-Wallula alignment, which passes along the southwest boundary of the Hanford Site. This geologic feature is over 16 kilometers (10 miles) from the 218-E-12B burial ground at the closest point. A maximum magnitude of 5.0 on the Richter Scale was estimated for a closer structure, Gable Mountain. The potential risk associated with the Gable Mountain seismic event dominated risks associated with other potential sources considered. A further discussion of this work is presented in DOE 1995.

Historical earthquake magnitudes at the Hanford Site are considerably less than estimated maximums. While seismic activity above magnitude 3.0 on the Richter Scale has occurred in the Central Columbia Plateau, activity above 3.5 on the Richter Scale is most commonly found around the northern and western portions of the plateau with a few such events occurring around the Oregon border. The largest recorded earthquake on the entire Columbia Plateau was the magnitude 5.75 on the Richter Scale Milton-Freewater earthquake of 1936 (DOE, 1987). However, this location is over 80 kilometers (50 miles) southeast of the 218-E-12B burial ground. The majority of seismic activity closer to the 218-E-12B burial ground occurs as shallow earthquake swarms not associated with known geologic structures. These swarms typically involve numerous quakes of magnitude generally less than 2.0 on the Richter Scale (DOE, 1989b). Seismic activity and related phenomena such as liquefaction, fault rupture, and subsidence are not believed to be events that could plausibly and directly cause a release of waste from DOE facilities (DOE, 1992b).

3.1.3.7 Geology/Groundwater

The 218-E-12B burial ground is underlain by the slightly alkaline gravelly sands, sands, and sandy gravels of the Hanford Formation. Thin discontinuous bands of finer silty sediment are interspersed in the formation but these do not represent a significant portion of the Hanford Formation. The Hanford Formation sediments are glaciofluvial from the Pleistocene age and, under the 218-E-12B burial ground, rest directly atop the basaltic lava of the Miocene Columbia River Basaltic flows. A complex Miocene Basalt structure exists under the burial ground which has a profound effect on its hydrology. The geology and hydrology under the 218-E-12B burial

ground are described in detail in Estimation of the Release and Migration of Lead through Soils and Groundwater at the Hanford Site 218-E-12B Burial Ground (PNL, 1992). In general, groundwater occurs under the burial ground in both unconfined and confined aquifers, with the confined (deeper) aquifers bounded above by relatively impermeable basalt layers and the unconfined (uppermost) aquifer lying at the interface between the Hanford Formation and the underlying basalt. The depth to the unconfined (uppermost) aquifer under the burial ground is approximately 61 meters (200 feet). The relatively impermeable Miocene Basalts project above the water table to the east/northeast and west/northwest of the burial ground with a lower basalt divide connecting these higher areas across/under the burial ground. The divide surface slopes southward under the burial ground. Measurements of the unconfined aquifer taken under the 218-E-12B burial ground indicate thicknesses of around 1 meter (3 feet), increasing quickly in thickness to 2.5 meters (8 feet) outside the area of the burial ground (PNL, 1992).

Recharge of the unconfined aquifer under the Hanford Site occurs from natural and artificial sources. Natural recharge occurs from precipitation at higher elevations bordering the Site, run-off from intermittent streams on the western margin of the Hanford Site, and from the Yakima River on the southwestern boundary of the Site. The Columbia River recharges the unconfined aquifer near the river during high water stages (PNL, 1994c). These sources are not adjacent to the 218-E-12B burial ground. The unconfined aquifer receives little, if any, recharge directly from precipitation that falls on vegetated areas of the Hanford site because of a high rate of evapotranspiration from native soil and vegetation. Surface precipitation may contribute recharge where soils are coarse textured and bare of vegetation (PNL, 1994c). Recharge rates of 0.5 cm/yr and 5 cm/yr have been used at the Hanford Site to model recharge to the unconfined aquifer from the current arid climate and potentially wetter conditions (DOE, 1987; DOE, 1992b). The effect of such low recharges and the good drainage provided by the Hanford Formation sediment is actually observed in the form of a low moisture content in the Hanford Formation at the 200 East Area (1-5% by weight for the sandy gravely sediment that predominates at the 218-E-12B burial ground) (PNL, 1992).

The B-ponds, a series of unlined, interconnected, waste water disposal ponds, are located about 3 kilometers (2 miles) southeast of the 218-E-12B burial ground. Recharge from these ponds and from other now deactivated sources of artificial recharge has raised the local water table by as much as 9 meters (30 feet) compared to the preexisting condition (PNL, 1994b). As the B-ponds are decommissioned and this source of recharge ceases, water tables are expected to drop. Groundwater modeling conducted by Pacific Northwest Laboratory for the 218-E-12B burial ground (PNL, 1992) suggests that in the absence of artificial recharge from the B-pond, under current climate conditions, the unconfined aquifer will recede southward and not be present under the burial ground and perhaps a majority of the 200 East Area.

Hanford formation sediments underlying the 218-E-12B burial ground exhibited a strong tendency to adsorb (immobilize) lead and a lesser although still significant, adsorption of nickel from groundwater in site specific testing (PNL, 1992, PNL, 1994a). Solubilities of these constituents in the groundwater itself were also found to be fairly low at about 0.3 ppm for lead and 2 ppm for nickel. In addition, the sediments at Trench 94 possess low chloride levels and high resistivity (over 30,000 ohm-cm)(NFESC, 1993). These conditions provide a corrosion resistant environment, that inhibits the transport of metals from the 218-E-12B burial ground.

3.1.3.8 Environmental Monitoring

Monitoring of the atmosphere, ground water, Columbia River water, foodstuffs, plants, animals, and soil is conducted routinely at locations on and off the Hanford Site by the Pacific Northwest Laboratory. A detailed discussion of monitoring methods, locations, and collected data is provided in the Hanford Environmental Report which is published yearly. Results from 1993 monitoring, with emphasis on the 218-E-12B burial ground and surrounding 200 East Area, are discussed below (PNL, 1994c).

Air monitoring showed consistently detectable levels of ^{90}Sr, ^{137}Cs, uranium, ^{239}Pu and ^{240}Pu in the 200 East and 200 West Areas. However, measured levels of these detected radionuclides are low, resulting in a combined radiological dose of less than 0.05 mrem/yr for these radionuclides. Average concentrations of ^{129}I in the air were elevated at the Hanford Site boundary relative to distant locations indicating the potential for migration off-site. However, measured concentrations in the air on-site result in low radiological doses (less than 0.001 mrem/yr for ^{129}I). Potential sources of ^{129}I exist at the 200 East Area associated with the Plutonium and Uranium Extraction (PUREX) facility, about 1-2 miles south of the 218-E-12B burial ground.

Columbia River monitoring showed that concentrations of ^{3}H, ^{129}I, and Uranium were higher at locations downstream of the Hanford Site than upstream. The observed increase statistically indicated a contribution from the Hanford Site. However, the measured concentrations of these radionuclides in the river remained well below Environmental Protection Agency and State of Washington drinking water standards.

Federal drinking water standards for beta particle and photon radioactivity from man-made radionuclides are based on a maximum 4 mrem per year dose. These standards, provided in the Code of Federal Regulations Title 40 "Environment" part 141 (40CFR141), are applied to public and DOE drinking water systems. This limit is not applied to the Hanford Site in general. DOE order 5400.5 "Radiation Protection of the Public and the Environment" limits the effective public dose from routine DOE activities to 100 mrem per year from all pathways combined. Where the Hanford Site Environmental Report for Calender Year 1993 (PNL, 1994c) references federal standards, these are included in the summary of groundwater monitoring results from PNL 1994c which is provided below.

Groundwater monitoring showed that ^{3}H is widespread through the 200 East Area at concentrations greater than the 20,000 pCi/L federal drinking water standards. Localized areas of ^{90}Sr exist at concentrations greater than the 8 pCi/L federal standard. ^{99}Tc, ^{129}I, and ^{137}Cs are also present at levels exceeding federal drinking water standards (i.e., 900 pCi/L, 1 pCi/L, and 200 pCi/L, respectively). A large groundwater plume of ^{3}H originated from the PUREX Facility, located about 1-2 miles south of the 218-E-12B burial ground. This plume has reached the Columbia River to the east/south east, the historical direction of groundwater flow in this area. An ^{129}I plume originated from the PUREX area with concentrations over the 1 pCi/L federal drinking water standard extending for many miles beyond the 200 East Area to the south east. Measured ^{60}Co levels in Hanford Site groundwater were at or below the detection limit of 20 pCi/L. One well in the 200 East Area had measured levels of ^{60}Co from 37 to 66 pCi/L, still below the federal drinking water standard of 100 pCi/L. ^{137}Cs and ^{60}Co are strongly absorbed in soil and thus normally immobile in Hanford soil (i.e., migration through soil via groundwater is slow). However, cyanide bearing compounds were present in the waste streams at Hanford that contained ^{60}Co. The cyanide compounds can form complexes with the ^{60}Co reducing soil adsorption.

Groundwater monitoring in 1993 identified eight hazardous chemicals at levels above applicable federal drinking water standards at Hanford: nitrate, cyanide, fluoride, chromium, carbon tetrachloride, chloroform, trichloroethylene, and tetrachloroethylene. The chlorinated organic compounds form distinct plumes under the 200 West Area as they are associated with production facilities in that area, but are not found under the 200 East Area. Nitrate plumes are present under the 200 East Area, coincident with ^{3}H plumes as a common source existed for both at the PUREX facility. Chromium is found in the 200 East Area at concentrations greater than federal drinking water standards (100 μg/L with a more restrictive Washington State limit at 50 μg/L). However, filtered samples tend to be below the federal drinking water standards. This suggests that the chromium is not truly solubilized in the water but is rather present as a fine suspended particulate that is removed by the filtration. Contamination from metal particulate generated by well construction and installation has been suggested as a possible source of the chromium found (PNL, 1994c). Polychlorinated biphenyls have not been detected in groundwater samples.

The submarine reactor compartments at the 218-E-12B burial ground are not a current or historic source for any of the radionuclides or hazardous chemicals identified by Hanford Site monitoring.

The general direction of groundwater movement in the unconfined aquifer under the Hanford Site can be inferred from the spread of ^{3}H and nitrate contamination since these constituents are mobile in groundwater. ^{3}H and nitrate plume maps for the Hanford Site show movement in directions skirting around and away from the 218-E-12B burial ground (extreme northeast corner of the 200 East Area)(PNL, 1994c, DOE 1989b). This effect is likely due to the subsurface basalt, structure which forms a divide under the burial ground, effectively shunting groundwater flow around this region.

Radiation doses to the general public from Hanford operations during 1993 are calculated and discussed in the Hanford Site Environmental Report for Calender Year 1993 (PNL, 1994c). The Maximally Exposed Individual (MEI or MI) is a hypothetical person who lives at a particular location and has a postulated lifestyle such that it is unlikely that other members of the public would receive higher doses. The location selected for the MI can vary from year to year depending on the relative importance of the several sources of radioactive effluents released to the air and to the Columbia River from Hanford facilities. Releases of ^{220}Rn and ^{222}Rn from the 300 Area in 1993 resulted in the MI for 1993 being located 1.5 km directly across the Columbia River from the 300 Area, different than past MI locations (Ringold and Riverview areas on the east side of the Columbia River). The calculated effective dose potentially received by the 1993 MI was 0.03 mrem/yr, up from 0.02 mrem/yr from 1992. The following exposure pathways were included in the calculation of this MI dose: inhalation of and submersion in air downwind of the Site, consumption of foods contaminated by radionuclides deposited on the ground from airborne materials and by irrigation with water from the Columbia River, direct exposure to radionuclides deposited on the ground, consumption of drinking water derived from the Columbia River, consumption of fish taken from the Columbia River, and external radiation during recreation activities on the Columbia River and its shoreline. Doses to the MI were calculated with the GENII computer code. The collective effective dose to the population living within 80 kilometers (50 miles) of the site was also estimated at 0.4 person-rem, compared with 0.8 person-rem estimated for 1992. The 0.03 mrem/year MI dose and the 0.4 person-rem collective dose for 1993 can be compared with the 300 mrem and 110,000 person-rem received annually by an average individual and by the surrounding population respectively, as the result of naturally occurring radiation (PNL, 1994c). The submarine reactor compartments in Trench 94 do not contribute to these doses.

3.2 No Action Alternative

3.2.1 Puget Sound Naval Shipyard

Puget Sound Naval Shipyard is the largest activity of the Bremerton Naval Complex, which also includes the Fleet and Industrial Supply Center, Puget Sound and Naval Sea Systems Command Detachment, and Planning Engineering for Repair/Alteration of Aircraft Carriers. Tenant activities include Naval Inactive Ship Maintenance Facility (NISMF), Naval Reserve Center, and the Defense Printing Service. Refer to Section 3.1.1 for more detailed information on Puget Sound Naval Shipyard. Figure 3.1 provides a shipyard vicinity map.

Puget Sound Naval Shipyard is the designated location on the West coast for storage of inactivated nuclear-powered ships. The Shipyard's inactive nuclear ship moorage facility will accommodate about 35 pre-LOS ANGELES Class Submarines. This facility could be used to berth approximately 32 LOS ANGELES Class submarines with space for three larger ships, either cruisers or OHIO Class submarines or a combination of both. Other combinations of cruiser, LOS ANGELES Class submarines and OHIO Class submarines are possible however it should be noted that, due to space requirements, approximately two LOS ANGELES Class submarines can be moored in the space required for one cruiser or OHIO Class submarine.

3.2.2 Norfolk Naval Shipyard

Norfolk Naval Shipyard is located in the Tidewater region in the South East corner of Virginia on the Southern Branch of the Elizabeth River. The shipyard is contiguous with the city of Portsmouth and occupies approximately 480 hectares (1200 acres). The shipyard is centrally located in a highly developed urban industrialized area. Six cities are within 24 kilometers (15 miles) of the shipyard: Portsmouth, Chesapeake, Norfolk, Virginia Beach, Hampton and Newport News, and Suffolk.

The Shipyard is centrally located in relation to the six-city population centers that comprise the Tidewater region. At the time of the 1990 census, approximately 1.5 million persons resided within a 80 kilometers (50 mile) radius of the shipyard. The six-city metropolitan area houses most of this population. The shipyard was founded in 1767 under the British flag and is currently a highly developed ships servicing and repair center and was authorized to perform naval nuclear propulsion work in 1963.

The shipyard is divided internally into a controlled industrial area and non-industrial area. All of the piers, drydocks, and work facilities accomplishing naval nuclear propulsion plant work are within the controlled industrial area. The shipyard includes over 500 administrative, industrial, and support structures and four miles of shoreline. Norfolk Naval Shipyard is the designated storage area on the East coast for inactive nuclear-powered ships. The current area at Norfolk Naval Shipyard designated for storage of decommissioned nuclear-powered ships would be capable of berthing eight to twelve ships made up of a combination of cruisers, and LOS ANGELES Class submarines.

The seismic risk related to structural damage for Norfolk Naval Shipyard is defined as Zone 1 by the Uniform Building Code (UBC, 1991). No major faults underlie the Tidewater region and the region is considered aseismic (SCIENCE, 1969).

Summer winds are predominantly from the south and southwest at Norfolk Naval Shipyard, pulling large amounts of moisture up from the Gulf of Mexico. During the summer months, afternoon thunderstorms due to daytime heating of the near surface air are very common. Large

areas of high pressure frequently stall just east of the southern coast. These "Bermuda Highs" can lead to extended periods of hot, humid weather with very little precipitation other than scattered thunderstorms. Thunderstorms occasionally spawn isolated tornadic activity throughout the region. Although locally destructive, the tornados move through the area rapidly along with storm centers.

Tropical cyclones of hurricane force are a probability in the Norfolk area. Tropical cyclones that pass within 180 nautical miles of the Norfolk area are considered a threat. Statistically, 1.6 tropical cyclones a year pose a threat to the Norfolk area. Because of the high latitude (37° N), most of these storms recurve from a westerly track to a more northerly track accelerating their forward movement as they do. This tends to move the cyclones away from the Norfolk area. Cyclones that stay on a westerly or northwesterly track tend to weaken as they move overland. Norfolk Naval Shipyard, located on the Southern fork of the Elizabeth River, is situated so that it is not susceptible to any significant wind generated waves from any direction. There are no long fetches of water that would result in significant wind generated waves. Norfolk Naval Shipyard is a recommended safe moorage location for small craft during gale force winds. The greatest threat at Norfolk Naval Shipyard from tropical cyclones is storm surge which can add several feet to the height of the usual tide. Action must be taken for ships moored in the area so storm surge possibilities will not break the mooring lines.

In accordance with the Clean Air Act and the required State Implementation Plan for achieving nationwide air quality goals, air pollution control in the State of Virginia is a coordinated effort directed by the Department of Environmental Quality via regional authorities within the state. The State is divided into intrastate Air Quality Control Regions (AQCRs). Each AQCR has the responsibility for developing its point and area source emissions inventory and for analyzing and reporting on air quality monitoring data within its jurisdiction. The Hampton Roads Intrastate Air Quality Control Region (Region 6) has the delegated authority for enforcement of the Clean Air Act in the area encompassing the Shipyard. The Code of Federal Regulations, Title 40, part 81 designates this area as being in attainment of national standards for suspended particulate matter and sulfur dioxide, however, a moderate nonattainment designation is given for ozone. Air quality with respect to carbonmonoxide and nitrogen dioxide has not been classified but is considered to be in attainment. Norfolk Naval Shipyard is not located in an area where degradation of air quality is severely restricted under the prevention of significant deterioration (PSD) regulations of Title 40, part 52.

The U.S. Fish and Wildlife Service lists the following species as endangered (E) or threatened (T) in the South Hampton Roads area from Suffolk eastward: Loggerhead turtle (T); Bald eagle (E); Peregrine falcon (E); Piping plover (T); Red-cockaded woodpecker (E); Eastern cougar (E); Dismal Swamp Southeastern shrew (T); and Northeastern beach tiger beetle (T). The exact location of specific habitats could not be located; however, surveys of the area have not identified any habitat on shipyard property. Additionally, there are no marine mammals that are routinely found within the lower Chesapeake Bay or its tributaries including the shipyard property. Past sounding records in the Norfolk Naval Shipyard area have indicated sedimentation at the rate of three inches per year. Ships in inactive status must be dry-docked about every 15 years for hull preservation. Therefore, dredge depths would be established below the minimum required for the ships in storage to allow maintenance dredging to be done when the ships are removed from storage for hull preservation work.

3.3 Disposal and Reuse of Subdivided Portions of the Reactor Plant

3.3.1 Operations Sites

The sites affected by this alternative are Puget Sound Naval Shipyard and Norfolk Naval Shipyard. Existing environments of those sites are discussed in the subsections for the following alternatives: the preferred alternative and the no-action alternative.

3.3.2 Disposal Sites

For purposes of evaluation, the primary disposal sites for waste from the subdivision alternative are considered to be the Department of Energy's Hanford Site in the State of Washington and the Department of Energy's Savannah River Site in the State of South Carolina. However, at the actual time for disposition of wastes generated from the subdivision alternative, disposition at other authorized sites would not be precluded. Some classified components may be able to undergo a declassification process prior to disposal at sites not controlled by D.O.E. Other classified components cannot be declassified or would require cost and personnel exposure to declassify.

3.3.2.1 Hanford Site

The existing environment of the Hanford Site is discussed in the preferred alternative subsection of this section.

3.3.2.2 Savannah River Site.

The following site information has been summarized from the Final F-Canyon Environmental Impact Statement for the Department of Energy Savannah River Site (DOE, 1994b).

The Savannah River Site (SRS) is on the Aiken Plateau of the Upper Atlantic Coastal Plain about 40 kilometers (25 miles) southeast of the Fall Line that separates the Atlantic Coastal Plain from the Piedmont, Figure 3.5.

A recent study of available geophysical evidence identified six faults under the SRS. Two major earthquakes have occurred within 300 kilometers (186 miles) of the SRS. The first was the Charleston, South Carolina, earthquake of 1886, which had an estimated Richter scale magnitude of 6.8 and occurred approximately 145 kilometers (90 miles) from the site. The second major earthquake was the Union County, South Carolina, earthquake of 1913, which had an estimated Richter scale magnitude of 6.0 and occurred about 160 kilometers (99 miles) from the Site. Several earthquakes have occurred inside the SRS boundary in recent years. One occurred on June 8, 1985, another occurred on August 5, 1988 and yet another occurred on August 8, 1993. They had local Richter scale magnitudes of 2.6, 2.0, and 3.2, respectively.

Five principal tributaries of the Savannah River drain almost all of the SRS. The Savannah River, which forms the boundary between the States of Georgia and South Carolina, supplies potable water to several municipalities (Savannah, Georgia; Beaufort County, South Carolina and Jasper County, South Carolina).

Groundwater is a domestic, municipal, and industrial water source throughout the Upper Coastal Plain. The groundwater beneath the SRS flows slowly toward the SRS streams and swamps and into the Savannah River at rates ranging from inches per year to several hundred feet per year.

Based on SRS data collected from onsite meteorological towers for the 5-year period from 1987 to 1991, maximum wind direction frequencies are from the northeast and west-southwest and the average wind speed is 3.8 meters per second (8.5 miles per hour). The average annual temperature at the SRS is 18°C (64°F). The atmosphere in the SRS region is unstable approximately 56 percent of the time, neutral 23 percent of the time, and stable about 21 percent of the time. The SRS experiences an average of 55 thunderstorm days per year with 50 percent of them occurring in June, July and August. From 1954 to 1983, 37 reported tornadoes occurred in a 1-degree square of latitude and longitude that includes the SRS. This frequency of occurrence is equivalent to an average of about one tornado per year. Since operations began at the SRS in 1953, nine tornadoes have been confirmed on or near the site. From 1700 to 1992, 36 hurricanes occurred in South Carolina, resulting in an average frequency of about one hurricane every 8 years. Because the SRS is about 160 kilometers (100 miles) inland the winds associated with hurricanes have usually diminished below hurricane force [i.e., equal to or greater than a sustained wind speed of 33.5 meters per second (75 miles per hour)] before reaching the SRS.

At present, SRS does not perform onsite ambient air quality monitoring. State agencies operate ambient air quality monitoring sites in Barnwell and Aiken Counties in South Carolina, and in Richmond County in Georgia. The counties, which are near SRS, are in compliance with National Ambient Air Quality Standards for particulate matter, lead, ozone, sulfur dioxide, nitrogen oxides, and carbon monoxide. The South Carolina Department of Health and Environmental Control has the delegated authority for enforcement of the Clean Air Act in the area encompassing the Savannah River Site. The Code of Federal Regulations, Title 40, part 81 designates this area as being in attainment of national standards for suspended particulate matter and sulfur dioxide. Air quality with respect to ozone, carbon–monoxide and nitrogen dioxide has not been classified but is considered to be in attainment. The Savannah River Site is not located in an area where degradation of air quality is severely restricted under the prevention of significant deterioration (PSD) regulations of Title 40, part 52.

3.4 Indefinite Storage Above Ground at Hanford

The affected environment for this alternative is the same as that for the preferred alternative, which is discussed previously.

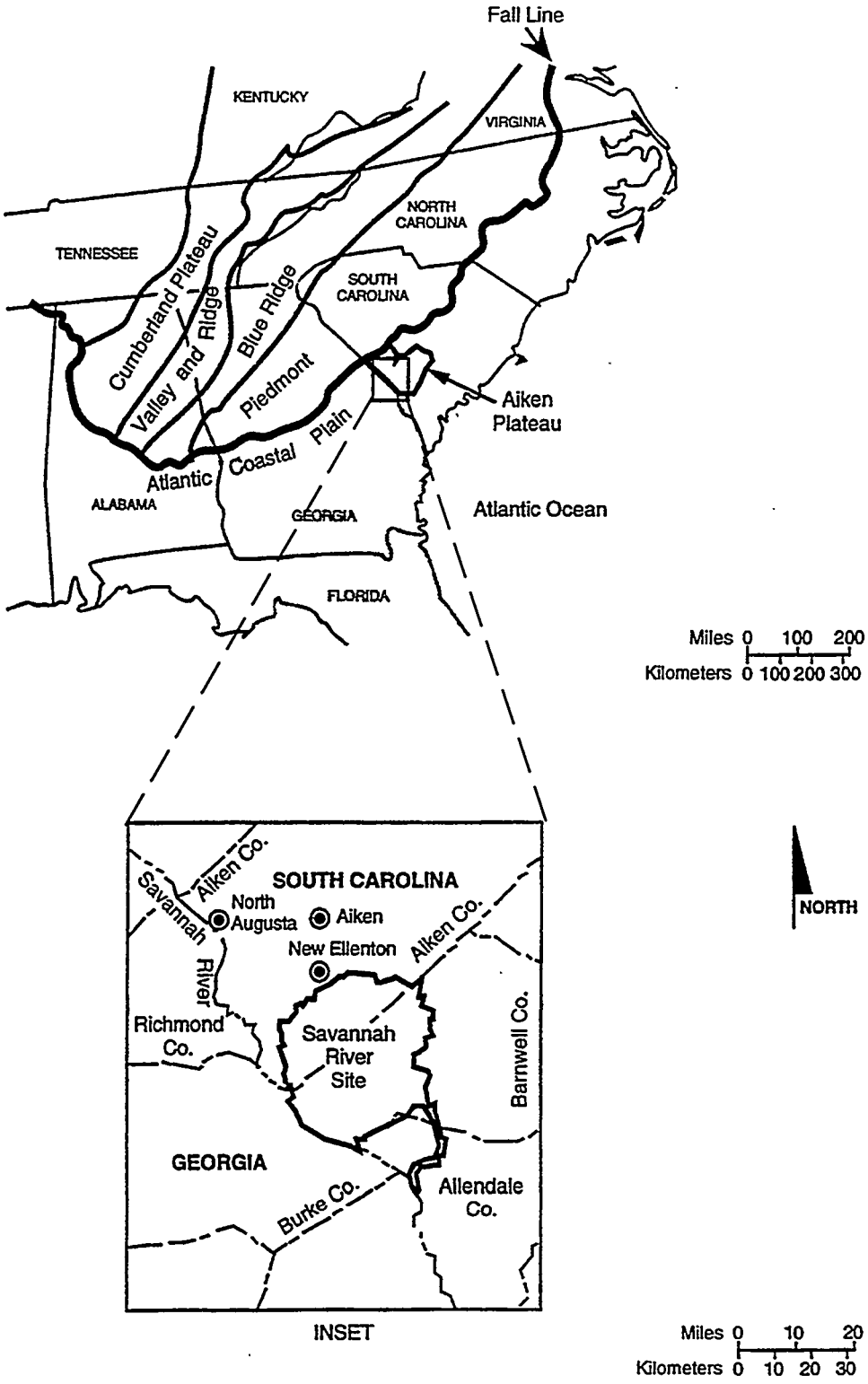


Figure 3.5. General Location of the Savannah River Site

4. ENVIRONMENTAL CONSEQUENCES

4.1 General

The following sections discuss the potential environmental consequences associated with the alternatives of land disposal of the reactor compartment at the Department of Energy Low Level Burial Grounds at Hanford, WA; the no action alternative; the disposal and reuse of subdivided portions of the reactor compartment alternative; and the indefinite storage above ground at Hanford alternative. Potential environmental consequences from disposal of reactor compartments from cruisers and OHIO Class and LOS ANGELES Class submarines relate to radionuclides and to toxic and hazardous materials such as asbestos, polychlorinated biphenyls (PCBs), lead and chromates found in compartments. The measures that would be employed by the Navy to protect its own workers from potential hazards during disposal work would be protective of off site personnel and the environment as well.

The decay of radioactive atoms produces radiation, which can cause damage to tissue if there is insufficient distance or shielding between the source and the tissue. The effects on people of radiation that is emitted during decay of a radioactive substance depends on the kind of radiation (alpha and beta particles, and gamma and x-rays) and the total amount of radiation energy absorbed by the body. Within kinds of radiation, the energy of the radiation varies depending on the source isotope. The more energetic radiation of a given kind, the more energy that will be absorbed, in general. The total energy absorbed per unit quantity of tissue is referred to as absorbed dose. The absorbed dose, when multiplied by certain quality factors and factors that take into account different sensitivities of various tissues, is referred to as effective dose equivalent, or where the context is clear, simply dose. The common unit of effective dose equivalent is the rem or mrem (0.001 or 10^{-3} rem).

An individual may be exposed to ionizing radiation externally, from a radioactive source outside the body, and/or internally, from ingesting radioactive material. The external dose is different from the internal dose. An external dose is delivered only during the actual time of exposure to the external radiation source. An internal dose, however, continues to be delivered as long as the radioactive source is in the body, although both radioactive decay and elimination of the radionuclide by ordinary metabolic process decrease the dose rate with the passage of time.

Doses are often classified into two categories: acute, which is a large dose received over a few hours or less; and chronic, which involves repeated small doses over a long time (months or years). Chronic doses are usually less harmful than acute doses because the time between exposures at low dose rates allows the body to repair damaged cells. Only chronic effects are considered here as the exposures discussed are much less than the threshold for acute effects. The most significant chronic effect from environmental and occupational radiation exposures is induction of latent cancer fatalities. This effect is referred to as latent because the cancer may take many years to develop.

Hypothetical health effects can be expressed in terms of estimated latent cancer fatalities. The health risk conversion factors used in this evaluation are taken from the International Commission on Radiological Protection which specifies 0.0005 latent cancer fatalities per person-rem of exposure to the public and 0.0004 latent cancer fatalities per person-rem for workers (ICRP, 1991).

To place exposure into perspective with normal everyday activities of the general public, a typical person in the United States receives 300 mrem of radiation exposure each year from natural background radiation, (NCRP, 1987). Natural background radiation is radiation that all people receive every day from the sun or from cosmic radiation, and from the natural radioactive materials that are present in our surroundings, including the rocks or soil we walk on.

The Navy has well established and effective Occupational Safety, Health, and Occupational Medicine programs at all of its shipyards. In regard to radiological aspects of these programs, the Naval Nuclear Propulsion Program policy is to reduce, to as low as reasonably achievable, the external exposure to personnel from ionizing radiation associated with naval nuclear propulsion plants. These stringent controls on minimizing occupational radiation exposure have been successful. No civilian or military personnel at Navy sites have ever exceeded the federal accumulated radiation exposure limit which allows a 5 rem dose for each year of age beyond age 18. Since 1967, no person has exceeded the federal limit which allows up to 3 rem per quarter year and since 1980, no one has received more than 2 rem per year from radiation associated with naval nuclear propulsion plants. The average occupational dose received by each person monitored at all shipyards is 0.26 rem per year. The average lifetime accumulated radiation dose associated with naval nuclear propulsion plants for all shipyard personnel who were monitored is 1.2 rem. This corresponds to the likelihood of a cancer fatality of 1 in 2083.

The control of radiation exposure to Shipyard workers is further discussed in the annual report NT-94-2 "Occupational Radiation Exposure from U.S. Naval Nuclear Plants and their Support Facilities" issued by the Department of the Navy. In 1991, researchers from the Johns Hopkins University in Baltimore, MD completed a comprehensive epidemiological study of the health of workers at eight shipyards that service nuclear-powered ships, including Puget Sound Naval Shipyard and Norfolk Naval Shipyard. This study of 70,730 Shipyard workers covering a period of 24 years, did not show any cancer links with radiation exposure at these Shipyards, (MATANOSKI, 1991). Additionally, a National Academy of Science report states that there is a possibility that there may be no risks from exposure comparable to external natural background radiation (BEIR, 1990).

The Navy's policy on occupational exposure from internal radioactivity is to prevent radiation exposure to personnel from internal radioactivity. The limits invoked to achieve this objective are one-tenth of the levels allowed by federal regulations for radiation workers. As a result of this policy, no civilian or military personnel at shipyards have ever received more than one-tenth the federal annual occupational exposure limit from internal radiation exposure caused by radioactivity associated with naval nuclear propulsion plants.

Public exposure resulting from activities within Naval Shipyards would be negligible. As discussed in the annual report NT-95-1 "Environmental Monitoring and Disposal of Radioactive Wastes from U.S. Naval Nuclear Powered Ships and their Support Facilities" issued by the Department of the Navy, procedures used by the Navy to control releases of radioactivity from U.S. Naval nuclear-powered ships and their support facilities have been effective in protecting the environment and health and safety of the general public. Independent radiological environmental monitoring performed by the U.S. Environmental Protection Agency and states have confirmed the adequacy of these procedures. These procedures have ensured that no member of the public has received measurable radiation exposure as a result of current operations of the Naval Nuclear Propulsion Program (NNPP, 1995a).

Regarding non radiological health hazards, the Navy complies with the Navy Occupational Safety and Health requirements, which have been approved by the Occupational Safety and Health Administration. The Navy policy is to maintain a safe and healthful work environment at all naval facilities. Due to the industrial nature of work at Naval Shipyards, there is a potential for certain employees to be exposed to physical and chemical hazards. These employees are routinely monitored during work and receive medical surveillance for physical hazards such as exposure to chemical hazards and where appropriate are placed into medical surveillance programs for these chemical hazards.

The process for identification and protection of historic sites provided in the National Historic Preservation Act (36CFR800) applies to all alternatives. The extent of effort required to complete the process will vary depending on the alternative selected. For the Hanford Site, previously performed archaeological surveys have not identified archaeological or historic sites located in the 200 East area (DOE 1992b, PNL, 1994b). One such survey included an area north of Trench 94 that forms a portion of the area available for placement of additional reactor compartments (PNL, 1990). This condition reduces the possibility that historic sites could be impacted by the Hanford alteratives. However, prior to implementation of any of the alternatives involving Department of Energy Sites, cultural resource, biological, and ecological surveys will be performed as applicable.

In accordance with Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," most of the actions contemplated by this final EIS would result in no significant environmental, human health, or economic effects on surrounding populations, including any minority or low-income populations that may exist in the areas. However, the subdivide and reuse alternative may result in significant human health effects to workers, who are neither disproportionately minority or low income.

4.2 Potential Effects of Primary Hazardous Materials found in Reactor Compartments

4.2.1 Asbestos (USN, 1993a)

Asbestos is a general term that applies to a variety of naturally occurring mineral silicates, e.g., chrysotile, amosite, crocidolite, tremolite, anthophylite, and actinolite. Asbestos is generally a fibrous material whose primary chemical and physical properties are resistance to combustion, good thermal and electrical resistance, tensile strength, and fair chemical resistance.

Asbestos is a health hazard when there is the potential for personnel exposure to its airborne fibers. The primary potential asbestos exposure hazard resulting from disposal of reactor compartments would be occupational exposure to the workers removing or handling asbestos, or disturbing asbestos in the course of other work. Other potential hazards would exist for the general population in the Shipyard of disposal site vicinity in the event of asbestos release.

The link between exposure to asbestos and certain illnesses has been well established by epidemiological and other studies. Studies have been conducted on persons occupationally exposed, families of these persons, and persons residing in areas where asbestos is mined. Increased rates of lung cancer, pleural and peritoneal mesothelioma, and gastrointestinal cancer have been directly tied to exposure. Mesothelioma is a rare cancer of the thin membrane lining the chest and abdomen. Also, asbestosis is a disabling fibrotic lung disease whose only known cause is exposure to asbestos. The above maladies generally occur long after initial exposure, generally in about 20 years. There are no known acute health problems caused by asbestos exposure.

Asbestos is regulated in the work place, in removal operations, and in the air, land, and water environments. There shall be no discharge of visible emission to the outside air during the collection, processing, packaging, or transportation of any asbestos containing material (40CFR61.150(a)).

4.2.2 Polychlorinated Biphenyls (USN, 1993a)

Polychlorinated Biphenyls (PCBs) were developed in the 1880s, but were not widely used until the 1930s. They were first regulated as toxic substances in 1976, Their primary physical and chemical characteristics are thermal stability, resistance to oxidation, resistance to bases and acids, and excellent dielectric qualities. They are soluble in organic solvents but their solubility in water is extremely low. PCBs persist and bioaccumulate in the environment. In 1980, the EPA determined an average biaoaccumulation factor of 31,200 times the ambient water concentration in freshwater fish and shellfish.

The effects of PCBs can be summarized with the following points:

They are readily absorbed through the gastrointestinal and respiratory systems, and skin.

They may initially concentrate in the liver, blood, and muscle mass in mammals.

The major metabolic products of PCBs are phenolic derivatives or dihydrodiols, which may be formed through pathways with arene oxide intermediates or by direct hydroxylation. The susceptibility of individual PCB congeners to metabolism is a function of the number of chlorines present on the biphenyl and their arrangement. Biphenyls that have one or more pairs of adjacent unsubstituted carbons are more rapidly metabolized than those that do not.

PCBs that are readily metabolized are also rapidly excreted in the urine and bile. Excretion in urine is most prominent for the least chlorinated, while bile becomes the more significant route of excretion for more highly chlorinated congeners.

Those congeners most refractory (resistant) to metabolism accumulate for increasing periods of time in fatty tissues. Highly chlorinated congeners are accumulated almost indefinitely.

PCBs can be transferred either transplacentally or in breast milk.

Non human primates may retain PCBs more efficiently than rodents.

A single PCB isomer, 4-chlorobiphenyl, has been found to be highly mutagenic. Mutagenicity decreased with increasing chlorination.

High levels of PCBs are carcinogenic in rodents. Several animal studies have resulted in reports that PCBs produce a carcinogenic response, and that they enhance carcinogenic activities of other substances. The National Institute for Occupational Safety and Health (NIOSH) and EPA consider PCBs to be animal carcinogens and suspected human carcinogens. PCBs were classified as carcinogenic by the International Agency for Research on Cancer.

PCBs are regulated both for use and disposal (40CFR761). Generally, there are no Federal restrictions when PCB concentration is less than 50 parts per million (40CFR761.60(a)).

Potential PCB exposure risk would occur during removal of felt sound damping material, when present. PCBs will be encountered less frequently, if at all, on the later classes of ships due to the ban on production of PCB manufacturing effectively established by Congress in 1976.

4.2.3 Lead (USN, 1993a)

Lead is metal whose primary chemical and physical properties are high density, high malleability, and high corrosion resistance. Health effects from lead fall into three categories: (a) alimentary, (b) neuromuscular, (c) encephalic. The alimentary effect is the most common, and is characterized by abdominal discomfort and pain, joint and muscle pain, vomiting, irritability, and various gastrointestinal symptoms. In the neuromuscular type, less severe gastrointestinal symptoms usually are present, accompanied by increased joint and muscle pain and muscular weakness. Encephalic effect is the most severe, and usually occurs following rapid, heavy lead ingestion. Symptoms range from headache and dizziness to coma and death.

Potential lead exposure risk occurs during reactor compartment disposal work if fine lead particles become dislodged from solid pieces and become airborne, or if vapors are emitted during cut-out and removal, thus leading to the potential for subsequent inhalation or ingestion.

Lead is regulated in the work place and in the water environment.

4.3 Preferred Alternative - Land Burial of the Entire Reactor Compartment at the Department of Energy Low Level Waste Burial Ground at Hanford, WA

4.3.1 Shipyard

4.3.1.1 Facilities

Puget Sound Naval Shipyard routinely conducts ship overhaul and repair work including docking, defueling and decommissioning of nuclear-powered naval vessels in the Controlled Industrial Area. Although the ships and their reactor compartments would be larger for cruiser, LOS ANGELES and OHIO Class submarines, the operations for the pre-LOS ANGELES submarine inactivation, defueling, and decommissioning program would apply. No new facilities would be required to support the reactor compartment disposal packaging work.

4.3.1.2 Preparations for Shipment

The reactor compartment disposal packaging work would involve draining fluid systems, cutting and sealing piping, removal of components, and installation of packaging materials and handling fixtures. Some of this work would involve occupational radiation exposure to Shipyard employees working in the gamma radiation fields of the reactor compartment.

The total radiation dose for the preferred alternative of preparing a cruiser reactor compartment for shipment to a land disposal site is expected to be about 25 rem (approximately 0.01 additional latent cancer fatalities). Similarly, the dose incurred in preparing LOS ANGELES and OHIO reactor compartments is expected to be 13 rem and 14 rem respectively (approximately 0.005 and 0.006 additional latent cancer fatalities respectively) total per reactor compartment. This dose would be to workers who are trained for work in radiation areas.

The average occupational dose for each radiological worker in the Shipyard work force is less than one-fifth of a rem (200 mrem) per year. For comparison, the radiation dose a typical person in the United States receives each year from natural background radiation is three-tenths of a rem (300 mrem). The work to prepare the cruiser, LOS ANGELES and OHIO Class submarine reactor compartments for any of the alternatives would be similar to and supplement work routinely being performed at Puget Sound Naval Shipyard and Norfolk Naval Shipyard to overhaul, maintain, or inactivate ships and submarines, and to prepare pre-LOS ANGELES Class submarine reactor

compartments for disposal. It would not cause a significant increase to the average radiation exposure of persons in the Shipyard work force. Individual worker exposure is strictly controlled to not exceed the federally established dose limits (5 rem per year to the total body).

Processes used by the Navy to control releases of radioactivity from U.S. Naval nuclear-powered ships and their support facilities have been effective in protecting the environment and the health and safety of the general public. Independent radiological environment monitoring performed by the Environmental Protection Agency and states have confirmed the adequacy of these processes. These processes have ensured that no member of the general public has received measurable radiation exposure as a result of current operations of the Naval Nuclear Propulsion Program (NNPP, 1995a).

Some cruiser and LOS ANGELES and OHIO Class submarine reactor compartment preparation work would involve working with hazardous materials. For example, PCB impregnated sound damping material would be removed when present. PCBs will be encountered less frequently, if at all, on the later classes of ships due to the ban on production of PCB manufacturing effectively established by Congress in 1976. All work involving hazardous materials would be carried out by trained people using appropriate personal protective equipment, in accordance with occupational safety and health regulatory requirements. Wastes generated in the Shipyard would be recycled or disposed of in accordance with applicable state and federal regulations using licensed transportation contractors and disposal sites.

Shipyard work practices and processes performed in connection with the preferred alternative would be in accordance with applicable Shipyard directives to minimize the discharge of air pollutants from the industrial procedures. These activities would be performed such that the emission standards established by the Puget Sound Air Pollution Control Agency would not be violated.

Mixed waste would require treatment in accordance with appropriate treatment standards before disposal or else would require placement in retrievable storage until a mixed waste disposal site became available. Similarly, radioactive PCB waste would require storage until sufficient treatment or disposal capacity became available. Typically, the waste generated would either be a solid (e.g., a piece of lead), a solid with a hazardous material tightly bound within its matrix as part of the formulation (e.g., PCB in paint chips, rubber gaskets, or insulation), sound damping felt, or solidified liquid (e.g., processed potassium chromate solution). Management of these wastes would not result in unauthorized exposures to workers or unpermitted releases to the environment.

4.3.2 Transport

The preferred alterative would involve transport of approximately 100 reactor compartments from Puget Sound Naval Shipyard to the Hanford Site for disposal. The water and land transportation of the cruiser, LOS ANGELES Class, and OHIO Class submarine reactor compartments would use the same proven processes that are being safely and successfully used to transport the pre-LOS ANGELES Class submarine reactor compartments. These processes are designed to minimize the potential for transportation accidents, to mitigate the consequences of potential accidents, and to facilitate recovery if necessary. The estimated impacts from transport of the reactor compartments are evaluated in Appendix E.

4.3.2.1 Radiation Exposure from Normal Condition of Transport

For normal conditions of transport (incident free), transport of 100 reactor compartment packages is estimated to result in exposure to the general population of 5.8 person-rem (0.0029 latent cancer fatalities), and the maximum exposed individual in the general population is estimated to receive 0.12 person-rem (0.000061 latent cancer fatalities). Exposure to the transportation crew for 100 shipments is estimated to be 5.79 person-rem (0.00232 latent cancer fatalities) and the maximum exposed transportation worker is estimated to receive 0.636 person-rem (0.000254 latent cancer fatalities). Non-radiological fatalities are estimated to be 0.000418.

4.3.2.2 Accident Scenarios

For hypothetical accident conditions depicted in Figure 2.13, exposure to the general population is estimated to be 0.186 person-rem (0.0000929 latent cancer fatalities) when both the probability and severity of an accident are considered. For non-radiological accidents, there are similarly estimated to be 0.000947 fatalities. Assuming an accident actually does happen, the maximum consequences are estimated to be 0.835 rem (0.000418 latent cancer fatalities) to a maximum exposed individual and a collective dose to the exposed population of 4,430 person-rem (2.22 latent cancer fatalities).

4.3.2.3 Waterborne Transport

The precautions currently in use for the pre-LOS ANGELES Class submarine reactor compartments, which would be continued for cruiser and later class submarine reactor compartment shipments, would insure that the probability of an accident is extremely small. Only experienced commercial towing contractors would be used, with the advantage of employing people experienced in the work and the route, using regularly operated and maintained equipment. Two tugs would be used, a primary tug for the tow and a backup tug traveling along with the shipment to take over in case of a problem with the primary tug. Fully crewed, American Bureau of Shipping certified, commercial ocean going tugs would be specified for the tow from the Shipyard to the Portland - Vancouver area on the Columbia River. These would be twin engine and twin propulsion unit vessels, with more power than would be normally employed for an equivalent sized cargo barge of a similar capacity. Two pusher type river tugs with full crews and more than adequate power, one primary and one backup, would be specified by the contract for the Columbia River above the Portland - Vancouver area. This would maximize maneuverability and control of the barge.

All towing operations, including the route to be followed, operating procedures, and casualty procedures, would be in accordance with a formal tow plan developed by a private contractor and approved by the Navy. Puget Sound's normal shipping lanes would be used to the maximum extent possible to minimize the potential for collision or inadvertent grounding. Shipments would not be scheduled when weather conditions are not favorable. Licensed ship pilots would be used in Puget Sound and on the Columbia River. Licensed Columbia River Bar pilots would be used when crossing the Columbia River Bar.

The barges that would be used are part of the disposal program for pre-LOS ANGELES Class submarine reactor compartments. These barges, when loaded with one of the heavier reactor compartment packages covered by this EIS, would have a draft of up to about 3 meters (nine feet). The Columbia River navigation channel is maintained for vessels with drafts up to 4.5 meters (14 feet). The barge length and width would be well within the capacity of the four navigation locks. Overhead clearances on the Columbia River have been evaluated and there are none that would

pose an interference problem for the transit following the pre-existing plans for raising of the Benton County Public Utilities District power lines at Kennewick - Pasco. The barge would be equipped with flooding alarms. A backup towing bridle and tow line would be installed on the barge with a trailing retrieval line behind the barge on the ocean transit portion for bringing the backup towing gear aboard the tug if the primary towing gear were lost.

Each of the barges proposed for use is highly compartmented (12 or more watertight compartments) and is designed to maintain its upright stability with any two compartments flooded. The welds attaching the reactor compartment package to the barge would be strong enough to hold the weight of the reactor compartment even if capsized. The barges meet (a) the United States Coast Guard intact and damaged (one tank flooded) upright stability requirements (46CFR151 and 172); and (b) Navy stability requirements which require stability with two adjacent flooded tanks under storm wind and wave conditions. The barges are able to remain floating after sustaining sugnificant damage. A barge sinking would take an extreme collision scenario. Breach of the reactor compartment package due to collision is not considered a credible event because the reactor compartment would sit well back from the edge of the barge and the exterior of the package would be designed to withstand severe accidents.

As an added safety and security measure, a Navy or Coast Guard escort vessel would accompany each tow. Coast Guard security personnel would be stationed aboard the escort vessel. The role of security personnel would be primarily to protect people and other boats. The escort vessel could act as an independent communication base. Shipyard personnel familiar with the towing procedures and radiological processes would accompany the tow to monitor the operations and provide assistance and advice to the tug captains if needed.

A Final Environmental Impact Statement (FEIS) prepared by the National Oceanic and Atmospheric Administration (NOAA) evaluated establishment of the Olympic National Marine Sanctuary off the Northern Washington State coast (NOAA, 1993). Existing reactor compartment shipments through the marine sanctuary area were described in the NOAA EIS as well as the reason for them and the extensive precautions taken to ensure that these barge shipments are made safely. The NOAA EIS preferred alternative was not to specifically regulate vessel traffic at the time of the sanctuary designation due to the preexisting shipping practices having the desired effect of minimizing risk to the Sanctuary. Continuation of the same prudent shipping practices for future reactor compartment shipments would have no adverse impact on the Marine Sanctuary.

In the extremely unlikely event of sinking, the proposed package designs could potentially be breached due to water pressure. However, the reactor vessel, components, and piping that contain radioactivity are designed to withstand much higher pressures and battle shock, and would continue to provide a barrier to the release of radioactivity. Only a small fraction of the tightly adhering radioactivity deposited on the piping and component internals would be exposed to the environment. This amount of radioactivity would have such a low concentration when deposited in sediment or in the surrounding volume of water as to have virtually no environmental consequences.

This conclusion is confirmed by the radiological monitoring of the USS THRESHER and USS SCORPION submarines which were lost in the deep Atlantic Ocean in 1963 and 1968, respectively. These were extreme accidents causing breakup of the ship. Water, sediment, marine life and debris sampling was conducted in 1965, 1977, 1983, and 1986 at the USS THRESHER site (KAPL, 1993), and in 1968, 1979, and 1986 at the SCORPION site (KAPL, 1993a). Sediment sampling found very low concentrations of cobalt-60 which were determined to be from the reactor

compartment piping systems. The amount of cobalt-60 radioactivity in these samples was small compared to the naturally occurring radioactivity in these sediments. From these samples, the total cobalt-60 activity in the sediment was estimated to be less than 0.001 curie for either site. No radioactivity above background levels due to naturally occurring radioisotopes or fallout from weapons testing was observed in any of the marine life samples analyzed. Water samples showed no detectable radioactivity, except for the naturally occurring radioactivity from isotopes such as Potassium-40 found in sea water. Thus, even the worst case reactor compartment transportation accident would have a negligible impact.

There would be no environmental consequences from a breached reactor compartment package with regard to the non-radiological constituents. This is based on the fact that nearly all the non-radiological constituents (PCBs, lead, chromium, iron, etc) are in a solid (insoluble) state. However, residual potassium chromate solution that cannot be drained and asbestos could be potentially released. In the unlikely event the potassium chromate solution is released to the environment, its concentration would be reduced by the surrounding water to negligible amounts. Asbestos, if present, could be disturbed in an accident and portions of the disturbed asbestos might mix with water entering through the breach. Any asbestos that eventually escaped would be expected to eventually settle out of the water and become incorporated into the sediment.

It would be the Navy's intention to recover a sunken package, and a number of engineered features would be provided to facilitate location and salvage. A buoy would be attached to the barge designed to float to the surface to mark its location. An emergency position indicating radio beacon (EPIRB) would float to the surface and transmit a distress signal on a frequency monitored by the National Transportation Safety Board. Heavy cables or other attachments would be installed on the exterior of the package before shipment to allow the attachment of salvage gear to raise the sunken package using commercial or Navy owned heavy lift ships if refloating the barge is not possible. The barge and package could be raised as a unit, or cut apart by divers for separate recovery, without any impact on the environment.

4.3.2.4 Port of Benton

The package would be off-loaded from the barge at a barge slip at the Port of Benton adjacent to the Hanford Site on the Columbia River. The river water level must be controlled during the off-load to assure the barge remains stable. This would be accomplished by adjustment of the McNary Dam pool level down stream of the barge slip and the flow rate from the up stream dam, Priest Rapids Dam.

The existing Port of Benton facilities would be used for off-loading. These off-loading operations would involve the use of mechanical equipment and vehicles at an existing facility intended for this kind of work. This work would not adversely affect the quality of the river or shore environment. The barge slip facility is currently used for pre-LOS ANGELES Class shipments and is periodically inspected both above and below water. Maintenance work is controlled under the provisions of required permits such as an Army Corps of Engineers permit, and permits from the Washington State Department of Ecology, the Washington State Department of Fisheries and the City of Richland Community Development Department to protect river quality.

4.3.2.5 Land Transport Route

Land transportation would involve moving the transport vehicle over existing roads. Individual transport vehicle wheel loads would be about twice those of commercial trucks, contributing to the need to perform routine maintenance of the roadway. This would involve no additional impact

beyond road maintenance routinely accomplished at the site. Because of the increased dimensions of some of the larger cruiser and submarine packages, at approximately six locations on the Hanford Site, Bonnevile Power Administration electrical lines may need to be modified to provide the safe clearance prescribed by the utilities for energized transmission lines. This would involve adding sections to existing power line support towers or adding additional towers. The Navy will coordinate this work with Bonneville Power Administration. The work would be confined to the immediate vicinity of the towers along the roadway. Some minor straightening of the curve in the road at the Port of Benton is also contemplated to accommodate the larger transporter configurations that would likely be employed for heavier loads.

The transport vehicles that would be specified are designed to transport heavy loads and are very stable. The disposal package would be welded to the transporter. The overland transit would be coordinated by Hanford Site transportation personnel. Pilot cars would provide an escort and assure a clear roadway for the transporter, minimizing the potential for collision by other vehicles due to the slow (about 5 mph) movement of the transport. Train traffic would be curtailed during the land transport on the Hanford Site (the rails crossing the route are only used by the Hanford Site and the usage is on an infrequent basis at limited speeds). Even if there were a collision, the package, which would be designed and certified to withstand more severe hypothetical accidents, would retain its integrity.

4.3.3 Hanford Site

The Hanford Site is located in the southeastern corner of the State of Washington, about 50 kilometers (30 miles) east of Yakima and three miles north of Richland. The 218-E-12B Low Level Burial Ground is situated near the center of the Hanford Site. The nearest barge slip is located at the Port of Benton, which is on the north edge of Richland and just south of the 300 Area of the Hanford Site, approximately 42 kilometers (26 miles) from the 218-E-12B burial grounds.

The Low Level Burial Grounds at Hanford are currently being used for the disposal of solid radioactive wastes similar to the contents of the reactor compartments considered in this Environmental Impact Statement. The burial grounds of the 200 Areas are situated in an isolated area in the Central Plateau region about 11 kilometers (seven miles) from the Columbia River.

The Hanford Future Site Uses Working Group had broad representation from federal, tribal, state and local governments with jurisdictional interests in Hanford, and from agricultural, labor, local cities, environmental, and public interest groups. The working group was charged with the task of articulating a range of visions for future use of the Hanford Site and discussing the implications of those visions.

The Final Report of the Hanford Future Site Uses Working Group, (REPORT, 1992) discussed possible future uses for the 200 Areas at Hanford. This report listed findings and recommendations concerning cleanup limits at the Hanford Site. The Working Group acknowledged "the existing obligations at the Hanford Site to dispose of submarine reactor compartments and commercial Low Level Waste (in accordance with the Northwest Low-Level Radioactive Waste Compact) at the US Ecology site on the state-leased lands in this area. Fulfillment of these obligations is assumed when considering other future use options for the Central Plateau."

Additionally, this report stated that "Waste management, storage and disposal activities in the 200 Area and immediate vicinity should be concentrated within the 200 Area whenever feasible to minimize the amount of land devoted to or contaminated by waste management activities. When bringing wastes to the area, adverse effects should be minimized, especially to currently uncontaminated areas of the Central Plateau."

The preferred alternative of this Environmental Impact Statement does not conflict with the findings and recommendations concerning the 200 Area listed in the Final Report of the Hanford Future Site Uses Working Group (REPORT, 1992). The 200 East Area would not need to be expanded to dispose of the reactor compartments from the cruiser, LOS ANGELES and OHIO Class submarines. Further, there would not be a conflict with the proposed use of the land between 200 East and 200 West Areas for disposal of Hanford cleanup wastes.

4.3.3.1 Extreme Natural Phenomena

The 1987 Final Environment Impact Statement on Disposal of Hanford Defense High Level, Transuranic and Tank Wastes (DOE, 1987) analyzed in detail the natural phenomena considered credible to occur and to have an adverse impact on the Hanford Site. The analysis and conclusions with respect to the 218-E-12B Low Level Burial Ground in the 200 East Area are summarized in this document.

4.3.3.1.1 Flooding

The analysis of the 1987 Final Environment Impact Statement on Disposal of Hanford Defense High Level, Transuranic and Tank Wastes (DOE, 1987) considered flooding scenarios for a variety of conditions; i.e., influences from the Columbia and Yakima Rivers, 25 % and 50 % instantaneous destruction of the center section of the Grand Coulee Dam, and flash flooding of the Cold Creek drainage area.

Maximum Columbia River floods of historical record occurred in 1894 and 1948, with flows of 21,000 m^3/sec and 19,600 m^3/sec, respectively. The likelihood of floods of this magnitude recurring has been reduced by the construction of several flood control/water storage dams upstream of the Hanford Site. The probable maximum flood (the flood discharge that may be expected from the most severe combination of meteorologic and hydrologic conditions reasonably possible in the region) would produce a flow of 40,000 m^3/sec. This flood would not affect the 200 East and West Areas. Similarly, it was determined that waters of a 100-year flood (13,000 m^3/sec) would also have no effect on the 218-E-12B Low Level Burial Ground.

The development of irrigation reservoirs within the Yakima River Basin has considerably reduced the flood potential of the river. It was concluded that the lands susceptible to a 100-year flood on the Yakima River are limited to areas near the southern sections of the Hanford Site and these waters would not reach the 218-E-12B Low Level Burial Ground. Additionally, much of the Yakima River is physically separated from the Hanford Site by Rattlesnake Mountain. This topographic barrier prevents potential flooding of the Yakima River from reaching the Low Level Burial Grounds.

A 50 % instantaneous breach of the Grand Coulee Dam center section would create a maximum flow of 227,000 m^3/sec, for a brief duration, with flood elevations of 143 to 148 meters (469 to 486 feet) above mean sea level in the 100 Areas. Normal river elevations within the Hanford Site range from 120 meters (394 feet) near Vernita (Northwest corner) to 104 meters (341 feet) near the 300 Area (Southeast corner). However, the 218-E-12B Low Level Burial Ground, at an average elevation of 180 meters (590 feet) above mean sea level, would not be reached by the 50 % breach of Grand Coulee Dam.

Potential for flash flooding from the Cold Creek drainage area was also examined and the estimated a maximum flood depth of 2.3 meters (7.5 feet) for the southwestern part of the 200 Areas. This estimated flood depth is not sufficient to reach the 218-E-12B Low Level Burial Ground.

4.3.3.1.2 Earthquakes

Seismic activity and related phenomena are not identified to be of a magnitude that would have significant effects on 218-E-12B burial ground operations.

4.3.3.1.3 Other

An average of ten thunderstorms occur each year. The probability of a tornado striking a point at the Hanford Site was documented as $4x10^{-6}$ per year or 1 in 250,000 per year (DOE, 1987). There have been no documented violent tornadoes for the region surrounding Hanford. Although locally destructive, the tornadoes would move through the area rapidly along with the storm centers and are not expected to be capable of inflicting damage to the reactor compartments.

Other natural phenomena are considered not possible or not capable of inflicting damage to the reactor compartments when disposed of at Hanford.

4.3.3.2 Radiological Impacts

4.3.3.2.1 Radiation Exposure Upon Disposal

There is little risk of radiation exposure to anyone in the general public during movement to the burial ground, actual burial, or after burial. This is because radiation outside the reactor compartment package would be well below the federal limits and the package would have been welded shut at the shipyard to prevent entry. After burial, direct radiation at the land surface would be insignificant (i.e., below detectable levels) due to the low contact radiation fields on the package and the shielding effect of the soil cover.

Over 99.9 % of the radioactivity associated with the reactor compartments from the cruisers, and LOS ANGELES Class and OHIO Class submarines is in the form of radioactive atoms metallurgically bound into the matrix of irradiated metal structural components of the heavy walled pressure vessel and its internal components. These atoms are an inseparable part of the metal and they are chemically just like the rest of the iron, nickel, or other metal atoms in the reactor compartment. These radioactive atoms can only be released from the metal as a result of the slow process of corrosion.

The remaining 0.1 % of the radioactive material that remains in the defueled, decommissioned reactor compartments is wear product activity. The wear product was carried by the primary system through the reactor vessel where it became activated. The activated wear product was then deposited as an adherent film on interior surfaces of the reactor pressure vessel, primary piping, pumps, and steam generator during reactor operation.

4.3.3.2.1.1 Corrosion Performance

High strength (HT/HS) carbon steels, and very high tensile strength nickel alloyed (HY-80), steels would form the exterior of Reactor Compartment Disposal Packages and provide containment for activity within the compartment. Corrosion Resistant Steel (CRES) 304 and Inconel A600 nickel-iron-chromium alloys are present inside the compartments, and would contain most of the

actual radioactivity in a compartment as activated metal. Site specific corrosion studies have been conducted to characterize the corrosion of these metal alloys in Hanford Soils (NCEL, 1992, NIST, 1992, DOE, 1992a, NFESC, 1993).

The soil environment around a buried metal component is a significant factor in determining the corrosion performance of the component. Soil at the 218-E-12B burial ground is a typical mix of sandy-gravel, sand, and gravely sand found in the Hanford Formation. The soil is dry (moisture content of 1-5% by weight), well drained, slightly alkaline (pH of 8.2), and low in chlorides at 0.08 milligram equivalents per 100 grams soil or about 30 ppm. Soil resistivity at the 218-E-12B burial ground is high, measured as greater than 30,000 ohm-cm (PNL, 1992, NFESC, 1993). These conditions, coupled with the average site rainfall of 16 centimeters per year (6.3 inches per year) minimize corrosion.

The corrosion studies showed that corrosion rates for carbon steels in the Hanford soil would be low, with an expected average pitting corrosion rate of 0.0025 centimeters per year (0.001 inch per year), and an expected average general corrosion rate of 0.0005 centimeters per year (0.0002 inch per year). The maximum pitting corrosion rate predicted was 0.0089 centimeters per year (0.0035 inch per year), with a corresponding maximum general corrosion rate of 0.0015 centimeters per year (0.0006 inch per year).

These corrosion rates were based on a comparison to actual test data from underground storage tanks exhumed at the Hanford Site as well as available data from National Institute of Standards (NIST) test sites with soil conditions approximating those at Hanford.

The actual corrosion values for compartment structure are expected to be less than these predictions. The studies were based on test data for open hearth carbon steel which is somewhat less corrosion resistant than the HT/HS carbon steel and HY-80 steel typically forming the exterior of reactor compartments. In addition, no credit was taken for the protective cover that will be installed over the trenches to minimize moisture in the soil. Even under these conservative assumptions, it was estimated that the first potential generation of leachate could not occur for at least 600 years, after general corrosion results in failure of endplates allowing soil to enter (DOE, 1992a). The reactor compartment disposal packages for the cruisers, LOS ANGELES, and OHIO class submarines will be as robust, composed of similar alloys, and as such would exhibit similar corrosion performance as the pre-LOS ANGELES class submarines.

Upper limit corrosion rates expressed in milligrams of metal alloy weight loss per square decimeter of surface per year, for HY-80, CRES 304, and A600 Inconel alloys present in Naval Reactor Compartments, were also estimated for the 218-E-12B burial ground (NFESC, 1993). These corrosion rates are as follows: for HY-80 - 70 milligrams per square decimeter per year, for CRES 304 - 0.02 milligrams per square decimeter per year, and for A600 Inconel alloy - 0.01 milligrams per square decimeter per year.

The estimated rates were based on a study of sites where NIST corrosion test data was available. For the subject alloys, an NIST site was selected based on soil characteristics that were considered similar to the compartment burial site; for example, sites with well drained, dry, alkaline soil, and low chlorides were considered most suitable. Alloy test data from the selected site was adjusted for the high soil resistivity of soil at the 218-E-12B burial ground (30,000 ohm-cm plus).

Actual weight loss rates for the CRES 304 and A600 Inconel alloys are expected to be much lower than the low rates already estimated. In the 218-E-12B burial ground environment, corrosion may not initiate on CRES and it is likely that corrosion would not initiate (at all) on the Inconel alloy (NFESC, 1993).

4.3.3.2.1.2 Site Specific Migration Studies, Radionuclides

Pacific Northwest Laboratory estimated the release and migration of nickel through soils and groundwater at the Hanford Site 218-E-12B burial ground (PNL, 1994a). This study considered the disposal of a group of 120 large metal components (i.e., reactor compartments) at the burial ground as a potential nickel radionuclide source due to the presence of metal alloys inside the compartments that contain activated nickel (nickel-59 and nickel-63). The number of compartments considered was based on the existing capacity of the burial trench at 218-E-12B dedicated for reactor compartment disposal (Trench 94). However, compartments were modeled with average quantities of nickel alloy and activated nickel based on total inventories in pre-LOS ANGELES, LOS ANGELES, and OHIO reactor compartments and all cruiser reactor compartments. If the preferred alternative for disposal of cruiser, LOS ANGELES, and OHIO reactor compartments was selected, Trench 94 could receive cruiser, LOS ANGELES, and OHIO Class submarine reactor compartments as well as or in lieu of pre-LOS ANGELES Class submarine reactor compartments which are currently being placed in the trench. This would fill the trench to its current capacity of 120 compartments. Additional capacity would be required for remaining compartments being disposed of (bounded 220 compartments combining the pre-LOS ANGELES Classes with the about 100 reactor compartments considered in this final EIS).

Potential concentrations of nickel-59 and nickel-63 resulting in the underlying aquifer from reactor compartment disposal were estimated as well as migration times for such concentrations to occur. Resulting radiological doses to persons using the aquifer were also calculated. The release and migration of total elemental nickel from the compartments was also estimated in order to accurately predict migration times to the aquifer.

Figure 4.1 shows the basic migration model for the nickel migration study. The TRANSS computer code, a one dimensional streamtube model (PNL, 1986a), was employed to predict migration through the soil, the compartments and in the aquifer itself. A Hanford Site aquifer model which incorporates site data and the Coupled Fluid, Energy, and Solute Transport (CFEST) computer code (PNL, 1982) was employed to provide required data for TRANSS. Geologic, geochemistry, and geohydraulic data inputs for these codes were obtained from available literature and from laboratory testing using actual 218-E-12B burial ground soil samples. The GENII computer code (the Hanford Environmental Radiation Dosimetry Software System) (PNL, 1988) was employed to calculate exposure.

The amount of precipitation falling on the site that would infiltrate through the soil to the buried compartments and downwards to the aquifer (recharge) was modeled at 0.5 centimeters per year (0.2 inches per year) for the current arid climate condition. A postulated wetter condition was also modeled with a recharge rate 10 times greater than that used for the current climate. The soil column from compartments to aquifer was modeled at 45 meters (approximately 150 feet) of thickness based on site measurements from the floor of the current excavation (Trench 94). This soil thickness represents the minimum distance from the compartments to the aquifer expected for disposal of reactor compartments at the 218-E-12B burial ground.

Nickel radionuclides were modeled as activated constituents of Corrosion Resistant Steel (CRES) 304 and Inconel Alloy 600 inside the compartments. Upper limit corrosion rates for these alloys when buried at the 218-E-12B burial ground were identified by the Naval Facilities Engineering Service Center at 0.01 milligrams alloy corroded per square decimeter of alloy surface per year (0.01 $mg/dm^2/yr$) (2.05E-7 $lb/ft^2/yr$) for the Inconel and 0.02 $mg/dm^2/yr$ (4.09E-7 $lb/ft^2/yr$) for the CRES (NFESC 1993). This corrosion study also identified that corrosion may not initiate on the

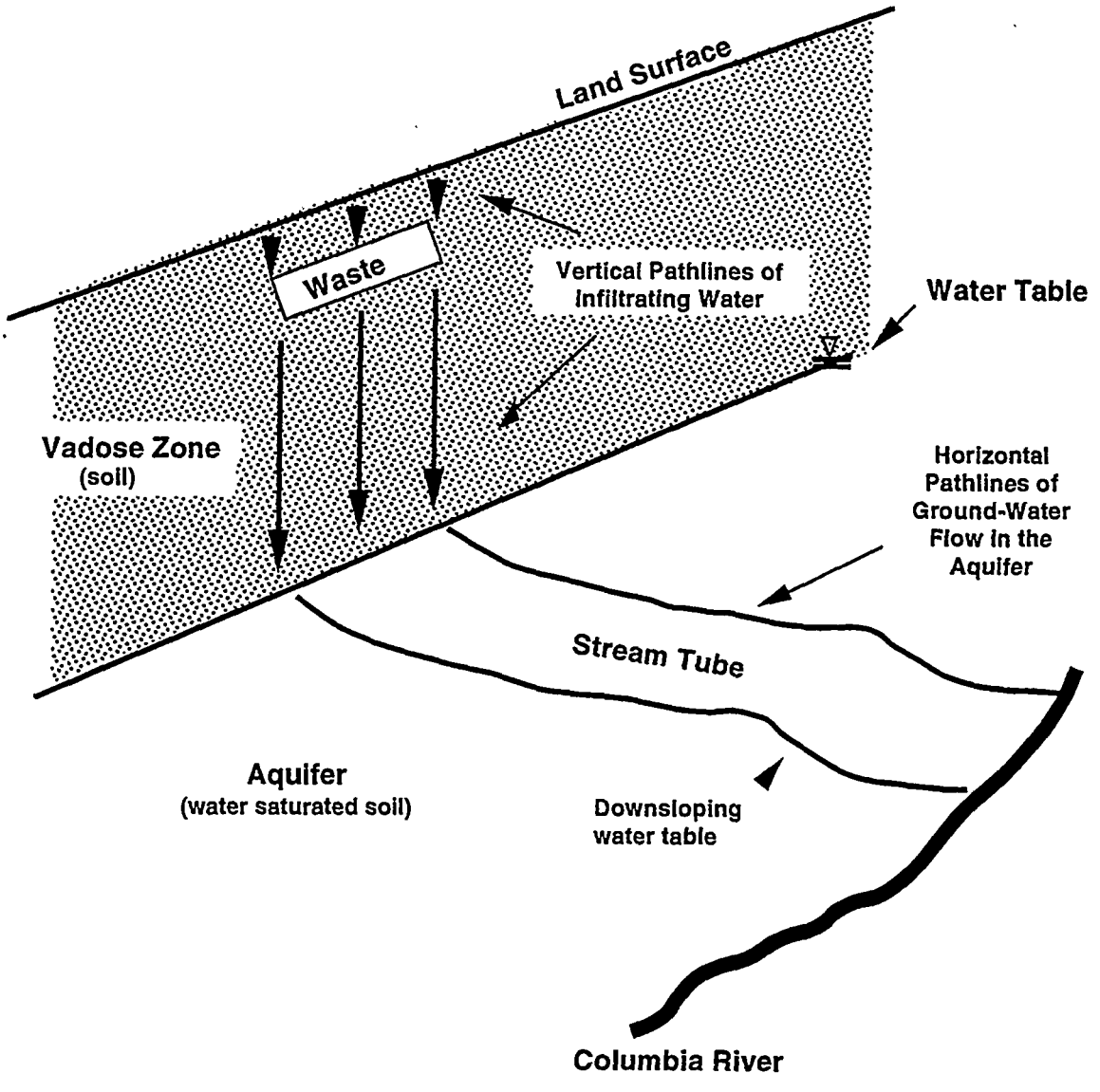


Figure 4.1. Basic Migration Model Including Depiction of the Streamtube Approach to Transport in the Underlying Aquifer

Inconel alloy at all after burial. Corrosion of these alloys would allow radionuclides to be transported if sufficient water were available in the soil to dissolve the corrosion products. Nickel-63 would decay to negligible levels in the magnitude of $1x10^{-10}$ picocuries per liter prior to reaching the aquifer even under the postulated wetter condition.

The 120 compartments considered were modeled in a compact rectangular array (the planned configuration for Trench 94), Figure 4.2. The TRANSS model effectively treated this array as a single large nickel source, Figure 4.1. Consequently, each compartment in the array was modeled with an average nickel alloy and nickel-59 content (per alloy). Quantities were averaged from the total inventory of Inconel Alloy 600, CRES 304, and nickel-59 in pre-LOS ANGELES, LOS ANGELES, and OHIO reactor compartments and all cruiser reactor compartments. The average nickel-59 content (per alloy) per compartment was coupled to the corrosion rates estimated for the CRES and Inconel 600 alloys and surface area terms for these alloys to estimate the quantity of nickel-59 released per compartment by corrosion. No credit was taken for the containment provided by the compartments. Nickel-59 release rates calculated by this method were also conservative if only pre-LOS ANGELES class compartments were disposed of at the 218-E-12B burial ground as these compartments contain a lower concentration of nickel-59 (in nickel alloy) than modeled by the average quantities determined for the nickel migration study (PNL, 1994a).

HY-80 steel alloy forms part of the exterior containment structure of most reactor compartments and contains non-radioactive nickel. This alloy was considered to be less corrosion resistant than the CRES 304 and Inconel alloys and recharge water contacting the compartments could become chemically saturated with dissolved nickel due to non-radioactive nickel released from the corrosion of the HY-80 steel alloy. The release of radioactive and non-radioactive nickel by corrosion would occur simultaneously, competing for the available capacity of the water to hold dissolved nickel (solubility). In order to conservatively predict nickel-59 transport, the migration model was configured to allow all nickel-59 released by CRES and Inconel corrosion to preferentially dissolve with the non-radioactive nickel making up the balance of the groundwater's nickel solubility. Even so, non-radioactive nickel occupied over 99.9% of the groundwater's dissolved nickel capacity (solubility) with this modeling approach. The solubility concentration of nickel in Hanford groundwater was determined initially by computer code and verified by laboratory experiments for estimating nickel migration.

Batch and flow-through column laboratory experiments with 218-E-12B soils showed that nickel dissolved in the groundwater (solubilized nickel) would be adsorbed in soil under the compartments, retarding the movement of nickel towards the aquifer. Radioactive nickel was considered to be adsorbed at the same rate as non-radioactive nickel; however, on a mass basis, virtually all solubilized nickel would be non-radioactive and thus occupy most available soil adsorption sites. Nickel adsorption was modeled using a Freundlich adsorption isotherm. This mathematical equation, dating from 1926, predicts adsorption from non-linear data and was considered appropriate for use in this study.

Iron and chromium (from steel alloys) would not be sufficiently soluble in a form that could compete with nickel for soil adsorption sites. Laboratory tests were conducted to determine the competitive effect of lead released from lead shielding in the compartment on nickel adsorption. These tests demonstrated that nickel adsorption was not influenced by the presence of lead at levels expected in the groundwater as a consequence of migration from the compartments.

The nickel released from each compartment was considered to migrate vertically downward, carried along through the soil by the groundwater which dissolved the nickel. Adsorption, as discussed previously, would delay the arrival of this nickel at the aquifer. Upon arrival at the aquifer, this larger body of water, modeled as a streamtube by the TRANSS code, would carry the nickel away from the burial ground.

For the nickel migration study, all nickel released from the 120 compartment array was modeled as entering a single hypothetical streamtube of width equal to the diagonal of this rectangular array is 461 meters (1513 feet) consistent with CFEST predictions of flow in the aquifer under the site in a general northerly direction for the future wetter condition, and the absence of an aquifer directly under the site under the current climate condition without artificial recharge, (groundwater would contact bedrock under the site and move southward through unsaturated sediment along the bedrock surface until entering the aquifer). Flow within the aquifer for the current climate conditions is predicted to be generally east to southeastward toward the Columbia river (Figures 4.1 and 4.2).

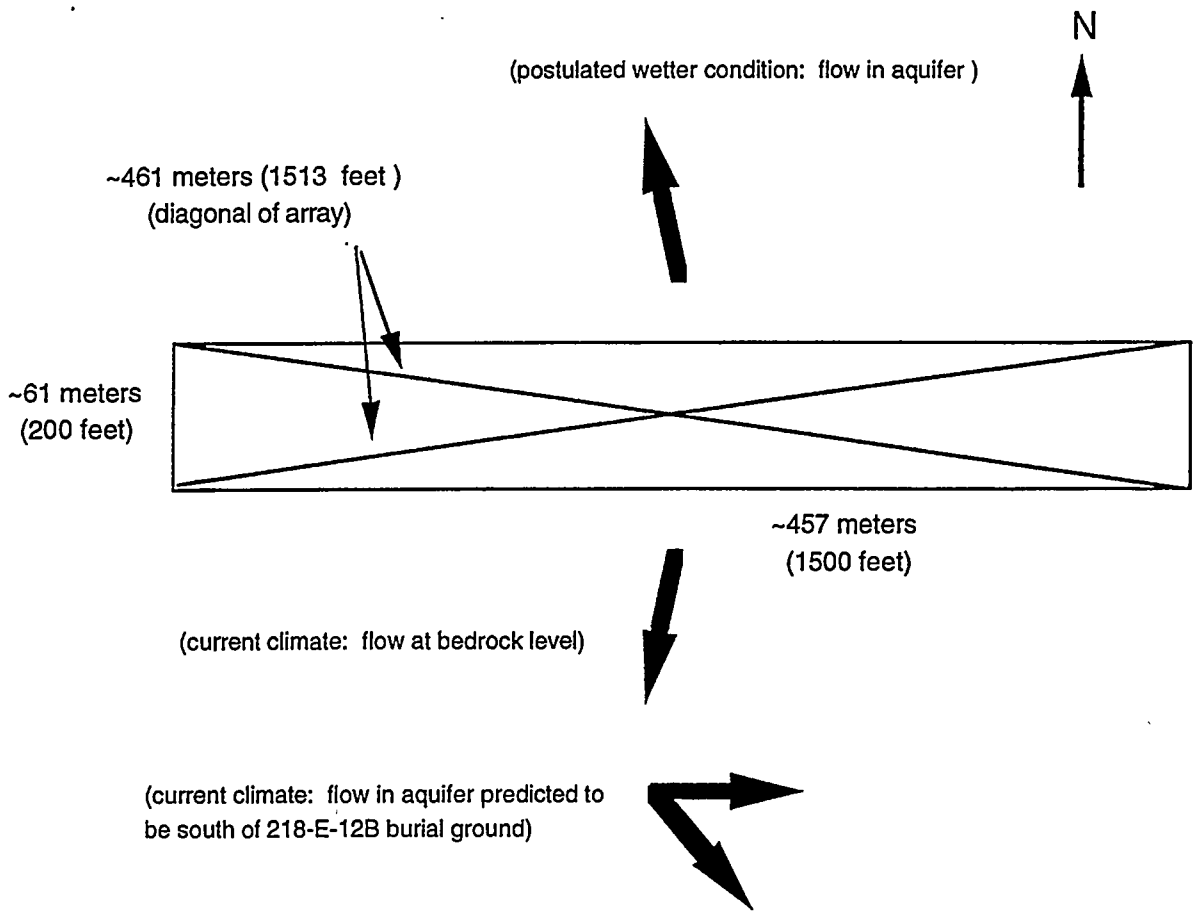
A complex geologic pattern is present in the basalt bedrock under the 218-E-12B burial ground. Although flow is predicted to be southerly across the diagonal of the array for the current climate case, the CFEST computer code does not model the exact contour or extent of "dry" bedrock under the burial ground, causing the predicted flow direction to be less certain than for the wetter condition modeled. Flow in alternate directions would reduce the width of the tube and the volume of water in the aquifer streamtube. As a result, predicted concentrations in the streamtube for the current climate condition would increase. The range of possible streamtube widths varies from the current 461 meters (1513 feet) down to 61 meters (200 feet) for a west to east flow direction, which although unlikely, could potentially occur if the aquifer did not recede to south of the burial ground and was still present under the site.

Streamtube depth of 2.5 to 5 meters (8.2 to 16.4 feet) were used to model the current and wetter condition, respectively. The modeling did not allow mixing of water between the streamtube and adjacent water at locations downgradient (downstream) of the burial ground (i.e., no dissipation of the nickel plume by spreading out).

Resulting concentrations of nickel and radioactive nickel for the 461 meter wide streamtube were estimated for the Columbia River and for hypothetical wells tapping the streamtube at 100 meters (330 feet) and 5000 meters (16,400 feet) from the burial ground (100 meter and 5000 meter wells, respectively). Radiological doses for a maximally exposed individual, identified as a farmer using the aquifer water at the site (100 meter well), and future downriver populations using Columbia River water were calculated based on predicted radioactive nickel concentrations.

In Title 10 of the Code of Federal Regulations, the U.S. Nuclear Regulatory Commission limit for nickel-59 in water effluent released to unrestricted areas is $3x10^{-4}$ microcuries per milliliter (equivalent to 300,000 picocuries per liter) (10CFR20). This requirement defines an unrestricted area as having no access controls for protection of individuals from exposure to radiation and radioactive materials and any area used for residential quarters.

Under current climate conditions, nickel-59 was not predicted to migrate to the 100 meter well for 800,000 years. Transit time through the soil column between compartments and aquifer accounted for almost all of this time, within 1000 years. Peak concentrations of nickel-59 in the aquifer at the 100 meter well occurred shortly after 800,000 years and were estimated at 0.007 picocuries per liter (and 0.009 milligrams per liter), respectively.



Note: Upper arrow shows predicted direction of flow in the aquifier under Trench 94 for the postulated wetter condition. Lower arrows show predicted movement of water under current climate (at bedrock level under Trench 94 and within the aquifer predicted to be south of the 218-E-12B burial ground). Directions are from CFEST based modeling based on orientation of Trench 94, 218-E-12B.

Figure 4.2. Overhead View of Trench 94 Hanford Site 218-E-12B Burial Ground

Under the postulated wetter condition (10 times current recharge assumed), nickel-59 was not predicted to migrate to the 100 meter well for about 66,000 years. Peak concentrations of nickel-59 in the aquifer at the 100 meter well occurred at 68,000 years and were estimated at 2.0 picocuries per liter, respectively. A 2.0 picocurie per liter concentration represents 0.0007% of the Nuclear Regulatory Commission limit discussed above.

The dose to a maximally exposed individual resulting from nickel-59 in the aquifer was calculated as 3.3×10^{-6} mrem/yr for the current climate condition and 0.00097 mrem/yr for the postulated wetter condition. These doses were calculated from all exposure pathways based on a farmer drawing water for irrigation, animal consumption, and human consumption at a well 100 meters downstream of the site. Exposure through the drinking water pathway alone results in a lower dose than provided above. In Title 40 "Environment" of the Code of Federal Regulations, the Environmental Protection Agency limits exposure from drinking water at a 2 liter/day (0.53 gallon/day) consumption to 4 mrem per year (40CFR141). The entire maximally exposed individual dose is less than 0.025% of the 4 mrem per year Environmental Protection Agency limit.

For the postulated wetter condition, nickel-59 (and nickel) was not predicted to reach the Columbia River for about 260,000 years. The dose to the maximally exposed downriver person was calculated at 1.8×10^{-10} mrem per year. This dose can be compared to the 0.02 mrem per year dose resulting from Hanford Site operations in 1993, which was calculated in the 1993 Hanford Environmental Report (PNL, 1994c) under similar assumptions for a maximally exposed individual.

The Environmental Protection Agency, under the National Primary Drinking Water Standards provides a Maximum Contaminant Level (MCL) of 0.1 milligrams per liter for nickel in community and non-community water systems serving 25 or more people (40CFR141). The Environmental Protection Agency states that drinking water which meets this standard should be considered safe with respect to nickel (40CFR141). For exposure via drinking water, the Environmental Protection Agency also has advised that a higher 0.35 milligrams per liter concentration of nickel represents a level at which adverse effects would not be anticipated to occur for a lifetime of exposure of adults (ATSDR, 1988). From the nickel migration study (PNL, 1994a), predicted total elemental nickel concentrations for the aquifer streamtube ranged from 0.009 to 0.051 mg/L depending on the recharge condition (i.e., current and wetter, respectively). These peak concentrations were predicted to occur at the same times as for nickel-59. Total elemental nickel concentrations in the Columbia River ranged from 1.8×10^{-9} to 2.2×10^{-8} mg/L as derived from predictions of peak nickel flux to the river and a river flow rate of 100 trillion liters/year (about 112,000 cfs) assumed by Pacific Northwest Laboratory. All predicted total nickel concentrations, which are below both standards discussed above, were based on a conservative assumption that all groundwater contacting the compartment would exit saturated with nickel.

4.3.3.2.1.3 Extrapolation of Pacific Northwest Laboratory Nickel Study Results

The results from the Pacific Northwest Laboratory nickel migration study (PNL, 1994a) were extrapolated by the Navy to consider the cumulative effects of cruiser, LOS ANGELES, and OHIO Class submarine reactor compartments with pre-LOS ANGELES Class submarine reactor compartments at the 218-E-12B burial ground. A total of 220 reactor compartments at the 218-E-12B burial ground were considered in the extrapolation for a conservative estimate of combined impact (pre-LOS ANGELES Class under the current disposal program plus the about 100 reactor compartments being considered under this final EIS). The detailed extrapolation study is documented in a Navy study (USN, 1995) and is summarized below.

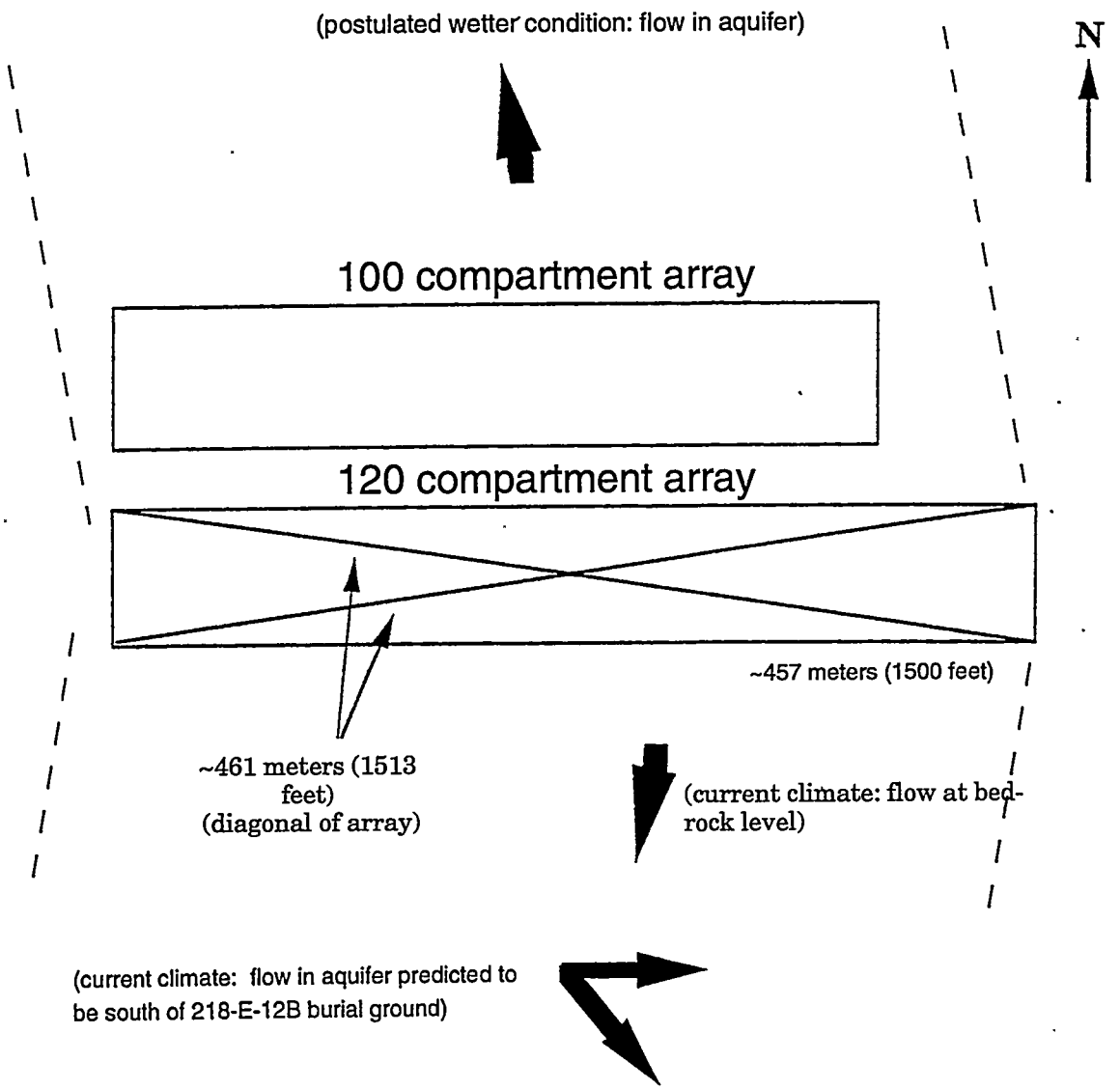
For the extrapolation, the 220 compartments were modeled in two parallel and adjacent arrays of 120 and 100 compartments each, Figure 4.3. Based on CFEST predictions from the lead and nickel migration studies (PNL, 1992, PNL, 1994a) this array configuration would introduce nickel from both arrays into essentially the same aquifer streamtube flowing under the burial ground and thus represents a worst case for the combined effect of the pre-LOS ANGELES and cruiser, LOS ANGELES, and OHIO class compartments.

The combined total of 220 compartments could be treated as a single large nickel source. Consequently, the compartments were modeled with average CRES 304, Inconel Alloy 600, and activated nickel quantities, consistent with the modeling conducted in the nickel migration study (PNL, 1994a). The average quantities for nickel alloy and activated nickel used by Pacific Northwest Laboratory reflected the average of pre-LOS ANGELES, LOS ANGELES, and OHIO classes of nuclear-powered submarines and all nuclear-powered cruisers. Thus, no change in these quantities was required for the extrapolation. Similarly, CRES 304 and Inconel Alloy 600 surface area estimates from the nickel migration study (PNL, 1994a) and corrosion rates from the Naval Facilities Engineering Service Center study (NFESC, 1993) remained applicable to the extrapolated condition.

Migration times as predicted in the nickel migration study (PNL, 1994a) were essentially unaffected by the extrapolation. The two arrays would not be considered by the modeling employed to release nickel into the same vertical soil column. However, within the aquifer, the two arrays would be considered to share the same streamtube, resulting in an increased concentration of nickel within the streamtube. With this condition, the use of an adsorption isotherm would result in a minor reduction in overall migration time compared to PNL, 1994a (a difference of less than 1% at the 100 meter well to less than 10% at the Columbia River).

As previously discussed, the U.S. Nuclear Regulatory Commission limit for nickel-59 in water effluent released to unrestricted areas is 0.0003 microcuries per milliliter (equivalent to 300,000 picocuries per liter) (10CFR20) and the Environmental Protection Agency limit for drinking water exposure dose is 4 mrem per year (40CFR141). For 220 reactor compartments in the assumed adjacent array configuration, under current climate conditions, peak nickel-59 concentration remained below 0.02 picocuries per liter (790,000 year migration time). For the postulated wetter climate condition (10 times higher recharge), peak concentration of nickel-59 was about 4 picocuries per liter, 0.0014% of the Nuclear Regulatory Commission limit (66,000 year migration time). Maximally exposed individual dose remained under 0.002 mrem per year under the wetter condition or less than 0.05% of the Environmental Protection Agency limit.

The Environmental Protection Agency (EPA) provides a Maximum Contaminant Level (MCL) of 0.1 milligrams per liter for nickel in community and non-community water systems serving 25 or more people (40CFR141). For exposure via drinking water, the Environmental Protection Agency also has advised that a higher 0.35 milligrams per liter concentration of nickel represents a level at which adverse effects would not be anticipated to occur for a lifetime of exposure of adults (ATSDR, 1988). For 220 reactor compartments in the assumed adjacent array configuration, under current climate conditions, peak total elemental nickel concentration in the aquifer at 100 meters downstream of the burial ground remained below 0.02 milligrams per liter (790,000 year migration time). For the postulated wetter climate condition (10 times higher recharge), peak total elemental nickel concentration in the aquifer at 100 meters downstream of the burial ground remained just below 0.1 milligrams per liter (66,000 year migration time). Only under the



Note: Upper arrow shows predicted direction of flow in the aquifer under Trench 94 for the postulated wetter condition. Lower arrows show predicted movement of water under current climate (at bedrock level under Trench 94 and with the aquifer predicted to be south of the 218-E-12B burial ground). Directions are from CFEST modeling based on orientation of Trench 94, 218-E-12B and orientation of adjacent 100 compartment array. Dashed lines define the streamtubes modeled.

Figure 4.3. Overhead View of Trench 94 and Second Trench to the North, Hanford Site 218-E-12B Burial Ground

postulated wetter condition was the lower of the two standards discussed above approached. However, the extrapolated total elemental nickel concentrations were based on a conservative assumption that all groundwater contacting the compartment would exit saturated with nickel.

Migration time to the aquifer for all forms of nickel and all migration scenarios considered was a minimum of 66,000 years. For comparison, the recorded history of human civilization is less than ten thousand years, and it is likely that human and geologic events occurring over the predicted time frame would result in impacts to the environment of a far greater nature. Figure 4.4 provides a timeline showing predicted migration times for nickel-59 and lead taken from 218-E-12B site specific studies (PNL, 1992, PNL, 1994a, USN, 1995).

The results of the extrapolation study (USN, 1995) can also be considered to bound the option of obtaining additional trench capacity by placing reactor compartments within Trench 94 closer together than currently done. The Pacific Northwest Laboratory nickel migration study (PNL, 1994a) employed a 150 square meter (1650 square foot) "storage area" per reactor compartment. Recharge passing through this area was assumed to contact the reactor compartment and exit saturated with nickel. The released nickel was then assumed to migrate vertically downward within a column of soil defined by this "storage area" and the depth to the vadose zone. The 150 square meter (1650 square foot) area is considerably smaller than the 230 square meter (2500 square foot) area of trench floor currently claimed per reactor compartment. Thus, placing reactor compartments closer together would not affect predicted nickel migration times as the nickel released from one reactor compartment would not enter a soil column modeled as receiving nickel from another compartment. In addition, predicted groundwater concentrations and resulting user doses would not be affected by the closer spacing of reactor compartments. The Pacific Northwest Laboratory modeling treated the entire array of reactor compartments as a single nickel source to the aquifer. The extrapolation study used a 457 meter (1500 foot) streamtube width for that portion of the aquifer receiving nickel from the reactor compartments above. Figure 4.2 would also represent the closer spacing of reactor compartments at Trench 94 except that the resulting array and stream tube width would actually be a little larger than shown. A larger streamtube width would result in lower predicted concentrations and doses.

4.3.3.2.1.4 Radioactive Corrosion Products Available for Migration

The predominant radionuclide present in Naval nuclear reactor compartments is cobalt-60, which emits highly penetrating energetic gamma radiation and decays by a factor of two every 5.3 years. From Table 1.1, over 10,000 curies of cobalt-60 could be present in a reactor compartment. This radionuclide also forms the bulk of the activated wear product distributed through the reactor plant. However, all of this radionuclide would decay to less than 1 microcurie in less than 200 years. During this time period, the compartment would remain intact, thus no migration could occur. At 50 years after disposal, Cobalt-60 decay would virtually eliminate external exposure to radiation even if someone were to enter the reactor compartment inadvertently (Appendix B).

Table 1.1 lists other radionuclides in quantities greater than 1% of total activity. Appendix D lists long lived radionuclides present in the reactor compartments which result from the neutron activation of structural materials. For most of the next millennium, the reactor compartment containment structure would effectively isolate this radioactivity from the environment. During this time the majority of the radioactivity would decay away. After 500 years, only about 1/50th to 1/200th of the activity of Table 1.1 would remain, all as nickel-63. Nickel-63 emits only beta particles. From Appendix D, at 2000 years, a few hundred curies, at most, of long lived activity would remain. Over 90%, of this activity would be nickel-59, which emits only weak X-rays and

electrons. The remainder would essentially be carbon-14 and niobium-94. Carbon-14 emits only beta particles, and niobium emits a less energetic gamma than cobalt-60 and is also in small quantity.

The reactor vessel itself would continue to provide containment well beyond the point at which the compartment is breached (Appendix B). Remaining long lived radioactive atoms would be metallurgically bound into the matrix of irradiated metal structural components of the heavy walled reactor pressure vessel and its internal components. Release of these radionuclides to the environment would occur primarily by the very slow corrosion of the CRES 304 and Inconel Alloy 600 alloys in the vessel and internal components and the subsequent dissolving of the corrosion products into available water contacting the alloys.

Nickel-59 and Nickel-63

The results of the Pacific Northwest Laboratory nickel migration study have been extrapolated to account for the cumulative effect of 220 compartments comprising cruisers and the pre-LOS ANGELES, LOS ANGELES, and OHIO classes at the Hanford 218-E-12B burial ground (USN, 1995). The Navy's extrapolation determined that under the current site conditions, the maximally exposed individual who utilizes a well located 100 meters downstream of the 218-E-12B burial ground as the sole source of water would receive a radiological dose of less than $1x10^{-5}$ mrem per year of exposure from the 220 compartments. This dose would result from nickel-59, the nickel-63 having fully decayed prior to reaching the aquifer.

This dose is less than one millionth of the radiological dose an average individual normally receives from natural background radiation. Natural background radiation is what all people receive every day from the sun or from cosmic radiation, and from the natural radioactive materials that are present in our surroundings, including the rocks or soil we walk on. A typical person in the United States receives a 300 mrem/yr dose each year from natural background radiation (NCRP, 1987).

Niobium-94

The typical niobium-94 content in cruiser, LOS ANGELES, and OHIO reactor compartments is less than 1 curie. The total niobium-94 content of 220 reactor compartments is expected to be about 100-200 curies. Niobium-94 constitutes only a very small fraction of the existing radioactive waste at Hanford.

Niobium-94 is present in the reactor compartments as an integral activated part of the corrosion resisting materials contained within the pressure vessel (e.g., CRES 304 and Inconel Alloy 600). Release of niobium-94 from the reactor compartments would be controlled by the corrosion rate of these corrosion resisting alloys. This corrosion rate would be bounded by the rate provided by the Naval Facilities Engineering Service Center for buried CRES 304 alloy at the 218-E-12B burial ground of 0.02 milligrams alloy corroded per square decimeter alloy surface per year ($mg/dm^2/yr$) (NFESC, 1993). Consequently, the time required for the full corrosion of all niobium-94 bearing alloy in the reactor compartment is so long, at greater than 10,000,000 years, as to allow only less than 0.4% of the total quantity of niobium-94 in a reactor compartment to be released to the environment prior to complete decay (Appendix B).

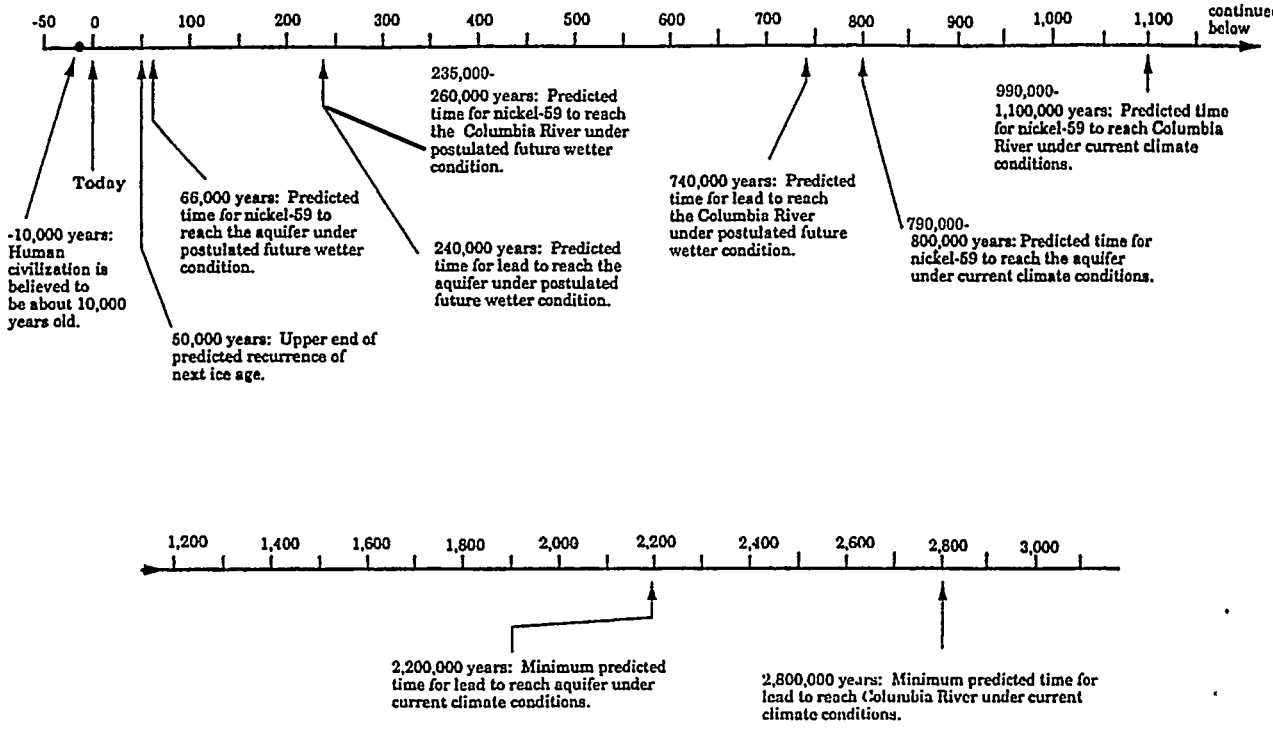


Figure 4.4. Timeline for Migration of Lead and Nickel-59 (time scale in thousands of years)

In Title 40 "Environment" of the Code of Federal Regulations, the Environmental Protection Agency limits radiological dose from drinking water at a 2 liter/day (0.52 gallon/day) consumption to 4 mrem per year (40CFR141). The Washington State Administrative Code (WAC), Part 173-200, establishes a 50 pCi/L limit for gross Beta activity in groundwaters. Given the long corrosion life of the materials containing Niobium-94, and adsorption of niobium-94 in subsurface soils, this radionuclide would enter the environment at such a minimal rate that its contribution to the radiological dose or groundwater concentration would be minor.

Carbon-14

Carbon-14 content in cruiser, LOS ANGELES, and OHIO reactor compartments ranges from less than 1 curie to over 10 curies. The total carbon-14 content of 220 reactor compartments is expected to be about 500-1,000 curies. Carbon-14 decays with a half-life of 5730 years; however, only low energy beta radiation is emitted as a result of this decay process. Carbon-14 in reactor compartments is locked in trace quantities within the molecular structure of metal alloys. Release of carbon-14 from the reactor compartments would be controlled by the corrosion rate of the corrosion resisting alloys containing the carbon-14. This corrosion rate would be bounded by the rate provided by the same CRES 304 corrosion rate discussed previously. Consequently, the time required for the full corrosion of all carbon-14 bearing alloy in the reactor compartment is so long, at greater than 10,000,000 years, as to allow only less than 0.2% of the carbon-14 in a reactor compartment to be released to the environment prior to complete decay (Appendix B). This release mechanism is much slower than the oxidation of pure carbon graphite evaluated in the Final Environmental Impact Statement on Decommissioning of Eight Surplus Production Reactors at the Hanford Site (DOE, 1992b).

Based on the expected carbon-14 inventory for 220 reactor compartments, less than 2 curies (less than 0.2% of the total) would be released to the environment over the corrosion life of the activated alloys containing the carbon-14. Since this corrosion life is very long, on the order of millions of years, the maximum release rate of carbon-14 would be less than 0.0001 curie/year. To put this small release rate into perspective, Title 10, Code of Federal Regulations, Part 20.2003 (10CFR20) allows NRC licensees to discharge up to one curie per year of carbon-14 containing compounds directly to sanitary sewers in concentrations below 0.3 microcuries per liter. Averaging the compartment release rate into the yearly volume of recharge water passing through the burial ground from the Pacific Northwest Laboratory migration modeling results in a Carbon-14 concentration in vadose zone groundwater at less than the 0.3 microcurie per liter standard.

The consequences of releasing carbon-14 in the quantities under consideration are small. For example, estimates of radiological dose resulting from the localized surface release to the atmosphere of one curie of carbon-14 over one year indicate that the maximally exposed individual 5,000 meters (16,400 feet) from the release would receive only 0.015 mrem when calculated using the EPA COMPLY Code, Version 1.4. However, for reactor compartments, this dose would be at least three orders of magnitude lower not only because of the much lower release rate but because releases of carbon-14 from buried naval reactor compartments will be by the groundwater pathway vice the surface pathway. This would be less than $5x10^{-9}$ of the dose to the same individual from natural background radiation in the same year.

4.3.3.2.1.5 Population Radiation Dose and Risk

The risk associated with disposal of long-lived radionuclides is the health effect upon future populations that may be exposed to this radioactivity through various environmental pathways. Models to estimate these health risks have been developed by both the Environmental Protection Agency and the United States Department of Energy. The Department of Energy estimates for Hanford releases are in a component of GENII (PNL, 1988), a computer program called "A Computer Program for Calculating Population Dose Integrated over Ten Thousand Years" (DITTY) (PNL, 1986b). DITTY results are in terms of a collective population dose (person-rem) over a 10,000 year period in a 3-million person stabilized population (ten times the current population in an 80 kilometer (50 miles) radius of the Hanford Site) per curie of a specific radionuclide released. Over a 10,000 year period, the 3 million person population would receive about 9 billion person-rem of collective dose due to naturally occurring radiation, resulting in about 4.5 million latent cancer fatalities. For the significant long-lived radionuclides in 220 reactor compartments the health effects have been predicted and are summarized as follows:

Nickel-59 - The maximum collective dose to the future population over 10,000 years has been estimated to be about 0.001 person-rem for 220 reactor compartments at the 218-E-12B burial ground (USN, 1995). This dose is substantially lower than the dose that would be expected to result in a single latent cancer fatality (2000 person-rem) over this 10,000 year period (PNL, 1994a).

Niobium-94 - DITTY (PNL, 1986b) estimated the total fatal cancers to the future population over 10,000 years from release of niobium-94 as 0.004 cancers per curie released. As discussed previously, less than 0.4% or approximately 0.6 curies is released to the environment with the remainder decaying while still locked within corroding alloy. Thus the number of latent cancer fatalities would be bounded by 0.003. However, this release is spread out over the very long corrosion life of the structure containing niobium 94 so that annual releases would be bounded at 10^{-5} curies/year. This slow release, combined with adsorption of niobium 94 in subsurface soil, would further reduce the potential for fatalities.

Carbon-14 - The Final Environmental Impact Statement on Decommissioning of Eight Surplus Production Reactors at the Hanford Site (DOE, 1992b) estimated the total latent cancer fatalities to the future population from the release of carbon-14 as $6x10^{-5}$ cancers per curie released. As discussed previously, less than 0.2% or about 2 curies of the total inventory of carbon-14 expected for 220 reactor compartments is released to the environment with the remainder decaying while still locked within alloy. This equates to less than $1.2x10^{-4}$ latent cancer fatalities.

Thus, the person-rem of total dose associated with the preferred alternative of land disposal has been estimated to result in much less than one latent cancer fatality to a future 3-million person population over a 10,000 year time period. This is insignificant compared to the expected 4.5 million latent cancer fatalities from natural background radiation occurring over the same 10,000 year period.

4.3.3.2.1.6 Waste Management Consequences

Approximately 4 hectares (10 acres) of land would be required for land disposal of the approximately 100 reactor compartment disposal packages from cruisers, LOS ANGELES, and OHIO Class submarines if additional capacity were obtained through expansion of Trench 94 or construction of a new trench. This would be a commitment of about 4 hectares (10 acres) of land from the 218–E–12B low level burial ground in the 200 East area of the Hanford Site. As is the

case with other areas of the Hanford Site used for radioactive waste disposal, the land area used for disposal of the reactor compartment disposal packages and the surrounding buffer zone would constitute a commitment of that land area and the natural resources contained therein. Obtaining additional capacity by placing reactor compartments closer together in Trench 94 would not require this additional land commitment. The cruiser, LOS ANGELES, and OHIO Class reactor compartment disposal packages would be regulated for their radioactivity, lead, and PCB content. The volume of mixed waste generated by this alternative would be less than 120,000 cubic meters (4,240,000 cubic feet). Approximately 1,625 cubic meters (57,400 cubic feet) of other mixed waste from the reactor compartments would be generated and disposed of separately, primarily consisting of solidified radioactive potassium chromate solution. This mixed waste would be managed in accordance with the approved Shipyard Site Treatment Plan developed pursuant to the Federal Facilities Compliance Act.

4.3.3.3 Site Specific Migration Studies

4.3.3.3.1 Lead

Pacific Northwest Laboratory estimated the release and migration of lead through soils and groundwater at the Hanford Site 218-E-12B burial ground (PNL, 1992). This study considered the disposal of a group of 120 large metal components at the burial ground. A range of average lead quantity was used for the compartments that reflected the average of pre-LOS ANGELES, LOS ANGELES, and OHIO class submarines and all nuclear-powered cruisers. The lead quantities also conservatively represented the disposal of pre-LOS ANGELES class reactor compartments alone. Potential concentrations of lead resulting in the underlying aquifer from reactor compartment disposal were estimated as well as migration times for such concentrations to occur.

If the preferred alternative for disposal of cruiser, LOS ANGELES, and OHIO reactor compartments was selected, Trench 94 could receive cruiser, LOS ANGELES, and OHIO Class submarine reactor compartments as well as or in lieu of pre-LOS ANGELES Class submarine reactor compartments which are currently being placed in the trench. This would fill the trench to its current capacity of 120 compartments. Additional capacity would be required for remaining compartments being disposed of (bounded 220 compartments combining the pre-LOS ANGELES Classes with the about 100 reactor compartments considered in this final EIS).

Figure 4.1 shows the basic migration model for the lead migration study. The TRANSS computer code, a one dimensional streamtube model (PNL, 1986a), was employed to predict migration through the soil underlying the compartments and in the aquifer itself. The Coupled Fluid, Energy, and Solute Transport (CFEST) computer code, a Hanford Site aquifer model (PNL, 1982), was employed to provide required data for TRANSS. Geologic, geochemistry, and geohydraulic data inputs for these codes were obtained from available literature and from laboratory testing using actual 218-E-12B burial ground soil samples.

The amount of precipitation falling on the site that would infiltrate through the soil to the buried compartments and downwards to the aquifer (recharge) was modeled at 0.5 centimeters per year (0.2 inches per year) for the current arid climate condition. A postulated wetter condition was also modeled with a recharge rate 10 times greater than that used for the current climate. The soil column from compartments to aquifer was modeled at 45 meters (150 feet) of thickness based on site measurements from the floor of the current excavation (Trench 94). This soil thickness represents the minimum distance from the compartments to the aquifer expected for disposal of

reactor compartments at the 218-E-12B burial ground. The 120 compartments considered were modeled in a compact rectangular array, the planned configuration for Trench 94, Figure 4.2. The TRANSS model effectively treated this array as a single large lead source, Figure 4.1.

Release of lead from the reactor compartments would occur by corrosion of the solid elemental lead and subsequent solubilization of the corrosion products into recharge water contacting the lead. However, corrosion rates for elemental lead in the 218-E-12B environment were not estimated, rather, lead was very conservatively assumed to be immediately available for dissolution so that all groundwater contacting a 15.2 by 15.2 meter square (50 by 50 foot square) area encompassing a compartment would exit this area being fully saturated with dissolved lead (no credit was taken for the containment provided by the compartment or soil cover to be placed over the compartment). The capacity of the water to hold dissolved lead (solubility) was determined initially by a computer code and for estimating lead migration, by laboratory experiments with "upper envelope" solubility set at roughly double experimental results.

The lead released from each compartment was considered to migrate vertically downward. Batch and flow-through column laboratory experiments with 218-E-12B soils showed that solubilized lead would be strongly adsorbed in soil under the compartments, retarding the movement of this lead towards the aquifer. This testing determined the ratio of lead adsorbed in soil vice remaining in surrounding solution. The fixed ratio used in the model would underestimate lead adsorption in 218-E-12B soils (and underestimate migration times) vice a more accurate but more complex isotherm model such as that used in the nickel migration study (PNL, 1994a).

Iron and chromium (from steel alloys) would not be sufficiently soluble in a form that could compete with lead for soil adsorption sites. Laboratory tests were conducted to determine the competitive effect of nickel released from nickel alloys in the compartment on lead adsorption. These tests demonstrated that lead adsorption was not influenced by the presence of nickel at levels expected in the groundwater as a consequence of migration from the compartments. Colloidal transport mechanisms (i.e., lead or nickel piggy-backing on iron oxide colloids) were also evaluated by Pacific Northwest Laboratory in separate work (PNL, 1993). It was found that the colloids clumped together to form larger particles (coagulated) in the Hanford ground water chemistry, causing them to be filtered out by the soil, thus trapping adsorbed constituents and rendering the colloids ineffective as an accelerated transport medium.

The lead released from each compartment would be transported downward through the soil by groundwater. Adsorption in soil would delay the arrival of this lead at the aquifer. Upon arrival at the aquifer, lead would be carried away from the burial ground within the streamtube modeled by TRANSS. For the lead migration study, all lead released from the 120 compartment array was modeled as entering into a single hypothetical streamtube of width equal to the diagonal of the rectangular array, 461 meters (1513 feet), consistent with CFEST predictions of flow in the aquifer under the site in a general northerly direction for the future wetter condition, and the absence of an aquifer directly under the site under the current climate condition without artificial recharge from local site operations. Under the conditions, groundwater would contact bedrock under the site, and move southward through unsaturated sediment along the bedrock surface until entering the aquifer. Flow within the aquifer for the current climate is predicted to be generally east to southeastward toward the Columbia river (Figure 4.1 and 4.2). Resulting concentrations of lead (for the 461 meter wide streamtube) were estimated for the Columbia River and for hypothetical wells tapping the streamtube at 100 meters (330 feet) and 5000 meters (16,400 feet) from the burial ground (100 meter and 5000 meter wells, respectively).

A complex geologic pattern is present in the basalt bedrock under the 218-E-12B burial ground. Although flow is predicted to be southerly across the diagonal of the array for the current climate case, the CFEST computer code dows not model the exact contour or extent of "dry" bedrock under the burial ground, causing the predicted flow direction to be less certain than for the wetter condition modeled. Flow in alternate directions would reduce the width of the tube and the volume of water in the aquifer streamtube. As a result, predicted concentrations in the streamtube for the climate condition would increase. The range of possible streamtube widths varies from the current 461 meters (1513 feet) down to 61 meters (200 feet) for a west to east flow direction, which although unlikely, could potentially occur if the aquifer did not recede to south of the burial ground and was still present under the site.

Streamtube depths of 2.5 and 5 meters (8.2 to 16.4 feet) were used to model the current and wetter conditions respectively. The modeling did not allow mixing of water between the streamtube and adjacent water in the aquifer at locations downgradient (downstream) of the burial ground (i.e., no dissipation of the lead plume by spreading out).

Washington State, in their Dangerous Waste Regulations, Chapter 173-303, established a 50 parts per billion groundwater protection standard for lead under subsection 645, Releases from Regulated Units (treatment, storage, and disposal of dangerous wastes) (WAC, 1993).

Under current climate conditions, lead was not predicted to migrate to the 100 meter well for about 2.2 million years. Transit time through the soil column between compartments and aquifer accounted for almost all of this time (within 1000 years). Peak concentrations of lead in the aquifer at the 100 meter well occurred shortly after 2.2 million years and were estimated at 4 parts per billion.

Under the postulated wetter condition (10 times current recharge assumed), lead was not predicted to migrate to the 100 meter well for about 240,000 years. Transit time through the soil column between compartments and aquifer accounted for almost all of this time (within 1000 years). Peak concentrations of lead in the aquifer at the 100 meter well occurred shortly after 240,000 years and were estimated at 43 parts per billion.

Migration to the Columbia River was predicted to occur in about 2.8 million years under assumed current climate conditions and 740,000 years under the postulated wetter climate condition with river lead concentrations remaining below $1x10^{-7}$ parts per billion.

Refinements in hydrological modeling developed for the nickel migration study (PNL, 1994a) were applicable to the earlier lead migration study and would reduce predicted concentrations even further if incorporated. Nevertheless, lead was not predicted to reach the groundwater aquifer under the 218-E-12B burial ground for about 240,000 years even under the conservative modeling used. For comparison, the recorded history of human civilization is less than ten thousand years, and it is likely that human and geologic events occurring over the predicted time frame would result in impacts to the environment of a far greater nature.

4.3.3.3.2 Extrapolation of Pacific Northwest Laboratory Lead Migration Study

The results from the Pacific Northwest Laboratory lead migration study (PNL, 1992) were extrapolated by the Navy (USN, 1995) to consider the cumulative effects of all cruiser, LOS ANGELES, and OHIO Class submarine reactor compartments at the 218-E-12B burial ground. A total of 220 reactor compartments at the 218-E-12B burial ground were considered in the extrapolation for a conservative estimate of combined impact (pre-LOS ANGELES Class under

the current disposal program plus the 100 reactor compartments being considered under this final EIS). The extrapolation also incorporated a few refinements from the Pacific Northwest Laboratory nickel migration study (PNL, 1994a). A more accurate estimate for the area occupied by each compartment in the original 120 unit array (i.e the area contacted by recharge water) and a more accurate aquifer streamtube depth under the burial ground for the postulated wetter condition were incorporated. Consequently, extrapolated lead concentrations for the wetter condition were lower for 220 reactor compartments vice the 120 reactor compartments modeled in the lead migration study (PNL, 1992). Migration time did not change. The detailed extrapolation study is documented in a Navy study (USN, 1995) and is summarized below.

For the extrapolation (USN, 1995), the 220 compartments were modeled in two parallel and adjacent arrays of 120 and 100 compartments each, Figure 4.4. Based on CFEST predictions from the lead and nickel migration studies (PNL, 1992, PNL, 1994a) this array configuration would introduce lead from both arrays into essentially the same stream aquifer streamtube flowing under the burial ground and thus represents a worst case for the combined effect of the pre-LOS ANGELES and cruiser, LOS ANGELES, and OHIO class compartments. The combined total of 220 units could be treated as a single large lead source. Consequently, the compartments were modeled with average lead quantities, consistent with the modeling conducted in the lead migration study (PNL, 1992). The average lead quantities used by Pacific Northwest Laboratory provided a conservative estimate of the total quantity of lead that would be present at the 218-E-12B burial ground after the addition of cruiser, LOS ANGELES, and OHIO Class submarine reactor compartments. Thus the quantities used in the Pacific Northwest Laboratory work were conservatively applicable to the extrapolation as well.

Migration times as predicted in the lead migration study (PNL, 1992) were not affected by the extrapolation as the two arrays would not be considered by the modeling employed to release lead into the same vertical soil column.

During the course of the nickel migration study (PNL, 1994a) which used the same aquifer modeling as for the earlier lead migration study (PNL, 1992), it was realized that, for the wetter climate scenario, a stream tube depth of 5 meters (16.4 feet) should have been used vice the 2.5 meter (8.2 feet) depth originally used in the lead study. In addition, the lead migration study (PNL, 1992) assumed that all water contacting a 15.2 meters (50 foot) square area contacted a reactor compartment (which actually occupied about 60% of this area). The nickel migration study subsequently used a more accurate package size. These refinements are applicable to the original lead study (PNL, 1992) and have been incorporated into the extrapolation process.

For 220 reactor compartments in the adjacent array configuration, under current climate conditions, peak lead concentration in the groundwater would be below 3 parts per billion (2.2 million year migration time). Under the postulated wetter condition, using the upper envelope transport parameters, peak lead concentration would be 0.026 mg/L or 26 parts per billion (240,000 year migration time). Transport to the Columbia River was predicted to occur in about 2.8 million years under assumed current climate conditions and 740,000 years under the postulated wetter climate condition with river water lead concentration remaining below $1x10^{-8}$ milligrams per liter (much less than one part per trillion, a value far too low to even detect).

Part 141 of the Code of Federal Regulations, Title 40 "Environment" (40CFR141) provides an "action level" of 15 parts per billion requiring public water systems (25 or more people) to treat their water (e.g. filtration) to reduce lead levels when the action level is exceeded. The extrapolated 3 part per billion prediction for 220 compartments under current climate conditions

was much below this action level. The action level was exceeded somewhat for the postulated wetter condition modeled, however, this condition involved a recharge rate 10 times that used to model the current climate condition at the burial ground. Recharge would have to increase some seven times over current climate assumptions to cause the 15 part per billion action level to be exceeded. In addition, the transport time for lead was a minimum of 240,000 years. For comparison, the recorded history of human civilization is less than ten thousand years, and it is likely that human and geologic events occurring over the predicted time frame would result in impacts to the environment of a far greater nature.

As discussed previously, Washington State, in their Dangerous Waste Regulations, Chapter 173-303, established a 50 part per billion groundwater protection standard for lead (WAC, 1993). This standard was not reached by predicted concentrations.

The results of the extrapolation study (USN, 1995) can also be considered to bound the option of obtaining additional trench capacity by placing reactor compartments within Trench 94 closer together than currently done. The extrapolation study employed a 150 square meter (1650 square foot) "storage area" per reactor compartment. Recharge passing through this area was assumed to contact the reactor compartment and exit saturated with lead. The released lead was then assumed to migrate vertically downward within a column of soil defined by this "storage area" and the depth to the vadose zone. The 150 square meter (1650 square foot) area of trench floor is considerably smaller than the 230 square meter (2500 square foot) area of trench floor currently claimed per reactor compartment. Thus, placing reactor compartments closer together would not affect predicted lead migration times as the lead released from one reactor compartment would not enter a soil column receiving lead from another compartment. The 150 square meter (1650 square foot) storage area is consistent with modeling refinements adopted by Pacific Northwest Laboratory in the more recent nickel migration study (PNL, 1994a). Also, predicted groundwater concentrations and resulting user doses would not be affected by the closer spacing of reactor compartments. The Pacific Northwest Laboratory modeling treated the entire array of reactor compartments as a single lead source to the aquifer. The extrapolation study used a 457 meter (1500 foot) streamtube width for that portion of the aquifer receiving lead from the reactor compartments above. Figure 4.2 would also represent the closer spacing of reactor compartments at Trench 94 except that the resulting array and streamtube width would actually be a little larger than shown. A larger streamtube width would result in lower predicted concentrations and doses.

4.3.3.3.3 Polychlorinated Biphenyls (PCB)

Pre-LOS ANGELES Class reactor compartment packages contain polychlorinated biphenyls (PCBs) in a solid form, tightly bound within the matrix of industrial materials (e.g., rubber, thermal insulation) but at levels greater than 50 parts per million, thus requiring regulation of the reactor compartment disposal under the Toxic Substances Control Act (TSCA). The maximum cumulative concentration of the PCB formulations found in reactor compartments that can be dissolved in water is 0.015 milligrams per liter. However, these PCBs are part of the formulation of solid materials within the reactor compartments and are tightly bound in the material's matrix. In this form the PCBs are not measurably soluble and cannot be removed by wipe sampling methods on a PCB bearing material surface even when using organic solvents (e.g., isooctane). Thus, the release of the PCBs would be over a long period of time as the parent materials break down.

Production of PCBs was banned in 1979 pursuant to the Toxic Substances Control Act, however, they have been found at greater than 50 parts per million in ship's materials dating to as late as 1983. LOS ANGELES and OHIO Class ships were constructed both before and after this time

frame (cruisers - before) and thus some compartments may not contain solid PCBs while others may contain several pounds of solid PCBs (typically less than 10 pounds). Based on the common design characteristics of the reactor plants and their reactor compartments and a general comparison of ship's materials to earlier classes, when PCBs are present, they are expected to be in the same form and materials as for the pre-LOS ANGELES reactor compartments.

At the 218-E-12B burial ground, the PCB bearing materials would be sealed within the strong, all welded steel containment of the reactor compartments which would not be breached by corrosion for hundreds of years. Even when the PCBs could ultimately escape the compartments, the bound nature of the PCBs and low water solubilities would severely restrict the release of PCBs from entering the food chain or being consumed by humans.

Upon release from the compartments, the minimum migration time to the aquifer for the trace amounts of PCB that may be present would be the same as the time required for the groundwater to travel through the soil from the compartments to the aquifer. Pacific Northwest Laboratory predicted a 50 year groundwater travel time under a postulated wetter climate and about 500 years for the current climate (PNL, 1992, PNL, 1994a). Soil adsorption would occur to a degree, retarding the movement of PCBs through the soil to longer times than indicated above. Using the aquifer/transport modeling from the lead and nickel migration studies (PNL, 1992, PNL, 1994a), if 1/2 the recharge water contacting the compartment were very conservatively assumed to dissolve PCBs from industrial materials at the solubility limited PCB concentration (15 parts per billion total), downstream concentrations of PCBs in the aquifer would be less than 0.5 part per billion (total PCB) for the postulated wetter condition and less than 0.1 part per billion for the current climate.

The Environmental Protection Agency, under the National Primary Drinking Water Standards provides a Maximum Contaminant Level (MCL) of 0.5 parts per billion for PCBs in community and non-community water systems serving 25 or more people (40CFR141). The Environmental Protection Agency states that drinking water which meets this standard should be considered safe with respect to PCBs (40CFR141). It can be concluded then that PCBs in the reactor compartments would not pose an unreasonable risk to human health or the environment.

4.3.3.4 Migration of Other Constituents

Reactor compartments also contain significant quantities of iron and chromium in the structural steel and corrosion resisting alloys of the reactor compartment and surrounding structure. In many cases the same chromium based stainless steels present in compartments are used for high quality cooking utensils and other food preparation purposes. These metals do not affect the reactor compartment waste designation under the Washington State criteria of WAC 173-303 (WAC, 1993). However, these metals are regulated in Federal or state drinking water or groundwater standards. These metals will slowly corrode and be released to the environment where they would become available for migration to the underlying aquifer. This process may require millions of years to complete for the more corrosion resistant alloys. The corrosion performance of these metals is further discussed in section 4.3.3.2.1.1. The corrosion performance of the compartments is also discussed in Appendix B. The following paragraphs discuss the potential impact of these metals.

4.3.3.4.1 Chromium

Chromium is found in the environment in three major states - trivalent chromium (Cr^{3+}) compounds, hexavalent chromium (Cr^{6+}) compounds, and metallic chromium (Cr^{0}). The first of these is naturally occurring and the latter two produced primarily by industrial processes.

Hexavalent chromium has a health effect as an irritant, with short-term high-level exposure potentially resulting in ulcers of the skin, irritation of the nasal mucosa, perforation of the nasal septum, and irritation of the gastrointestinal tract. Hexavalent chromium may also cause adverse effects to the kidney and liver. On the other hand, trivalent chromium does not result in these effects. Trivalent chromium is considered to be an essential nutrient that helps to maintain normal metabolism of glucose, cholesterol, and fat in humans, with a daily ingestion of 50-200 micrograms estimated to be safe and adequate. Long term exposure to airborne chromium has been associated with lung cancer in workers, with hexavalent chromium substances regarded as the probable cause of these cancers based on animal studies. Long term studies in which animals were exposed to low levels of chromium compounds, particularly trivalent chromium compounds in food or water have not resulted in harmful health effects (ATSDR, 1989).

EPA regulates total chromium (trivalent chromium and hexavalent chromium) in drinking water based on the toxicity of hexavalent chromium, establishing a maximum concentration limit of 0.1 mg/l (Federal Register, Volume 56, 3536, January 30, 1991). The State of Washington has established a chromium ground water concentration limit of 0.05 mg/l, Table 1, WAC 173-200.

The long term corrosion of metallic chromium containing steels buried in Hanford soils would be expected to result in trivalent chromium compounds, most likely in the form of relatively insoluble hydroxides such as $CrOH_3$ and $FeOH_3$. Soluble trivalent chromium would be expected to adsorb onto soils with soil retention similar to that for nickel due to similar chemical properties. The production of toxic hexavalent chromium compounds would not be expected to occur in the Hanford soil and groundwater chemistry since, with the exception of the manganese oxides and dissolved oxygen, there are no other generally occurring inorganic oxidants that conceivably could oxidize trivalent chromium to hexavalent chromium in most waste materials and soils (EARY and RAI, 1987). Furthermore, ferrous ions rapidly reduce hexavalent chromium to trivalent chromium, tending to limit chromium solubility in water to less than 10^{-6} moles/liter (0.05 mg/L) at the chromium source for pH between 4 and 12 (Eary and RAI, 1989). The amount of MnO_2 in Hanford soils is small and the quantity of iron from the packages would be large. Thus, the presence of hexavalent chromium from metallic chromium corrosion would not be anticipated, and it can be concluded that the chromium content of the alloys in the reactor compartments would not be expected to pose any risk to future populations.

In addition to metallic chromium, a small amount of corrosion inhibitor, potassium chromate, would be dissolved in residual liquids present in reactor compartments. Potassium chromate contains hexavalent chromium. Under the WAC 173-303 (Dangerous Waste Regulations), the non-regulated limit for potassium chromate is 0.01% of the weight of the waste. For reactor compartments considered in this EIS, this limit would range from about 127-181 kilograms (280 to 400 pounds) per compartment, depending on the class. Actual quantities of potassium chromate remaining in cruiser, LOS ANGELES Class and OHIO Class submarine reactor compartments are not expected to exceed 1 kilogram (2 pounds) of chromate contained in residual potassium chromate solution that cannot be drained.

The potassium chromate would be contained in a tank within the thick hull and structure of the compartments which is conservatively predicted to provide containment for 600 years (DOE, 1992a). Absorbent would be added to the tank that contains the chromated water, in sufficient quantity to absorb twice the volume of water present, thus once exposed to soil, little potassium chromate may be released. If all of the chromated water at the 218-E-12B burial ground could be simultaneously released, this would represent less than 10% of one year's recharge through the

area occupied by the reactor compartments under the current dry climate condition and less than 1% under a potential future wetter condition modeled by Pacific Northwest Laboratory in their lead and nickel migration studies (PNL, 1992, PNL, 1994a).

As discussed previously, ferrous ions, from the corrosion of iron, rapidly reduce hexavalent chromium to trivalent chromium and limit total chromium solubility at the source to a value less than the WAC standard of 0.05 mg/L for a pH range encompassing burial site conditions. The concentration in the underlying ground waters would be even lower. Corrosion of compartment hull steels would produce a ready supply of iron corrosion products (ferrous ion). Any hexavalent chromium that remained may also undergo a soil adsorption process, however, soil retention could be lower than for trivalent chromium due to the anionic nature of the chromate ion. Regardless, given the conditions discussed above, hexavalent chromium would not be found in sufficient quantity to pose a significant risk to future populations.

From this information it is considered that there is little reason to be concerned about an adverse effect of chromium from the reactor compartments on the Hanford environment, or upon the health of future populations.

4.3.3.4.2 Iron

Iron and its oxides are essentially non toxic and non carcinogenic. Iron is an essential human nutrient, being a constituent of hemoglobin, an important factor in cellular oxidation mechanisms. Because of aesthetic effects (noticeable bitter astringent taste and pronounced staining problems at 1.0 mg/l), EPA has listed iron as a secondary contaminant, with a limit of 0.3 mg/l in drinking water (Federal Register Volume 44, 42200, July 19, 1979). Based on the Federal guideline, the State of Washington lists iron as a secondary contaminant with a limit of 0.3 mg/l in groundwater.

From this information it is considered that there is little reason to be concerned about an adverse effect of iron from the reactor compartments on the Hanford environment, or upon the health of future populations.

4.3.3.5 Cumulative Impacts

There are no cumulative impacts specifically associated with the preferred alternative at the Shipyard. Because the radiation dose to the public is insignificant during transportation, there would be no cumulative transportation impacts.

The cumulative radiation dose to the shipyard workers to perform the preferred alternative of permanent land disposal at the 218-E-12B Low-Level Burial Ground at Hanford is estimated to be 8 to 20 rem (0.003 to 0.008 additional latent cancer fatalities) per reactor compartment package. The total radiation dose for the 100 reactor compartments under study in this EIS is estimated at 1018 rem (0.4 additional latent cancer fatalities).

The Hanford Site has procedures and controls to ensure the protection of individuals during site operations. The reactor compartment disposal packages typically would have exterior radiation levels of less than 1 mrem/hr on contact at the time of placement for burial. Areas with higher radiation levels would be typically found under the compartments and would have standard radiation markings. After 10 years, radiation levels would be reduced by a factor of 4. Within 50 years after placement for burial, typical exterior radiation levels at the compartment surface would be reduced to less than 0.002 mrem/hr with all contact levels less than 0.1 mrem/hr. The highest contact radiation levels would be found under the compartments where contact with the

surface is improbable. Backfill placed over the compartments upon burial would effectively prevent direct contact and significantly reduce radiation levels. For comparison, radiation levels measured at Hanford in 1993 from fixed monitoring devices, were a maximum of 14,640 mrem/yr within the 100-N area and 1,100 mrem/yr at a tank farm in the 200 East area (PNL, 1994c). Contact readings at "hot spots" within these facilities would likely be higher. The present locations of the low-level radioactive waste burial grounds and other waste management facilities at the Hanford Site have already impacted the local environment. Given the conditions discussed above, additional impacts to Hanford workers and the environment from external radiation emitted by reactor compartment disposal packages are expected to be minimal.

The potential for cumulative impact would be from the addition of the cruiser, LOS ANGELES Class, and OHIO Class reactor compartments to the waste already at the Hanford burial grounds, or waste planned to be buried at Hanford. However, the cumulative impact from the addition of these reactor compartments to the Low Level Burial Ground at Hanford will be delayed for long periods of time, possibly long after the impacts from the other activities at Hanford have dissipated.

A comparison of the Hanford radioactive waste (DOE, 1991) and the reactor compartment waste shows differences. The Hanford radioactive wastes resulted primarily from the plutonium production process. The radioisotopes are predominantly strontium-90 and cesium-137 which will decay away relatively rapidly, leaving after 1000 years iodine-129, technetium-99, uranium-238, plutonium-239, 240, americium-241, and carbon-14 as the significant radionuclides of concern.

For the initial several hundreds of years following burial, Hanford generated strontium and cesium will be undergoing decay, while the reactor compartment radioactivity will be isolated from the environment by the heavy walled disposal package. The piping and equipment inside the reactor compartment would provide additional isolation for this radioactivity after the package is breached. Short lived radionuclides would thus decay prior to radioactivity being released to the environment and would not be additive to Hanford waste. Long lived radionuclides would be further isolated within the reactor vessel internal structure (discussion in Appendix B). Very low corrosion rates for this structure would restrict the release of this activity (e.g. less than 0.2% of the initial carbon-14 inventory would ever be released to the environment prior to decay). Soil adsorption effects would delay the migration of long lived activity allowing for further decay (e.g. 66,000 years for nickel-59 to reach the groundwater under wetter conditions). Only carbon-14, technetium-99, and trace amounts of iodine-129 are common to both Hanford waste and reactor compartments.

The potential impacts resulting from reactor compartment radioactivity are very small and in the far distant future. The major isotope of concern, nickel-59, would not migrate to groundwater for at least 66,000 years, and then only in a quantity so small that any resulting health effects would be insignificant compared to those resulting from other causes including normal background radiation. Also, reactor compartment contaminants would only enter the narrow aquifer streamtube passing under the reactor compartment burial trenches and would only be additive to other contaminants that could enter the same streamtube (which would exclude most Hanford radioactive waste). Columbia River impacts in the future could be additive, but the reactor compartment component would be vanishingly small.

The cumulative effect of the reactor compartment lead shielding with other hazardous metal constituent sources, including lead which may have been buried at the Hanford Site, would not shorten the very long times (over 240,000 years) calculated for lead in the reactor compartments to

migrate to the aquifer. The disposal of additional lead at the Hanford Site, such as from the Hanford production reactors (DOE, 1992b) would not change this conclusion. Initially, migration is through the vadose zone at the Navy reactor compartment burial site. The direction is essentially downward (vertically), so that interference from another source elsewhere on the site is unlikely, even if within the 200 East area. Also, once through the vadose zone, Navy reactor compartment lead would only enter the aquifer streamtube passing under the reactor compartment burial site and would only be additive in terms of dissolved concentration to other contaminants that could enter the same streamtube. The streamtube under the Navy reactor compartment burial is shown by modeling to only be under a portion of the 200 East area. No significant lead quantities are expected to be disposed at the 200 East area. Also, the streamtube does not flow under 200 West area, which is a potential disposal location for the Hanford production reactors.

Columbia River impacts in the future could be additive, but the reactor compartment component would be vanishingly small. Similarly the small volume of PCBs released over very long time frames would have negligible impact in the large 200 East area burial grounds.

The cumulative impact of the preferred action was also evaluated against the performance criteria of DOE Order 5820.2A issued September 26, 1988 (DOE, 1988). This Order requires that DOE low-level waste disposed after the issuance of the Order shall be managed to "assure that external exposure to the waste and concentrations of radioactive material which may be released into surface water, ground water, soil, plants and animals results in an effective dose equivalent that does not exceed 25 mrem/yr to any member of the public." DOE requires that the 25 mrem dose shall not be exceeded for at least 1,000 years after disposal (DOE, 1990). The contribution to the dose from the reactor compartments would be essentially zero during this time, therefore there would be no cumulative impact as determined by the requirements of the DOE Order. Furthermore, if long-lived radionuclides from the reactor compartments ultimately migrates to the aquifer and the Columbia River, any resulting dose to the maximally exposed person would be below 25 mrem per year.

In view of the foregoing, there will be no significant cumulative impact on the Hanford site from disposal of the cruiser reactor compartments, LOS ANGELES Class submarine or OHIO Class submarine reactor compartments.

4.3.4 Potential Air and Water Quality Effects

Operations that would be conducted in connection with the Preferred Alternative would not be expected to have an impact on air resources. Work practices and precautions at the Shipyard would be in accordance with applicable Shipyard directives to minimize the discharge of air pollutants. Work associated with the preferred alternative would be performed such that the Shipyard air [discharge] permit and the regulations of the Puget Sound Air Pollution Control Authority would not be violated. At the Hanford Site, the Department of Energy would meet applicable regulations regarding the maintenance of air quality. Facility construction work, such as earth moving, could negatively impact air quality through the emission of fugitive dusts and pollutants from diesel and gasoline powered equipment. The increase in off–site ambient levels would be small because of the large distance to the nearest public access, and the use of control measures when necessary, such as water spray to contain dust. Pollutants from the transport of reactor compartments to the Hanford Site would be generated from moving sources, diluted across large areas, with the result being de–minimus (non–significant) with respect to regional air quality.

Operations that would be conducted in connection with the Preferred Alternative would not be expected to have an impact on water resources. Shipyard operations would be performed under a National Pollution Discharge Elimination System (NPDES) permit. Procedures used by the Navy to control releases of radioactivity from U.S. Naval nuclear-powered ships and their support facilities have been effective in protecting the environment. Shipyard spill prevention and spill contingency directives would be in effect. Secondary containment for containers of hazardous waste would be built into storage facilities for this waste. Procedures used for water and land transportation of the cruiser, LOS ANGELES, and OHIO Class reactor compartment disposal packages would be designed to minimize the potential for accidents and to mitigate the consequences of potential accidents. The reactor compartment disposal packages would provide a durable containment for hazardous and radioactive constituents, which would not be readily released even if exterior package containment were to be breached.

Groundwater monitoring would be conducted at the 218-E-12B burial ground as part of site operations through a system of Resource Conservation and Recovery Act compliant groundwater monitoring wells already in place along the burial ground boundary. In addition a Resource Conservation and Recovery Act compliant cover would be placed over the disposal packages after burial of all packages to reduce the infiltration of moisture from the surface. The Hanford Site is not located above a "sole source aquifer" as designated in the provisions of the Safe Drinking Water Act (40CFR149). Regardless, as discussed in previous sections, impacts on water resources from the Preferred Alternative would be minimal, occurring only after the long periods of time required for corrosion and groundwater migration processes to occur.

4.3.5 Socioeconomic Impacts of the Preferred Alternative

The preferred alternative involves no socioeconomic change in any of the involved regions since it merely continues the type and volume of work already on-going for pre-LOS ANGELES Class reactor compartment disposal work.

4.4 No Action - Indefinite Waterborne Storage at Puget Sound Naval Shipyard and Norfolk Naval Shipyard

A conceptual plan to provide the additional space needed for indefinite waterborne storage of the defueled cruisers, and later class submarines has been developed, taking into account the fact that since such storage would occur after the vessels have been defueled, the stringent and onerous requirements that would otherwise apply to ensure safe storage with spent fuel aboard can be avoided. Specifically, there is no need to have a large portion of each vessel's crew remain assigned to ensure vessel upkeep, and to ensure reactor plant conditions are maintained for spent fuel safety. Further, there is no need to operate ship systems for that purpose, which avoids the need to consume shore supplied services such as electricity and pure water.

Figure 4.5 shows a conceptual mooring layout for the defueled ships that could be placed in indefinite waterborne storage at Norfolk Naval Shipyard at the existing inactive nuclear ship mooring facility, Pier E. Pier E would have to be modified and upgraded to accommodate the proposed berthing arrangement. Some repairs to the existing structure may be required to strengthen the piers to accept the increased breasting loads from the nests of ships over a long period. A complete inspection above and below the pier decks and underwater would be required to determine the full scope and cost of the required work.

The most significant work required to accommodate the storage of the proposed ships is dredging. Current depths between the piers range from approximately 17 feet to 23 feet. These drafts are insufficient for the proposed ships with drafts ranging from 24 feet to 33 feet. The latter draft is

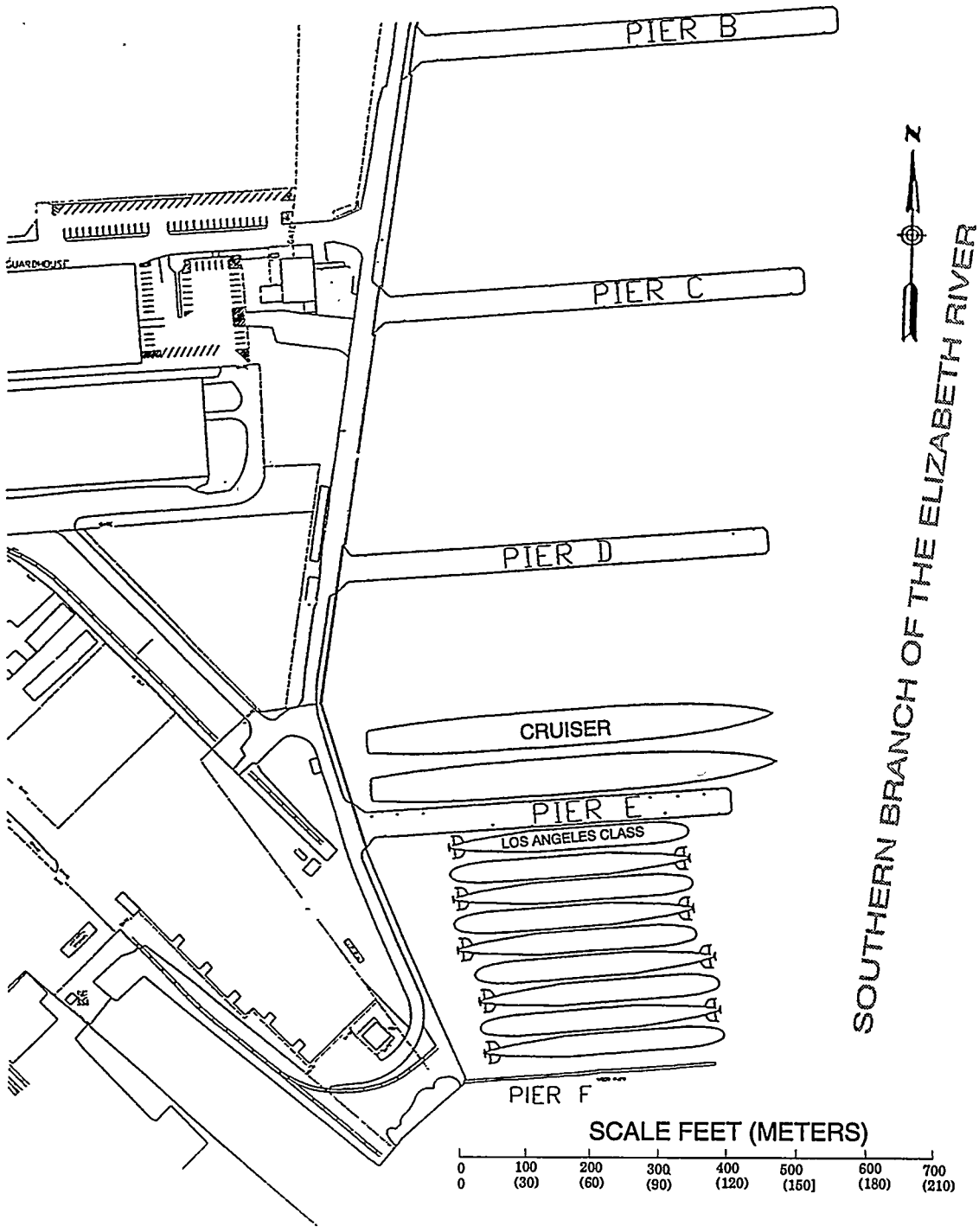


Figure 4.5. Norfolk Naval Shipyard Conceptual Mooring Arrangement at South Gate Annex

for OHIO Class submarines. To minimize the amount of dredging required, it might be possible to store all defueled OHIO Class submarines at Puget Sound Naval Shipyard where deeper draft storage is available without dredging.

Past soundings have indicated sedimentation at the rate of three inches per year in the Norfolk area. Ships in inactive status are dry docked approximately every 15 years for hull preservation. Dredge depth would be established to allow for 45 inches of sedimentation between dredgings to preclude having to move the ships between the planned hull preservation periods. One foot depth would be added to allow for variations due to trim and one foot added for absolute under-hull clearance. Dredging depths would have to be the maximum hull drafts plus six feet (measured at low tides). These depths would be 30 feet for cruisers, and 33 feet for LOS ANGELES Class submarines. An estimated cost for the initial dredging would be $1.1 million to remove approximately 165,000 cubic yards of material. Maintenance dredging at 15 year intervals would require removal of only about 50% as much material. This amount of dredging is based on having any defueled decommissioned OHIO Class submarines at Puget Sound Naval Shipyard and defueled decommissioned cruisers and LOS ANGELES Class submarines at both Puget Sound and Norfolk Naval Shipyards.

At Norfolk Naval Shipyard, no long term adverse environmental impacts due to the required dredging are anticipated. Dredging is routinely performed in this area with no known adverse effects. The Virginia Marine Resources Commission functions as the point of contact for all dredging permitting actions at Norfolk Naval Shipyard. They receive permitting applications and in turn notify and coordinate the involvement of all other regulatory and oversight agencies. These agencies are the U.S. Army Corps of Engineers, the Virginia Department of Environment, the Wetlands Board of the City of Portsmouth, and the State Environmental Protection Agency. Norfolk Naval Shipyard maintenance dredging permits specify Craney Island as the disposal site for dredge spoils. It is anticipated that a permit for deepening the berths at the Southgate Annex north and south of Pier E would similarly specify Craney Island as the disposal site because it is the only active disposal site in the area. The Craney Island spoils area is available to accept any dredge spoils removed from the Hampton Roads Basin (of which the Southgate Annex is a part). Craney Island currently receives approximately 3,500,000 cubic yards of dredge spoils from the Hampton Roads area annually. Approximately 1,000,000 cubic yards of dredge spoils are from dredging at naval facilities in the area. The dredge spoils from this project would make up less than 1/3% of the total dredge spoils received on an annual basis.

At Puget Sound Naval Shipyard no dredging is expected as a result of this alternative because the sediment rate in the area is less than one foot per 50 years.

At Norfolk Naval Shipyard, required modifications to accommodate the proposed ships would include the installation of high capacity fixtures for tying off mooring lines and replacement of the existing bumpers with a new bumper system. The total estimated cost of repairs and modifications is approximately $850,000. The existing utilities on Pier E should be adequate to accommodate the proposed inactive ships.

Figure 4.6 shows a conceptual mooring layout for indefinite water borne storage at Puget Sound Naval Shipyard. The current inactive nuclear-powered ship moorage facility could be used to berth approximately 32 defueled LOS ANGELES Class submarines with space for three larger defueled ships, either cruisers or OHIO Class submarines or a combination of both. Other mooring configurations and mix of ships would be possible but based on space requirements, roughly two defueled LOS ANGELES Class submarines can be berthed in place of one defueled cruiser or OHIO Class submarine.

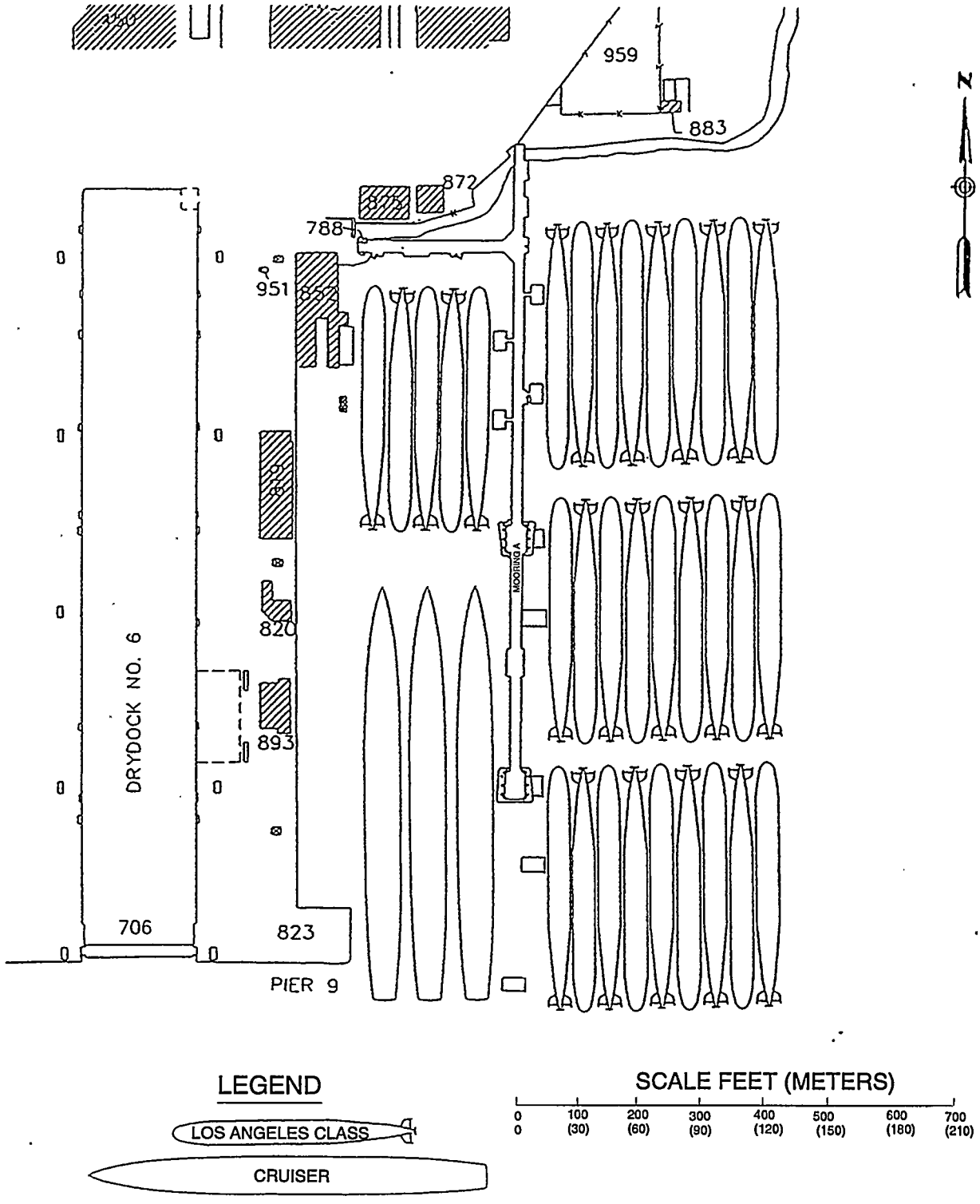


Figure 4.6. Puget Sound Naval Shipyard Conceptual Mooring Arrangement

The existing inactive nuclear-powered ship mooring facility at Norfolk Naval Shipyard and Puget Sound Naval Shipyard would accommodate nearly half of the ships considered by this EIS. This would be adequate to handle the cruisers and submarines inactivated until after the year 2000. At that time, some action would be needed to accommodate additional ships.

This evaluation does not include maintenance costs for the facilities at either shipyard since there is no change in the use of these areas for storage. Although maintenance would be required, it is primarily a result of weather and time and not directly connected to the use of the facilities. Any maintenance required would not be increased by using the facility as indefinite waterborne storage sites. Actual maintenance requirements may be less due to the low activity at the facilities.

Puget Sound Naval Shipyard lies within the usual and accustomed fishing area of the Suquamish Tribe. The activities at Puget Sound Naval Shipyard resulting from the no-action alternative would have no impact on the tribal fishing rights because the moorage would not be extended beyond the existing mooring areas of the shipyard.

Hull preservation would be accomplished at about 15 year intervals. The process would involve grit blasting and repainting the hulls with antifouling paint. This is a normal industrial operation and there are procedures in place at the Shipyards to dispose of used grit that are protective of the environment. This process of hull preservation will prevent any adverse impact on the water quality at either Puget Sound Naval Shipyard or Norfolk Naval Shipyard.

4.4.1 Socioeconomics Impact of the No Action Alternative

As part of the socioeconomic analysis it was assumed that no more than half of the Shipyard workforce would be dedicated to accomplish the work to prepare ships for indefinite waterborne storage. Personnel used to accomplish this work would be the same as those currently performing work in support of pre-LOS ANGELES Class reactor compartment disposal work. No new employees would be hired.

The cruisers and submarines can be placed in waterborne storage as soon as inactivation is complete. The limiting factor for this alternative is immediate availability of adequate storage facilities. The socioeconomic impacts in the Puget Sound Region result from Puget Sound Naval Shipyard workload decrease following completion of pre-Los Angeles Class reactor compartment disposal work.

This reduction in Shipyard workload would result in a loss of 5,253 jobs at Puget Sound Naval Shipyard. These jobs are postulated to result in a County/region population reduction of approximately 31,862 persons or 15%.

The loss of 5,253 jobs equates to 13,658 excess housing units. This is 18% of the housing units existing in 1990. The loss of jobs also equates to the loss of 7,880 school-age children from the schools in the region. School district studies indicate that a new school is required for every increase of 500 students. The postulated reduction in school-age population could require school closure with resultant loss of teacher, maintenance and administrator employment.

Since this alternative would not affect Norfolk Naval Shipyard's currently planned work, there would be no socioeconomic impact at Norfolk Naval Shipyard.

4.4.2 Extreme Natural Phenomena

The two Shipyards capable of protective waterborne storage are located in areas which experience relatively few extreme natural phenomena.

The credible flooding hazard for the Puget Sound Area would be from locally generated tsunamis and seiches. The system of straits and inlets surrounding Puget Sound provides a natural barrier for the Puget Sound Area, which effectively dampens the propagation of distantly generated tsunamis. The potential damage from tsunamis and seiches was found to be minimal by the Seismic Design Study for the Water Pit Facility at Puget Sound Naval Shipyard conducted by Shannon and Wilson, Inc. in December 1978 (STUDY, 1978). The principal hazard from a seiche is the same as that of a tsunami, which is flooding. Based on the historic record, the risk of a seismically induced seiche of magnitude to cause flooding at Puget Sound Naval Shipyard is highly unlikely. A more detailed description of the Puget Sound regional conditions is documented in the Seismic Design Study for the Water Pit Facility at Puget Sound Naval Shipyard (STUDY, 1978). These events would not significantly impact the waterborne storage of defueled, decommissioned cruisers, and LOS ANGELES Class and OHIO Class submarines because the methods to be used to moor the vessels would allow for these affects. Extreme weather conditions, such as thunderstorms, tornados, etc., rarely occur in the Puget Sound area.

There is no known fault line within 915 kilometers (3000 feet) of the Bremerton Naval Complex. There has been no known surface faulting in conjunction with earthquakes in the Shipyard vicinity. The potential hazards from volcanism for Puget Sound Naval Shipyard are minimal and limited to wind-borne volcanic ash. Both the distance from the Cascade vents and the configuration of the intervening topography exclude other volcanic products, such as lava flows and volcaniclastic units, from being hazardous to the site. Only ash from a "large" or "very large" eruption would potentially reach the site.

No major faults underlie the Tidewater region which includes Norfolk Naval Shipyard and the region is considered aseismic (SCIENCE, 1969). The 1980 eruption of Mount St. Helens, Washington, approximately 195 kilometers (120 miles) south of the Shipyard, resulted in a very slight coating of ash at the Shipyard. No volcanic hazards have been identified for Norfolk Naval Shipyard.

Hurricanes and other tropical storms are considered to be credible natural phenomena for Norfolk Naval Shipyard. However, the Shipyard is located south of the average path of storms originating in the higher latitudes and north of the usual tracks of hurricanes and other tropical storms. Norfolk Naval Shipyard is situated so that it is not susceptible to any significant wind generated waves from any direction. There are no long fetches of water that would result in significant wind generated waves. Norfolk Naval Shipyard is a recommended safe moorage location for small craft during gale force winds. The greatest threat at Norfolk Naval Shipyard from tropical cyclones is storm surge which can add several feet to the height of the usual tide. In the event of storm surge, the mooring lines of ships would be adjusted to preclude breaking.

North to northeast winds predominate during the winter months at Norfolk Naval Shipyard. Strong northeast winds and heavy rains could cause localized flooding of low-lying areas of the Tidewater region. Since the Chesapeake Bay is shallow, a strong northeast wind could move large amounts of water from the north end of the bay southward. When this elevated water level is combined with a high tide, flooding occurs. Added to this is the heavy rainfall and poor drainage due to the low elevation. High tide levels six to eight feet above normal could be experienced during major northeast winds. However, flooding at Norfolk Naval Shipyard is not considered to be a natural phenomena capable of impacting waterborne storage because the methods to be used to moor the vessels would allow for tidal affects.

Other natural phenomena are considered not possible or not capable of inflicting damage to these vessels should the decision be made to moor them at either Puget Sound or Norfolk Naval Shipyards.

4.4.3 Radiological Impacts

The radiation exposure rate at the surface of the hull of the cruisers, and defueled LOS ANGELES Class and OHIO Class submarines is generally below 1 mrem per hour; however, localized spots of elevated rates could exist. The designated storage areas would be within fenced and guarded areas at the two Shipyards; consequently, entry into the storage areas would be strictly controlled and Shipyard personnel would be monitored for radiation exposure, if entering radiation areas. Radiation levels above background levels would not be detected at the fence to the storage area, nor at the boundary of the shipyard.

The radioactivity contained in the defueled cruisers and LOS ANGELES Class and OHIO Class submarines is in the form of solid activated metal corrosion products and solid activated metal fully contained with the sealed reactor compartment. Initially the primary source of radiation is from solid activated metal corrosion products; but after an extended period of waterborne storage (over 20 years), the solid activated metal would become predominant. The solid activated metal corrosion products consist primarily of the relatively short lived, high energy emitting radionuclide cobalt-60 (5.3 year half-life, gamma emitter); while the solid activated metal is primarily long lived, low energy radionuclides such as nickel-59 and nickel-63 (nickel-59, 76,000 year half-life, X-rays; nickel-63, 100 year half-life, beta emitter). The radioactivity would not be readily releasable under the protective waterborne storage alternative because it is an integral part of the metal in the reactor compartment or is contained by the sealed reactor compartment; therefore, the general public could not be exposed to radioactivity under this alternative.

The radiation exposure dose to the general public is expected to be zero for this alternative. There is essentially no risk of radiation exposure to anyone in the general public as a result of protective waterborne storage of the defueled cruisers, and LOS ANGELES Class and OHIO Class submarines since the radiation dose rate outside the reactor compartments would be well below the federal transportation limits specified in Part 173 of Title 49, Code of Federal Regulations (49CFR173). Additionally, the storage areas would fenced and within the security confines of the Shipyard.

4.4.4 Hazardous Material Impacts

The inactivated, defueled, and decommissioned cruisers and LOS ANGELES Class and OHIO Class submarines are expected to contain regulated quantities of lead as shielding, asbestos, and solid PCBs which would be fully contained within the sealed reactor compartments. The OHIO Class submarines and most LOS ANGELES Class submarines are expected to contain much less asbestos and PCBs than earlier classes since they were built after these materials started to be removed from commerce. Sea connections would be blanked, ensuring the preservation of containment barriers such as the hull, and installing fire and flooding alarms. The designated waterborne storage areas would be within fenced and guarded areas of Puget Sound Naval Shipyard and Norfolk Naval Shipyard; consequently, entry into the storage areas would be strictly controlled. The general public is not expected to experience any exposure to hazardous materials from the waterborne storage alternative because the hazardous material would be contained by the ship's hull. Periodic preservation of the ship's hull would be performed to maintain the containment barriers.

4.4.5 Potential Air and Water Quality Effects

Operations that would be conducted in connection with the No Action Alternative would not be expected to have an impact on air resources. Work practices and precautions at the Shipyard would be in accordance with applicable Shipyard directives to minimize the discharge of air pollutants. Work associated with the preferred alternative would be performed such that the Shipyard air [discharge] permit and the regulations of the Puget Sound Air Pollution Control Authority would not be violated.

Operations that would be conducted in connection with the No-Action alternative would not be expected to have an impact on water resources. Shipyard operations would be performed under a National Pollution Discharge Elimination System (NPDES) permit. Procedures used by the Navy to control releases of radioactivity from U.S. Naval nuclear-powered ships and their support facilities have been effective in protecting the environment. Periodic preservation of the ship's hull and methods used for securing ships would maintain the containment barrier to keep contaminants out of the environment.

At Norfolk Naval Shipyard, no long term adverse environmental impacts due to the required dredging are anticipated. Dredging is routinely performed in this area with no known adverse effects. The Virginia Marine Resources Commission functions as the point of contact for all dredging permitting actions at Norfolk Naval Shipyard. They receive permitting applications and in turn notify and coordinate the involvement of all other regulatory and oversight agencies such as the U.S. Army Corps of Engineers, the Virginia Department of Environment, the Wetlands Board of the City of Portsmouth, and the State Environmental Protection Agency. Norfolk Naval Shipyard maintenance dredging permits specify Craney Island as the disposal site for dredge spoils. It is anticipated that a permit for deepening the berths at the Southgate Annex north and south of Pier E would similarly specify Craney Island as the disposal site because it is the only active disposal site in the area. The Craney Island spoils area is available to accept any dredge spoils removed from the Hampton Roads Basin (of which the Southgate Annex is a part).

At Puget Sound Naval Shipyard no dredging is expected as a result of this alternative because the sediment rate in the area is less than one foot per 50 years.

4.5 Disposal and Reuse of Subdivided Portions of the Reactor Plants.

4.5.1 Radiological Consequences

Radiological consequences include off-site exposure to the public and on-site exposure to workers. Off site exposure is discussed in Appendix E. On Site exposure is discussed in this subsection and Appendix C. For the subdivision alternative of this EIS, the exposures are considered to be bounded by actual exposures reported by DOE for decommissioning of the Shippingport reactor compartment and NRC estimates for commercial plants. The Shippingport pressurized water reactor was operated for the first time in December of 1957. During its lifetime it had three different cores that produced 68 MWe, 150 MWe, and 72 MWe respectively. The reactor plant operated for almost 25 years and produced over 84,000 effective full power hours of power. Operations were terminated in October of 1982. The reactor plant was subsequently dismantled and the site was certified for unrestricted use in December of 1989. Dismantling of the Shippingport reactor cost 155 rem of worker exposure (DOE, 1989c).

Estimated on site exposures to workers for the subdivision alternative are provided in Appendix C. The values are based on the 155 rem from dismantling of the Shippingport nuclear power plant, which began 3 years after operations ceased. NRC data tabulated in NUREG-0586 (NRC, 1988) for similar operations involving dismantling of a large, commercial pressurized water reactor are included for comparison. In order to be consistent with exposure estimates for the other alternatives, which do not include exposure received in the course of decommissioning operations, the estimates do not include exposures for decommissioning work.

These estimates involve a considerable amount of uncertainty. Based solely on the comparative sizes of the reactor compartments and relative amounts of radioactive waste to be processed, the subdivision alternative would require less radiation exposure per reactor compartment than Shippingport. The exposure estimate for subdividing the reactor compartments based on the Shippingport data is 22,500 person-rem (6,090 person-rem after 10 years). However the curie contents of the Naval plants are typically much higher than Shippingport. Also, the estimate based on NUREG-0586 is nearly five times the Shippingport based estimate. Per NUREG/CR-0130 (NRC, 1978) the estimated dose would be about the dose from three typical refueling and maintenance outages, which would be from 24,000 to 83,000 person-rem (6,440 to 22,300 person-rem after ten years). Therefore, worker exposure for the subdivision alternative is expected to be bounded by the Shippingport-based estimate on the low end and by the NUREG-0586 based estimate on the high end.

4.5.2 Waste Management Consequences

The subdivision alternative would generate toxic, hazardous, radioactive and mixed wastes. The most significant wastes would be asbestos bearing materials, PCB bearing materials and radioactive waste, including lead made radioactive by exposure of impurities in lead to neutrons during reactor operation. The subdivision alternative's adverse impacts are far greater than any of the other alternatives based on occupational radiation exposure at the shipyards without adding any of the potential impacts due to waste management at the disposal sites. Since detailed estimates of the waste management impacts of subdivided pieces would not affect the relative environmental ranking of the alternatives, a detailed analysis was not performed. For disposal of subdivided portions at Hanford, the long term radiological impacts should be similar to the whole reactor compartments since the amount of radioactivity and the physical characteristics of the disposal site would be the same. For a more humid site with a high water table, somewhat greater impacts would be expected, but still within the requirements of DOE Order 5820.2.

Decommissioning of the Shippingport pressurized water reactor compartment produced 6,060 cubic meters (214,000 cubic feet) of low-level radioactive waste that weighed 4,200 tons (DOE, 1989c). It was smaller than most commercial power plants and underwent dismantlement shortly after operations ceased. Consequently, results reported for the Shippingport Decommissioning Project are considered to be relevant to subdivision of Naval reactor compartments.

The volumes within the boundaries of reactor compartment packages from cruisers and LOS ANGELES class and OHIO class submarines would range from about 850 cubic meters (30,000 cubic feet) to about 2,150 cubic meters (76,000 cubic feet) and the weights of the packages would range from about 1,400 tons to 2,700 tons. Using these volumes and weights, an upper bound on the waste from subdivision can be determined. The volume of radioactive waste from subdivision of a single Naval reactor compartment should be about 13% to 36% of the Shippingport volume. The weight would be about 33% to 65% of the Shippingport weight. The volume and weight of radioactive waste from subdivision of a reactor compartment would be less than that of the corresponding intact package due to reductions achieved through reuse and consolidation.

The total quantity of waste that would be produced by the subdivision alternative can conservatively be bounded by the 120,000 cubic meter (4,240,000 cubic foot) combined volume of the various reactor compartments that are to be disposed of. The actual quantity would be less due to recycling and volume reduction. The 120,000 cubic meter (4,240,000 cubic foot) volume is 6% of the 2,005,000 cubic meters (70,800,000 cubic feet) of low-level waste that is projected to be buried at DOE sites in the 20-year period from 1996 to 2016 (DOE, 1994a, Table 4.2). It is estimated that from 2,255 to 6,255 cubic meters (79,600 to 221,000 cubic feet) of mixed and radioactive–PCB waste would be generated. This waste would consist of approximately 630 cubic meters (22,200 cubic feet) of activated shielding lead, from zero to 4,000 cubic meters (141,000 cubic feet) of insulating material and approximately 1,625 cubic meters (57,400 cubic feet) of other mixed waste, primarily solidified radioactive potassium chromate. This mixed waste would be managed in accordance with the approved Shipyard Site Treatment Plan developed pursuant to the Federal Facilities Compliance Act.

An intermediate estimate of radioactive waste volume for the subdivision alternative is based on the assumption that the entire reactor compartment structure and 75% of the shielding lead could be recycled. Large items, such as reactor pressure vessels, steam generators, pressurizers and coolant pumps would be disposed of in one piece, while smaller items would be disposed of in bulk containers. These assumptions result in an estimated radioactive waste volume of about 24,000 cubic meters (847,000 cubic feet).

The lower bound on the volume of radioactive waste for the subdivision alternative is about 10,000 cubic meters (353,000 cubic feet). This volume is based on the same assumptions as the intermediate estimate except it is assumed that the reactor pressure vessels, steam generators, pressurizers, coolant pumps and other metal components could be reduced to a solid mass by melting.

The NRC, in its Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities indicated that there could be a ten-fold reduction in the volume of radioactive waste if dismantlement of a commercial pressurized water reactor compartment was deferred 30 to 50 years (NRC, 1988, Table 4.4-1). Deferral of Naval reactor compartment subdivision by an equivalent amount of time would not result in any significant reduction in radioactive waste volume, however, largely due to Ni^{63}, which emits beta radiation, distributed throughout the interior of reactor plant systems. Ni^{63} has a half life of 100 years and will decay to only 81% and 71% of its initial levels after 30 and 50 years respectively. Therefore, items that are radioactive when plant operations cease will still be radioactive 30 to 50 years later.

Large quantities of recyclable lead and lead made radioactive by contact with radioactive material or by neutron activation would need to be processed. Disposition of this lead is discussed in Appendix A.

Foundry technology has recently been licensed which could be used to reduce the overall volume of waste metal from the subdivision alternative. The Navy has used the technology to process some Navy radioactive waste metals. In December of 1993, Norfolk Naval Shipyard awarded a contract for processing of radioactive waste, which included provisions for recycling of radioactively contaminated metals by foundry melting. The amount of metal involved was estimated to be 136,000 kilograms (300,000 lb). The contract precluded processing of mixed waste, transuranic waste, and Class B and Class C waste per 10CFR61. It has not been demonstrated that this technology is suitable for disposition of reactor vessels.

4.5.3 Transport

The subdivision alternative would involve the transport of an estimated 1571 packages from either Puget Sound Naval Shipyard or Norfolk Naval Shipyard to one or more appropriate disposal sites. Impacts along transportation routes that would be used are evaluated in Appendix E. Four origin-destination cases are evaluated (Puget Sound to Hanford, Puget Sound to Savannah River, Norfolk to Hanford and Norfolk to Savannah River). Since two of the cases are for origins and destinations on the same coast and two are for origins and destinations on opposite coasts, the evaluation is considered to bound shipments from either of the two origins (Puget Sound and Norfolk) to any disposal site within the 48 contiguous states.

4.5.3.1 Radiation Exposure from Normal Conditions of Transport

For normal conditions of transport (incident free), exposure to the general population is estimated to be 11 to 119 person-rem (0.00551 to 0.0597 latent cancer fatalities) and the maximum exposed individual in the general population is estimated to receive 1.28 to 1.73 person-rem (0.000638 to 0.000861 latent cancer fatalities. Exposure to the transportation crew is estimated to be 11.7 to 96.3 person-rem (0.00466 to 0.0386 latent cancer fatalities) and the maximum exposed transportation worker is estimated to receive 5.11 to 48.0 person-rem (0.00204 to 0.0192 latent cancer fatalities). Non-radiological fatalities are estimated to be from 0.00310 to 0.0334.

4.5.3.2 Accident Scenarios

For hypothetical accident conditions, when both the probability and severity of an accident are considered, exposure to the general population from radiological accidents is estimated to be from 0.0145 to 0.106 person-rem (0.00000724 to 0.0000532 latent cancer fatalities) and there are estimated to be from 0.0271 to 0.781 fatalities from non-radiological accidents. Assuming an accident actually does happen, the maximum consequences are estimated to be 0.287 rem (0.000143 latent cancer fatalities) to a maximum exposed individual and a collective dose to the exposed population of 3,643 person-rem (1.82 latent cancer fatalities).

4.5.4 Socioeconomics Impacts of the Land Disposal and Reuse of Subdivided Portions of the Reactor Plant

The following are the major assumptions made in performing the socioeconomic analysis of this alternative:

All ships have been previously inactivated and defueled.

No more than half the Shipyard Workforce would be dedicated to performing this work.

Overall Shipyard employment levels would not change.

Based on these assumptions, maximum throughput was determined to be a total of 3.11 per year (1.85 Puget/1.26 Norfolk). This throughput results in a minimum duration for the work of 32.2 years with the limiting factor being available workforce. This alternative involves no socioeconomic change in either of the shipyard regions since the work performed would neither increase nor decrease employment levels.

No socioeconomic impacts from the subdivision alternative associated with waste disposal sites were identified. Waste from the subdivision alternative would only be a small fraction of the volume of other waste that will require disposal during the same time period. Little or no change in employment levels or infrastructure would be anticipated.

4.5.5 Potential Water Quality Effects

Operations that would be conducted in connection with the subdivision alternative would not be expected to have an impact on water resources.

Shipyard operations would be performed under a National Pollution Discharge Elimination System (NPDES) permit. There would be the potential for a spill of hazardous waste or radioactive waste during transferring and loading operations. Shipyard spill prevention contingency directives would be in effect. The secondary containment for containers of liquid hazardous waste would be large enough to contain either 100 percent of the largest single container or 10 percent of the total volume of all stored containers of hazardous waste.

Neither of the representative disposal sites (Hanford Site and Savannah River Site), are above a "sole source aquifer" as designated by provisions of the Safe Drinking Water Act implementing regulations (40CFR149).

4.5.6 Potential Air Quality Effects

Air quality could potentially be affected by the removal, handling, and disposal of asbestos, polychlorinated biphenyls (PCBs), lead, and radioactive materials.

Work practices and precautions at the affected Shipyards would be in accordance with applicable Shipyard directives to minimize the discharge of air pollutants. For Puget Sound Naval Shipyard, work would be performed such that the Shipyard's air permits and the regulations of the Puget Sound Air Pollution Control Authority would not be violated. Likewise, for Norfolk Naval Shipyard, work would be performed such that the Shipyard's air permits and the regulations of Region 6 of the Department of Environmental Quality would not be violated. The Department of Energy would meet applicable regulations regarding the maintenance of air quality at their disposal sites. Facility construction work, such as earth moving, could negatively impact air quality through the emission of fugitive dusts and pollutants from diesel and gasoline powered equipment. The increase in offsite ambient levels would be small because of the large distance to the nearest public access, and the use of control measures when necessary, such as water spray to contain dust. Pollutants from the transport of subdivided components to burial sites would be generated from moving sources, diluted across large areas, with the result being de–minimus (non–significant) with respect to regional air quality.

4.6 Indefinite Storage Above Ground at Hanford

The cruiser, LOS ANGELES, and OHIO class reactor compartments would be packaged in the same manner and with the same resulting impacts as for the preferred alternative (i.e. minimal socioeconomic impact, radiation dose to workers packaging the compartments of between 13 and 25 mrem (or 0.005 to 0.01 latent cancer fatalities) per compartment). The transport method and route for these compartments would be the same as for the preferred alternative with the same resulting impacts.

Compartment packaging and transport costs for this alternative would be identical to those described in Appendix C for the preferred alternative. Costs associated with the maintenance of surface coatings (paint) on the compartments are discussed in Appendix C as well. The need or extent of foundation maintenance will be affected by the length of the storage period and the actual design of the foundations when built.

The Hanford Site, a Department of Energy managed facility, has adequate procedures and controls to ensure the protection of individuals during site operations. The reactor compartment disposal packages typically would have exterior radiation levels of less than 1 mrem/hr on contact at the

time of storage. Areas with higher radiation levels would typically be found under the compartments and would be reduced by a factor of 4 after 10 years of storage. Within 50 years after placement in storage, typical exterior radiation levels at the compartment surface would be reduced to less than 0.002 mrem/hr with all contact levels less than 0.1 mrem/hr. Under these conditions, added radiation doses to Hanford site workers maintaining the compartments would be minimal compared to the 5,000 mrem/yr federal limit under 10CFR20.

The present locations of the low-level radioactive waste burial grounds and other waste management facilities at the Hanford Site have already impacted the local environment. Additional impacts to plants and wildlife from external radiation emitted by stored reactor compartment disposal packages are also expected to be minimal. The highest contact radiation levels are found under the packages where contact with the surface is improbable. For comparison, external near facility radiation levels measured at Hanford in 1993 from fixed monitoring devices, were a maximum of 14,640 mrem/yr within the 100-N area and 1,100 mrem/yr at a tank farm in the 200 East area (PNL, 1994c). Contact readings at "hot spots" within these facilities would likely be higher.

Air quality impacts would be bounded by those discussed for the preferred alternative. Groundwater monitoring would be conducted at the storage site as part of site operations through a system of Resource Conservation and Recovery Act compliant groundwater monitoring wells already in place along the burial ground boundaries. The Hanford Site is not located above "sole source aquifer" as designated in the provisions of the Safe Drinking Water Act (40CFR149). Regardless, in the arid climate of the Hanford Site, with periodic maintenance of compartment surface coatings (paint) and foundation structures as required, the reactor compartments in storage would retain their structural integrity indefinitely. Thus, no migration of lead, polychlorinated biphenyls, or radioactivity would occur, regardless of whether the compartments were outdoors or enclosed under a roof. Consequently, no impacts to the environment are foreseen.

4.6.1 Socioeconomic Impacts of Indefinite Storage Above Ground at Hanford

This alterative would have the same socioeconomic effects as the Preferred alternative.

4.7 Environmental Justice

In February 1994, Executive Order 12898 titled *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* was released to Federal Agencies. This order directs Federal Agencies to incorporate environmental justice as part of their missions. As such, Federal Agencies are specifically directed to identify and address as appropriate disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low-income populations.

In accordance with Executive Order 19898, this action has been evaluated for potential disproportionately high and adverse impacts on minority or low-income populations. There is not a high and adverse impact on the general public from any of the alternatives. There would be an adverse impact on the shipyard workforce from the subdivide and reuse alternative; however, these workers are neither disproportionately minority nor low-income.

The DOE Programmatic Spent Nuclear Fuel Management and INEL Environmental Restoration and Waste Management Final Environmental Impact Statement (DOE, 1995) analyzed potential environmental justice concerns based on a qualitative assessment of the impacts identified. The methodology, data, maps, and conclusions for environmental justice analysis is contained in Appendix L of Volume I of this EIS. The appendix is titled "Environmental Justice" (pages L-1 to L-41). On page L-40, this analysis concluded the potential impacts present no significant risk and do not constitute a reasonably foreseeable adverse impact to the surrounding population. Therefore, the impacts do not constitute a disproportionately high and adverse impact on any particular segment of the population, minorities or low-income communities included, and thus do not present an environmental justice concern.

The potential impacts to the general public from the alternatives evaluated for reactor compartment disposal are less than those evaluated in the Programmatic Spent Nuclear Fuel Management Environmental Impact Statement. In addition, the sites and transport routes analyzed in that EIS encompass those for reactor compartment disposal alternatives. Therefore, the conclusions from the Programmatic Spent Nuclear Fuel Management Environmental Impact Statement are also valid for this analysis.

Even if all the potential exposure to the general public from any of the reactor compartment disposal alternatives was received solely by minority or low-income populations, clearly a conservative and bounding assumption, no significant increase in latent cancer fatalities would occur. The impacts to the general public do not constitute a disproportionately high and adverse impact on any particular segment of the population, minorities or low-income communities included, and thus do not present an environmental justice concern.

4.8 Summary of Environmental Consequences

4.8.1 Preferred Alternative - Land Burial of the Entire Reactor Compartment at the Department of Energy Low Level Waste Burial Grounds at Hanford, WA

4.8.1.1 Shipyard Operations

Radiation exposure to Shipyard workers associated with reactor compartment disposal packaging operations to accomplish the preferred alternative has been estimated to be 1508 rem (approximately 0.6 additional latent cancer fatalities).

In all of the alternatives, the Navy would generate radioactive waste, PCB waste, and hazardous waste for disposal. However, the Navy would minimize the amount generated and any waste generated would be disposed of in accordance with applicable state and federal regulations using licensed transportation contractors and disposal sites.

4.8.1.2 Transport Route

The impacts along the transportation route that would be used to move reactor compartments from Puget Sound Naval Shipyard to the Hanford Site for disposal are evaluated an Appendix E. It is estimated that the preferred alternative would involve 100 reactor compartment shipments and would result in exposure to the general population of 5.8 person-rem (0.003 latent cancer fatalities). For the transportation crew it is estimated that exposure would be 5.8 person-rem (0.002 latent cancer fatalities).

In order to use the existing land transport route, six overhead power lines may need to be modified to accommodate the larger reactor compartment disposal packages under consideration in this EIS. If necessary, these modifications would only affect the sections of the power line within the immediate vicinity of the land transport route.

4.8.1.3 Land Disposal Site

Approximately 4 hectares (10 acres) of land would be required for land disposal of the approximately 100 reactor compartment disposal packages from the cruisers, LOS ANGELES, and OHIO Class submarines. This would be a commitment of about 4 hectares (10 acres) of land from the 218-E-12B low level burial ground in the 200 East area of the Hanford Site. As is the case with other areas of the Hanford Site used for radioactive waste disposal, the land area used for disposal of the reactor compartment disposal packages and the surrounding buffer zone would constitute an irretrievable and irreversible commitment of that land area and the natural resources contained therein. The cruiser, LOS ANGELES, and OHIO Class reactor compartment disposal packages would be regulated for their radioactivity, lead, and PCB content. The release rates for these constituents are expected to be extremely small such that applicable environmental standards are not expected to be exceeded. The total volume of reactor compartments would be about 120,000 cubic meters (4,240,000 cubic feet). The migration of these constituents from the reactor compartments to the groundwater aquifer and to the Columbia River is also expected to be slow. For radioactivity, only the longer lived radionuclides are expected to be released. Approximately 1,625 cubic meters (57,400 cubic feet) of other mixed waste from the reactor compartments would be generated and disposed of separately, primarily consisting of solidified radioactive potassium chromate solution.

4.8.2 No-Action Alternative

4.8.2.1 Shipyard Operations

Radiation exposure to the Shipyard workers associated with preparing the ships for indefinite waterborne storage following inactivation and decommissioning to accomplish the No Action alternative is estimated to result in a dose of approximately 50 rem (0.02 latent cancer fatalities). This would include the first 15 years of waterborne storage maintenance operations and inspections. Because radiation exposure to the workers is primarily due to Cobalt-60 which has a half life of 5.3 years, during each 15 years storage period nearly three half lives of radioactive decay occur. As a result, exposure during the second 15 years waterborne storage period would result in a dose of only 5.3 rem (0.002 latent cancer fatalities).

At Norfolk Naval Shipyard, no long term adverse environmental impacts due to the required dredging are anticipated. Dredging is routinely performed in this area with no known adverse effects. The Virginia Marine Resources Commission functions as the point of contact for all dredging permitting actions at Norfolk Naval Shipyard. They receive permitting applications and in turn notify and coordinate the involvement of all other regulatory and oversight agencies. These agencies are the U.S. Army Corps of Engineers, the Virginia Department of Environment, the Wetlands Board of the City of Portsmouth, and the State Environmental Protection Agency. Norfolk Naval Shipyard maintenance dredging permits specify Craney Island as the disposal site for dredge spoils. It is anticipated that a permit for deepening the berths at the Southgate Annex north and south of Pier E would similarly specify Craney Island as the disposal site because it is the only active disposal site in the area. The Craney Island spoils area is available to accept any dredge spoils removed from the Hampton Roads Basin (of which the Southgate Annex is a part).

At Puget Sound Naval Shipyard no dredging is expected as a result of this alternative because the sediment rate in the area is less than one foot per 50 years.

4.8.3 Disposal and Reuse of Subdivided Portions of the Reactor Compartment

4.8.3.1 Shipyard Operations

Based on results from dismantling of the Shippingport nuclear power plant and NRC projections for decommissioning of a commercial nuclear power plant, this alternative would result in from 22,500 to 109,000 rem (9.1 to 43.7 additional latent cancer fatalities) of worker radiation dose if performed immediately after decommissioning of the ships. Worker radiation dose would be reduced by about one–half for every 5 years that operations are deferred such that after a ten year deferral, worker radiation dose would be reduced to between 6,090 and 33,100 rem. (2.4 to 13.2 additional latent cancer fatalities).

4.8.3.2 Transport Routes

The impacts along transportation routes that would be used to move subdivided portions of reactor compartments to disposal sites are evaluated in Appendix E. Four origin-destination cases are evaluated (Puget Sound to Hanford, Puget Sound to Savannah River, Norfolk to Hanford and Norfolk to Savannah River). Since two of the cases are for origins and destinations on the same coast and two are for origins and destinations on opposite coasts, the evaluation is considered to bound shipment of subdivided components from either of the two origins (Puget Sound and Norfolk) to any disposal site within the 48 contiguous states. It is estimated that the subdivision alternative would involve 1571 shipments and would result in exposure to the general population of 11 to 119 person-rem (0.006 to 0.060 latent cancer fatalities). For the transportation crew it is estimated that exposure would be from 12 to 96 person-rem (0.005 to 0.039 latent cancer fatalities).

4.8.3.3 Disposal Sites

The amount of waste estimated for the subdivision alternative ranged from a high of 120,000 cubic meters (4,240,000 cubic feet), assuming no volume reduction, to a low of 10,000 cubic meters (353,000 cubic feet) assuming extensive volume reduction. An assumption of moderate volume reduction resulted in an intermediate estimate of 24,000 cubic meters (847,000 cubic feet). In all three cases the amount of mixed waste and radioactive-PCB waste was estimated to be from 2,255 to 6,255 cubic meters (79,600 to 221,000 cubic feet).

4.8.4 Indefinite Storage Above Ground at Hanford

As in the No Action alternative, storage is not a disposal alternative. Such storage would only defer the need to permanently disposition the radioactive and hazardous material contained by the reactor compartment. As discussed in section 4.6, the impacts of this alternative would be the same as those summarized in section 4.8.2.

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GLOSSARY

absorbed dose	When ionizing radiation passes through a material, some of its energy is imparted to the material. The amount of energy retained per unit mass of the material is called the absorbed dose and is measured in rads. Rads are usually converted to dose units of rem when referring to the absorbed dose in humans. This conversion considers the different impacts that various forms of ionizing radiation produce in the human body. Consequently absorbed doses expressed in rad and equivalent rem may not be numerically equal.
activation	The process of making a material radioactive by exposing the material to neutrons, protons, or other nuclear particles. In this EIS, a large percentage of the radioactivity present in defueled nuclear reactor plants was formed by activating the metal structures in the reactor compartment with neutrons during normal reactor plant operations. Activation is also referred to as radioactivation.
adsorption	Taking up of molecules by physical or chemical forces by the surfaces of solids or liquids with which they are in contact.
beta particle	[Symbol β (beta)] A charged particle emitted by certain radioactive materials. It has a unit electrical charge and a mass which is equal to 1/1837 of a proton. A negatively charged beta particle is identical to an electron and is the more common form of beta activity. A positively charged beta particle is called a positron and is less common. Exposure to large levels of beta particles may cause skin burns, and materials that emit beta particles are harmful if they enter the body. Most beta particles are stopped by a few millimeters of lead or steel.
curie	[Abbreviation Ci] A unit of radioactivity. One curie of radioactivity in a material results in 37 billion (3.7×10^{10}) nuclear disintegrations per second. This unit does not give any indication of the radiological hazard associated with the disintegration.
decommissioning	Actions to remove a Naval vessel from active service.
dose	A general term which denotes the quantity of radiation or energy absorbed; usually expressed in rem for doses to man.
dose commitment	The total radiation dose accrued by an individual over a specified period of time due to the exposure of the individual to radiation during a given interval of time. This includes the total time the radioactive material would reside in the body, if ingested or inhaled. Dose commitments are usually expressed in rem.

gamma ray	[Symbol γ (gamma)] High-energy, short wavelength electromagnetic radiation. Gamma radiation frequently accompanies beta particle emissions. Gamma rays are very penetrating and are stopped most effectively by dense materials such as lead or uranium. They are essentially similar to x-rays but are usually more energetic and originate from the nucleus. Cobalt-60 is an example of a radionuclide that emits gamma rays.
inactivation	The process by which a nuclear-powered ship is prepared for decommissioning and for eventual disposition of the ship. Thus term is often used interchangeable with deactivation.
half-life	The time required for half of the atoms of a radioactive material to decay to another nuclear form.
inner bremsstrahlung	Electromagnetic radiation produced by the sudden retardation of an electrical particle (electron or positron) in the intense electrical field of the atomic nucleus.
ionizing radiation	Any radiation which displaces electrons from atoms or molecules, thereby producing ions. Examples include alpha, beta, and gamma radiation. Exposure to ionizing radiation may produce skin or tissue damage.
latent cancer fatality	The increased number of fatal cancers is based on the calculated increase in exposure to radiation that would be seen by the general public. The average annual dose received by a member of the population of the United States from background radiation is approximately 300 millirem. When people are exposed to additional radiation, the number of radiation induced cancer and other health effects increase. In a typical group of 10,000 persons who do not work with radioactive material, a total of about 2,000 (20 percent) will normally die of cancer. If each of the 10,000 persons received an additional 1 rem of radiation exposure (10,000 person-rem) in their lifetime, then an estimated 5 additional cancer deaths (0.05 percent) might occur. Therefore, the likelihood of a person contracting fatal cancer during their lifetime could be increased nominally from 20 percent to 20.05 percent by receiving a dose of 1 additional rem of radiation. The factor used in this EIS to obtain fatal cancers is 0.0004 fatal cancers per person-rem for workers and 0.0005 fatal cancers per person-rem for the general public.
radioactivity	The process of spontaneous decay or disintegration of an unstable nucleus of an atom; usually accompanied by the emission of ionizing radiation.
rem	An acronym for roentgen equivalent man. A special unit for measuring dose equivalents. A rem gives the same biological effects as one roentgen of x-rays gamma or beta radiation.

seiche	A wave caused by seismic or atmospheric disturbances which oscillates in enclosed bodies of water. Oscillations occur from a few minutes to a few hours.
x-rays	Penetrating electromagnetic radiation with wavelength shorter than visible light. They are usually produced (as in medical diagnostic x-ray machines) by irradiating a metallic target with large numbers of high-energy electrons. In nuclear reactions, it is customary to refer to photons originating outside the nucleus as x-rays and those originating in the nucleus as gamma rays.

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