NUREG/CR-0672
Addendum 4

Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station

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ABSTRACT

This study presents the results of a comparison of a previous decommissioning cost study by Pacific Northwest Laboratory (PNL) and a recent decommissioning cost study by TLG Engineering, Inc., for the same commercial nuclear power reactor station. The purpose of this comparative analysis on the same plant is to determine the reasons why subsequent estimates for similar plants by others were significantly higher in cost and external occupational radiation exposure (ORE) than the PNL study.

The primary purpose of the original study by PNL (NUREG/CR-0672) was to provide information on the available technology, the safety considerations, and the probable costs and ORE for the decommissioning of a large boiling water reactor (BWR) power station at the end of its operating life. This information was intended for use as background data and bases in the modification of existing regulations and in the development of new regulations pertaining to decommissioning activities. It was also intended for use by utilities in planning for the decommissioning of their nuclear power stations.

The TLG study, initiated in 1987 and completed in 1989, was for the same plant, Washington Public Power Supply System's Unit 2 (WNP-2), that PNL used as its reference plant in its 1980 decommissioning study. Areas of agreement and disagreement are identified, and reasons for the areas of disagreement are discussed.

FOREWORD
BY
NUCLEAR REGULATORY COMMISSION STAFF

The Nuclear Regulatory Commission (NRC) has issued regulations related to the decommissioning of nuclear facilities.[1] As part of this activity, the NRC initiated two series of studies through technical assistance contracts. These contracts were undertaken to develop information to support the preparation of new standards covering decommissioning.

The first series of studies covers the technology, safety, and costs of decommissioning reference nuclear facilities.[2-26] Light water reactors (LWRs) and fuel-cycle and non-fuel-cycle facilities were included. Facilities of current design on typical sites were selected for the studies. Separate reports were prepared as the studies of the various facilities were completed.

The second series of studies covers supporting informati[illegible] on [illegible]e decommissioning of nuclear facilities.[27-31] This series incl[illegible]ted bibliography on decommissioning and studies on facilitat[illegible] survey methods appropriate for decommissioning, as well as an examination of regulations applicable to decommissioning.

This report contains information concerning a comparison of two decommissioning cost estimates developed for the same commercial nuclear reactor power station, prepared by two independent entities.

The information provided in this report on decommissioning of a reference BWR, including any comments, will be included in the record for consideration by the Commission in establishing criteria and new standards for decommissioning. Comments on this report should be mailed to:

Chief
Radiation and Health Effects Branch
Division of Regulatory Applications
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

REFERENCES

1. Final Rule Amendments to 10 CFR Parts 30, 40, 50, 51, 70, and 72: General Requirements for Decommissioning Nuclear Facilities, Federal Register, 53 FR 24018, June 27, 1988.

2. Technology, Safety and Costs of Decommissioning a Reference Nuclear Fuel Reprocessing Plant. 1977. NUREG-0278, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

3. Technology, Safety and Costs of Decommi... ...ng a Reference Pressurized Water Reactor Power Station. 1978. NUREG/CR-0130, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

4. Technology, Safety and Costs of Decommissioning a Reference Small Mixed Oxide Fuel Fabrication Plant. 1979. NUREG/CR-0129, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

5. Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station. 1979. NUREG/CR-0130 Addendum, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

6. Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground. 1980. NUREG/CR-0570, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

7. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station. 1980. NUREG/CR-0672, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

8. Technology, Safety and Costs of Decommissioning a Reference Uranium Fuel Fabrication Plant. 1980. NUREG/CR-1266, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

9. Technology, Safety and Costs of Decommissioning Reference Non-Fuel-Cycle Nuclear Facilities. 1981. NUREG/CR-1754, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

10. Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground - Environmental Surveillance Programs. 1981. NUREG/CR-0570 Addendum. U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

11. Technology, Safety and Costs of Decommissioning a Reference Uranium Hexafluoride Conversion Plant. 1981. NUREG/CR-1757, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

12. Technology, Safety and Costs of Decommissioning Nuclear Reactors at Multiple-Reactor Stations. 1982. NUREG/CR-1755, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

13. Technology, Safety and Costs of Decommissioning Reference Nuclear Research and Test Reactors. 1982. NUREG/CR-1756, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

14. Technology, Safety and Costs of Decommissioning Reference Light Water Reactors Following Postulated Accidents. 1982. NUREG/CR-2601, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

15. Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station - Effects on Decommissioning of Interim Inability to Dispose of Wastes Offsite. 1983. NUREG/CR-0130, Addendum 2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

16. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station - Effects on Decommissioning of Interim Inability to Dispose of Wastes Offsite. 1983. NUREG/CR-0672, Addendum 1, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

17. Technology, Safety and Costs of Decommissioning Reference Nuclear Research and Test Reactors - Sensitivity of Decommissioning Radiation Exposure and Costs to Selected Parameters. 1983. NUREG/CR-1756 Addendum, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

18. Technology, Safety and Costs of Decommissioning Reference Independent Spent Fuel Storage Installations. 1984. NUREG/CR-2210, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

19. Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station - Classification of Decommissioning Wastes. 1984. NUREG/CR-0130, Addendum 3, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

20. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station - Classification of Decommissioning Wastes. 1984. NUREG/CR-0672, Addendum 2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

21. Technology, Safety and Costs of Decommissioning Reference Nuclear Fuel Cycle and Non Fuel Cycle Facilities Following Postulated Accidents. 1985. NUREG/CR-3293, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

22. Technology, Safety and Costs of Decommissioning Nuclear Reactors at Multiple-Reactor Stations - Effects on Decommissioning of Interim Inability to Dispose of Wastes Offsite. 1985. NUREG/CR-1755, Addendum 1, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

23. Technology, Safety and Costs of Decommissioning Reference Nuclear Fuel Cycle Facilities - Classification of Decommissioning Wastes. 1986. NUREG/CR-4519, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

24. Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station - Technical Support for Decommissioning Matters Related to Preparation of the Final Decommissioning Rule. 1988. NUREG/CR-0130, Addendum 4, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

25. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station - Technical Support for Decommissioning Matters Related to Preparation of the Final Decommissioning Rule. 1988. NUREG/CR-0672, Addendum 3, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

26. Technology, Safety and Costs of Decommissioning Reference Non-Fuel-Cycle Nuclear Facilities - Compendium of Current Information. 1989. NUREG/CR-1754, Addendum 1, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

27. Decommissioning of Nuclear Facilities - An Annotated Bibliography. 1979. NUREG/CR-0130, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

28. Decommissioning of Nuclear Facilities - A Review and Analysis of Current Regulations. 1979. NUREG/CR-0671, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

29. Facilitation of Decommissioning of Light Water Reactors. 1979. NUREG/CR-0569, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

30. Monitoring for Compliance with Decommissioning Termination Survey Criteria. 1981. NUREG/CR-2082, U.S. Nuclear Regulatory Commission Report by Oak Ridge National Laboratory, Oak Ridge, Tennessee.

31. Technology and Cost of Termination Surveys Associated with Decommissioning of Nuclear Facilities. 1982. NUREG/CR-2241, U.S. Nuclear Regulatory Commission Report by Oak Ridge National Laboratory, Oak Ridge, Tennessee.

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The editorial review prior to publication was provided by David R. Payson of the Pacific Northwest Laboratory.

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1.0 INTRODUCTION

This study presents the results of a comparison of a previous decommissioning cost study, NUREG/CR-0672 (Oak et al. 1980), and a recent decommissioning cost study (TLG 1989) for the same (except for possible differences in postulated plant equipment inventories between the two decommissioning analyses) commercial nuclear reactor power station, prepared by two independent organizations. The purpose of this comparative analysis on the same boiling water reactor (BWR) plant is to determine the reasons why subsequent estimates for similar plants by others were significantly higher in cost and external occupational radiation exposure (ORE) than the estimates derived in NUREG/CR-0672.

At the direction of the U.S. Nuclear Regulatory Commission (NRC), Pacific Northwest Laboratory (PNL) contracted with TLG Engineering, Inc. (TLG) to have TLG prepare a decommissioning cost estimate for the same reference plant, Washington Public Power Supply System's Unit 2 (WNP-2), that PNL used in its 1980 BWR decommissioning study (NUREG/CR-0672). In this way, it is possible to make direct comparisons of the various portions of the decommissioning cost and ORE estimates, to see which portions are significantly different and what causes the differences. This contract was initiated in mid-1987, and a draft report was received from TLG in February 1988, with the final revisions to the final report submitted in June 1989. To assure the reader would have a balanced perspective to the comparative studies, PNL provided draft copies of its report to TLG for review and comment. TLG comments were provided to the NRC in March 1990 (LaGuardia 1990). In turn, selected constructive TLG comments were incorporated into this report, where applicable.

The decommissioning study delineated in NUREG/CR-0672 was performed for the NRC by PNL to conceptually decommission a present-generation BWR power station. The primary purpose of the original study was to provide information on the available technology, the safety considerations, and the probable costs for the decommissioning of a large BWR power station at the end of its operating life. This information was intended for use as background data and bases in the modification of existing regulations and in the development of new regulations pertaining to decommissioning activities. It was also intended for use by licensees in planning for the decommissioning of their nuclear power stations.

Original NRC guidance on decommissioning was provided in the form of the June 1974 issue of Regulatory Guide 1.86 (NRC 1974). R. G. 1.86 defines four decommissioning alternatives acceptable to the NRC, including prompt removal/dismantling, mothballing, entombment, and conversion, and that terminology was used throughout the TLG report. However, the NRC uses new terminology in the Decommissioning Rule for the first three alternatives (the Rule does not consider conversion as a true decommissioning alternative and it is no longer referred to). In the Rule, prompt removal/dismantling is referred to as the DECON alternative, mothballing is referred to as SAFSTOR, and entombment is referred to as ENTOMB. Because the R. G. 1.86 terms and the newer Rule terms are so similar, the more recent NRC terminology is used in this addendum when making comparisons between the TLG report and NUREG/CR-0672.

Dismantlement, either immediate or after an extended safe storage period, permits termination of the owner's reactor operating license. Safe storage and entombment require the continuance of an amended version of the license and are not necessarily complete modes. The amended operating license, allowing the licensee to possess but not operate the facility, is termed a "possession-only" license (NRC 1974). A comparison of the summary descriptions of each of these alternatives as considered in the PNL and TLG studies is presented in Table 1.1.

The comparison made in this report examines only the DECON (immediate dismantlement) mode of decommissioning, since the SAFSTOR (safe storage) and ENTOMB (entombment) analyses are, basically, outgrowths of the DECON analysis. This comparison is further restructured to consideration of only the scenario wherein the owner (utility) employs a decommissioning operations contractor (DOC) to accomplish the actual decommissioning.

Following this introduction, a summary of the information and findings resulting from this analysis is presented in Chapter 2. Chapter 3 contains the supporting information associated with updating the NUREG/CR-0672 cost estimates to mid-1987 (July-August) dollars. A summary of the results of the TLG study is presented in Chapter 4. The analysis performed to determine the differences between the two decommissioning studies on the same BWR and the conclusions reached from that analysis are presented in Chapter 5. Supporting information for the PNL cost updating bases and methodology is provided in Appendix A.

1.1 REFERENCES

LaGuardia, T. S. 1990. "Final Proposed Re-Write on PNL Report NUREG/CR-0674, Addendum 4." Bridgewater, Connecticut. Letter Document N10-20-GC-9001 to Dr. Carl Feldman, U.S. Nuclear Regulatory Commission.

Oak, H. D., G. M. Holter, W. E. Kennedy, and G. J. Konzek. 1980. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station. NUREG/CR-0672, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

TLG Engineering, Inc. (TLG). 1989. Decommissioning Cost Study for the WPPSS Nuclear Project No. 2. Document B04-25-001 Revision 1. Bridgewater, Connecticut.

U.S. Nuclear Regulatory Commission (NRC). June 1974. Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors," Washington, D.C.

TABLE 1.1. Characteristics of the Decommissioning Alternatives Considered in the PNL and TLG Studies

Decommissioning Alternatives Used by PNL and TLG

PNL Study	TLG Study
• DECON (Immediate Dismantlement): The station is decontaminated and the radioactive materials are removed. Upon completion, the nuclear license is terminated and the property is released for unrestricted use. The demolition and removal of uncontaminated structures and site restoration is not included.	• DECON (Prompt Removal/Dismantling) of a power reactor consists of removing from the site all fuel assemblies and source material, radioactive fission and corrosion products, and all other radioactive materials having activities above release limits. The facility operator may then have unrestricted use of the site with no requirement for a license. This scenario is delineated in the rule on decommissioning issued by the Nuclear Regulatory Commission (NRC) "General Requirements for Decommissioning Nuclear Facilities." This study further assumes that the remainder of the reactor facility will be dismantled and all vestiges removed. The site is then restored and made available for alternative use.
• SAFSTOR (Safe Storage with Delayed Dismantlement): The radioactive materials and contaminated areas are decontaminated or secured and the structures and equipment are maintained as necessary to ensure the protection of the public from the residual radioactivity. During the period of safe storage, use of the property remains limited by the nuclear license. Eventual dismantlement is necessary if unrestricted release and license termination is desired.	• SAFSTOR (Mothball with Delayed Dismantling) also consists of placing and maintaining the facility in protective storage. Fuel and source material is removed from the site. Initial mothball operations consist of general plant decontamination, radiation surveys, processing and the disposal of radioactive waste materials, securing a possession-only license, and implementing security, surveillance and maintenance plans for the delay period. Delayed dismantling activities are initiated after the dormancy period and are basically those described for the DECON alternative, resulting in the restoration and release of the site for alternative use.
• ENTOMB (Entombment): The radioactive materials and contaminated areas are decontaminated and the nonreleasable materials are confined within a monolithic structure that provides integrity to ensure the protection of the public from the entombed radioactivity for a time period of sufficient length to permit the decay of the radioactivity to unrestricted release levels. During the period of entombment, the property is maintained as necessary and remains restricted in use by the nuclear license. Two postulated entombment scenarios are considered: 1) entombment with the reactor vessel internals removed, and 2) entombment with the reactor vessel internals in place.	• ENTOMB (Entombment with Delayed Dismantling) consists of placing the facility into protective storage, with the reactor vessel internals in place. All fuel and source material is removed from the site. Initial activities consist of removing from the site all contaminated components, systems and structures outside the designated entombment boundary and sealing the remaining radioactivity within an entombment structure (usually the massive, concrete central portion of the containment or reactor building). This structure provides for isolation of the entire radioactive inventory on the site during the delay period. Additional activities involve the securing of a possession-only license, and the implementation of security and surveillance plans for the delay period. Delayed dismantling activities are initiated after the delay or dormancy period and consist of radiation surveys, removal of the entombment structure and materials within it, processing and the disposal of any remaining solid and liquid radioactive wastes followed by the restoration and release of the site as described in the DECON alternative.

2.0 SUMMARY

The results of this study to compare a previous decommissioning cost study by Pacific Northwest Laboratory (PNL), NUREG/CR-0672 (Oak et al. 1980), and a recent decommissioning cost study by TLG Engineering, Inc. (TLG 1989) for the same (except for possible differences in postulated plant equipment inventories between the two decommissioning analyses) commercial nuclear power reactor station are summarized in this chapter. The purpose of this comparative analysis on the same plant, Washington Public Power Supply System's Unit 2 (WNP-2), is to determine the reasons why subsequent estimates for similar plants by others were significantly higher in cost and external occupational radiation exposure (ORE) than the PNL study. The U.S. Nuclear Regulatory Commission (NRC) sponsored this work.

The primary purpose of the original study by PNL was to provide information on the available technology, the safety considerations, and the probable costs and ORE for the decommissioning of a large boiling water reactor (BWR) power station at the end of its operating life. This information was intended for use as background data and bases in the modification of existing regulations and in the development of new regulations pertaining to decommissioning activities. It was also intended for use by utilities in planning for the decommissioning of their nuclear power stations.

This summary is organized as follows. The study approach is presented in Section 2.1. Section 2.2 contains the results of the updated PNL study. The results of the TLG study are summarized in Section 2.3. A summary of the results of the comparison between the two studies is presented in Section 2.4. Areas of agreement and disagreement are identified, and reasons for the areas of disagreement are briefly discussed, with more complete discussions presented in Chapter 5.

2.1 STUDY APPROACH

With the exception of some possible differences in plant equipment inventories between 1980 and 1987, common grounds (e.g., WNP-2 drawings and inventory documents, rates for shipping radioactive wastes, base burial costs, etc.) provided the bases for the reference plant study by PNL and the site-specific study by TLG. The costs reported in each study are examined and tabulated for the DECON (immediate dismantlement) decommissioning alternative and escalated to a common base of mid-1987 dollars to provide a reasonable comparison. The areas of agreement and disagreement concerning decommissioning costs and ORE reported by both studies are then identified, clarified where possible, and the various factors that contribute to the differences are discussed.

2.2 RESULTS OF THE UPDATED PNL STUDY

Because of rising costs and a changing regulatory climate, the NUREG/CR-0672 (Oak et al. 1980) reference plant cost estimates, originally developed in 1978 dollars, were updated to reflect 1984 cost conditions in a report prepared by PNL for the Electric Power Research Institute (Smith et al. 1985). Using the new cost estimates as a base, revised cost estimates were developed for several alternatives identified to increase decommissioning costs, including: predecommissioning engineering; additional staff to assure meeting the 5 rem/year dose limit for personnel; extra supplies for the additional staff; and the additional costs associated with the option of using a decommissioning operations contractor (DOC) external to the utility organization to conduct the decommissioning effort.

In addition to the EPRI cost update, three addendums (Holter and Murphy 1983; Murphy 1984; Konzek and Smith 1988) to the original BWR report (NUREG/CR-0672) have been prepared. The first addendum examined the effects on costs and safety of decommissioning plants of being unable to dispose of wastes offsite. The second addendum presented a classification of the wastes resulting from decommissioning. The third addendum examined pertinent topics in support of the Final Generic Environmental Impact Statement on Decommissioning and the final Decommissioning Rule, including assessing the cost and dose impacts of post-TMI-2 backfits and developing a revised scaling formula for plants different in size than the reference plant, and an escalation formula for adjusting current cost estimates for future escalation. Information from these addenda useful to this analysis is incorporated into these updated study results.

The pertinent cost adjustment factors used to update the decommissioning costs for the reference BWR to an August 1987 cost base for this study are described in detail in Appendix A of this report.

The various cost items for the utility-plus-decommissioning operations contractor (DOC) approach are separated into utility costs and DOC costs in Table 2.1 for comparison with the costs for the utility-only approach, which are also shown. A 15% fee is applied to all DOC costs. The utility-DOC approach for immediate dismantlement of the BWR increases the total decommissioning cost by about 27%, to about \$138 million. This total does not include any incentive or bonus payments that might be negotiated for an undertaking of this magnitude.

The accumulated ORE impact associated with implementation of the post-TMI-2 requirements is estimated to be 3.1 man-rem, raising the total ORE for immediate dismantlement of the reference BWR to about 1889 man-rem. The accumulated disposal volume of radioactive waste associated with implementation of the post-TMI-2 requirements is estimated to be about 36 m^3, raising the total disposal volume of radioactive waste for immediate dismantlement to about 18,975 m^3.

2.3 RESULTS OF THE TLG STUDY

A site-specific cost estimate was prepared for WNP-2 by TLG (1989). The methodology used to develop the cost estimates follows the basic approach originally presented in Manion and LaGuardia (1976 and 1980) and LaGuardia (1986). The TLG study examines DECON (prompt removal/dismantling) for two

TABLE 2.1. Summary of PNL Estimated Costs for Immediate Dismantlement of the Reference BWR Using the Utility-Only Approach or the Utility-DOC Approach

Cost Category	Estimated Cost (millions 1987$)[a,b] Utility-Only	Utility-DOC	
Radioactive Material Disposal	32.782	32.782	--
Shipping Containers	6.522	--	6.522
Staff Labor	32.230	7.831	38.125
Energy	6.000	6.000	--
Special Equipment	3.347	--	3.347
Miscellaneous Supplies	3.249	--	3.249
Specialty Contractors	0.591	--	0.591
Nuclear Insurance	1.626	1.626	--
Licensing Fees	0.123	0.123	--
Mobilization and Demobilization	--	--	2.038
Subtotals, Utility-DOC Costs	--	48.362	53.872
Total DOC Fee (15%)	--	--	8.081
Total, DOC Costs			61.953
Subtotal	86.470	110.315	
Contingency (25%)	21.618	27.579	
Totals, DECON Costs	108.088	137.894	

(a) Costs adjusted to August 1987.
(b) Number of figures shown is for computational accuracy and does not imply precision to the nearest thousand dollars.

alternatives concerning management of the decommissioning programs. The TLG report states: "In the base case, the licensee uses a DOC in the decommissioning of WNP-2. It is assumed that the DOC provides sufficient staff to perform the preparatory demolition[(a)] planning and scheduling and manage the demolition efforts. Site security during demolition is provided by the licensee or its subcontractor. The demolition work is performed by the DOC or a demolition subcontractor who will provide adequate staff, labor, equipment, materials and overhead to complete the demolition. As an alternative, the decommissioning programs were reanalyzed with the premise that the licensee performed the DOC function--i.e., the licensee operated as its own DOC."

The TLG study provides a breakdown, comprised of three periods, of the basic activities necessary for a demolition/site-restoration scenario:

- Period 1 - Preparations
- Period 2 - Decommissioning Operations and License Termination
- Period 3 - Site Restoration.

Although not required for license termination, it was assumed in the TLG analyses of the DECON alternatives during Period 3 that the remainder of the reactor facility was dismantled and all vestiges were removed. It was further assumed that the site was restored by regrading the site to conform to the adjacent landscape and thus made available for alternative use.

The total projected cost of dismantling the WNP-2 facility for the DECON alternative in the base case scenario (i.e., licensee and decommissioning operations contractor or DOC) is about $281.2 million (1987 dollars), and the cost of DECON in the reanalyzed case (i.e., licensee acting as its own DOC) is estimated to cost about $262.7 million (1987 dollars).

In the TLG study, approximately $190.1 million of the $281.2 million total projected cost of DECON (base case) is directly attributable to the engineering and planning for and the actual disposition of the residual radioactivity in the WNP-2 facility.

The TLG study points out, however, that a direct accounting of only these costs is not entirely accurate in portraying the actual cost of "decommissioning" as defined by the NRC, and that consideration must also be given to the methods of executing the decontamination processes as well as "cascading costs." The TLG study defines cascading costs as the costs associated with the removal of noncontaminated and releasable material in support of the decommissioning process. The TLG study further states that it is estimated that about $11.3 million in cascading costs will be incurred in the decommissioning process for the licensee to meet the intent of the NRC's definition

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(a) Demolition as used here appears to include some license termination activities encompassed in Periods 1 and 2 as well as nonlicense-related demolition and site restoration activities during Period 3.

of decommissioning, resulting in a total DECON cost of $201.5 million. A summary listing from the TLG study for license termination, including cascading costs, for DECON (base case) is shown in Table 2.2.

The projected ORE for either of the DECON alternatives is 3777 man-rem. The estimated radioactive waste volume generated during DECON is approximately 24,489 cubic meters. The waste volume attributed to DECON is primarily generated over a 48-month period.

TABLE 2.2. License Termination Including Cascading Costs from the TLG Study for the DECON (base case) Mode

	Millions 1987$			
Period Number	Direct Cost for License Termination	Cascading Costs	Total Decommissioning Cost	Total Cost Including Demolition/ Restoration
1[(a)]	15.971	0.0	15.971	15.971
2[(b)]	135.802	9.078	144.880	144.880
3[(c)]	0.329	0.000	0.329	64.117
Subtotal	152.102	9.078	161.180	224.968
25% Contingency	38.026	2.269	40.295	56.242
Total	190.128	11.347	201.475	281.210

(a) Preparations.
(b) Decommissioning Operations and License Termination.
(c) Site Restoration.

2.4 RESULTS OF THE COMPARISON BETWEEN THE TWO STUDIES

This section contains the results of the comparison between the reference plant study by PNL (Oak et al. 1980) and the site-specific study by TLG (TLG 1989) for the same (except for possible differences in postulated plant equipment inventories between the two decommissioning analyses) commercial nuclear reactor power station, WNP-2, a BWR. The results of the comparison are based on examination and analyses of the DECON alternative (immediate dismantlement), with a utility plus decommissioning operations contractor (DOC) organizational structure.

The PNL cost estimate and the TLG cost estimate are compared in Table 2.3, in the same breakdown of cost components and in the same-year dollars (1987). Examination of Table 2.3 shows that the principal reason for the difference between the two estimates for the same plant is due to the

TABLE 2.3. Comparison of Cost Estimates Without Demolition[a]

Cost Item	Millions of 1987 Dollars PNL Estimate	TLG Estimate
Waste Disposal	50.4	53.7
Energy	7.5	7.7
Equipment and Supplies	9.5	10.3
Other[b]	6.0	25.9
Subtotal	73.4	97.6
Labor		
Utility	9.8	32.3
DOC	19.8	25.5
Workers	35.0	46.1
Subtotal	64.6	103.9
Total	138.0	201.5[c]

(a) Includes 25% contingency.
(b) This cost includes DOC mobilization and demobilization, nuclear liability insurance, specialty contractors, and licensing fees.
(c) Adapted from Table 2.2; does not include costs for Period 3 Site Restoration.

large difference in labor costs, a factor of 1.6. In the other areas of the estimate, the estimates are reasonably comparable. In examining the bases for the TLG labor cost estimates, a number of reasons were identified as to why the TLG estimates were larger than the PNL estimates. The principal factors are:

- The size and composition of what are essentially overhead staff of the utility and the DOC are significantly different, with the staff postulated by TLG resulting in the total man-years of effort being larger by roughly a factor of two.

- Different assumptions about the duration of the pre-license termination activities (TLG: 6.23 years, PNL: 4.5 years) also contribute to the increased labor costs from the utility and DOC overhead staff in the TLG estimate. The estimated direct labor requirements differ between the two studies by about 30%, with the TLG estimate being the larger.

- The work difficulty factors used by TLG in developing the unit cost factors applied to each decommissioning task are applied at the upper bound of their ranges for all tasks. If the work difficulty factors in the TLG estimate were reduced to their lower bound values, the TLG estimate would be reduced by about 45%, becoming 15% smaller than the PNL estimate. Thus, the estimated direct labor costs are very sensitive to the assumed working conditions in the plant.

- Different assumptions about where to assign the costs of removing clean materials from the plant, and whether these materials had any salvage value, also contribute to a difference in license termination costs. PNL assumed removal of only those clean materials necessary to gain access to contaminated materials, leaving the rest for removal by the demolition contractor. TLG assumed removal of all clean materials from the structures during pre-license termination activities.

- The larger plant systems and structure inventory postulated in the TLG study contributes to a larger worker labor requirement than was developed in the PNL study. This larger inventory also contributes to the larger worker radiation dose developed in the TLG analyses.

Areas of agreement and disagreement identified between the PNL study and the TLG study are summarized in Table 2.4 and Table 2.5, respectively. More detailed discussion of these comparisons are given in Chapter 5 of this report.

TABLE 2.4. Summary of the Areas of Reasonable Agreement Between the PNL Study and the TLG Study on Decommissioning WNP-2

Area of Comparison	Comments and Qualifying Statements
• Planning and Preparation	• Both studies recognize that immediate dismantlement is a complex undertaking and that its success depends greatly on good planning and preparation work before final reactor shutdown. A difference exists in the time postulated for these efforts, however, with the PNL study allocating two years prior to reactor shutdown and the TLG study allocating three years--two years prior to shutdown and the first year after shutdown.
• Decontamination of Systems	• There is a general agreement between the two studies on the need for decontamination of reactor piping systems and components during decommissioning. Chemical decontamination methods (recirculating and once-through) and water-jet cleaning are clearly envisioned as being both necessary and effective in both studies. However, major differences exist in postulated application methodology and techniques which greatly impact the estimated cost and occupational radiation exposure projections for these decontamination tasks, as outlined in Table 2.5.
• Nuclear Liability Insurance (NLI)	• The costs for NLI during DECON are reasonably comparable between the two studies at $1.6 million for the PNL study and at $1.9 million for the TLG study, without contingency.
• Plant Energy Budget	• The costs of energy (electricity and oil) to license termination during DECON are reasonably comparable between the two studies at $7.5 million and $7.7 million (including contingency) for the PNL study and the TLG study, respectively.
• Demolition and Site Restoration	• Both studies are in agreement that the NRC has no jurisdiction over removal of uncontaminated structures and restoration of the site once all radioactive materials in the reference BWR are removed or decontaminated. In the PNL study, these materials are removed by a demolition contractor after license termination. In the TLG study, they are removed during Period 3 after license termination by decommissioning workers.
• Contingency	• Both decommissioning studies use a 25% contingency for their final cost estimates.

TABLE 2.5. Summary of the Areas of Disagreement Between the PNL Study and the TLG Study on Decommissioning WNP-2

Area of Comparison	Comments and Qualifying Statements	
• Estimating Methodology	• The PNL study and the TLG study each use different basic methods for determining the engineering cost and occupational radiation exposure (ORE) estimates for DECON	
	PNL Study	**TLG Study**
	- A detailed engineering study was done, based on task-by-task activities, ORE, and costs needed to decommission the reference BWR.	- A unit factors approach was used to identify the projected doses and costs associated with each activity (decontamination, removal, and packaging) for given types of material and equipment in the reference BWR.
	- The ORE estimates include varying levels of difficulty for each task and varying dose rates throughout the facility, based upon composite dose rate maps drawn from 7 operable BWRs (Oak et al. 1980).	- Constant dose rates were applied to all worker types on a given system, and over all tasks associated with that system. These levels were considered to be appropriate for a large BWR at end of life.
	- Varying levels of difficulty were considered in developing the man-hours and exposure hours estimated for each decommissioning activity.	- Maximum levels of difficulty given in LaGuardia et al. (1986), considered appropriate for a large BWR at end of life, were applied in developing the man-hours and exposure hours estimated for each decommissioning activity.
		- Cost per activity was multiplied by the number of similar activities (decontamination, removal, and packaging) to obtain the cost estimate.
	- All uncontaminated materials are left for removal by the demolition contractor after license termination.	- Uncontaminated material and equipment are removed during Period 2 by decommissioning workers.
• Decommissioning Staffing		
- Utility and DOC Overhead Staffing		
Utility overhead (man-years)	172	493
DOC overhead (man-years)	182	352
Total (man-years)	354	845
Cost (millions 1987 dollars, without contingency)	~24	~48
- Dedicated Decommissioning Workers		
Total Labor (man-years)	390	566
Total Cost (millions 1987 dollars)	~28	~37
	- For a discussion of staffing differences, see Chapter 5.	

TABLE 2.5. (contd)

Area of Comparison	Comments and Qualifying Statements	
	PNL Study	TLG Study
• Decontamination of Systems		
- Chemical Decontamination (recirculatory)		
Estimated ORE (man-rem)	33	704
Estimated Cost (millions 1987 dollars, without contingency)	~1	~4.5
- Water-Jet Cleaning		
Estimated ORE (man-rem)	27	175
Estimated Cost (millions 1987 dollars, without contingency)	~0.85	~2.1
• Work Difficulty Factors	- The cost and ORE estimates include varying levels of difficulty for each task and varying dose rates throughout the facility, based upon composite dose rate maps drawn from 7 operable BWRs (Oak et al. 1980).	- Maximum values of work difficulty factors given in LaGuardia et al. (1986), considered appropriate for a large BWR at end of life, were used in the development of unit cost factors for removal of material, and all difficulty factors were applied to all steps within each operation. Constant dose rates were applied to all worker types on a given system, and over all tasks associated with that system.
• Cascading Costs (The costs associated with the removal of nonradioactive materials to facilitate decontamination and retrieval of radioactive materials.)	- This activity was not considered as a separate work element in the PNL study in 1980, but was included in each activity, as appropriate.	- Cascading costs in the TLG study are estimated to be about $11.3 million, including contingency.
• Radioactive Waste Volume		
- Packaged waste, Volume, m^3	18,975	24,489
	NOTE: The differences in packaged waste are believed due largely to different assumptions regarding postulated plant equipment inventory, how selected materials are packaged, and whether certain contaminated materials could be sufficiently decontaminated to be released as clean scrap.	
- Estimated Transportation Cost (millions 1987 dollars, without contingency)	4.5	3.0

2.5 REFERENCES

Holter, G. M., and E. S. Murphy. 1983. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station - Effects on Decommissioning of Interim Inability to dispose of Wastes Offsite. NUREG/CR-0672, Addendum 1, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

Konzek, G. J., and R. I. Smith. 1988. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station - Technical Support for Decommissioning Matters Related to Preparation of the Final Decommissioning Rule. NUREG/CR-0672, Addendum 3, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

LaGuardia, T. S., et al. 1986. Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates. AIF/NESP-036, Atomic Industrial Forum, Washington, D.C.

Manion, W. J., and T. S. LaGuardia. 1976. An Engineering Evaluation of Nuclear Power Reactor Decommissioning Alternatives. AIF/NESP-009, Atomic Industrial Forum, Washington, D.C.

Manion, W. J., and T. S. LaGuardia. 1980. Decommissioning Handbook. DOE/EV/10128-1, U.S. Department of Energy, Washington, D.C.

Murphy, E. S. 1984. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station - Classification of Decommissioning Wastes. NUREG/CR-0672, Addendum 2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

Oak, H. D., G. M. Holter, W. E. Kennedy, and G. J. Konzek. 1980. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station. NUREG/CR-0672, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

Smith, R. I., G. J. Konzek, E. S. Murphy, and H. K. Elder. 1985. Updated Costs for Decommissioning Nuclear Power Facilities. EPRI NP-4012, Electric Power Research Institute Report by Pacific Northwest Laboratory, Richland, Washington.

TLG Engineering, Inc. (TLG). 1989. Decommissioning Cost Study for the WPPSS Nuclear Project No. 2. Document B04-25-001 Revision 1. Bridgewater, Connecticut.

3.0 PNL STUDY: COST UPDATING BASES, METHODOLOGY AND RESULTS

Because of rising costs and a changing regulatory climate, the NUREG/CR-0672 (Oak et al. 1980) generic cost estimates, originally developed in 1978 dollars, were updated to reflect 1984 cost conditions in a report prepared by PNL for the Electric Power Research Institute (Smith et al. 1985). Using the new cost estimates and the original reference plant inventory as a base, revised reference plant cost estimates were developed for several alternatives identified to increase decommissioning costs, including: predecommissioning engineering; additional staff to assure meeting the 5 rem/year dose limit for personnel; extra supplies for the additional staff; and the additional costs associated with the option of using a contractor external to the utility organization to conduct the decommissioning effort.

In addition to the EPRI cost update, three addendums (Holter and Murphy 1983; Murphy 1984; and Konzek and Smith 1988) to the original BWR report (NUREG/CR-0672) have been prepared. The first two addendums examined the effects on costs and safety of decommissioning plants 1) of being unable to dispose of wastes offsite, and 2) of classifying the wastes resulting from decommissioning. The third addendum examined the topics listed below in support of the Final Generic Environmental Impact Statement on Decommissioning and the final Decommissioning Rule:

- updating the previous cost estimates to January 1986 dollars
- assessing the cost and dose impacts of post-TMI-2 backfits
- developing a revised scaling formula for plants different in size than the reference plant and an escalation formula for adjusting current cost estimates for future escalation.

3.1 STUDY BASES

For consistency, the analyses of the impact of post-TMI-2 backfits followed the same basic structure, content, and study approach delineated in the original BWR study (Oak et al. 1980). The estimated impacts of post-TMI-2 requirements on the reference BWR decommissioning costs, described by Konzek and Smith (1988), are included in the overall cost update presented in this study as well.

The pertinent cost data, including the cost adjustment factors used to update the decommissioning costs for the reference BWR to an August 1987 cost base for this study, are described in detail in Appendix A of this report. The results of the application of the cost escalation data given in Appendix A are presented in this chapter.

3.2 APPLICATION METHODOLOGY

The emphasis of this study is on the DECON (immediate dismantlement) mode of decommissioning, using the utility-plus-decommissioning operations contractor (DOC) organizational structure. The SAFSTOR (safe storage) and ENTOMB (entombment) analyses are not treated in this comparison because they are basically outgrowths of the DECON analysis (i.e., they rely largely on data generated for DECON). This is true for both the PNL study and the TLG study. Therefore, the application methodology used in this study for updating the decommissioning costs consisted of a detailed review of all elements that make up each of the major cost categories given in the parent document (Oak et al. 1980) for the DECON decommissioning alternative. The appropriate cost adjustment factors were then applied to the respective line items and the items were added to form updated cost categories for the DECON decommissioning alternative. In addition to the values escalated from the parent document, the cost adders developed in Smith et al. (1985) were allocated to their appropriate categories and included in the update. A 25% contingency was then applied to the sum of the categories to establish the estimated costs of decommissioning the reference BWR in August 1987 dollars.

3.3 ESTIMATED DECOMMISSIONING COSTS

The various cost items for the utility-plus-DOC approach are separated into utility costs and DOC costs in Table 3.1 for comparison with the costs

TABLE 3.1. Summary of PNL Estimated Costs for Immediate Dismantlement of the Reference BWR Using the Utility-Only Approach or the Utility-DOC Approach

	Estimated Cost (millions 1987$)[a,b]		
Cost Category	Utility-Only	Utility-DOC	
Radioactive Material Disposal	32.782	32.782	--
Shipping Containers	6.522	--	6.522
Staff Labor	32.230	7.831	38.125
Energy	6.000	6.000	--
Special Equipment	3.347	--	3.347
Miscellaneous Supplies	3.249	--	3.249
Specialty Contractors	0.591	--	0.591
Nuclear Insurance	1.626	1.626	--
Licensing Fees	0.123	0.123	--
Mobilization and Demobilization	--	--	2.038
Subtotals, Utility-DOC Costs	--	48.362	53.872
Total DOC Fee (15%)	--	--	8.081
Total DOC Costs			61.953
Subtotals Contingency (25%)	86.470 21.618	110.315 27.579	
Totals, DECON Costs	108.088	137.894	

(a) Costs adjusted to August 1987.
(b) Number of figures shown is for computational accuracy and does not imply precision to the nearest thousand dollars.

for the utility-only approach, which are also shown. A 15% fee is applied to all DOC costs. The utility-DOC approach for immediate dismantlement of the BWR increases the total decommissioning cost by about 27%, to about $138 million. This total does not include any incentive or bonus payments that might be negotiated for an undertaking of this magnitude.

3.4 REFERENCES

Holter, G. M., and E. S. Murphy. 1983. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station - Effects on Decommissioning of Interim Inability to Dispose of Wastes Offsite. NUREG/CR-0672, Addendum 1, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

Konzek, G. J., and R. I. Smith. 1988. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station - Technical Support for Decommissioning Matters Related to Preparation of the Final Decommissioning Rule. NUREG/CR-0672, Addendum 3, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

Murphy, E. S. 1984. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station - Classification of Decommissioning Wastes. NUREG/CR-0672, Addendum 2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

Oak, H. D., G. M. Holter, W. E. Kennedy, and G. J. Konzek. 1980. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station. NUREG/CR-0672, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

Smith, R. I., G. J. Konzek, E. S. Murphy, and H. K. Elder. 1985. Updated Costs for Decommissioning Nuclear Power Facilities. EPRI NP-4012, Electric Power Research Institute Report by Pacific Northwest Laboratory, Richland, Washington.

4.0 RESULTS OF THE TLG STUDY

The TLG Engineering, Inc., study (TLG 1989) examines DECON (prompt removal/dismantling), SAFSTOR (mothballing with delayed dismantling), and ENTOMB (entombment with delayed dismantling) for two alternatives concerning management of the decommissioning programs. In the base case, the licensee uses an outside contractor in the decommissioning of WNP-2. This decommissioning operations contractor (DOC) provides sufficient staff to perform the preparatory demolition planning and scheduling and to manage the demolition efforts. Site security during demolition is provided by the licensee or its subcontractor. The demolition work is performed by the DOC or a demolition subcontractor who will provide adequate staff, labor, equipment, materials and overhead to complete the demolition. As an alternative, the decommissioning activities were reanalyzed with the premise that the licensee performed the DOC function (i.e., the licensee operated as its own DOC).

As previously mentioned in Chapter 1, the primary emphasis of this comparative study is on the DECON mode of decommissioning, using the utility-plus-DOC organizational structure. The other modes are, in nature, outgrowths of the DECON analysis, in that they rely largely on data generated for DECON. This is true for both the TLG study as well as the PNL study. The information concerning the TLG study that follows continues to reflect this emphasis on the DECON mode of decommissioning the reference BWR.

4.1 DECOMMISSIONING PERIOD ACTIVITY DESCRIPTIONS

The TLG study provides a breakdown, comprised of three periods, of the basic activities necessary for a demolition/site-restoration scenario. The following sections briefly describe each period.

4.1.1 Period 1: Preparations

Beginning approximately two years prior to the commencement of decommissioning operations, detailed preparations are undertaken to provide a smooth transition from plant operations to decommissioning for the site and the personnel involved in decommissioning. These preparations include engineering planning, filing of a decommissioning plan, surveys of plant areas to determine contamination levels, activation analyses of the vessel and vessel internals, as well as the assembly of a decommissioning management organization. Following final shutdown, more detailed surveys and benchmarking of calculated estimates are performed to validate results. Final planning for activities and writing of activity specifications and detailed procedures also begin at this time. Following approval of the decommissioning plan by the NRC, the NRC will issue a dismantling order authorizing implementation. Period 1 ends upon receipt of the dismantling order from the NRC.

4.1.2 Period 2: Decommissioning Operations and License Termination

The dismantling procedures and the decommissioning operations may begin upon receipt of the dismantling order from the NRC. Upon completion of all license-related decommissioning operations contained in the decommissioning plan, the licensee conducts a final radiation survey to assure that all radioactive materials have been removed. This survey will coincide with the final NRC onsite inspection, which verifies that the acceptable activity and contamination levels are satisfied. When the requirements are satisfied, the NRC can terminate the license and any further NRC jurisdiction over the facility.

4.1.3 Period 3: Site Restoration

Although not required for license termination, it was assumed for both cases of DECON in the TLG study that the remainder of the reactor facility was dismantled and all vestiges were removed. It was further assumed that the site was then restored by regrading the site to conform to the adjacent landscape and thus made available for alternative use.

4.2 COST ESTIMATE

A site-specific cost estimate was prepared for WNP-2 by TLG Engineering, Inc. The basis of the estimate, including brief descriptions of the source of information, methodology, site-specific considerations, cost estimates for both cases of DECON, and cascading costs, are described in this section.

4.2.1 Basis of Estimate

The cost estimate was developed using WNP-2 drawings and the inventory documents provided by the licensee. The drawings and documents were used in the TLG study to develop the general arrangement of the facility and to determine estimates of building concrete volumes, steel quantities, numbers and size of components, and landscaping requirements. The licensee provided typical craft labor rates and salary data for its personnel for the positions identified by TLG.

Rates for shipping radioactive wastes were obtained from Tri-State Motor Transit published tariffs (Tri-State). The Washington Nuclear Center burial facility operated by U.S. Ecology at Hanford, Washington, was assumed as the destination for the wastes generated in the decommissioning process (U.S. Ecology).

4.2.2 Methodology

The methodology used to develop the cost estimates follows the basic approach originally presented in Manion (1976 and 1980) and LaGuardia (1986). These references use a unit cost factor method for estimating decommissioning activity costs. With the item quantity (e.g., tons, yards, etc.) developed from plant drawings and inventory documents, the activity-dependent costs are estimated.

The activity-duration critical path was used to determine the total decommissioning program schedule. The program schedule was used to determine period-dependent costs for program management, administration, field engineering, equipment rental, quality assurance, and security. The licensee provided typical salary and hourly rates for personnel associated with period-dependent costs. The costs for conventional demolition of nonradioactive structures, materials, backfill, landscaping, and equipment rental were taken from R. S. Means (Means 1987). The activity- and period-dependent costs were summed to estimate the total decommissioning costs. A 25% contingency was then added.

4.2.3 Site-Specific Considerations

The TLG study specifically lists major component removal and transportation methods for moving nuclear steam supply system (NSSS) components overland as site-specific considerations that are deemed to affect the method for dismantling and removing equipment from the site. Although not required for license termination, it is assumed that the site is restored by regrading the site to conform to the adjacent landscape.

4.2.4 Cost Estimate Summaries

Summaries of the decommissioning costs for DECON in the base case (licensee and DOC) and the reanalyzed case (licensee as DOC) are given in Tables 4.1 and 4.2, respectively. It can be seen from Table 4.1 that the total projected cost of dismantling the WNP-2 facility, for the DECON alternative in the base case scenario (i.e., licensee and decommissioning operations contractor or DOC), is about \$281.2 million (1987 dollars). Similarly, it can be seen from Table 4.2 that the cost of DECON in the reanalyzed case (i.e., licensee acting as its own DOC) is estimated to cost about \$262.7 million (1987 dollars).

4.2.5 Cascading Costs

As previously mentioned in Section 4.2.4, the total projected cost of DECON (base case) was about \$281.2 million. Approximately \$190.1 million of this total is estimated to be directly attributable to the engineering and planning for and the actual disposition of the residual radioactivity of the WNP-2 facility. The TLG study points out, however, that a direct accounting of only these costs is not entirely accurate in portraying the actual cost of "decommissioning" as defined by the NRC and that consideration must also be given to the methods of executing the decontamination processes as well as cascading costs.

The TLG study defines cascading costs as those costs associated with the removal of noncontaminated and releasable material in support of the

TABLE 4.1. Summary of DECON Costs (licensee and DOC)[a]

Cost Category	Period	Calendar Year	Cost (millions 1987$)
Preparations	1	2022	0.077
		2023	1.002
		2024	3.128
		2025	15.757
Subtotal			19.964
Decommissioning Activities	2	2025	4.679
		2026	56.150
		2027	56.150
		2028	56.150
		2029	7.970
Subtotal			181.099
Structure Demolition	3	2029	26.636
		2030	31.042
		2031	22.469
Subtotal			80.147
Total			281.210

(a) All costs include a 25% contingency.

TABLE 4.2. Summary of DECON Costs (licensee as DOC)[a]

Cost Category	Period	Calendar Year	Cost (millions 1987$)
Preparations	1	2022	0.066
		2023	0.861
		2024	2.770
		2025	14.437
Subtotal			18.134
Decommissioning Activities	2	2025	4.413
		2026	52.954
		2027	52.954
		2028	52.954
		2029	7.517
Subtotal			170.792
Structure Demolition	3	2029	24.507
		2030	28.560
		2031	20.672
Subtotal			73.739
Total			262.666

(a) All costs include a 25% contingency.

decommissioning process (e.g., if it is considered necessary to remove portions of the top floors to get at a bottom-floor nuclear component). The TLG study further states that it is estimated that $11.3 million of cascading costs will be incurred in the decommissioning process for the licensee to meet the intent of the NRC's definition of decommissioning, resulting in a total DECON cost of $202.3 million. A summary listing from the TLG study for license termination, including cascading costs, for DECON (base case) is shown in Table 4.3.

TABLE 4.3. License Termination Including Cascading Costs from the TLG Study for the DECON (Base Case) Mode

	Millions 1987$			
Period No.	Total Cost (including demolition/restoration)	Direct Cost for License Termination	Cascading Costs	Total Decommissioning Cost
1[(a)]	15.971	15.971	0.0	15.971
2[(b)]	144.880	135.802	9.078	144.880
3[(c)]	64.117	0.329	0.0	0.329
Subtotal	224.968	152.102	9.078	161.180
25% Contingency	56.242	38.026	2.269	40.295
Total	281.210	190.128	11.347	201.475

(a) Preparations.
(b) Decommissioning Operations and License Termination.
(c) Site Restoration.

4.3 SCHEDULE ESTIMATE

Commercial operation of the WNP-2 nuclear unit was initiated in December 1984. For the purposes of the TLG study, the shutdown date (license expiration) was taken as 40 years following the date of commercial operation, with decommissioning operations commencing on December 1, 2024. This time frame was used as input in scheduling analysis. The exact dates for DECON (prompt removal) are presented in Table 4.4. In addition, the following assumptions were used in the development of the schedule given in the table:

- All work except vessel and internals removal activities is performed during an 8-hour workday, 5 days per week with no overtime. There are 11 paid holidays per year.
- Vessel and internals removal activities are performed by using separate crews for different activities working on different shifts, with a corresponding backshift charge for the second shift.
- Multiple crews work parallel activities to the maximum extent possible consistent with optimum efficiency, adequate access for cutting, removal and laydown space, and with the stringent safety measures necessary during demolition of heavy components and structures.

TABLE 4.4. Schedule for DECON from the TLG Study

Period	Begin Date	Incremental Months	Cumulative Months
1 Pre-Shutdown	01-Dec-2022	24.02	24.02
1 Post-Shutdown	01-Dec-2024	11.99	36.01
2 Pre-NSSS Removal	01-Dec-2025	8.38	44.39
2 NSSS Removal	13-Aug-2026	18.10	62.49
2 Post-NSSS Removal	15-Feb-2028	12.22	74.71
License Termination			
3 RB Demolition	21-Feb-2029	30.19	104.90
3 Post-RB Demolition	29-Aug-2031	0.79	105.69
End of Project	22-Sep-2031	--	

4.4 RADIOACTIVE WASTE VOLUME

The estimated radioactive waste volume generated during DECON is shown in Table 4.5. It can be seen from this table that approximately 24,489 m^3 (32,030 y^3) of material are generated. This waste volume attributed to DECON is primarily generated over a 48-month period. Waste volumes are quantified consistent with 10 CFR 61 classifications. The waste volumes shown in the table are calculated based on the gross container volume to be shipped and buried in controlled burial grounds. Commercially available steel containers with external dimensions measuring 4 ft x 4 ft x 8 ft are used in the TLG study for piping, small components, and concrete.

The reactor vessel and internals are categorized as large-quantity shipments and are shipped in reusable shielded casks with disposable liners. The liner volume is taken as the waste volume.

TABLE 4.5. Radioactive Waste Burial Volumes for DECON from the TLG Study

Mode	Waste Class	Volume, m^3
DECON	A	23,702.5
	C	603.7
	>C	183.0
Total		24,489.2

4.5 OCCUPATIONAL EXPOSURE

Radiation doses to decommissioning workers in the TLG study are calculated as the product of the estimated radiation zone work force requirements and the radiation exposure rates postulated for each decommissioning task. The occupational exposure estimates from decommissioning are based on the following assumptions:

- Occupational exposure estimates include only the craft labor necessary for decontamination, removal and packaging activities as well as all required health physics personnel exposures in support of those activities. Casual exposures to the plant staff are not included in the estimates.
- Personnel exposure to radiation is minimized by using shielding and remote handling techniques and avoiding higher radiation fields when presence is not necessary.
- Local exposure rates near items such as tanks and pipes are reduced by a successful chemical decontamination program prior to work in that area.
- Careful prompt accounting of accumulated radiation exposure is maintained to rapidly identify tasks causing excessive dose accumulation by workers so that corrective action can be taken.
- Cobalt-60 is the primary contributor to radiation exposure.

A summary of the occupational exposure, by periods, for DECON from the TLG study is given in Table 4.6.

TABLE 4.6. Occupational Exposure for DECON from the TLG Study

Period No.	Total Dose, man-rem
1	21
2	3756
3	0
Total	3777

4.6 REFERENCES[a]

LaGuardia, T. S., et al. 1986. Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates. AIF/NESP-036, Atomic Industrial Forum, Washington, D.C.

Manion, W. J., and T. S. LaGuardia. 1976. An Engineering Evaluation of Nuclear Power Reactor Decommissioning Alternatives. AIF/NESP-009, Atomic Industrial Forum, Washington, D.C.

Manion, W. J., and T. S. LaGuardia. 1980. Decommissioning Handbook. DOE/EV/10128-1, U.S. Department of Energy, Washington, D.C.

Robert Snow Means Company, Inc. (Means). 1987. "Building Construction Cost Data 1987." Kingston, Massachusetts.

TLG Engineering, Inc. (TLG). 1989. Decommissioning Cost Study for the WPPSS Nuclear Project No. 2. Document B04-25-001 Revision 1. Bridgewater, Connecticut.

Tri-State Motor Transit Company, Docket No. MC-109397 and Supplements.

U.S. Ecology, Washington Nuclear Center Schedule of Charges.

(a) All references in this chapter are taken directly from the TLG study, page 89 of 100.

5.0 RESULTS OF THE COMPARISON BETWEEN THE TWO STUDIES FOR THE DECON ALTERNATIVE

This chapter contains the results of the comparison between the reference plant study by PNL (Oak et al. 1980) and the site-specific study by TLG Engineering, Inc. (TLG 1989) for the same commercial nuclear reactor power station, Washington Public Power Supply System's Unit 2 (WNP-2), a boiling water reactor (BWR). With the exceptions of some possible differences in plant equipment inventories between 1980 and 1987 and postulated transport distances, common grounds (e.g., WNP-2 drawings and inventory documents, rates for shipping radioactive wastes, base burial costs, etc.) provided the bases for both studies. This comparison focuses on the DECON alternative (immediate dismantlement), with a utility-plus-decommissioning operations contractor (DOC) organizational structure. All costs are on a common base of mid-1987 dollars to provide a reasonable comparison.

The cost and occupational radiation exposure (ORE) estimates in both studies are based on their respective assumptions. The assumptions are the keys to a proper understanding of the methods and limitations of the estimates in both studies. A knowledge of the differences in assumptions is necessary before comparisons can reasonably be made between the two studies. Such differences are clearly identified in this chapter, where appropriate.

Areas of agreement and disagreement concerning decommissioning costs and ORE reported by both studies are identified. Areas of disagreement are clarified where possible, and the various factors that contribute to these disagreements are discussed. It should be recognized that, within selected requirements common to the overall decommissioning project, there are aspects of those common requirements in which both areas of agreement as well as disagreement could be expected. For example, in the area of planning and preparation there are commonalities as well as differences between the studies; both will be discussed in subsequent sections.

5.1 AREAS OF REASONABLE AGREEMENT

Although both the PNL study and the TLG study are separate and distinct studies examining the same BWR, there are a number of areas of commonality. Subsequent sections provide information on the areas of reasonable agreement associated with the DECON alternative, in the following order:

- planning and preparation
- decontamination of systems
- nuclear liability insurance
- plant energy budget

- demolition and site restoration
- contingency.

5.1.1 Planning and Preparation

Both studies recognize that immediate dismantlement of the reference BWR is a complex undertaking, and that its success depends greatly on good planning and completion of preparatory work before final reactor shutdown. In both studies, planning and preparation for immediate dismantlement is accomplished during the two years prior to final reactor shutdown and includes an almost identical listing of preparatory activities; however, there are several major exceptions. In the PNL study, prior to the start of the actual decommissioning tasks, additional HEPA filters are installed outboard of the blowers in the HVAC exhaust systems of the Reactor Building and the Turbine Generator Building. The Radwaste and Control Building HVAC system is already equipped with HEPA filters. These additional filters are installed to lessen the potential for atmospheric release of airborne radioactivity generated during immediate dismantlement, because many of the tasks are expected to generate airborne contamination levels that exceed levels produced during normal plant operation. In the TLG study, during this same period, contamination control envelopes are installed in various locations during dismantlement for similar purposes.

Period 1 (Preparations) in the TLG study spans three years - two years prior to shutdown and the first year after shutdown. TLG assumes that the first year after shutdown will be needed to accurately determine the final radiation levels, contamination and activation of components. By comparison, most of the planning and preparation tasks in the PNL study are postulated to be completed during the two years prior to shutdown. The comprehensive radiation survey schedule developed by PNL assumes surveys of the reactor building/primary containment, turbine generator building, and selected support facilities are needed soon after final shutdown. To accurately determine the final radiation/contamination levels associated with cleanup of the radwaste and control building, the survey of this building is postulated to occur 16 months after shutdown.

5.1.2 Decontamination of Systems

There is general agreement between the two studies on the need for decontamination of reactor piping systems and components during decommissioning. Chemical decontamination methods (recirculatory and once-through) and water-jet cleaning are clearly envisioned as being both necessary and effective in both studies. However, in spite of these commonalities, major differences exist in postulated application methodology and techniques which greatly impact the estimated cost and ORE projections for these decontamination tasks. These areas of disagreement are discussed in detail in Section 5.2.3.

5.1.3. Nuclear Liability Insurance

The costs for nuclear liability insurance (NLI) during DECON are reasonably comparable between the two studies. The costs for NLI are estimated in NUREG/CR-0672 for an assumed policy limit of $160 million carried through the decommissioning period and are shown in Table 5.1. The total estimated cost for NLI is about $1.63 million, which represents a little more than 1.5% of the total DECON cost.

The costs for NLI during prompt dismantlement are estimated in the TLG study through three decommissioning periods and are shown in Table 5.2.

TABLE 5.1. Estimated Costs for Nuclear Liability Insurance During DECON from the PNL Study[a]

Year After Shutdown	Estimated Premium ($ thousands)[b]
1	357
2	476
3	476
4	317
Total	1626

(a) Personal Communication: Letter from Maura Labriola, American Nuclear insurers, to G. J. Konzek, Battelle-Northwest, June 8, 1988.
(b) The costs shown do not include contingency.

TABLE 5.2. Estimated Costs for Nuclear Liability Insurance During DECON from the TLG Study[a]

Period	Estimated Premium ($ thousands)[b]
1 - Preparations	309
2 - Decom. Activities	1365
3 - Structure Demolition	228
Total	1902

(a) Source: WPPSS data, adjusted by TLG per information from American Nuclear Insurers.
(b) The costs shown do not include contingency.

5.1.4 Plant Energy Budget

The costs of energy (electricity and oil) to license termination during DECON are reasonably comparable between the two studies. The total plant energy budget is estimated at about $7.5 million (including contingency) in NUREG/CR-0672. In the TLG study, the total plant energy budget to license termination at the end of Period 2 is about $7.7 million (including contingency).

5.1.5 Demolition and Site Restoration

Both studies are in agreement that the NRC has no jurisdiction over removal of uncontaminated structures and restoration of the site once all radioactive materials in the reference BWR are removed or decontaminated. Therefore, the NRC is requested to terminate the possession-only license at the conclusion of the active decommissioning phase in both studies and release the site for unrestricted use. Following license termination, the owner decides whether the remaining onsite structures are to be demolished or left standing.

There is a significant disagreement between the studies as regards the costs of clean facility demolition and site restoration, due largely to different assumptions about how the job is accomplished. TLG postulates using decommissioning workers and continuing much of the utility/DOC supervisory staff through the demolition period, while PNL postulates bringing in a demolition contractor who provides his own supervisory staff for demolition activities.

Development of demolition and site restoration costs is presented in the NUREG/CR-0672 decommissioning cost estimates for completeness. Based on the discussion above, such site restoration and demolition costs are considered only as an adjunct to and not part of the primary cost estimate presented in NUREG/CR-0672.

By way of comparison, the TLG study (p. 10 of 100) states: "Although not required for license termination, this study alternative (i.e., DECON) also assumes the removal of the remaining structures from the site; thereby ending the System's liability and permitting return of the WNP-2 site for other use."

5.1.6 Contingency

Both of the decommissioning studies use a 25% contingency for their final cost estimates.

5.2 AREAS OF DISAGREEMENT

This section provides information on the areas of disagreement associated with accomplishment of the DECON alternative, in the following order:

- estimating methodology
- decommissioning staffing
- decontamination of systems
- work difficulty factors
- cascading costs
- radioactive waste volume
- occupational radiation exposures
- radioactive waste transport costs.

Differences in the estimated costs and occupational radiation exposure (ORE) between the two studies are examined in these selected areas for the DECON alternative, assuming the utility-plus-DOC organizational structure.

5.2.1 Estimating Methodology

The PNL study and the TLG study each use variations of the same basic methods for determining the engineering cost and occupational radiation exposure estimates for DECON. Selected examples of the results of using these different variations are briefly described below.

5.2.1.1 Development of Occupational Radiation Exposure and Engineering Cost Estimates

The PNL study was based on task-by-task analyses of the activities, ORE, and costs needed to decommission the reference BWR. Varying levels of difficulty (which are not documented in the report) and varying dose rates throughout the facility were reflected throughout the analyses. The attempt was made to optimize the decommissioning tasks under consideration. After an inventory of all items in the facility was performed, the ORE and cost for decontamination, removal, and packaging individual items and systems were calculated and summed. The study based its ORE estimates on detailed analyses of personnel exposure hours and expected radiation dose rates associated with each task. The expected radiation dose rates varied in the study depending upon the system and/or component and upon the time after reactor shutdown, and were based on composite dose rate maps drawn from seven operable BWRs (Oak et al. 1980, Appendix D).

TLG performed a detailed task-by-task analysis using a unit cost factor approach to identify the doses and costs associated with the decontamination, removal, and packaging for given types of material and equipment in the reference BWR (LaGuardia 1990). Constant dose rates were applied to all worker hours assigned to a given system and over all tasks associated with that system. After an inventory of all items in a given system was performed, the cost per item was then multiplied by the number of items to provide the cost estimate for that system. All system costs were summed to provide the total facility engineering cost estimate.

5.2.1.2 Treatment of Uncontaminated Materials

A major difference that becomes apparent in comparing the PNL study with the TLG study is that the TLG study removes significant amounts of uncontaminated material and equipment during the pre-license termination period, whereas the PNL study leaves the removal of essentially all uncontaminated materials to the demolition contractor, after license termination, with any scrap values being incorporated into the contractor's bid proposal.

TLG study assumption number 12 (p. 34 of 100) states: "Scrap processing and site removal costs are not included in the estimate." Instead, TLG assumes that the value of the scrap will be sufficient to offset the cost of loading and shipping. However, while scrap processing, per se, is not included in the estimate, the total costs for removal of the uncontaminated materials from 26 systems are included in Period 2 (Decommissioning Operations and License Termination). The projected costs for removal of these uncontaminated materials are about $5.6 million (without contingency), and encompass a total projected effort of 85 man-years. About $1.2 million (without contingency) of these costs and 17 man-years of effort are identified in the study as cascading costs[a] in support of license termination.

The cost and schedule estimate for DECON presented in the TLG study are based on the complete removal of all components within the facility. The total projected dedicated worker effort for removing all systems (clean and contaminated) in Period 2 is about 566 man-years. Removal of the noncascading clean material comprises about 12% of this total.

5.2.2 Decommissioning Staffing

Another area where the PNL and TLG studies differ significantly is in the levels of staffing assigned to the project, and a related question: the duration of the pre-license termination period. To permit a side-by side examination of the staffing levels postulated in the two studies, the staffing in the PNL study, including later additions for engineering support and for assuring that individual worker radiation doses do not exceed the 5 rem/year limit, has been rearranged to match as closely as possible the positions identified by TLG. For purposes of this comparison, the discussion is limited to the case of DECON, with the decommissioning organization structure appropriate for the case of the utility providing the overview surveillance and a decommissioning operations contractor (DOC) providing the engineering support and overall operations direction and control. These groups (the utility staff and the DOC staff) are principally overhead staff, with the dedicated decommissioning workers being subcontractors to the DOC.

(a) See Section 5.2.5 for additional description of these costs.

The positions identified within each of these groups, the fully-burdened annual salary rates, the number of man-years per position, and the cumulative staff labor cost for each position are presented in Table 5.3. The positions that are common to both studies are listed on the left side of the table. Positions that are unique to the TLG study are listed to the right in the table. Comparisons of the staffing estimates for each of the three groups (utility overhead, DOC overhead, and DOC dedicated workers) are discussed in the following sections.

5.2.2.1 Utility and DOC Overhead Staffing Comparisons

The postulated overhead staffing levels from each study and their approximate distributions in time over the pre-license termination period (TLG periods 1 and 2) are illustrated in Figure 5.1.

For the utility staff that is common to both studies, the TLG study postulates about 1.5 times as many man-years as the PNL study, and has an additional group of utility staff that (by itself) exceeds the total utility staff postulated by PNL by more than a factor of 1.3. As a result, the total cost for utility staff in the TLG study is about 3.5 times larger than in the PNL study. A significant contributor to this difference was the TLG assumption that the security forces were kept at the same size throughout the pre-license termination period, while the PNL study reduced the security force to a minimal industrial security level as soon as the spent fuel was removed from the site. This difference in assumptions accounts for about 25% of the difference in the utility staff man-years. The largest contribution to the difference in utility staff comes from the additional supervisors (9), the additional engineers (9), the force of additional operators (12), and the team of craftsmen and laborers (32) that appear on the TLG-postulated utility staff and that are not included in the PNL-postulated utility staff.

A similar situation exists for the overhead staff assigned to the DOC. For those DOC staff that were common to both studies, the longer pre-license termination period postulated by TLG resulted in nearly 1.5 times as many man-years for those staff as did the PNL study. The larger total DOC staff postulated in the TLG study resulted in about 352 man-years being expended by the DOC staff. However, differences in the assumed charge-out rates for the various staff positions between the two studies tend to reduce the magnitude of the cost difference due to the difference in staff size and activity duration. As a result, the estimated DOC overhead staff labor cost for the TLG study was only about 30% greater than that estimated in the PNL study, even though TLG estimated nearly twice as many man-years as did PNL.

The total utility and DOC overhead staffing was 354.5 man-years for the PNL study and 836.6 man-years for the TLG study, with corresponding labor costs of $23.7 million and $46.3 million, respectively.

TABLE 5.3 Comparison of Salary Rates, Staffing, and Labor Costs for Decommissioning (excluding clean demolition)

	PNL Study			TLG Study						
	$/man-yr ($ 1987)	man-yr	Labor Cost ($ 1987)	$/man-yr ($ 1987)	man-yr	Labor Cost ($ 1987)	Added Positions	$/man-yr ($ 1987)	man-yr	Labor Cost ($ 1987)
Utility Overhead Position										
Plant Manager (decommissioning support)	121,212	5.1	618,181	139,050	4.32	601,348	Assistant Plant Manager	115,875	4.32	501,126
Contracts/Accounting Specialist	62,477	5.1	318,633	75,705	4.23	31?,876	Chemistry Supervisor	83,430	3.72	310,773
Secretary	33,028	9.1	300,555	37,080	10.78	399,546	Nuclear Records Supervisor	60,255	3.93	236,507
Clerk	33,028	7.5	247,710	33,217	6.45	214,272	Building Services Supervisor	67,980	3.83	260,025
Quality Assurance Supervisor	71,263	5.1	363,441	91,155	4.23	385,158	Training Supervisor	75,705	3.93	297,150
Quality Assurance Engineer	64,104	6.0	384,624	60,255	4.62	278,674	Operations Supervisor	100,425	3.72	374,078
Health Physicist Supervisor	82,001	5.8	475,606	87,292	3.83	333,895	Shift Supervisor	75,705	10.84	820,015
Health Physicist	64,104	4.0	256,416	64,117	3.72	238,834	Control Operations Supervisor	83,430	10.84	904,792
Control Operator	47,183	17.1	806,829	60,255	20.69	1,246,706	Plant Equipment Operator	52,530	30.54	1,604,060
Security Supervisor	53,528	3.5	187,348	64,117	4.32	277,289	Site Engineer (9)	63,678 (ave.)	40.61	2,585,671
Security Shift Supervisor	49,949	17.5	874,108	56,392	21.12	1,191,184	Maintenance Supervisor	74,932	3.83	286,610
Security Patrolman	34,655	86.5	2,997,658	43,260	168.98	7,310,202	Craft Crew Leader	60,255	17.09	1,029,601
Subtotals		172.3	7,831,109		257.29	12,796,571	Craftsman	52,530	32.16	1,689,206
					227.24	13,045,893	Laborer	37,080	57.88	2,146,283
									227.24	13,045,893
Total Utility Overhead		172.3	7,831,109		484.53	25,842,464				
DOC Overhead Positions[a]										
Project Manager	127,624	5.8	740,219	102,600	5.53	566,921	Stores Supervisor	93,100	3.43	318,893
Assistant Project Manager	88,030	5.4	475,362	93,100	5.53	514,428	Chemistry Technician	47,600	4.22	201,092
Lawyer/Financial Administrator	127,624	2.5	319,060	117,800	4.33	509,530	Decontamination Technician	47,600	55.22	2,628,530
Contracts Specialists/Buyer	77,177	5.0	385,885	59,850	4.23	252,885	Instrument Technician	54,600	5.73	313,034
Procurement Specialist	61,702	5.4	333,191	78,85?	3.83	301,603	Senior Chemical Technician	51,100	4.22	215,878
Accountant	61,702	5.0	308,510	74,100	4.33	320,513	Senior Decontamination Technician	51,100	4.22	215,878
Quality Assurance Engineer	79,267	5.0	396,335	74,100	5.53	409,444	Senior Instrument Technician	51,100	4.22	215,878
Quality Assurance Technician	52,959	14.5	767,906	54,600	14.18	774,362	Janitor	26,600	7.45	198,167
Engineering Supervisor	149,732	4.0	598,928	107,350	5.53	593,167			88.71	4,307,350
Engineers	127,621	20.0	2,552,420	78,193 (ave.)	55.04	4,303,667				
Designers	79,187	5.0	395,935	64,600	8.75	565,303				
Secretary/Clerk	40,799	10.0	407,990	31,573 (ave.)	20.73	654,508				
Industrial Safety Specialist	88,151	4.8	423,125	93,100	5.32	496,559				
Radioactive Shipment Specialist	65,942	4.4	290,145	64,600	3.83	247,096				
Shift Engineer	88,151	10.0	881,510	(no equivalent position)						
Senior Health Physicist Technician	65,942	8.8	580,290	51,100	4.22	215,878				
Health Physicist Technician	57,401	50.0	2,870,050	47,600	86.00	4,093,647				
Protective Equipment Technician	52,959	7.0	370,713	47,600	14.18	675,085				
Tool Crib Attendant	52,959	6.8	360,121	30,100	8.46	254,611				
Safety Consultant	109,009	2.8	305,225	97,850	3.83	374,278				
Subtotals			13,762,919 x 1.15[b]		263.39	16,123,482				
					88.71	4,307,350				
Total DOC Overhead		182.2	15,827,357		352.10	20,430,823				
Dedicated Decontamination Workers[a,c]										
Craft Supervisor	79,267	7.4	586,576							
Crew Leader	74,823	31.5	2,357,019							
Utility Operator	61,501	160.0	9,840,160							
Craftsman	61,501	120.7	7,423,170							
Laborer	59,109	70.3	4,155,363							
		389.9	24,362,288 x 1.15[b]		566	36,869,240[d]				
Total Dedicated Decontamination Workers			28,016,631							
Total for DECON		744.4	51,675,097		1,402.6	83,142,536				

(a) Salary rates include 110% overhead.
(b) 15% DOC profit on labor.
(c) Man-years include allocations from 80 man-yr of decommissioning worker labor added to reduce the average individual doses.
(d) Approximate value, calculated as described in text.

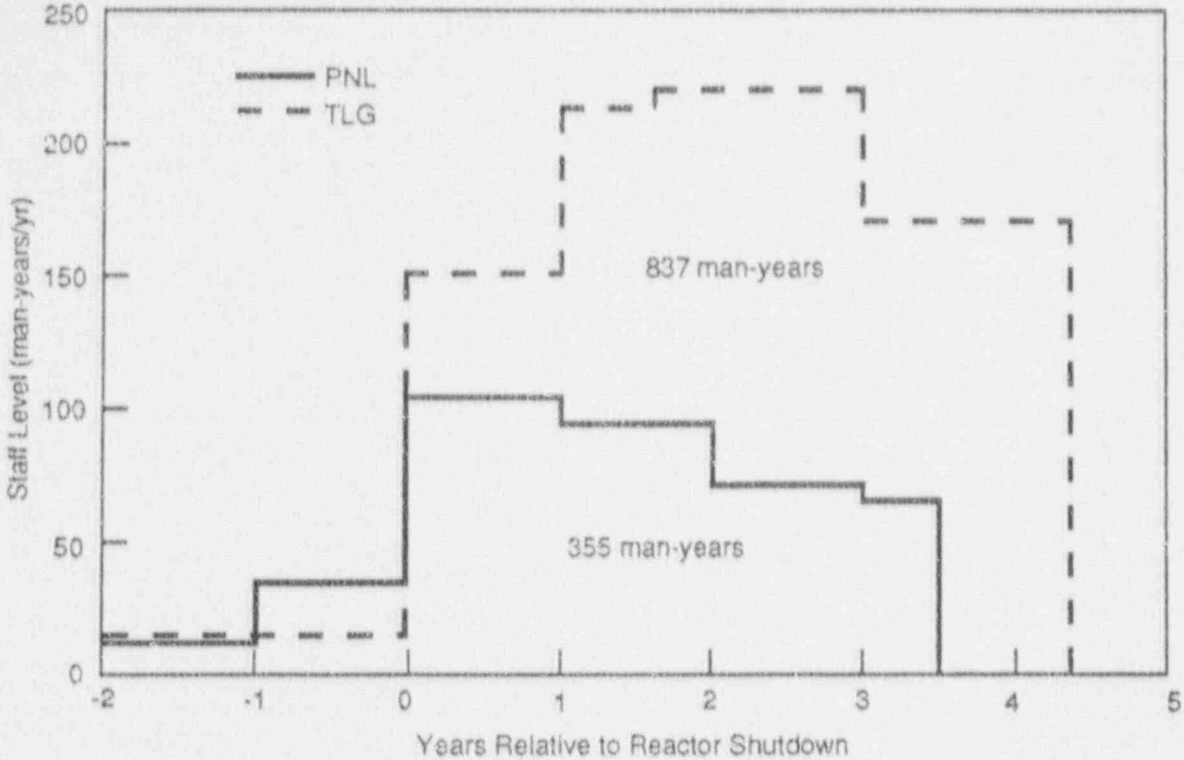

FIGURE 5.1. Time Distribution of Postulated Utility and DOC Overhead Staff

5.2.2.2 Dedicated Decommissioning Worker Comparisons

In the area of dedicated decommissioning workers, the PNL study estimated about 390 man-years of effort by the hands-on workers and their immediate supervision. The TLG study estimated about 566 man-years for the same group. The approximate dedicated worker staffing levels from each study and their distribution in time over the pre-license termination period are illustrated in Figure 5.2. The differences between these estimates are attributable to three principal causes. First, the difference in approaches to decontaminating the various piping and equipment systems (discussed in Section 5.2.3) resulted in the TLG analysis expending at least 34 more man-years to perform these system decontaminations than did the PNL analysis. A second contributor to the difference in dedicated worker man-years is that, in the TLG analysis, all of the clean piping and equipment, etc., was removed during the pre-license termination period, while in the PNL analysis, that material was left in place within the decontaminated structures for removal by the demolition contractor later. As discussed previously in Section 5.2.1.2, the removal of the non-cascading uncontaminated materials resulted in an additional 68 man-years being assigned to the pre-license termination period in the TLG study. A third contributor to the difference in dedicated worker man-years (about 45 man-years) is attributed to differences in application of the various work difficulty factors for the various tasks, as discussed in Section 5.2.4.

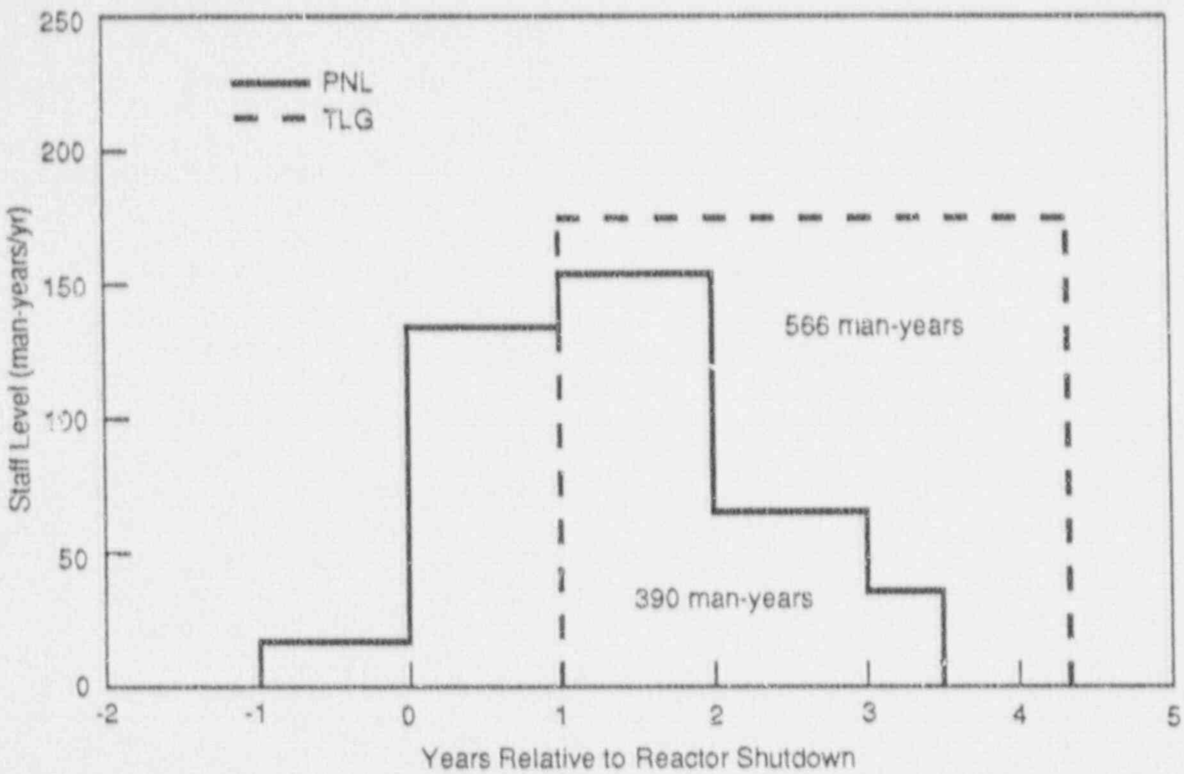

FIGURE 5.2. Time Distribution of Estimated Dedicated Decommissioning Workers

A reasonable approximation of the TLG direct labor costs can be made by calculating the average worker cost, based on a crew size and composition typical of crews utilized in many of the unit cost factors, and multiplying the number of man-years of dedicated labor by that average annual worker cost. Assuming a crew consisting of 2 laborers, 1 craftsman, and 0.5 foreman, the average annual worker cost is about $65,140. Thus, the dedicated labor cost would be the product of that value times the 566 man-years of dedicated labor, for a total of about $36.9 million, without contingency. The total dedicated labor cost estimated in the PNL study is about $28.0 million, roughly $9 million less than TLG's estimate.

5.2.2.3 Total Pre-License Termination Labor Costs

Assuming the approximation made above for calculating the TLG dedicated worker costs is reasonably accurate, the total labor costs for the pre-license termination period are $51.7 million for the PNL study and $83.1 million for the TLG study, as shown in Table 5.3.

5.2.3 Decontamination of Systems

This section contains a discussion of the BWR systems considered for chemical decontamination and water-jet cleaning in the PNL study and in the TLG study. Both study approaches to cleaning the systems by these selected methods are discussed, and the analysis performed to determine the differences between the two studies and the conclusions reached from that analysis are presented in subsequent sections.

5.2.3.1 PNL Study Approach to Decontamination of Systems

In the PNL study (Oak et al. 1980, Section G.1 of Appendix G), the basic methods postulated to be used to decontaminate contaminated system surfaces are described. The two methods that are selected for system decontamination activities at the reference BWR are briefly described below. They are:

- chemical decontamination (recirculatory and single-pass methods)
- water-jet cleaning.

The recirculatory method is used where the chemical solution can be recirculated until the desired degree of decontamination is obtained. The single-pass method completes the decontamination in one pass and is used where recirculation is impractical. In general, the water-jet decontamination activity proceeds concurrently with draining the particular volume of contaminated water. However, for effective decontamination, the internal surfaces of the main condenser are water-jet cleaned as they become exposed during disassembly.

Chemical Decontamination - Chemical decontamination is considered for selected systems or components in the reference BWR that contain deposited contamination representing a radiation dose rate hazard once the system or component is drained and dried for further decommissioning effort. The systems or components to be chemically decontaminated are selected on the following bases, in descending order of importance:

- expected contact radiation dose rate after draining; systems or components with expected readings <15 mR/hr are not considered
- flow capability
- operational heating capability
- size.

Since the presence of minimal amounts of residual chemical decontamination solution was not expected to present an industrial safety hazard during subsequent decommissioning activities, a water flush was assumed not cost-effective for circulatory systems in the reference BWR.

The three categories of systems or components within the reference BWR that are selected for either recirculatory or once-through chemical decontamination, together with their decontamination flow capabilities, are: 1) six reactor piping systems located primarily in the Reactor Building--recirculatory (some with piping jumpers); 2) three contaminated drain systems located in the Reactor Building, the Turbine Generator Building, and the Radwaste and Control Building--once-through (with mobile chemical mixing and heating units); and 3) thirty-two pieces of equipment in the liquid and solid radwaste systems located in the Radwaste and Control Building--recirculatory (with mobile chemical decontamination units described later in this section).

The six reactor systems are depicted in Figure 5.3 and include the reactor water recirculation (RRC) system, the reactor water cleanup (RWCU) system, the residual heat removal (RHR) system, the low-pressure core spray (LPCS) system, the high-pressure core spray (HPCS) system, and the fuel pool cooling and cleanup (FPC) system. The latter four systems require special piping jumpers to complete recirculation loops. The recirculation loop for each system may or may not include all the system piping. The reactor core isolation cooling (RCIC) system is not selected for chemical decontamination because it requires nuclear steam for operation of the steam-driven pump and none is available following final reactor shutdown.

While too extensive to judicially depict in a single figure in this report, the three contaminated drain piping systems--equipment drain (radioactive), floor drain (radioactive), and miscellaneous liquid waste (radioactive)--are shown in Figure C.1 of Appendix C in NUREG/CR-0672 as are the equipment pieces in the liquid and solid radwaste systems that are selected for chemical decontamination in the PNL study. Because of the assumed lack of operational heating capability to achieve and maintain the proper solution temperature and because of the large volumes involved, these systems are assumed to be drained to a minimum working volume of water prior to decontamination. This volume is assumed to be too small to prime the system pumps for recirculation through the system piping. Therefore, each individual equipment piece is assumed to be isolated from the piping and chemically decontaminated in a recirculatory loop formed with a mobile chemical decontamination unit (described later). A special spray nozzle connection is required for a piece of equipment that exceeds the volumetric capacity of the mobile chemical decontamination unit.

Some contaminated systems in the reference BWR, for example, the main steam system, the condensate (nuclear steam) system, and the reactor feedwater system, are extremely difficult to isolate for recirculatory chemical decontamination. In addition, some equipment is not amenable to individual decontamination because of complex design or other detrimental reasons. In such cases, ALARA principles must be judiciously applied and all alternative dismantlement methods should be considered to ensure optimization of costs versus anticipated occupational radiation exposure (ORE) during decommissioning activities.

As previously mentioned, the recirculatory method is used where the chemical solution can be recirculated until the desired degree of decontamination is obtained. Isolatable equipment and piping sections in the reference BWR that are highly contaminated but not amenable to system-wide internal decontamination are postulated to be chemically decontaminated using mobile, shielded, decontamination units. Five such units are assumed to be used. Each unit is used for chemical recirculation and, after use, is itself decontaminated by backflushing. Each unit consists of two parts: 1) a

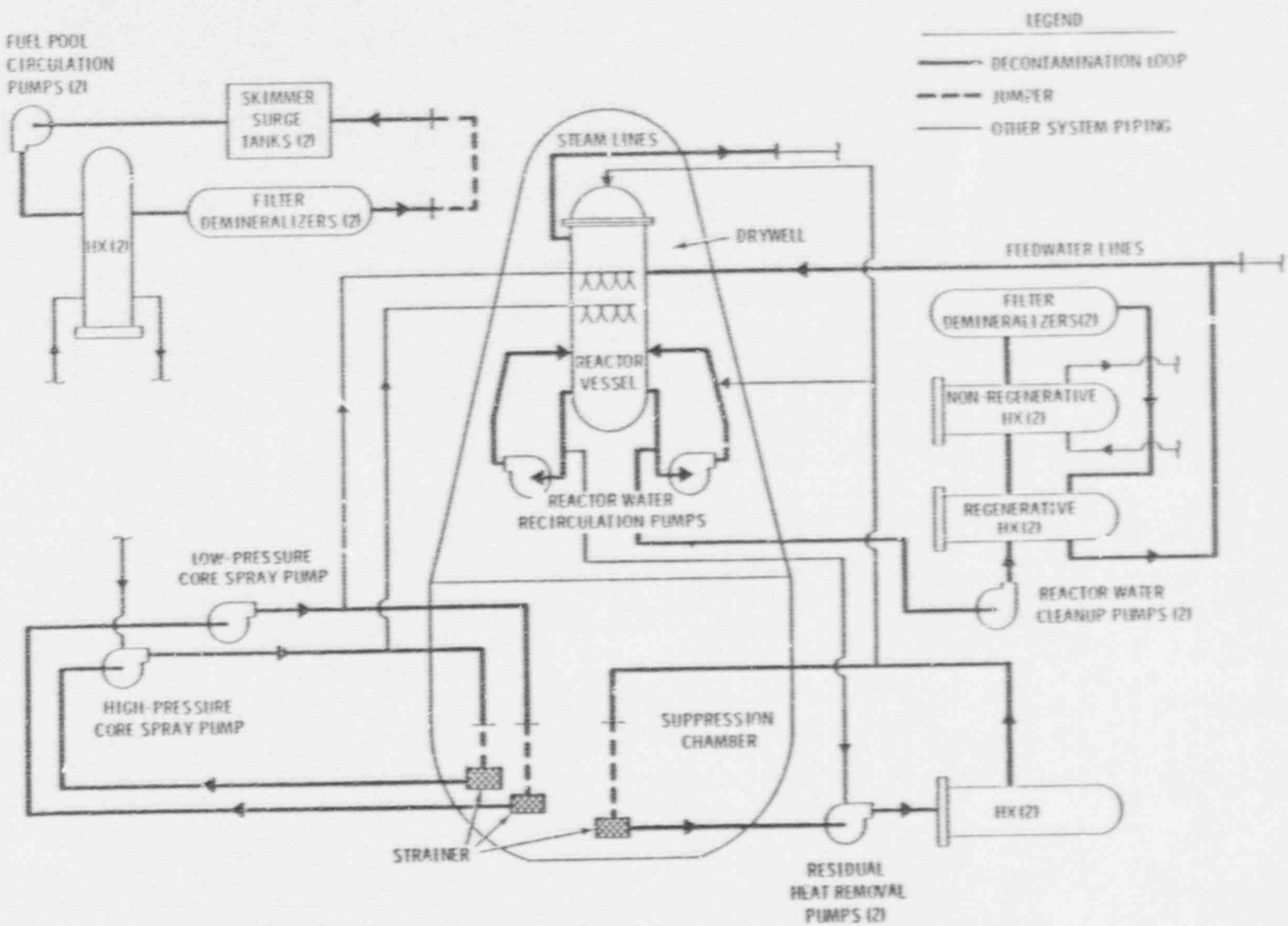

FIGURE 5.3. Reference BWR Reactor Piping Systems Selected for Chemical Decontamination in the PNL Study

remotely controlled operating unit containing a recirculating pump, an expansion tank, a thermostatically controlled electric heater, and a valve manifold; and 2) a control unit, connected by an electrical cable to the operating unit, located an appropriate distance away from the operating unit for ALARA considerations. After isolation, the item being decontaminated is connected (with short-run flexible hoses) to the mobile decontamination unit to form a recirculation loop. Chemicals are injected into the loop through the valve manifold at the unit, valving is aligned, and recirculation is begun. The required solution temperature is automatically maintained by the unit's electric heater during the entire recirculation period. Limited operator attention is required during recirculation.

The once-through method completes the decontamination in one pass and is used where recirculation is impractical. Because of the harsher nature of the chemicals used in the once-through method, water rinses are necessary for these system/components to prevent creation of industrial safety hazards for subsequent disassembly operations.

In the PNL study, detailed estimates are made of costs as well as the ORE that is accumulated by the decommissioning workers during system decontamination and draining and radioactive liquid handling tasks. The ORE estimates are based on a task-by-task analysis of personnel exposure hours and expected radiation dose rates associated with each task. System decontamination and draining and radioactive liquid handling tasks are performed 24 hours per day, 7 days per week. Recirculatory chemical decontamination is postulated to take two days of loop operation at the proper temperature (353°K) to achieve the desired decontamination factor. The estimated cost, time, and ORE for systems internal decontamination are presented in Table 5.4.

It can be seen from Table 5.4 that the radiation doses for the chemical decontamination of the different systems vary considerably. For each system, the total dose is comprised of the sum of the doses to dedicated workers. These doses are based on composites of measured shutdown radiation dose rates obtained from seven operational BWRs (Oak et al. 1980, Appendix D). In addition, it is assumed that the decontamination achieves a minimum decontamination factor (DF) of 10. Subsequent disassembly and removal operations reflect this DF as evidenced by the varying radiation exposure rates associated with these decommissioning tasks (Oak et al. 1980, Table I.4-1).

Water-Jet Cleaning - In the PNL study (Oak et al. 1980), water-jet cleaning at the rate of 0.77 m^2/min and a flow rate of 23 L/min was assumed used to clean the surfaces of the following:

- suppression chamber
- reactor well pool cavity
- dryer separator pool cavity

TABLE 5.4. Estimated Cost, Time, and Occupational Radiation Exposure (ORE) for Systems Internal Decontamination in the PNL Study

Building[a]	Decontamination Activity	Estimated Task Totals: Cost, $[b]	Time, days	Dose, man-rem[c]
	Systems (Recirculatory)			
PC	Reactor Recirculation	413,570	29	4.456
RB, PC, RB	Reactor Water Cleanup	14,774	5	2.301
RB, PC	Residual Heat Removal	139,840	26	6.978
RB, PC	Low-Pressure Core Spray	19,184	5	0.616
RB, PC	High-Pressure Core Spray	23,069	5	0.829
RB, PC, RW	Fuel Pool Cooling and Cleanup	16,324	5	0.416
	In Situ			
RW	32 Tanks in Various Systems	293,832	40	15.450[d]
	Systems (Once-Through)[e]			
RB, PC	Drains	28,421		0.539
TG	Drains	18,853	13	0.381
RW	Drains	44,484		0.544
	Totals	1,012,351	128	32.510

(a) PC = Primary Containment; RB = Reactor Building; RW = Radwaste Building; and, TG = Turbine Generator Building.
(b) Costs are in mid-1987 dollars and do not include contingency, radwaste preparation, or radwaste disposal costs. They do include auxiliary equipment (including decon rigs and jumpers, where applicable), energy (electricity and oil), chemicals, and dedicated staff labor.
(c) Adapted from Table H.5-11 of Oak et al. 1980.
(d) The ORE associated with in situ decontamination of tanks was inadvertently omitted from Table H.5-11 of Oak et al. 1980, but is included here for completeness.
(e) It is assumed that this chemical decontamination activity is the last one to be done in each building. The three contaminated drain piping systems are equipment drain (radioactive), floor drain (radioactive), and miscellaneous waste (radioactive).

- spent fuel pool cavity

- the internal surfaces of the condensate storage tanks and the main condenser

- the external surfaces of the liquid and solid radwaste systems equipment.

5.2.3.2 TLG Study Approach to Decontamination of Systems

The two basic methods that are selected for system decontamination activities at the reference BWR in the TLG study are briefly described below. They are:

- chemical decontamination (recirculatory)

- water-jet cleaning.

Chemical Decontamination - Assumption Number 6 in the TLG study states that a DF of 10 is postulated from the chemical decontamination of the nuclear steam supply system (reactor vessel and recirculation system); no DF is given concerning the other contaminated reactor systems. The study worksheets for specific system decontamination tasks as well as for the subsequent disassembly and removal operations associated with those systems show identical, across-the-board occupational exposure rates for both supervisory and dedicated workers.

The chemical decontamination of the remaining contaminated systems piping in the TLG study is performed segment by segment. A detailed review of TLG's chemical decontamination worksheets shows that the decontamination rigs are hooked up about every 100 feet of piping in all the contaminated systems, as shown in Table 5.5. Thus, this approach results in an estimated total of 755 decon rig hookups at a cost of $4.5 million, without contingency. Overall, about 704 man-rem (greater than 17% of the total ORE for the DECON alternative in the TLG study) is incurred during the decontamination of systems during decommissioning.

A major schedule estimate assumption proffered in the TLG study (Assumption Number 1) states: "All work except vessel and internals removal activities is performed during an 8-hour workday, 5 days per week with no overtime. There are eleven paid holidays per year." Unit Cost Factor (UCF) number 89 states that 8-hour flushes are required for each decontamination rig hookup and a total duration of 41.4 hours is required per hookup. With a single-shift operation, only one hookup per decontamination rig could be completed every 5 days (41.4 hours). Thus, a total of 3,916 rig operating days would be required to complete the system decontaminations. It would appear that the circulatory decontamination efforts are likely to be on the

TABLE 5.5. Summary of Decontamination Rig Hookups, Costs, and External Occupational Radiation Exposure (ORE) for Decontamination of Systems and Drains from the TLG Study[a]

Plant System[b]	Number of Decontamination Rig Hookups[c]	Totals: Piping (ft)	Totals: Number of Valves	Decontamination Labor Cost ($000)[d]	Total Decontamination Cost ($000)[d]	Decontamination Occupational Radiation Exposure (man-rem)[e]
Residual Heat Removal*[f]	58	5,848	94	275	408	54.05
Reactor Water Cleanup*	28	2,810	54	133	164	26.10
Fuel Pool Cooling and Cleanup*	42	4,152	67	199	263	39.14
Radwaste - Floor Drain Process	6	634	65	28	92	5.59
Radwaste - Equipment Drain Process	10	960	67	47	173	9.32
Chemical Waste Processing	120	11,993	61	569	743	111.84
Equipment Drains - Reactor Building*	230	22,987	9	1,089	1,228	214.36
Equipment and Floor Drains - TB*	230	22,987	0	1,089	1,228	214.36
Floor Drains - Reactor Building*	17	1,706	23	81	90	15.84
Equipment and Floor Drains - RW*	14	1,399	11	66	79	13.05
Totals	755	75,476	451	3,576	4,468	703.65

(a) Based on TLG study, Volumes 1 and 2, Section 5 worksheets for utility and DOC DECON scenario.
(b) Does not include Nuclear Steam Supply System recirculation system piping decontamination.
(c) See text for a description of a decon rig hookup and unit cost factor derivation.
(d) Costs are in 1987 dollars and do not include contingency.
(e) Based on a total adjusted exposure man-hours incurred per hookup of 93.198 and radiation dose rate of 10 mR/hr.
(f) System decontaminations of a similar name to those described in the PNL study are designated with an asterisk. See Table 5.6 for comparison with PNL study concerning piping and valves.

critical path, and could extend the duration of the pre-license termination period unless 5 to 10 decontamination rigs were in service simultaneously.

<u>Water-Jet Cleaning</u> - The external surface decontamination of large volume components in the TLG study is described in UCF number 88. A decontamination rate of 0.023 m^2/minute, using a 46 L/min fluid flow rate is delineated therein.

5.2.3.3 Results of the Comparison of the Approaches to Decontamination of Reactor Systems

A comparison between the TLG study and the PNL study of the radioactively contaminated piping systems selected for chemical decontamination is presented in Table 5.6. Unfortunately, the discrepancies seen in the table concerning the number of valves and piping lengths were not resolved in this study, and they have some effect on the differences in decontamination costs.

The principal differences found in this analysis between the PNL study and the TLG study concerning the chemical decontamination and water-jet cleaning of contaminated reactor systems are presented in Table 5.7. It can be seen from the table that these differences include the overall approaches envisioned in getting the job done, constant versus variable radiation dose rates assigned to the workers performing the tasks, and the number of feet of piping involved in the project.

The PNL study employed a system-wide decontamination approach, including the use of jumpers where appropriate, and calculated the ORE based on the dose rates, which varied depending on the system. In addition, the PNL study considered both the solution heating requirements necessary for effective chemical decontamination as well as the optimum utilization of the onsite radwaste processing systems for concentration and solidification of the spent decontamination solutions. The TLG study chose a segment-by-segment approach whereby some 755 separate hookups were envisioned, based on connections being made about every 100 feet of systems piping, and with the resultant contaminated waste fluids being processed in numerous batches.

The TLG study applied constant dose rates to all worker types over all systems and over all systems tasks. The PNL study based its ORE estimates on a task-by-task analysis of personnel exposure hours and expected radiation dose rates associated with each task. The expected radiation dose rates varied in the PNL study depending on the system and/or component and were based on composites drawn from seven operable BWRs (Oak et al. 1980, Appendix D).

In both studies, only one system volume of chemical decontamination solution is required for the nuclear steam supply system (reactor vessel and recirculation system). However, in the TLG study, two water rinses are

TABLE 5.6. Comparison Between the TLG Study and the PNL Study of Radioactively Contaminated Piping Systems Selected for Chemical Decontamination

Plant System	TLG Study Totals(a) Piping, LF(c)	TLG Study Totals(a) Number of Valves	PNL Study Totals(b) Piping, LF(c)	PNL Study Totals(b) Number of Valves
Reactor Water Recirculation	NDC(d)	NDC	604	8
Reactor Water Cleanup	2,810	54	3,649	57
Residual Heat Removal	5,848	94	5,450	75
Low-Pressure Core Spray	NDC	NDC	1,024	13
High-Pressure Core Spray	NDC	NDC	788	19
Fuel Pool Cooling and Cleanup	4,152	67	3,419	66
Radwaste Drain Systems:(e)				
- Reactor Building/Primary Containment	NDC	NDC	2,212	24
- Turbine-Generator Building	NDC	NDC	3,275	14
- Radwaste and Control Building	NDC	NDC	4,718	202
Radwaste - Floor Drain Process	634	65	NDC	NDC
Radwaste - Equipment Drain Process	960	67	NDC	NDC
Chemical Waste Processing	11,993	61	NDC	NDC
Equipment Drains - Reactor Building	22,987	9	NDC	NDC
Equipment and Floor Drains - TG	22,987	0	NDC	NDC
Floor Drains - Reactor Building	1,706	23	NDC	NDC
Equipment and Floor Drains - RW	1,399	11	NDC	NDC
Totals	75,476	451	25,139	478

(a) Information adapted from TLG study, Section 5 worksheets for utility and DOC DECON scenario.
(b) Information adapted from Oak et al. (1980), Tables C.3-7 through C.3-10.
(c) LF means linear feet.
(d) NDC means No Direct Comparison is apparent between the studies.
(e) In the PNL study, these are some of the last tasks done in each building. They include 215 floor and equipment drains in the Reactor/Primary Containment, 115 floor and equipment drains in the Turbine-Generator Building, and 217 floor and equipment drains in the Radwaste and Control Building, as well as process and miscellaneous wastes (radioactive) systems (see Tables C.3-7 through C.3-10 in Oak et al. 1980).

postulated prior to segmentation. The segmentation itself is to be done underwater; therefore, it is presumed (but not stated) that the reactor vessel will again be filled with water. This approach effectively requires three or four system volumes of decontamination solution and/or rinse water that must subsequently be dealt with.

TABLE 5.7. Comparison of the PNL Study and the TLG Study Approaches to Decontamination of Reactor Systems

Category	Description of Difference	
	TLG Study[a]	PNL Study[b]
1. Decontamination of Systems Approach	Two basic methods: 1. Chemical decontamination (recirculatory) 2. Water-jet cleaning	Two basic methods: 1. Chemical decontamination (recirculatory, and once-through, depending on piping system) 2. Water-jet cleaning.
2. Work Schedule	8-hr workday, 5 days per week	Round-the-clock, 7 days per week[c]
3. Radiation Dose Rates	Constant on all systems at 0.010 R/hr[d]	Variable depending on system and/or component, based on composites drawn from 7 operable BWRs
4. Estimated Occupational Radiation Exposure, man-rem	704	33
5. Decontamination criterion	None stated in the report[e]	No chemical decontamination required on miscellaneous systems with expected contact readings of <15 mR/hr, after draining.
6. Piping (all sizes) selected for decontamination, LF	75,476	25,139
7. Selected Reactor Systems:		
a. Nuclear Steam Supply System (reactor vessel and recirculation system)	a. Using one chemical flush and two water rinses prior to segmentation	a. Using one chemical flush, at temperature, with <u>no</u> water rinse prior to segmentation.
b. Residual Heat Removal c. Reactor Water Cleanup d. Fuel Pool Cooling and Cleanup e. Low-Pressure Core Spray f. High-Pressure Core Spray	b., c., d., g., and h. systems: 1. Recirculatory 2. Decontamination rig working on consecutive sections[f] 3. 755 decontamination rig hookups 4. Deconcontaminate all piping in approximately 100-foot sections	b., c., d., e., and f. systems: 1. Recirculatory at temperature 2. System-wide using system pumps; jumpers used, where appropriate. 3. No decontamination rigs used 4. Decontaminate entire system
g. Equipment and Floor Drains		g: 1. Mobile heating unit with remote controls used 2. Once-through with water flush
h. Chemical Waste Processing i. In situ (32 tanks)		i: 1. Five decontamination rigs working in parallel; decontaminate at temperature required 2. Two hookups per tank 3. Recirculatory
8. Cost, $ Millions[g]	4.468	1.012

(a) Based on Table 5.4.
(b) Based on Figure 5.3.
(c) Based on chemical solution heating requirements and contaminated solutions draining and processing times.
(d) TLG assumed contaminated systems had high radiation levels prior to decontamination. These systems were decontaminated to a constant level of 0.010 R/hr after decontamination (LaGuardia 1990).
(e) No decontamination of systems that were not exposed to contamination during normal operation of the reactor (LaGuardia 1990).
(f) Exact number of decontamination rigs not stated in the TLG report; however, LaGuardia (1990) states: "Multiple mobile decontamination rigs (five) working on several systems at one time."
(g) Costs are in mid-1987 dollars and do not include contingency.

PNL believes that in the chemical decontamination of radioactively contaminated systems during decommissioning, the fewer hookups, the better. Because there are fewer opportunities for leaks, less surveillance is required, leading to less ORE. In addition, chemical decontamination is only justified if the ORE expenditure during the decontamination activity is at least recovered during subsequent removal operations. TLG also believes that in chemical decontamination, the fewer the hookups, the better, for the same reasons (LaGuardia 1990).

The chemical decontamination activities postulated in the TLG study, covering about 3 times as many linear feet of pipe as the PNL study, resulted in an estimated total ORE of about 704 man-rem, compared with less than 33 man-rem from those activities in the PNL study. The approach taken in the TLG study resulted in an estimated cost of about \$4.5 million, without contingency, compared with an estimated cost of slightly greater than \$1.0 million, without contingency, in the PNL study.

In the PNL study, the water-jet decontamination rate was assumed to be 0.77 m^2/minute, while in the TLG study, the water-jet decontamination rate was assumed to be 0.023 m^2/minute. The TLG study worksheets indicate that water-jet cleaning was limited to the containment vessel liner and various pool liners in the Reactor Building. No concrete cleaning was done with water jet. The estimated cost, without contingency, for these tasks is \$2.1 million and includes 27.5 man-years of effort. By way of comparison, the PNL study (Oak et al. 1980, Table H.5-5) indicates water-jet cleaning activities in the Reactor Building (178 schedule days), the Turbine Generator Building (128 schedule days), and the Radwaste Building (50 schedule days). The estimated cost, without contingency, is \$0.85 million and includes 12.9 man-years of effort. Overall, decontamination costs differed between the two studies by about \$4.7 million, with the TLG estimate being the larger.

5.2.4 Unit Cost and Work Difficulty Factors

The heart of the TLG estimating methodology is the development of unit cost factors for performing many repetitions of the same or very similar operations. This methodology is presented in detail in LaGuardia (1986). A simple example is the cutting of contaminated piping of a given size range (e.g., < 2 in. dia.). The steps necessary to remove a section of piping approximately 5 ft. in length from a given system are identified, time durations assigned to each step, and the elapsed times necessary to complete each step are estimated and summed over the complete operation. An appropriate crew makeup is identified (e.g., 2 laborers, 1 craftsman, 0.5 foreman), with appropriate salary rates and cost multipliers (i.e., overheads and profit). A set of work difficulty factors is also identified and applied to the base time duration to reflect the increases in time duration for the operation that result from such considerations as working above floor level, wearing respiratory protection, time devoted to obtaining and understanding the instructions associated with operations in radiation zones and to reducing radiation dose rates applicable to those operations, time for putting on and removing protective clothing necessary for radiation zone work, and time for work breaks. In Laguardia (1986), these time duration multipliers were identified and ranges of applicable values were presented, as given below.

- Height: 10 to 20% of basic task duration
- Respiratory Protection: 25 to 50% of basic time duration
- Rad. Protection/ALARA: 10 to 40% of basic time duration
- Protective Clothing: 30% of adjusted time duration
- Work Breaks: 8.33% of total adjusted duration

These work difficulty factors are used in developing unit cost factors for removing material used in the TLG analysis for WNP-2 (TLG 1988). For the removal of contaminated materials, each difficulty factor was set at the upper limit of its range, and all difficulty factors were applied to all steps within each operation.

The above approach has the result of markedly increasing the total duration of the times estimated for each operation. In many instances, these factors are appropriate and proper. In other instances, indiscriminate application of these factors results in an overestimate of the time duration of a given operation. An example is in the application of the maximum Radiation Protection/ALARA difficulty factor to every cut of contaminated piping made during decommissioning. A given crew will spend some time at the beginning of each shift being instructed about what system(s) they will work on and what conditions they may encounter during that shift relative to radiation protection needs. It seems highly unlikely that they should spend the equivalent of over 3 hours for every 8 hours of work receiving these instructions, and/or installing shielding to reduce the dose rates they would encounter during the shift.

Another unit cost factor that appears to PNL to be significantly inflated by inappropriate use of work difficulty factors is the use of the solution circulation rig for piping decontamination. For each use of the rig, 6 hours are assigned to disconnecting from the last use, moving to the next location, and connecting for the next use. Once connected, 8 hours are assigned to circulating the decontamination solution through the piping. To perform this operation, a crew of 2 laborers, 1 craftsman, and 0.5 foreman are assigned. In the TLG unit cost factor for decon rig operation, the maximum values of the full set of work difficulty factors are applied to all 14 hours of all crew members. In other words, these 3.5 persons are postulated to spend the entire 14 hours working at elevated heights, in masks, and under severe conditions relative to radiation protection. Examination of the listed steps for decon rig operation shows that 5 hours are devoted to connecting and disconnecting the rig from the piping, 1 hour for moving the rig to the next location, and 8 hours for circulating the decontamination solution. While the difficulty factors certainly apply during the connecting/disconnecting steps, it is not obvious that these factors should apply during the movement of the rig, and seems highly unlikely that they should apply during the period of solution circulation.

If one were to assume that the postulated work difficulty factors were appropriate for everything except the circulation time, the total time duration would be reduced from 41.4 hours/operation to 29.0 hours. The total labor cost for decon rig operation would be reduced from about $3.6 million to about $2.5 million. With 755 operations of the rig estimated in the TLG analysis, at an average cumulative dose of 93.198 man-mrem/operation, this operation alone contributes over 700 man-rem to the total dose (4085 man-rem) accumulated by the dedicated decommissioning workers. Reducing the number of crew labor hours per operation would also reduce the cumulative dose in roughly the same proportion, from about 700 man-rem to about 500 man-rem.

These obviously extreme examples illustrate the compounding effects on cost and dose that can result when generalized unit cost factors (developed with upper-bound work difficulty factors applied to all activities within a given operation) are applied to all operations of a given type without consideration of the differences in conditions that may exist between steps of a given operation.

5.2.5 Cascading Costs

An extensive literature search revealed that cascading costs[a] have not been given any selective or distinctive consideration in decommissioning cost estimates until recently. This is not surprising, since the history of decommissioning cost estimating has proved to be an evolutionary and iterative process. This highly subjective cost category was not considered as a separate entity in the 1980 PNL study. Rather, the time/manpower estimated for each task included creating the minimum number of additional points of access and egress necessary to accomplish license termination.

A summary listing from the TLG study for license termination and site restoration in the base case (i.e., licensee and decommissioning operations contractor) for DECON, including cascading costs, is shown in Table 5.8. It can be seen from the table that the total projected cost of dismantling the WNP-2 facility is about $281.2 million (1987 dollars). Approximately $190.1 million of the $281.2 million total projected cost is directly attributable to license termination activities (e.g., the engineering and planning for and the actual removal and disposal of the residual radioactivity of the WNP-2 facility). The TLG study points out, however, that an accounting of only these costs is not entirely accurate in portraying the actual cost of "decommissioning" as defined by the NRC and that consideration must also be given to the methods of executing the decontamination processes, which

(a) Cascading costs are defined as those costs associated with removing noncontaminated and releasable material in support of the decommissioning process (e.g., if it is considered necessary to remove portions of the top floors to get at a bottom-floor nuclear component).

TABLE 5.8. Summary of Estimated Costs from the TLG Study for the DECON (base case) Mode

Period No.	Direct Cost for License Termination	Cascading Costs	Total Decommissioning Cost	Total Cost (Including Demolition/Restoration)
	Millions 1987$			
1[a]	15.971	0.0	15.971	15.971
2[b]	135.802	9.078	144.880	144.880
3[c]	0.329	0.0	0.329	64.117
Subtotal	152.102	9.078	161.180	224.968
25% Contingency	38.026	2.269	40.295	56.242
Total	190.128	11.347	201.475	281.210

(a) Preparations.
(b) Decommissioning Operations and License Termination.
(c) Site Restoration.

include "cascading costs." The TLG study further states that about $11.3 million in cascading costs are estimated to be incurred during the decommissioning process for the licensee to meet the intent of the NRC's definition of decommissioning, resulting in a total DECON cost of about $201 million.

5.2.6 Comparison of Radioactive Waste Volumes

Direct comparison of disposal volumes on an item-by-item basis is not always possible between the two studies, because of differences in how the information was assembled and presented. However, it is possible to compare selected groupings of waste volumes, as shown in Table 5.9.

For the components associated with the reactor vessel, the internals, and the control rod drives, the total estimated volumes for the packaged materials agree amazingly well. The total packaged volumes associated with piping and valves also agree fairly well. There is a significant difference between the studies in the volumes of activated and contaminated concrete packaged for disposal, which probably reflects different assumptions about how the sacrificial shield is packaged. Also, there is a large difference between the two studies relative to the treatment of the containment vessel liner. TLG packaged the liner for disposal as radioactive wastes, while PNL assumed the liner could be cleaned sufficiently to permit release as scrap. There is a significant difference between the volumes associated with the spent fuel racks and pool liners from the Reactor Building. It is likely that this difference is also a result of different assumptions about how the material is packaged. A major difference appears when considering piping hangers. TLG worksheets show that all piping 2-1/2 inches or greater in diameter required a pipe hanger about every 22 ft, each of which occupied nearly 13 ft^3 in burial volume and weighed about 250 lb. On the other hand, PNL considered only snubbers/hangers within the containment vessel.

TABLE 5.9. Selected Comparisons of Radioactive Waste Volumes for DECON

Item	Packaged Waste Volume (m^3) PNL	TLG
Reactor Vessel/Internals/CR Drives	1,022	1,020
Piping and Valves	4,295	4,604
Activated/Contaminated Concrete	1,766	1,105
Containment Vessel Liner	(cleaned/released)	922[(a)]
Spent Fuel Racks/Pool Liners	381	856
Piping Hangers	270	1,553
All Other Wastes	11,241	14,429
Totals	18,975	24,489

(a) TLG believes that a BWR suppression pool liner will not be releasable without extensive decontamination, and that a cost-benefit study would have to be performed at the time of decommissioning to determine whether or not decontamination of the liner is reasonable. At current burial ground prices and current decontamination technology, TLG believes that decontamination of the suppression pool liner is not cost effective (LaGuardia 1990).

Overall, the total packaged volumes of radioactive waste estimated by the two studies agree reasonably well (i.e., to within about 10%) once the largest identified differences are removed, with the TLG estimate being the larger of the two. With disposal costs in the vicinity of $40 million, this difference corresponds to a cost difference of about $4 million.

5.2.7 Comparison of Occupational Radiation Exposures

For DECON of the reference BWR, the estimated total ORE by PNL is 1845 man-rem. As a result of a re-examination (Smith et al. 1985), PNL increased the decommissioning worker staff by about 80 man-years to assure meeting the 5 rem/year dose limit.

The TLG study shows an estimated ORE of 20 man-rem in Period 1 plus 3756 man-rem in Period 2 for DECON, based upon 566 man-years of dedicated decontamination workers (see Table 5.3). This manpower loading would appear to result in exceeding current regulatory dose limits of 5 rem/yr. However, the TLG approach (not stated in the report) was to lay off workers as they reached their annual exposure limit and to hire new workers, to avoid individual over-exposures.

5.2.8 Comparison of Packaged Waste Transportation Costs

There is a significant difference between the estimated cost of transporting the packaged wastes to the low-level disposal site (PNL, \$4.5 million; TLG, \$3.0 million). This difference arises from two competing factors: a difference in the estimated volumes of waste (PNL, 18,975 m^3; TLG, 24,489 m^3), and a difference in the postulated transport distance and rates (PNL, 1000 miles round trip at \$1.61 per mile; TLG, ≤100 miles one-way at \$5.25 per mile). The net result of these differences is about \$1.5 million, without contingency.

5.3 REFERENCES

Allen, R. P. 1982. "Development of Improved Technology for Decommissioning Operations." 1982 International Decommissioning Symposium, October 10-14, 1982, Seattle, Washington.

LaGuardia, T. S., et al. 1986. Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates. AIF/NESP-036, Atomic Industrial Forum, Washington, D.C.

LaGuardia, T. S. 1990. "Final Proposed Re-Write on PNL Report NUREG/CR-0674, Addendum 4." Bridgewater, Connecticut. Letter Document N10-20-GC-9001 to Dr. Carl Feldman, U.S. Nuclear Regulatory Commission.

Oak, H. D., G. M. Holter, W. E. Kennedy, and G. J. Konzek. 1980. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station. NUREG/CR-0672, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

Smith, R. I., G. J. Konzek, E. S. Murphy, and H. K. Elder. 1985. Updated Costs for Decommissioning Nuclear Power Facilities. EPRI NP-4012, Electric Power Research Institute Report by Pacific Northwest Laboratory, Richland, Washington.

TLG Engineering, Inc. (TLG). 1989. Decommissioning Cost Study for the WPPSS Nuclear Project No. 2. Document B04-25-001 Revision 1. Bridgewater, Connecticut.

APPENDIX A

COST UPDATING BASES AND METHODOLOGY

APPENDIX A

COST UPDATING BASES AND METHODOLOGY

This appendix contains the cost adjustment factors and other pertinent cost-related information used to update the PNL decommissioning costs to a mid-1987 (mid-August) cost base for the purpose of subsequent comparison with the TLG Engineering, Inc., cost estimate.

Cost adjustment factors used to update decommissioning costs to a mid-1987 cost base are shown in Table A.1. The rationale for these cost adjustment factors is given in the following paragraphs.

TABLE A.1. Cost Adjustment Factors for Updating Decommissioning Costs to a Mid-1987 Cost Base

Cost Category	Cost Adjustment Factor Applied to 1978 Costs
Staff Labor	1.63
Equipment	1.66
Miscellaneous Supplies	1.66
Energy	
Electricity	1.95
Fuel Oil	1.50
Specialty Contractors	1.66
Regulatory Fees	See rationale
Insurance	2.03
Waste Management	
Containers	See rationale
Transportation	1.56
Burial	See rationale

Staff Labor. Cost adjustment factors for staff labor were determined by using the July 1987 Handy Whitman Index of Public Utility Construction Costs. Average values, determined by averaging cost escalation factors for building trades labor for the six regions of the United States defined by the Handy-Whitman index, were used in making comparisons between 1978 and 1987.

Equipment. Equipment costs were escalated based on national average cost escalation values for capital equipment obtained from the U.S. Department of Labor publication, "Producer Prices and Price Indexes."

Miscellaneous Supplies. Cost adjustment factors used for miscellaneous supplies are the same as those used for equipment.

Electricity. Costs of electricity were escalated based on national average values of the electric power index in the U.S. Department of Labor publication, "Producer Prices and Price Indexes."

Fuel Oil. Costs of fuel oil were escalated based on national average values of the index for No. 2 fuel oil in the U.S. Department of Labor publication, "Producer Prices and Price Indexes."

Specialty Contractors. Specialty contractor costs are primarily costs associated with labor and equipment. The same cost escalation factors were used for specialty contractor labor and equipment as were used for facility licensee labor and equipment.

Regulatory Fees. Fees charged for licensing services performed by the NRC are on a cost recovery basis as defined in 10 CFR Part 170. For these cost updates it is assumed that licensee submittals are of a quality such that one NRC staff-year is required to accomplish the appropriate reviews, operational surveillance, and termination inspections, with an estimated cost in 1987 dollars of about $123,000.

Insurance. Based on telephone discussions with American National Insurers (ANI) representatives, 1978 insurance premiums were escalated by a factor of 2.03.

Containers. Insofar as possible, container costs were updated using actual 1987 costs determined by telephone contact with a supplier. For cases where this was not practicable, 1978 container costs were escalated by a factor of 1.7.

Transportation. From the published rates of a carrier licensed to transport radioactive materials (ICC TSMT 1988), it was determined that the 1987 cost of a legal-weight, exclusive-use truck shipment employing a single driver for a 1,000 mile round-trip distance is $1.61/mile. The 1978 cost of a similar shipment was $1.03/mile. This value was used to establish the transportation cost adjustment factor.

Low-Level Waste Burial. Current rate schedules for disposal of radioactive waste were obtained from both U.S. Ecology and Chem-Nuclear Systems, Inc.

The two companies use different bases for determining surcharges, and, therefore, their rate schedules are not directly comparable. Chem Nuclear's charges appear to be somewhat higher than U.S. Ecology's. Waste disposal costs in the original BWR decommissioning study (Oak et al. 1980) were based on U.S. Ecology rate schedules.

The calculations necessary to determine the costs for burial of the radioactive wastes postulated to result from decommissioning of the reference BWR are performed using a detailed spreadsheet (NRC 1988). The spreadsheet evaluates the burial costs for each of the items originally costed in the reference BWR decommissioning cost study. The costs in this study are based on the burial price schedule of August 17, 1987, for the U.S. Ecology's Washington Nuclear Center, located on the Hanford Site near Richland, Washington. The spreadsheet calculations, which are too voluminous to present here, are summarized in Table A.2. The costs shown in the table do not contain a cost contingency.

Since the original BWR decommissioning report was prepared, a number of post-TMI-2 backfit requirements have been imposed on operating nuclear power stations. These requirements were actions judged necessary by the NRC to correct or improve the safety of operation of nuclear power plants based on the experience from the accident at TMI-2. The costs for disposing of the additional contaminated materials associated with post-TMI-2 requirements imposed on the licensee are included in Table A.2. A summary of these estimated additional disposal costs for the DECON alternative is presented in Table A.3. The costs given in Table A.3 are based on the additional materials inventory delineated in NRC (1988), updated to the aforementioned August 17, 1987, burial price schedule, and contain a 25% contingency. The addition of these materials brings the total radwaste burial volume to 670,180 cubic feet.

TABLE A.2. Burial Volumes and Costs at the U.S. Ecology Washington Site, Reference BWR[(a)]

Waste Material	Burial Volume (ft^3)	1987$ (without contingency) Crane Surcharge	Cask Handling	Slings (Special)	Curie	Liner Dose Rate	Burial Charge	Disposal Cost
Activated								
Steam Separator	353	0	33,600	0	23,689	291,200	10,449	358,938
Fuel Support and Pieces	177	0	16,800	0	0	53,200	5,239	75,239
Control Rods/Incores	530	0	9,600	0	52,074	320,000	15,688	397,362
Control Rod Guides	141	0	6,600	0	0	18,792	4,174	29,566
Jet Pumps	495	0	48,000	0	35,160	610,000	14,652	707,812
Top Fuel Guides	848	0	86,400	0	117,776	1,098,000	25,101	1,327,277
Core Support Plate	389	0	17,050	0	0	48,546	11,514	77,110
Core Shroud	1,660	0	168,000	0	1,539,720	1,792,000	49,136	3,548,856
Reactor Vessel Wall	283	17,435	12,100	0	0	34,452	8,377	72,364
Sacrificial Shield	3,178	48,857	0	0	0	0	94,069	142,926
Contaminated								
Other Primary Containment	124,870	0	0	0	0	0	3,696,152	3,696,152
Reactor Water Recirc.	3,108	35,978	0	0	0	0	91,997	127,974
Sacrificial Shield	10,948	138,788	0	0	0	0	324,061	462,849
Containment Atmospheric	1,695	931	0	0	0	0	50,172	51,103
High-Pressure Core Spray	600	4,531	0	0	0	0	17,760	22,291
Low-Pressure Core Spray	353	1,416	0	0	0	0	10,449	11,864
Reactor Building Closed Cooling	1,130	2,747	0	0	0	0	33,448	36,195
Reactor Core ISO Cooling	459	716	0	0	0	0	13,586	14,302
Residual Heat Removal	2,190	12,909	0	0	0	0	64,824	77,733
Pool Lines and Racks	13,455	51,833	0	0	0	0	398,268	450,101
Contaminated Concrete	15,327	9,848	0	0	0	0	453,679	463,528
Other Reactor Building	50,110	0	0	0	0	0	1,483,256	1,483,256
Turbine	49,652	128,303	0	0	0	0	1,469,699	1,598,002
Nuclear Steam Condensate	12,819	18,687	0	0	0	0	379,442	398,129
Low-Pressure Feedwater Heater	26,026	140,751	0	0	0	0	770,370	911,121
Main Steam	2,508	4,747	0	0	0	0	74,237	78,983
Moisture Separator Reheaters	25,250	86,204	0	0	0	0	747,400	833,604
Reactor Feedwater Pumps	6,851	9,155	0	0	0	0	202,790	211,945
High-Pressure Feedwater Pumps	4,273	27.724	0	0	0	0	126,481	154,205
Other TG Building	171,520	0	0	0	0	0	5,076,992	5,076,992
Radwaste Building	84,931	0	0	0	0	0	2,513,958	2,513,958
Reactor Building	10,710	0	35,200	0	0	0	322,664	357,864
TG Building	7,230	0	23,100	0	0	0	217,372	240,472
Radwaste and Control	6,240	0	20,900	0	0	0	187,607	208,507
Concentrator Bottoms	22,500	0	123,750	0	0	150,898	666,000	940,648
Post-TMI-2 Wastes	1,271	0	0	0	0	0	37,651	37,651
Other	6,100	0	33,550	0	0	3,677	180,560	217,787
Total BWR	670,180	741,559	634,650	0	1,768,419	4,420,765	19,849,272	27,414,664

(a) Surcharge for non-Northwest Compact users at $\$20/ft^3$ equals an incremental cost of $13,403,600.

TABLE A.3. Summary of Estimated Costs for Disposal of Additional Contaminated Materials from the Reference BWR[a]

Description:	All materials shown in Table 4.4 of Konzek and Smith (1988)
Estimated Mass, kg[b]:	11,270
Number of Disposable Containers[c]:	14[d]
Container Costs, $[e]:	15,000
Number of Shipments[f]:	1
Transport Costs, $[g]:	4,320
Handling Costs, $:	0
Burial Volume, m^3:	36
Burial Cost, $[h]:	47,039
Total Disposal Cost, $[i]:	66,359

(a) Values include 25% contingency and are in August 1987 dollars.
(b) Obtained or estimated from information supplied by Washington Public Power Supply System.
(c) Assumed to be 1.2-m by 1.2-m by 2.4-m metal boxes, unless otherwise indicated.
(d) Seven of these containers are self-contained disposable containers on which the openings or surfaces are capped or covered and seal-welded.
(e) Based on information in Section M.2 of Appendix M by Oak et al. (1980) and escalated to August 1987 dollars.
(f) Assumed to be overweight shipment.
(g) Based on Table M.4-4 by Oak et al. (1980) and escalated to August 1987 dollars.
(h) Based on Table M.5-1 by Oak et al. (1980) and escalated to August 1987 dollars; based on an assumed container surface dose rate of <0.20 R/hr.
(i) The number of figures shown is for computational accuracy and does not imply precision to that many significant figures.

REFERENCES

ICC TSMT 4007-A, 1988. Naming Specific Truckload Commodity Rates -- Also Mileage Truckload Commodity Rates Applying on Radioactive Materials, Related Articles Classified or Declared Sensitive by the U.S. Government, and Empty Radioactive Material Containers From, To, Between All Points and Places in The United States Except Alaska and Hawaii, Tri-State Motor Transit Co., Joplin, Missouri.

Konzek, G. J., and R. I. Smith. 1988. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station: Technical Support for Decommissioning Matters Related to Preparation of the Final Decommissioning Rule. NUREG/CR-0672, Addendum 3, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

Oak, H. D., G. M. Holter, W. E. Kennedy, and G. J. Konzek. 1980. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station. NUREG/CR-0672, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington.

U.S. Nuclear Regulatory Commission (NRC). 1988. Report on Waste Burial Charges. NUREG-1307, Office of Nuclear Regulatory Research, Washington, D.C.

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10. SUPPLEMENTARY NOTES

11. ABSTRACT (200 words or less)

This study presents the results of a comparison of a previous decommissioning cost study by Pacific Northwest Laboratory (PNL) and a recent decommissioning cost study by TLG Engineering, Inc., for the same commercial nuclear power reactor station. The purpose of this comparative analysis on the same plant is to determine the reasons why subsequent estimates for similar plants by others were significantly higher in cost and external occupational radiation exposure (ORE) than the PNL study.

The primary purpose of the original study by PNL (NUREG/CR-0672) was to provide information on the available technology, the safety considerations, and the probable costs and ORE for the decommissioning of a large BWR power station at the end of its operating life. This information was intended for use as background data and bases in the modification of existing regulations and in the development of new regulations pertaining to decommissioning activities. It was also intended for use by utilities in planning for the decommissioning of their nuclear power stations.

The TLG study was performed in 1989 for the same plant, Washington Public Power Supply System's Unit 2 (WNP-2), that PNL used as its reference plant in its 1980 decommissioning study. Areas of agreement and disagreement are identified, and reasons for the areas of disagreement are discussed.

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