Attachment

Zion Nuclear Power Station

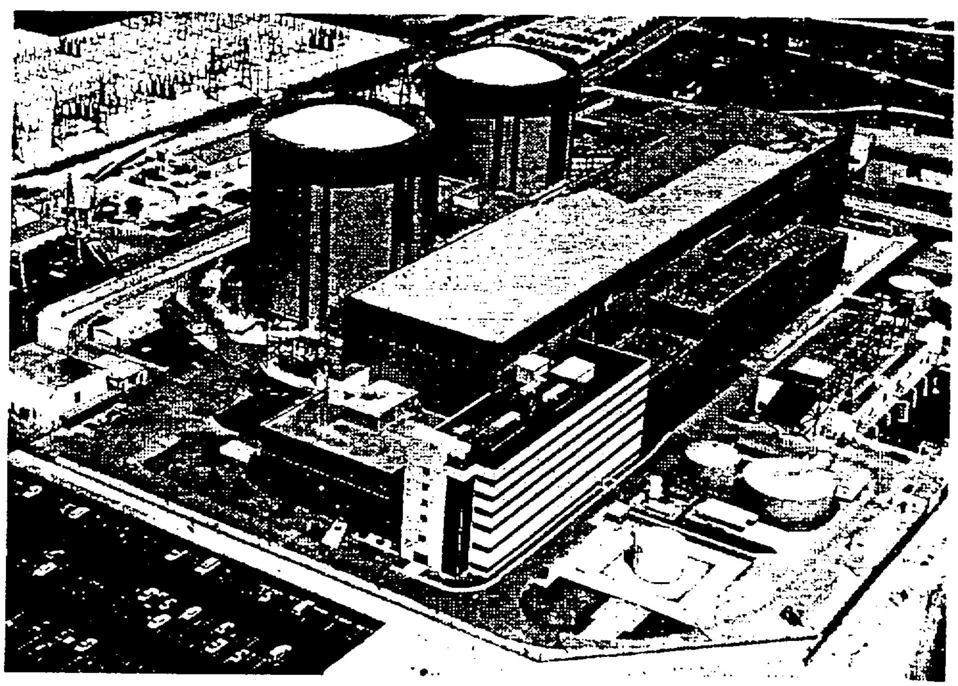
Units 1 and 2

Site-Specific Decommissioning

Cost Estimate

Document No. C04-1326-002

DECOMMISSIONING COST ESTIMATE
for the
ZION NUCLEAR POWER STATION
UNITS 1 AND 2



prepared for

Commonwealth Edison Company

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TABLE OF ACRONYMS / ABBREVIATIONS

ALARA	As-Low-As-Reasonably-Achievable
ComEd	Commonwealth Edison
DAW	Dry Active Waste
DECCER	TLG's proprietary decommissioning cost model
DF	Decontamination Factor
DOC	Decommissioning Operations Contractor
DOE	Department of Energy
DOT	Department of Transportation
DSC	Dry Shielded Canister
FSAR	Final Safety Analysis Report
GTCC	Greater Than Class C
HVAC	Heating Ventilation and Air Conditioning
ICC	Illinois Commerce Commission
ISFSI	Independent Spent Fuel Storage Installation
LSA	Low Specific Activity
MSCS	Zion's plant component computer database
MUC	Multi-Use Container
NRC	Nuclear Regulatory Commission
P&ID	Piping & Instrument Diagram
PERT	Program Evaluation and Review Technique
PSDAR	Post-Shutdown Decommissioning Activities Report

REVISION LOG

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EXECUTIVE SUMMARY

A site-specific cost analysis was prepared for decommissioning the Zion Nuclear Station (Zion Station) for the Commonwealth Edison Company (ComEd). The projected costs to decommission the nuclear portion of the station is estimated at approximately $904 million. The major cost contributors to the overall decommissioning cost are labor, radioactive waste disposal and other (e.g. recycling of LLW, engineering, undistributed costs). The costs are based on several key assumptions, including regulatory requirements, estimating methodology, contingency requirements, low-level radioactive waste disposal availability, high-level radioactive waste disposal options, and site restoration requirements. A complete discussion of the assumptions used in this estimate is presented in Section 4.

Given the total project cost for the DECON alternative, labor accounts for approximately 39.65% of the total project cost, radioactive waste burial accounts for approximately 17.17% of the total project cost, and all other costs total to 43.18% of the total project cost.

A detailed breakdown of these major cost contributors to the decommissioning cost estimate is reported in Section 8 of this document. Cost and schedule summaries are reported in Section 1. Schedules of annual expenditures in Section 4 and detailed cost, waste volume and man-hour schedules are provided in the Appendices. Costs are reported in 1996 dollars. The costs include the continued operation of the Fuel Handling Building's fuel storage pool as an interim wet fuel storage facility through the year 2025.

Alternatives and Regulations

The Nuclear Regulatory Commission (NRC) promulgated general requirements for decommissioning nuclear facilities on June 27, 1988[1]. In this rule, requirements for the NRC set forth technical and financial criteria for decommissioning licensed nuclear facilities. The regulations addressed planning needs, timing, funding methods, and environmental review requirements for decommissioning. Supplementary information accompanying the rule also addressed three decommissioning alternatives as being acceptable to the NRC — DECON, SAFSTOR and ENTOMB.

> DECON was defined as "the alternative in which the equipment, structures, and portions of a facility and site containing radioactive

1 U.S. Code of Federal Regulations, Title 10, Parts 30, 40, 50, 51, 70 and 72 "General Requirements for Decommissioning Nuclear Facilities," Nuclear Regulatory Commission, Federal Register Volume 53, Number 123 (p 24018+), June 27, 1988.

contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations." [2]

SAFSTOR was defined as "the alternative in which the nuclear facility is placed and maintained in a condition that allows the nuclear facility to be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use." [3]

ENTOMB was defined as "the alternative in which radioactive contaminants are encased in a structurally long-lived material, such as concrete; the entombed structure is appropriately maintained and continued surveillance is carried out until the radioactive material decays to a level permitting unrestricted release of the property." [4]

In 1996, the NRC published revisions to the general requirements for decommissioning nuclear power plants to clarify ambiguities and codify procedures and terminology as a means of enhancing efficiency and uniformity in the decommissioning process. The amendments allow for greater public participation and better define the transition process from operations to decommissioning. The costs and schedules presented in this estimate follow the general guidance and sequence in the amended regulations.

Methodology

The methodology used to develop the decommissioning cost estimates for Zion Station follows the basic approach originally presented in the Guidelines.[5] This reference describes a unit cost factor method for estimating decommissioning activity costs. The unit cost factors used in this study reflect site-specific costs, as well as the latest available information about worker productivity in decommissioning. The information obtained from the Shippingport Station Decommissioning Project, completed in 1989, as well as from TLG's involvement in the decommissioning planning and engineering for the Shoreham, Yankee Rowe, Trojan, Rancho Seco, Pathfinder, and Cintichem reactor facilities, is reflected within this estimate.

An activity duration critical path is used to determine the total decommissioning program schedule required for calculating the carrying costs which include program

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2 Ibid. Page FR24022, Column 3.

3 Ibid.

4 Ibid. Page FR24023, Column 2.

5 T.S. LaGuardia et al., "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates," AIF/NESP-036, May 1986.

management, administration, field engineering, equipment rental, quality assurance, and security. This systematic approach for assembling decommissioning estimates has ensured a high degree of confidence in the reliability of the resulting costs.

This study assumes that ComEd's primary contractor is already experienced in the techniques and technology of nuclear power plant decommissioning, and therefore performs all work (both field activities and project management) in an optimally efficient manner. Therefore, this study does not attempt to quantify any cost impact for any increase in efficiency from experience gained in decommissioning other plants in the past.

Contingency

Consistent with industry practice, contingencies are applied to the decontamination and dismantling costs developed as, "specific provision for unforeseeable elements of cost within the defined project scope, particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events which will increase costs are likely to occur."[6] The cost elements in this estimate are based on ideal conditions; therefore, the types of unforeseeable events that are almost certain to occur in decommissioning, based on industry experience, are addressed through a percentage contingency applied on a line-item basis. This contingency factor is a nearly universal element in all large-scale construction and demolition projects. It should be noted that contingency, as used in this estimate, does not account for price escalation and inflation in the cost of decommissioning over the remaining operating life of the units.

The use and role of contingency within decommissioning estimates is not a safety factor issue. Safety factors provide additional security and address situations that may never occur. Contingency funds, by contrast, are expected to be fully expended throughout the program. Application of contingency on a line-item basis is necessary to provide assurance that sufficient funding will be available to accomplish the intended tasks.

Low-Level Radioactive Waste Disposal

The contaminated and activated material removed in the decontamination and dismantling of a commercial nuclear reactor is classified as low-level radioactive waste, although not all of the material is suitable for "shallow-land" disposal. With the passage of the Low-Level Radioactive Waste Policy Act in 1980, and its Amendments of 1985, the states became ultimately responsible for the disposition of low-level

6 Project and Cost Engineers' Handbook, Second Edition, American Association of Cost Engineers, Marcel Dekker, Inc., New York, New York, p. 239.

radioactive waste generated within their own borders. Consequently, low-level radioactive waste removed in the decontamination and dismantling of ComEd's nuclear generating units is destined for the future Central Midwest Compact disposal site in Illinois (designated as host state). The process of selecting and developing a suitable site is in the early stages, with work progressing on siting and selection criteria. The opening of a low-level radioactive waste disposal facility in Illinois is not anticipated until around the year 2012.

For this decommissioning cost estimate, a base disposal charge for a regional facility was estimated by Vance & Associates. Published schedules from the operating Barnwell Low-Level Radioactive Waste Management Facility were referenced in the application of special handling and waste isolation surcharges.

Spent Nuclear Fuel

Congress passed the Nuclear Waste Policy Act in 1982, assigning the responsibility for disposal of spent nuclear fuel created by the commercial nuclear generating plants to the Department of Energy (DOE). This legislation also created a Nuclear Waste Fund to cover the cost of the program, which is funded by the sale of electricity from ComEd, and an estimated equivalent for assemblies irradiated prior to April, 1983. The DOE was to begin accepting spent nuclear fuel no later than January 31, 1998.

After several delays, DOE now indicates that they will not begin acceptance of spent fuel before 2010. For the basis of this cost study, ComEd has assumed that DOE will begin acceptance of spent fuel in 2010. The slow progress in the development of DOE's Waste Management System, make it necessary to include spent fuel storage in the cost and schedule of commercial reactor decommissioning.

For estimating purposes, a spent fuel storage scenario was developed from the current ComEd plan using DOE published information. ComEd plans to keep the fuel in the existing spent fuel pool and decommissioning the facility around the Fuel Handling Building. It is estimated that all fuel will be removed from the site in 2025, at which time the Fuel Handling Building will be decommissioned and dismantled and the Part 50 license for the site terminated.

Site Restoration

Site restoration is generally considered to be part of the decommissioning process. This study does not include nonradiological costs for demolition of systems and structures. Such costs have been provided in a separate report.

1. SUMMARY

The Zion Nuclear Power Station (Zion Station) is the third multi-unit station to be built in Commonwealth Edison Company's (ComEd) network serving Chicago and northern Illinois. The power generating station is located in Northeast Illinois on the west shore of Lake Michigan, approximately 40 miles north of Chicago, Illinois, and 42 miles south of Milwaukee, Wisconsin. This study addresses the decommissioning of two nuclear units; essentially identical pressurized water reactors with common supporting facilities. Schedule estimates, waste generation/disposition schedules, and occupational exposure projections were also produced for each decommissioning alternative in conjunction with developing the actual cost estimate.

ComEd has chosen a Delayed-DECON decommissioning scenario which involves removal of all radioactive material from the site commencing at the original license expiration date of Zion Station and ending with the shipment of spent fuel from the site. The owner may then have unrestricted use of the site with no further requirement for a license. This study assumes that a number of plant systems and structures on site affected by the decontamination effort are dismantled to the extent necessary to support NRC license termination, allowing the remaining structures on site to be available for alternative use. The estimated cost for this alternative, as reported in Table 1.1, is $904,261,580.

The presence of spent fuel assemblies on site has a bearing on the cost to decommission, and NRC regulations (10CFR50.54(bb)) require licensees to report on their plans for spent fuel storage and funding. This study recognizes that the fuel handling building at the Zion Station will be operational until all fuel as been taken by the DOE. ComEd has estimated the spent fuel will be present at the Zion site and stored into 2025.

This study provides estimates for decommissioning the Zion Station under current requirements and is based on present-day costs and available technology. While the cost and schedule estimates presented herein assume the complete removal of all significant station elements, as the station is presently configured, site restoration costs are not included in the cost estimates of this report, but instead are provided in a separate report. A summary of costs and schedule, for each alternative, is provided in Table 1.1. Detailed cost reports for each nuclear unit are provided in Appendix C. The schedule and sequence of decommissioning activities is identified in Section 5.

TABLE 1.1

ZION NUCLEAR STATION UNITS 1 AND 2
COST AND SCHEDULE ESTIMATE SUMMARY

	Cost, 96$ (thousands) [1]	Schedule (years)
Delayed-DECON		
Unit 1	406,580.41	28.25
Unit 2 & Common	497,681.17	28.33
STATION TOTAL	**$904,261.58**	**28.33** [2]

1. Columns may not add due to rounding.
2. Total duration calculated from shutdown of Unit 1 to overall project completion, including completion of on-site wet spent fuel storage.

2. INTRODUCTION

This analysis is designed to provide ComEd with sufficient information to prepare financial planning documents required by the ICC and the NRC. It is not a detailed engineering document, but a cost estimate prepared in advance of the detailed engineering preparations required to carry out the decommissioning of Units 1 and 2 at the Zion Nuclear Station.

2.1 OBJECTIVE OF STUDY

The objective of this study is to prepare an estimate of the cost, schedule, occupational exposure and waste volume generated to decommission Zion Station, including all common and supporting facilities. The study considers the integration of two-unit dismantling, as discussed below.

Operating licenses were issued on April 6, 1973, for Unit 1 and November 14, 1973, for Unit 2. Zion Unit 1 was shutdown on February 21, 1997, Zion Unit 2 was shutdown on September 19, 1996 never to be restarted. For the purposes of this study, decommissioning operations are assumed to begin at the original license termination date of Unit 2 on November 14, 2013, following a period of fuel storage dormancy.

2.2 SITE DESCRIPTION

The Zion Nuclear Station is located in northeast Illinois on the west shore of Lake Michigan. The site is approximately 40 miles north of Chicago, Illinois, and 42 miles south of Milwaukee, Wisconsin. Figure 2.1 provides a general arrangement of the site and major structures.

The station is comprised of two essentially identical pressurized water reactors with supporting facilities. The primary coolant system consists of a pressurized water reactor system designed by the Westinghouse Corporation. The reactor coolant system is comprised of the reactor vessel and four heat transfer loops. Each loop contains a reactor coolant pump, steam generator, and associated piping and valves. In addition, the system includes a pressurizer, a pressurizer relief tank, interconnecting piping, and the instrumentation necessary for operational control. All components of the reactor coolant system are located in the containment building. The design reactor thermal power level is 3250 Megawatts thermal (MWth). The corresponding electrical output is approximately 1,085 Megawatts electric (MWe) for both Units 1 and 2. Figure

2.2 shows a schematic of a typical 1100 MWe Westinghouse pressurized water reactor.

The containment structure at Zion is cylindrical, with a shallow dome roof and a flat foundation slab. The cylindrical portion is prestressed by a post-tensioning system consisting of horizontal and vertical tendons. The entire structure is internally lined with steel plate, which acts as a leak-tight membrane. The containment completely encloses the entire primary coolant system, consisting of the pressurized water reactor, steam generators, reactor coolant loops, and portions of the auxiliary and engineered safety features systems.

Heat produced in the reactor is converted to electrical energy by the power conversion system. A turbine-generator system converts the thermal energy of steam produced in the reactor into mechanical shaft power and then into electrical energy. The main turbine is a four casing, tandem-compound, six-flow exhaust unit consisting of one double-flow, high-pressure turbine and three double-flow low-pressure turbines. The generator is driven at 1800 rpm and rated at 1220 MVA. The exhaust steam from the turbine is condensed and deaerated in the main condenser. The heat rejected to the main condenser is removed by the circulating water system.

The circulating water system provides the heat sink required for removal of waste heat in the power plant's thermal cycle. The system has the principal function of removing heat by absorbing this energy in the main condenser. Water is withdrawn from Lake Michigan via the intake pipes by the circulating water pumps. After passing through the plant condensers, the discharge is routed back to the lake.

2.3 REGULATORY INFORMATION

The NRC issued a final rule "General Requirements for Decommissioning Nuclear Facilities," (Ref. 1) on June 27, 1988. This rule amended NRC regulations to set forth technical and financial criteria for decommissioning licensed nuclear facilities. The amended regulations address decommissioning planning needs, timing, funding methods, and environmental review requirements. The intent of the amendments was to ensure that decommissioning would be accomplished in a safe and timely manner and that adequate licensee funds would be available for this purpose. Subsequent to the rule, the NRC issued Regulatory Guide 1.159, "Assuring the Availability of Funds for Decommissioning Nuclear Reactors," (Ref. 2) which provided guidance to the licensees of nuclear facilities on methods acceptable to the NRC staff for complying with the requirements of the rule. The regulatory guide addressed the funding requirements and provided guidance on the content and form of the financial assurance mechanisms indicated in the rule amendments.

In 1996, the NRC published revisions to the general requirements for decommissioning nuclear power plants (Ref. 3). When the decommissioning regulations were adopted in 1988, it was assumed that the majority of licensees would decommission at the end of the operating license life. Since that time, several licensees have permanently and prematurely ceased operations. The NRC has amended the decommissioning regulations to clarify ambiguities and codify procedures and terminology as a means of enhancing efficiency and uniformity in the decommissioning process. The amendments allow for greater public participation and better define the transition process from operations to decommissioning.

Under the revised regulations, licensees would submit written certification to the NRC within 30 days after the decision was made to cease operations. Certification would also be required once fuel had been permanently removed from the reactor vessel. Submittal of these notices would entitle the licensee to a fee reduction and eliminate the obligation to follow certain requirements needed only during operation of the reactor. Within two years of submitting notice of permanent cessation of operations, the licensee would be required to submit a Post-Shutdown Decommissioning Activities Report (PSDAR) to the NRC. This report would describe the planned decommissioning activities, the associated sequence and schedule, and an estimate of expected costs. Prior to completing decommissioning, the licensee would be required to submit an application to the NRC to terminate the license, along with a license termination plan.

2.3.1 Nuclear Waste Policy Act

Congress passed the Nuclear Waste Policy Act in 1982 (Ref. 4), assigning the responsibility for disposal of spent nuclear fuel from the commercial generating plants to the Department of Energy (DOE). Two permanent disposal facilities were envisioned as well as an interim facility. To recover the cost of permanent spent fuel disposal, this legislation created a Nuclear Waste Fund through which money was to be collected from the consumers of the electricity generated by commercial nuclear power plants. DOE was to begin accepting spent nuclear fuel not later than January 31, 1998.

After pursuing a national site selection process, the Act was amended in 1987 to designate Yucca Mountain, Nevada, as the only site to be evaluated for geologic disposal of high-level waste. Also in 1987, DOE announced a five-year delay in the opening date for the repository, from 1998 to 2003. Two years later, in 1989, an additional 7-year delay was announced, primarily due to problems in obtaining the required permits from the state of Nevada to perform the required characterization of the site. DOE has projected additional delays as a result of proposed Congressional reductions in appropriations for the program.

Utilities have responded to this impasse by initiating legal action and constructing supplemental storage as a means of maintaining operating margins. On November 14, 1997, the U.S. Court of Appeals for the District of Columbia Circuit issued a decision in Northern States Power Company, et al., v. U.S. Department of Energy. In the decision, the Court reaffirmed its earlier Indiana Michigan ruling that DOE has an unconditional obligation to begin disposal of the utilities spent nuclear fuel by January 31, 1998. On July 30, 1998, ComEd filed a complaint with the Court of the Federal Claims for DOE's failure to begin accepting spent nuclear fuel on January 31, 1998. DOE has no plans to receive spent fuel before the year 2010. For purposes of constructing the decommissioning cost estimate, DOE is assumed to initiate spent fuel receipt in the year 2010.

2.3.2 Low-Level Radioactive Waste Policy Act

Congress passed the Low-Level Radioactive Waste Policy Act in 1980, declaring the states as being ultimately responsible for the disposition of low-level radioactive waste generated within their own borders. The federal law encouraged the formation of regional groups or compacts to implement this objective safely, efficiently and economically, and set a target date of 1986. With little progress, the Amendments Act of 1985 (Ref. 5) extended the target, with specific milestones and stiff sanctions for non-compliance. However, more than 20 years later, no new sites have been developed and even the most advanced program is far behind schedule.

The low-level radioactive waste generated in the decontamination and dismantling of ComEd's nuclear generating units is destined for the Central Midwest Compact's future disposal site. Illinois has been designated as the host state for the disposal facility. The process of selecting and developing a suitable site is in the early stages, with work progressing on siting and selection criteria. The opening of a low-level radioactive waste disposal facility in Illinois is not anticipated until sometime around the year 2012.

For purposes of constructing the decommissioning cost estimate, a base burial rate of $364 per cubic foot was developed by Vance & Associates (Ref. 6) as a reasonable estimate for the cost of low-level radioactive waste disposal at the Illinois regional site. Surcharges for high curie or special handling are included for those packages, as appropriate. Surcharges were established using data from the schedule of rates in effect at the operating Barnwell Low-Level Radioactive Waste Management Facility.

For non-metallic low-level radioactive materials such as scabble dust, contaminated concrete and contaminated soils, disposal costs were estimated based on burial at the Envirocare facility located in Clive, Utah. Based on industry experience, a base burial rate of $87 per cubic foot of material was used for this site.

Figure 2.1

GENERAL ARRANGEMENT of the ZION NUCLEAR STATION

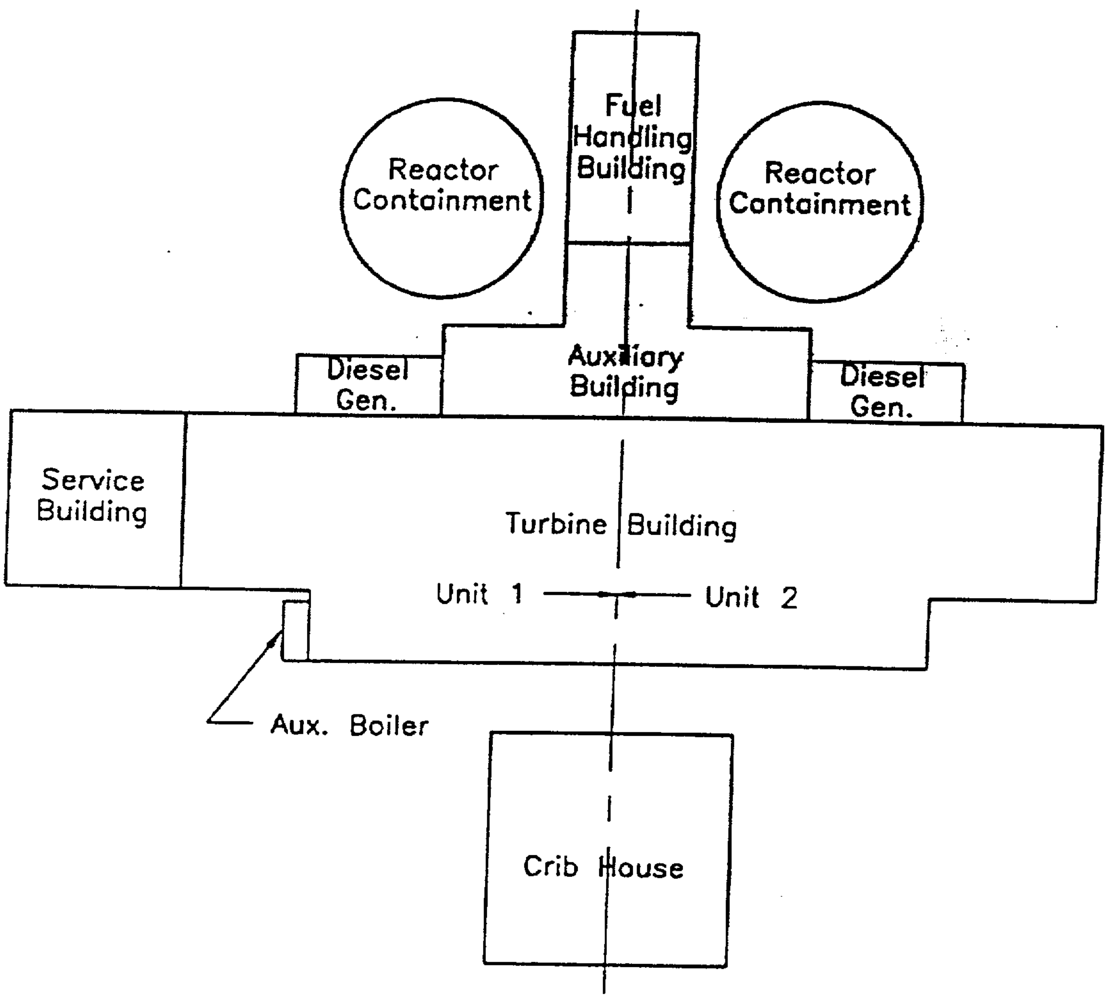
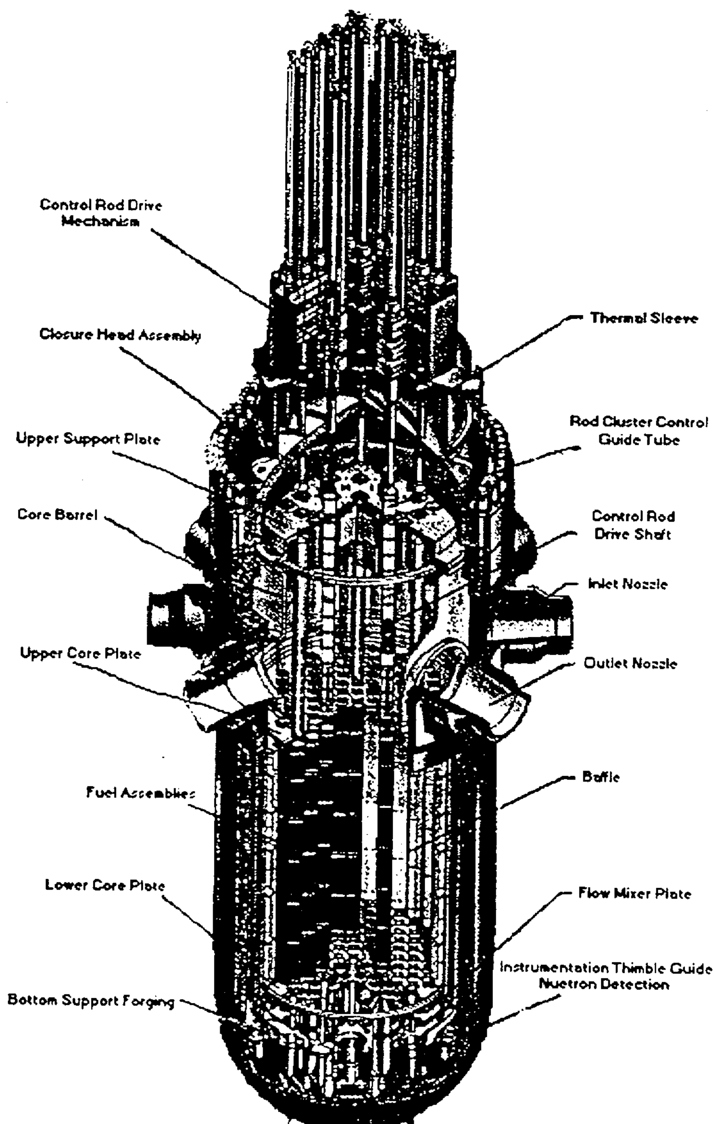


Figure 2.2

TYPICAL 1,100 MWe WESTINGHOUSE PRESSURIZED WATER REACTOR VESSEL



3. DELAYED-DECON DECOMMISSIONING ACTIVITIES

The following sections describe the basic activities associated with the decontamination and disassembly of the plant. Although detailed procedures for each activity identified are not provided, and the actual sequence of work may vary, these activity descriptions provide a basis not only for estimating, but also for the expected scope of work, i.e., engineering and planning at the time of decommissioning.

ComEd has chosen a modified version of DECON, referred to as Delayed-DECON, which decommissions the site in a timely manner, but recognizes constraints associated with storage of the spent fuel and decommissioning funding availability for the site. Decommissioning field activities are forecast to begin on the same schedule as if the plant operated to the end of its licensed lifetime. This permits the decommissioning trusts to be fully funded prior to field activities, plus it allows the spent fuel situation in the United States to coalesce and a definite plan of action to begin.

This study does not address the cost to transport fuel from the site and dispose of it; such costs are assumed to be funded through the surcharge on electrical generation (1 mill/kWhr). However, the study does recognize the constraint imposed by the spent fuel residing on site during the decommissioning process; preparing and packaging the fuel for transportation, and also the costs associated with storage of the fuel in the pool awaiting transfer to DOE.

3.1 PERIOD 1 - DORMANCY PREPARATIONS

This study assumes a majority of the preparations have been performed and estimated costs begin to accrue in the year 2000. The following section describes the activities associated with preparations for dormancy.

Detailed preparations are undertaken to provide a smooth transition from plant operations to site decommissioning. The organization required to manage the intended decommissioning activities is assembled from available plant staff and outside resources, as required. This staffing transition process covers retraining of selected plant staff and offering retention incentives for key personnel. Preparations include the planning for permanent defueling of the reactor, revision of technical specifications appurtenant to the operating conditions and requirements, a characterization of the facility and major components, and the development of the PSDAR.

Much of the work in the preparation of the PSDAR is also relevant to the development of the detailed engineering plans and procedures. This work includes, but is not limited to, the following activities.

1. Isolate spent fuel storage services and fuel handling systems located in the fuel handling building from the power block so that decommissioning operations may commence on the balance of the plant. This activity may be carried out by plant personnel in accordance with existing operating technical specifications.

2. Drain/de-energize/secure all non-contaminated systems not required to support decommissioning operations.

3. Dispose of contaminated filter elements and resin beds not required for processing wastes from decontamination activities.

4. Reactor vessel remains full; internals will remain in place.

5. Drain/de-energize/secure all contaminated systems. Decontaminate systems as required for future maintenance and inspection.

6. Prepare lighting and alarm systems whose continued use is required. De-energize and/or secure portions of fire protection, electric power, and HVAC systems whose continued use is not required.

7. Clean loose surface contamination from building access pathways.

8. Perform an interim radiation survey of plant; post warning signs as appropriate.

9. Erect physical barriers and/or secure all access to radioactive or contaminated areas, except as required for controlled access, i.e., inspection and maintenance.

10. Install security and surveillance monitoring equipment and relocate security fence around secured structures, as required.

11. This study assumes that demolition would be delayed for those structures which are located outside the secured area until after the termination of the license. No costs for demolition of structures either before or following decommissioning have been included in this estimate.

3.2 PERIOD 2 – WET FUEL STORAGE DORMANCY

Activities required during the planned dormancy period for the include a 24-hour guard force, preventive and corrective maintenance on security systems, area lighting, general building maintenance, heating and ventilation of buildings, routine radiological inspections of contaminated structures, maintenance of structural integrity, and a site environmental and radiation monitoring program.

Equipment maintenance, inspection activities and routine service are performed by resident maintenance personnel. This work force will maintain the structures in a safe condition, provide adequate lighting, heating, and ventilation, and perform periodic preventive maintenance on essential site services.

An environmental surveillance program is carried out during the dormancy period to ensure that potential releases of radioactive material to the environment are detected and controlled. Appropriate emergency procedures are in place and would be initiated for potential releases that exceed prescribed limits. The environmental surveillance program constitutes an abbreviated version of the program in effect during normal plant operations.

Security during the dormancy period is conducted primarily to prevent unauthorized entry and to protect the public from the consequences of their own actions. Security will be provided by the security fence, sensors, alarms, surveillance equipment, etc., which must be maintained in good condition for the duration of this period. Fire and radiation alarms are also to be monitored and maintained. While remote surveillance is an option, it does not offer the immediate response time of a physical presence.

Although the initial radiation levels due to ^{60}Co will decrease during the dormancy period, the internal components of the reactor vessel will still exhibit sufficiently high radiation dose rates to require remote sectioning under water due to the presence of long-lived radionuclides such as ^{94}Nb and ^{59}Ni.

Variations in the length of the dormancy period are expected to have little effect upon the quantities of radioactive wastes generated from system and structure removal operations. While there will be a decrease in the contamination levels present on all surfaces due to radioactive decay over an increased dormancy duration, it is not expected that any material that is non-releasable at the time of shutdown will decay to a releasable state over the permissible time frame (i.e. 60 years maximum.) Without detailed contamination characterization information, it is not possible to make any further assumptions concerning contamination levels.

The delay in decommissioning yields lower working area radiation levels. Because this alternative provides a period of decay for the residual radioactive material, lower radiation fields are encountered than with the immediate decommissioning. Some of the dismantling activities may employ manual techniques rather than remote procedures. Thus, dismantling operations may be simplified for some tasks. However, this study does not attempt to quantify this effect, because it would have an immaterial impact on overall costs.

3.3 PERIOD 3 - PREPARATIONS

In anticipation of decommissioning activities, detailed preparations are undertaken to provide a smooth transition from plant storage to site decommissioning. The organization required to manage the intended decommissioning activities is assembled from available plant staff and outside resources, as required.

Following the initial dormancy period and in preparation for actual decommissioning activities, the following activities are initiated.

1. Prepare site support and storage facilities, as required.

2. Perform site characterization study to determine extent of site contamination.

3. Clean all plant areas of loose contamination and process all liquid and solid wastes.

4. Conduct radiation surveys of work areas, major components (including the reactor vessel and its internals), sampling of internal piping contamination levels, and primary shield cores.

5. Correlate survey data and normalize for development of packaging and transportation procedures.

6. Determine transport and disposal container requirements for activated materials and/or hazardous materials, including shielding and stabilization. Fabricate or procure such containers.

7. Develop activity specifications and task-specific procedures for occupational exposure control, control and release of liquid and

gaseous effluent, processing of radwaste including DAW, resins, filter media, metallic and non-metallic components generated in decommissioning, site security and emergency programs, and industrial safety.

3.4 PERIOD 4A - DECOMMISSIONING OPERATIONS

During this period, significant decommissioning activities involve the following steps:

1. Construct temporary facilities and modify existing storage facilities to support the dismantling activities. These may include additional changing rooms and contaminated laundry facilities for increased work force, establishment of laydown areas to facilitate equipment removal and preparation for off-site transfer, upgrading roads to facilitate hauling and transportation, and modifications to the containments to facilitate access of large/heavy equipment.

2. Design and fabricate shielding in support of removal and transportation activities as well as contamination control envelopes; specify/procure specialty tooling and remotely operated equipment. Modify the refueling canal to support segmentation activities and prepare rigging for segmentation and extraction of heavy components, including the reactor vessel and its internals.

3. Procure required shipping canisters, cask liners, and low specific activity (LSA) containers from suppliers.

4. Conduct decontamination of components and piping systems as required to control (minimize) worker exposure. Remove, package, and dispose of all piping and components that are no longer essential to support decommissioning operations.

5. Remove control rod drive housings and the head service structure from reactor vessel head and package for controlled disposal.

6. Segment reactor vessel closure head and vessel flange for shipment in cask liners. Load overpack liners into shielded casks or place in shielded vans for transport.

7. Segment upper internals assembly, including upper support assembly, deep beam weldment, support columns, and upper core plates; package segments in shielded casks. These operations are

performed remotely by cutting equipment located underwater in the refueling canal. Package and dispose of items that meet Part 61 "Class C" criteria or less.

8. Disassemble/segment remaining reactor internals in shielded casks. These internals include core barrel, core baffle/former assembly, thermal shields, lower core plate, and lower core support assembly. The operations are also conducted under water using remotely operated tooling and contamination controls. Package and dispose of items that meet Part 61 "Class C" criteria or less.

9. Package Part 61 GTCC components into fuel bundle containers for handling and storage.

10. Segment/section the reactor vessel, placing segments into shielded containers. The operation is performed remotely in air using a contamination control envelope. Sections are placed in containers stored under water (for example in an isolated area of the refueling canal) using a remote or shielded crane. Transport the containers using shielded truck casks.

11. After the vessel water level drops below the elevation of the reactor vessel inlet and outlet nozzles during vessel segmentation, remove the reactor coolant piping and pumps. Package the piping in standard LSA containers; the reactor coolant pumps are sealed with steel plate so as to serve as their own containers. Ship piping and pumps for controlled disposal.

12. Remove systems and associated components as they become non-essential to the vessel removal operation, related decommissioning activities or worker health and safety (e.g., waste collection and processing systems, electrical and ventilation systems, etc.).

13. Remove activated concrete biological shield and accessible contaminated concrete (excluding steam generator and pressurizer cubicles). If dictated by the steam generator and pressurizer removal scenarios, remove those portions of the associated cubicles necessary for access and component extraction.

14. Pump low-density cellular concrete into the primary side of the steam generator to control movement of loose contamination during transport. Pump low-density cellular concrete into the secondary side of the steam generator to provide additional shielding for transport.

Portions of the steam generator may require a steel shield to meet transportation regulations.

15. Remove steam generators and pressurizer for shipment and controlled disposal. Decontaminate exterior surfaces, as required, and seal-weld openings (nozzles, inspection hatches, and other penetrations). These components can serve as their own burial containers provided that all penetrations are properly sealed and the internal contaminants are stabilized.

The preparation of a termination plan is required at least two years prior to the anticipated date of license termination. The plan must include a site characterization, description of the remaining dismantling activities, plans for site remediation, procedures for the final radiation survey, designation of any reuse of the site, an updated cost estimate to complete the decommissioning, and any associated environmental concerns. The NRC will notice the receipt of the plan and make the plan available for public comment. Plan approval may be subject to conditions and limitations as deemed appropriate by the NRC. The licensee may then commence with the final remediation of site facilities and services, including:

1. Material removed in the decontamination and dismantling of the nuclear units will be routed to an on-site central processing area. Material certified to be free of contamination will be released for unrestricted disposition, e.g., as scrap, recycle or general disposal. Contaminated material will be characterized and segregated for additional on-site decontamination, off-site processing (disassembly, chemical cleaning, volume reduction, waste treatment, etc.) and/or packaged for controlled disposal at the regional low-level radioactive waste disposal facility.

2. Remove steel liners from the refueling canal and containment. Package contaminated material in standard LSA containers, including any contaminated canal concrete, for controlled disposition.

3. Remove contaminated equipment and material from the Auxiliary Building. Remediate until radiation surveys indicate that the structure can be released for unrestricted access.

4. Decontaminate remaining site buildings and facilities with residual contaminants around the Fuel Handling Building. Package and

dispose of all remaining low-level radioactive waste along with any remaining hazardous and toxic materials.

5. Remove remaining components, equipment, and plant services in support of the area release survey(s).

3.5 PERIOD 4B – WET FUEL STORAGE DORMANCY

Once the plant has been dismantled around the fuel handling building, the remaining facility remains to support the fuel in wet storage until it is transferred to the DOE. The activities are the same as Section 3.2, however the security perimeter and monitoring facilities will be modified to only cover the fuel handling building. Transfer of the fuel to the DOE will occur during this period.

3.6 PERIOD 4C - FUEL HANDLING BUILDING DECOMMISSIONING AND LICENSE TERMINATION.

Once ComEd has removed all of the spent fuel, the systems that supported wet fuel storage will be removed and the fuel handling building decontaminated. The final site survey, deferred until after the fuel was removed can now be performed.

Incorporated into the license termination plan, the final survey plan, details the radiological surveys to be performed once the decontamination activities are completed. Statistical approaches to survey design and data interpretation acceptable to the Environmental Protection Agency (EPA), and the NRC will be delineated by these plans. They will also identify state-of-the-art, commercially available, instrumentation and procedures for conducting radiological surveys. Using these guidelines ensures that the surveys' design and implementation are conducted in a manner that provides a high degree of confidence that NRC criteria area satisfied. Once the survey is complete, the results are provided to the NRC in a format that can be verified. The NRC then reviews and evaluates the information, performs an independent confirmation of radiological site conditions, and makes a determination on final termination of the license.

The NRC will terminate the Part 50 license if it determines that site remediation has been performed in accordance with the license termination plan, and that the terminal radiation survey and associated documentation demonstrate that the facility is suitable for release.

3.7 PERIOD 5 – SITE RESTORATION

Site restoration is generally considered to be part of the decommissioning process. This study does not include nonradiological demolition of systems and structures. Such costs have been provided in a separate report.

4. COST ESTIMATE

A site-specific cost estimate was prepared for decommissioning the Zion Station. This estimate accounts for the unique features of the site, including the primary coolant system, electric power generation systems, site buildings, and structures. The basis of the estimate and its sources of information, methodology, site-specific considerations, assumptions and total costs are described in this section.

4.1 BASIS OF ESTIMATE

A site-specific cost estimate was developed using the Zion Station drawings and plant documents provided by ComEd. This information included a valve database (MSCS) from which the plant systems inventory was developed. Components other than valves were inventoried from the mechanical and electrical Piping & Instrument Diagrams (P&ID). Structural drawings and design documents were used to analyze the general arrangement of the facility and to determine estimates of building concrete volumes, steel quantities, numbers and sizes of major components, and areas of the plant to be addressed in remediation of the site.

Representative labor rates for each designated craft and salaried worker were provided by ComEd for use in construction of the unit removal factors, as well as for estimating the carrying costs for site management, worker supervision and essential support services, e.g., health physics and security.

For use in developing the estimated burial cost for low-level radioactive waste generated from decommissioning, a unit disposal charge of $364 per cubic foot was estimated by Vance & Associates for disposal at the regional site (Illinois is a member of the Central Midwest Compact).

4.2 METHODOLOGY

The methodology used to develop this cost estimate follows the basic approach originally presented in the AIF/NESP-036 study report, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates," (Ref. 7) and the US DOE "Decommissioning Handbook" (Ref. 8). These references utilize a unit cost factor method for estimating decommissioning activity costs, which simplifies the estimating calculations. Unit cost factors for concrete removal ($/cubic yard), steel removal ($/ton), and cutting costs ($/inch) were developed from the labor cost information provided by ComEd. The <u>activity-dependent</u> costs are estimated with the item quantities (cubic yards, tons, inches, etc.) developed from plant drawings and inventory documents.

The unit cost factors used in this study reflect the latest available information about worker productivity in decommissioning, including the Shippingport Station Decommissioning Project completed in 1989, as well as from TLG's involvement in the decommissioning planning and engineering for the Shoreham, Yankee Rowe, Trojan, Rancho Seco, Pathfinder, and Cintichem reactor facilities.

An activity duration critical path was used to determine the total decommissioning program schedule. The program schedule is used to determine the period-dependent costs for program management, administration, field engineering, equipment rental, quality assurance, and security. The study used typical salary and hourly rates for personnel associated with period-dependent costs for the region in which the station is located. Some of the costs for removal of radioactive components / structures were based on information obtained from the "Building Construction Cost Data," published by R. S. Means (Ref. 9). Examples of unit cost factor development are presented in the AIF/NESP-036 study (Ref. 7). Appendix A presents the detailed development of a typical site-specific unit cost factor. Appendix B provides the values contained within one set of factors developed for the Zion Station analyses.

The unit cost factor method provides a demonstrable basis for establishing reliable cost estimates. The detail of activities provided in the unit cost factors for activity time, labor costs (by craft), and equipment and consumable costs provides assurance that cost elements have not been omitted. These detailed unit cost factors, coupled with the plant-specific inventory of piping, components and structures, provide a high degree of confidence in the reliability of the cost estimates.

4.3 FINANCIAL COMPONENTS OF THE COST MODEL

The DECCER cost model is composed of a number of distinct cost line items, calculated using the unit cost factor methodology described earlier, as well as additional cost elements in support of the field activities. These calculated costs in and of themselves, however, do not comprise the total cost to accomplish the project goal, i.e. the license termination of the Zion Station.

Inherent in any cost estimate that does not rely on historical data is the inability to specify the precise source of costs imposed by factors such as tool breakage, accidents, illnesses, weather delays, labor stoppages, etc. In the DECCER cost model, contingency fulfills this role. Contingency is added to each line item to account for costs that are difficult or impossible to develop analytically. Such costs are historically inevitable over the duration of a job of this magnitude; therefore, this cost analysis includes monies to cover these types of expenses. Further discussion of this subject is presented below.

In addition to the routine uncertainties that contingency addresses, another cost element that is necessary to consider when answering the question of decommissioning costs relates to other types and levels of uncertainties. These consist of changes in work scope, pricing, job performance and other variations that could conceivably, but not necessarily, occur. Consideration of such items may be necessary to address the question concerning how costly the decommissioning project could become, within a range of probabilities. TLG considers these types of costs under the broad term "financial risk." This cost study, however, does not add any additional costs to the estimate for financial risk.

4.3.1 Contingency

The activity- and period-dependent costs are combined to develop the total decommissioning costs. A contingency is then applied on a line-item basis, using one or more of the contingency types listed in the AIF/NESP-036 study. "Contingencies" are defined in the American Association of Cost Engineers "Project and Cost Engineers' Handbook" (Ref. 10) as "specific provision for unforeseeable elements of cost within the defined project scope; particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events which will increase costs are likely to occur." The cost elements in this estimate are based upon ideal conditions and maximum efficiency; therefore, consistent with industry practice, a contingency factor has been applied. In the AIF/NESP-036 study, the types of unforeseeable events that are likely to occur in decommissioning are discussed and guidelines are provided for percentage contingency in each category. It should be noted that contingency, as used in this estimate, does not account for price escalation and inflation in the cost of decommissioning over the remaining operating life of the units.

The use and role of contingency within decommissioning estimates is not a "safety factor issue." Safety factors provide additional security and address situations that may never occur. Contingency funds are expected to be fully expended throughout the program. They also provide assurance that sufficient funding is available to accomplish the intended tasks. Some of the rationale for (and need to incorporate) contingency within any estimate is offered in the following discussion. An estimate without contingency, or from which contingency has been removed, can disrupt the orderly progression of events and jeopardize a successful conclusion to the decommissioning process.

The most technologically challenging task in decommissioning a commercial nuclear station will be the disposition of the reactor vessel and internal components, which have become highly radioactive after a lifetime of exposure to radiation produced in the core. The disposition of these highly radioactive components forms the basis for the critical path (schedule) for decommissioning operations. Cost and schedule are interdependent and any deviation in schedule has a significant impact on cost for performing a specific activity.

Disposition of the reactor vessel internals involves the underwater cutting of complex components that are highly radioactive. Costs are based upon optimum segmentation, handling, and packaging scenarios. The schedule is primarily dependent upon the turnaround time for the heavily shielded shipping casks, including preparation, loading and decontamination of the containers for transport. The number of casks required is a function of the pieces generated in the segmentation activity, a value calculated on optimum performance of the tooling employed in cutting the various subassemblies. The risk and uncertainties associated with this task are that the expected optimization may not be achieved, resulting in delays and additional program costs. For this reason, contingency must be included to mitigate the consequences of the expected inefficiencies inherent in this complex activity, along with related concerns associated with specialty tooling modifications and repairs, field changes, discontinuities in the coordination of plant services, system failure, water clarity, lighting, computer-controlled cutting software corrections, etc. Experience in decommissioning other plants in the past has shown that many of these problem areas have occurred during, and in support of, the segmentation process. Contingency dollars are an integral part of the total cost to complete this task. Exclusion of this component puts at risk a successful completion of the intended tasks and, potentially, follow-on related activities.

The following list is a composite of some of the activities, assembled from past decommissioning programs, in which contingency dollars were needed to respond to, compensate for, and/or provide adequate funding of decontamination and dismantling tasks:

Incomplete or Changed Conditions:

- Unavailable/incomplete operational history which led to a recontamination of a work area, because a sealed cubicle (incorrectly identified as being noncontaminated) was breached without controls.
- Surface coatings covering contamination which could not have been identified by a reasonable characterization, required additional cost and time to remediate.
- Additional decontamination, controlled removal, and disposition of previously undetected (although at some sites, suspected) contamination due to access gained to formerly inaccessible areas and components.
- Unrecorded construction modifications, facility upgrades, maintenance, enhancements, etc., which precipitated scheduling delays, more costly removal scenarios, additional costs (e.g., for re-engineering, shoring, structural modifications), and compromised worker safety.

Adverse Working Conditions:

- Lower than expected productivity due to high temperature environments, resulting in a change in the working hours (shifting to cooler periods of the day) and additional manpower.
- Confined space, low-oxygen environments where supplied air was necessary and additional safety precautions prolonged the time required to perform required tasks.

Maintenance, Repairs and Modifications

- Facility refurbishment required to support site operations, including those needed to provide new site services, as well as to maintain the integrity of existing structures.

- Damage control, repair, and maintenance from birds' nesting and fouling of equipment and controls.

- Building modification, i.e., re-supporting of floors to enhance loading capacity for heavily shielded casks.

- Roadway upgrades on site to handle heavier and wider loads; roadway rerouting, excavation, and reconstruction.

- Requests for additional safety margins by a vendor.

- Requests to analyze accident scenarios beyond those defined by the removal scenario (requested by the NRC to comply with "total scope of regulation").

- Additional collection of site runoff and processing of such due to disturbance of natural site contours and drainage.

- Concrete coring for removal of embedments and internal conduit, piping, and other potentially contaminated material not originally identified as being contaminated through a reasonable site characterization.

- Modifications required to respond to higher than expected worker exposure, reduced water clarity, water disassociation and resulting hydrogen generation from high temperature cutting operations.

- Additional waste containers needed to accommodate cutting particulates (fines), inefficient waste geometries and excess material.

Labor

- External (e.g. market) forces creating turnover of personnel, e.g., craft and health physics. Replacement of labor is costly, involving additional training, badging, medical exams, and associated processing procedures. Recruitment costs are incurred for more experienced personnel and can include relocation and living expense compensation.

- Additional personnel required to comply with NRC mandates and requests.

Schedule

- Schedule slippage due to a conflict in required resources, i.e., the licensee was forced into an unavoidable delay until prior (non-licensee) commitments of outside resources were resolved.

- Rejection of material by ComEd Quality Control inspectors, requiring refabrication and causing program delays in activities required to be completed prior to decommissioning operations.

Weather

- Unavailability of construction facilities required to support site operations (with compensation for delayed mobilization made to vendor).

- Frozen crane hydraulics prior to a major lift.

- Destruction of an exterior asbestos containment enclosure due to violent winds.

The cost model incorporates considerations for items such as those described above, generating contingency dollars (at varying percentages of total line-item cost) with every activity.

4.3.2 Financial Risk

Financial risk, as defined previously in this cost study, refers to the possibility and associated probabilities of certain events occurring that could increase or decrease costs for decommissioning. TLG's methodology, when asked to perform a risk analysis, is to use a Monte Carlo simulation program such as @Risk (Ref. 11) for Microsoft Excel.

A Monte Carlo analysis of a decommissioning project examines the range of values that certain inputs could assume. The model requires the input of a distribution of values over this range; the distribution most often used for cost estimating is a triangular distribution. All independent variables to be examined are assigned a high endpoint, low endpoint, and most likely midpoint to define their distribution. The actual analysis involves picking random values from within each range for each variable and recalculating the total cost at each iteration. The output of a Monte Carlo simulation typically includes a curve and range of probabilities for various cost estimates.

Included within the category of financial risk are:

- Delays in approval of the license termination plan due to intervention, public participation in local community meetings, legal challenges, state and local hearings, etc.

- Changes in the project work scope from the baseline estimate, involving the discovery of unexpected levels of contaminants, contamination in places not previously expected, contaminated soil previously undiscovered (either radioactive or hazardous material contamination), variations in plant inventory or configuration not indicated by the as-built drawings.

- Regulatory changes, e.g., affecting worker health and safety, site release criteria, waste transportation, and disposal.

- Policy decisions altering federal and state commitments, e.g., in the ability to accommodate certain waste forms for disposition, or in the timetable for such.

- Pricing changes for basic inputs, such as labor, energy, materials, and burial. Some of these inputs may vary slightly, e.g. -10% to +20%; burial could vary from -50% to +200% or more.

It has been TLG's experience that the results of a risk analysis, when compared with the base case estimate for decommissioning, indicate that the chances of the base decommissioning estimate's being too high is a low probability, and the chances that the estimate is too low is a much higher probability. This is mostly due to the pricing uncertainty for burial, and to a lesser extent due to schedule increases from changes in plant conditions, and to pricing variations in the cost of labor (both craft and staff). TLG did not perform a risk analysis for the Zion station and therefore the cost estimates in this report do not include any increase in decommissioning costs as a result of any risk analysis performed for ComEd or any other TLG client.

4.4 SITE-SPECIFIC CONSIDERATIONS

There are a number of site-specific considerations that affect the method for dismantling and removal of equipment from the site and the degree of restoration required. The cost impact of the considerations identified below is included in this cost study.

4.4.1 Spent Fuel Disposition

ComEd provided a spent fuel scenario management plan that addressed the storage scenario for all six ComEd nuclear plants. The anticipated spent fuel disposition scenario for Zion Station assumes that all fuel remains in wet storage in the spent fuel pool until it is taken by the DOE. The site will be decommissioned around the Fuel Building, and the fuel will remain in wet storage through 2025, at that time the Fuel Handling Building and supporting systems will be decommissioned, the license termination survey conducted, and the license terminated.

4.4.2 Reactor Vessel and Internal Components

The reactor pressure vessel and reactor internal components are segmented for disposal in shielded transportation casks. Segmentation and packaging of the internals' packages are performed in the refueling canal where a turntable and remote cutter will be installed. The vessel is segmented in place, using a mast-mounted cutter supported off the lower head and directed from a shielded work platform installed overhead in the reactor cavity. Transportation cask specifications and Department of Transportation (DOT) regulations dictate segmentation and packaging methodology. All packages must meet the current physical and radiological limitations and regulations. Cask shipments will be made in DOT-approved, currently available, truck casks.

The dismantling of reactor internals at the Zion Station will generate radioactive waste generally unsuitable for shallow land disposal. This waste is generally referred to as "Greater-than-Class-C" (GTCC). The Federal Government is responsible for the disposal of this waste (Ref 12). The DOE has not yet established an acceptance criteria or a disposition schedule for this material, and numerous questions remain as to the ultimate disposal cost and waste form requirements. For purposes of this study, the GTCC waste has been packaged and disposed of at a cost equivalent to the cost envisioned by the DOE for disposal of spent fuel.

Reactor coolant piping is cut from the reactor vessel once the water level in the vessel (used for personnel shielding during dismantling and cutting operations in and around the vessel) is dropped below the nozzle zone. The piping is boxed and shipped by shielded van. The reactor coolant pumps and motors are lifted out intact, packaged, and transported together with the steam generators for disposal.

4.4.3 Steam Generators and Other Primary Coolant System Components

The steam generators' size and weight, as well as their configuration in the containment building and limited access in the containment building itself, places constraints on the intact removal of these components. Modifications to the containment building are necessary for component extraction, due to the fact that the only large access to the building is the existing equipment hatch, located above grade level. To remove the generators through the equipment hatch requires that the units be positioned horizontally, which becomes impossible due to physical impediments within the structure.

Determination of the removal strategy requires several different considerations. Considerations for the extraction process include modifications to the containment building for removal of the generators, rigging needed to maneuver and extract the generators from the structure, and the component preparations needed to transport the generators to a disposal site.

A potential method for removal (and the one used as the basis in this estimate) is the extraction of the generators in a manner similar to that used for their installation, i.e., through a construction hatch that was subsequently sealed when the containment building was completed. This method requires modifications to the building since the construction hatch would have to be re-created. The hatch was approximately forty feet square, twenty-six feet above grade level, at an approximate 20-degree offset from the equipment hatch. Re-opening this hatch will provide the needed room for extraction of the generators and the rigging equipment required for their removal. Removal of sections of the steam generator cubicle walls, adjoining floor slabs, and floor grating will also have to be accomplished to allow for the generators to be maneuvered to the opening.

The hatch would be re-created using a diamond wire saw to section the containment wall into large blocks which could be removed. Once the building is opened, grating within the work area will be decontaminated and removed. Next, a trolley crane will be set up for removal of the generators. By setting the trolley crane first, it can be used to lower portions of the steam generator cubicle walls that will have to be removed as part of the modification effort. It also can be used to help remove portions of the floor slab. A 15-foot section of the cubicle wall will be dismantled, which is the minimum portion of the cubicle wall requiring removal to allow the maneuvering of the generators within the building. Large cubicle wall sections will be lowered out of the containment building using the trolley crane, where they can be decontaminated and transported to the material handling area. Figure 4.1 shows removal of cubicle walls for removal of a primary coolant system component.

The generators will be rigged for removal, disconnected from the surrounding piping and supports, and maneuvered into the open area where they will be lowered onto a dolly. The dolly will allow the lower end of the steam generator to rotate through the opening as it is being lowered. Once the steam generator has been lowered to the horizontal position, it will be filled with low-density cellular concrete for stabilization of the internal contamination. Nozzles and other openings will be welded closed. When this stage has been completed, the generator will be lifted onto a multi-wheeled transporter and moved to an on-site storage area to await transport to the disposal facility. The three remaining steam generators and pressurizer will be removed using the same technique. Once the components have been removed, a portion of the opening will be closed using concrete blocks. A smaller opening will be covered with a temporary barrier to allow for future access. Figure 4.2 shows the rigging process used for removal of steam generators from the reactor building.

Once at the storage area, each generator will have a two-inch thick carbon steel membrane welded to its outside surface for shielding during transport. The generators will then be loaded onto a multi-wheeled transporter and moved to an on-site rail head where they will be shipped to the Central Midwest Compact's waste disposal facility. Depending upon the proximity of the rail head to the disposal location, the generators may be off-loaded from the train and onto multi-wheeled transporters to be moved for the remaining distance to the disposal site. Figure 4.3 shows the typical overland transport used to move a steam generator about the work site.

The size and weight of the generator packages was a concern in evaluating transportation alternatives. As such, discussions were held with both the railroad and Lampson, Inc. (rigging), on the moving of the generators. Both companies have had experience with moving large nuclear components, and were able to supply costs based on the specific generator dimensions and weight. TLG was also able to apply its experience gained in the planning of the disposition of the steam generators at the Trojan site, where Lampson was a subcontractor.

4.4.4 <u>Transportation Methods</u>

For the purposes of the cost estimate, it was assumed that the low-level radioactive waste produced in the decontamination and dismantling of the nuclear units will be moved overland by truck, shielded van, rail, and/or multi-wheeled transporter to the regional burial facility. Transport costs were derived assuming a common destination for all ComEd waste within the Central Midwest Compact. Figure 4.4 shows a typical rail transport of a steam generator.

4.4.5 <u>Low-Level Radioactive Waste Disposal</u>

Burial cost projections for the regional radioactive waste disposal facility were derived using a unit disposal charge of $364 per cubic foot. The value was developed by Vance & Associates as an estimate for the waste disposal cost at the future Central Midwest Compact facility. Special handling surcharges (e.g., based upon curie content and/or weight) were included, as applicable, using the published schedule in effect in 1996 at the Barnwell, South Carolina, facility (Ref. 13).

Some low-level radioactive waste may meet the disposal criteria for the Envirocare facility located in Clive, Utah. This estimate assumed that all concrete scabble dust and any contaminated soils would be disposed of at the Envirocare facility at a disposal rate of $87 per cubic foot. The trucking distance from Zion Station to Clive, Utah, was estimated at 1,635 miles.

To the greatest extent practical, noncompactable low-level radioactive waste is treated to reduce the total volume of radioactive material requiring controlled disposal. The treated material meeting the regulatory and/or site release criteria is released as clean scrap, requiring no further cost consideration. Material not meeting release criteria will be processed for volume reduction and packaged for controlled disposal as radioactive waste. Material/waste recovery and recycling are assumed to be performed off site by a licensed processing center.

After the plant shutdown, low levels of contamination have been detected remaining in secondary side systems. For purposes of this estimate these systems, including the turbine and condenser were estimated being removed by controlled methods as if in a radiological environment. A metallic material was assumed to be sent to an outside vendor that specializes in the survey and reprocessing of LLW. A cost of $1.29 per pound was used as an industry average for this material. While some of this material will ultimately be sent for disposal by the off-site vendor, the $1.29 per pound rate is all inclusive rate for all material, and no burial volumes are reported.

Compactable DAW, such as booties, glove liners, respirator filter cartridges, shipping containers, radiological controls survey materials, etc. will be assumed to be drummed and compacted to 10% of their original volume. This is the minimum practical volume to which LLW can be compacted to reduce costs.

4.4.6 <u>Secondary Side Contamination</u>

This estimate recognizes that the systems on the secondary side of the main steam generators, primarily Main Steam, Condensate, and Feedwater, along with connecting systems and equipment, may contain some radioactive contamination. Existing Zion site procedures, as well as the TLG estimating basis, require a 100% scan of all wetted surfaces prior to release from the site. This is done to verify that no material that leaves the site contains any radioactive contamination. This survey can be performed at a lower cost by a radioactive waste-processing vendor. Therefore, it was assumed, that all material from the secondary side of the plant, while removed in a manner similar to clean components, will be shipped off site to a waste processor for 100% survey, decontamination where possible, and burial as LLRW as necessary.

4.4.7 TLG On-Site Evaluation of Plant Inventory

A team of TLG engineers reviewed the inventory at the Zion site in January 1999, to reassess the 1996 TLG systems inventory for the Zion Nuclear Station. A field survey of major components was undertaken to compare with the TLG inventory. TLG walked down the entire plant with the exception of locked high radiation areas. The survey included direct visual inspection of over 75% of the major plant components, and a comparison of the valves used in the 1996 estimate to the plant operators safety related documentation.

The survey resulted in finding some minor discrepancies, which were modified in this estimate. These areas as follows

- The Safety Injection Pumps SI-003&4 were categorized with components in a weight class of 300 to 1,000 pounds, when they should have been categorized in a weight class of pumps 1,000 to 10,000 pounds.

- The Refueling Water Storage Tank was accounted for in both the plant systems inventory as a free-standing tank, and in the plant building inventory as a steel-lined pool. The estimate was modified to include the tanks only as a steel-lined pool.

- Two additional heat exchangers were double accounted for in the Condensate System for each unit, this double accounting has been eliminated..

- The Cavity Fill System was scheduled to be installed when the 1996 estimate was conducted. This system was subsequently never installed before the final cessation of plant operations. This system has been deleted from the estimate.

4.4.8 Site Conditions Following Decommissioning

Following the decommissioning effort, the structures and remaining systems will meet the specified NRC site release limit. The NRC involvement in the decommissioning process typically will end at this point. Local building codes, state environmental regulations and ComEd's own future plans for the site will dictate the next step in the decommissioning process. TLG assumed the total removal of all plant systems and all of the above-grade structures from the site, however, these non-radiological costs are not part of this study, and are detailed in a separate report.

FIGURE 4.1

Reactor Building Modification for Pressurizer Removal

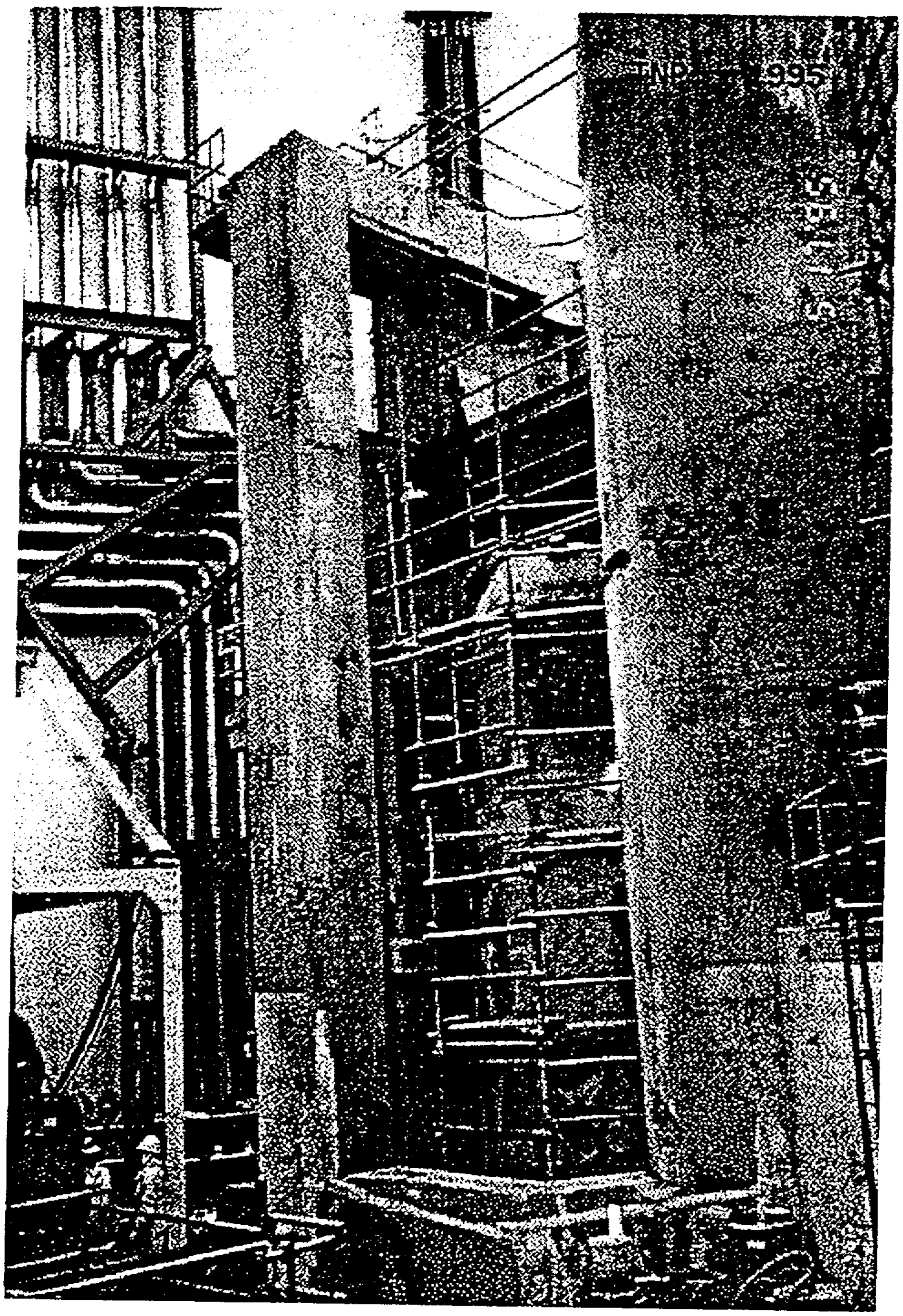


FIGURE 4.2

Removal of Steam Generator from Reactor Building

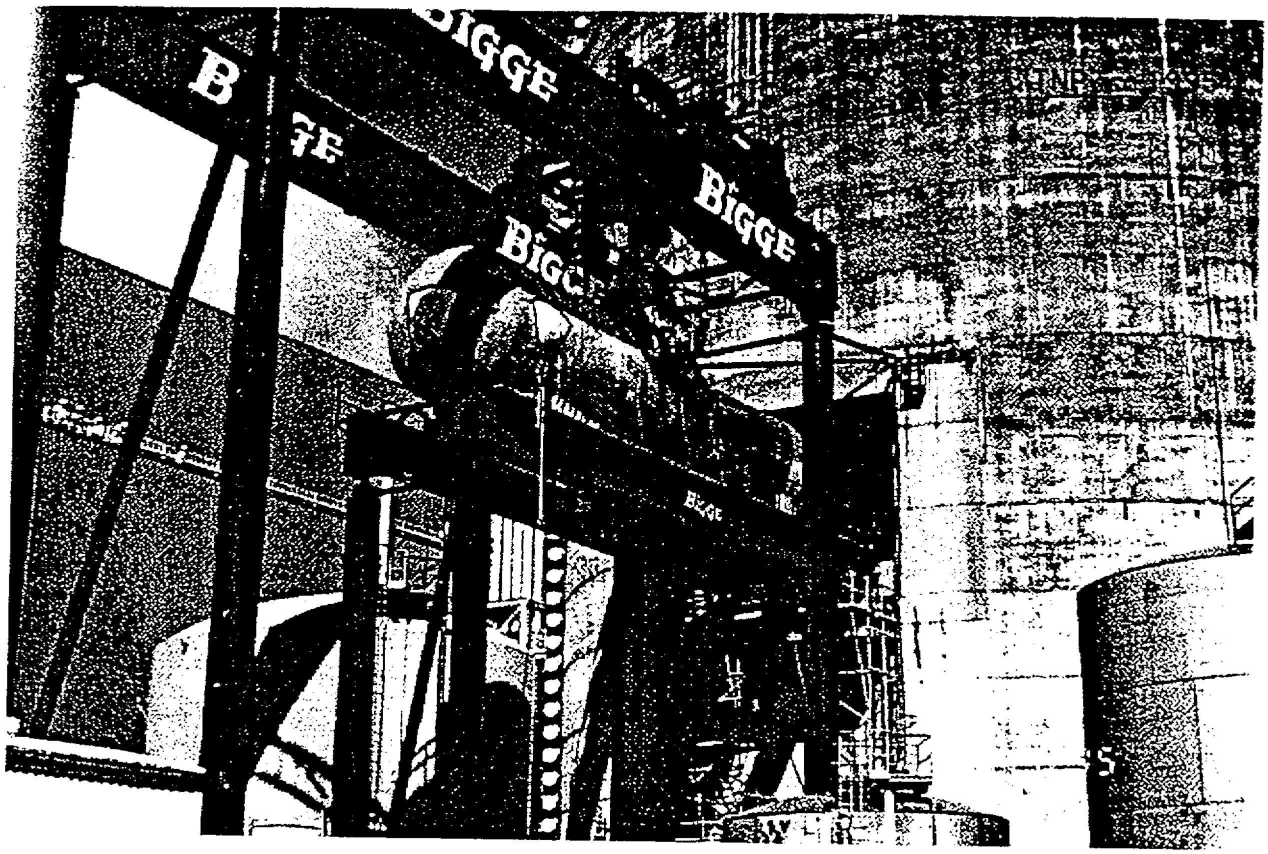


FIGURE 4.3

Overland Transport of Steam Generator

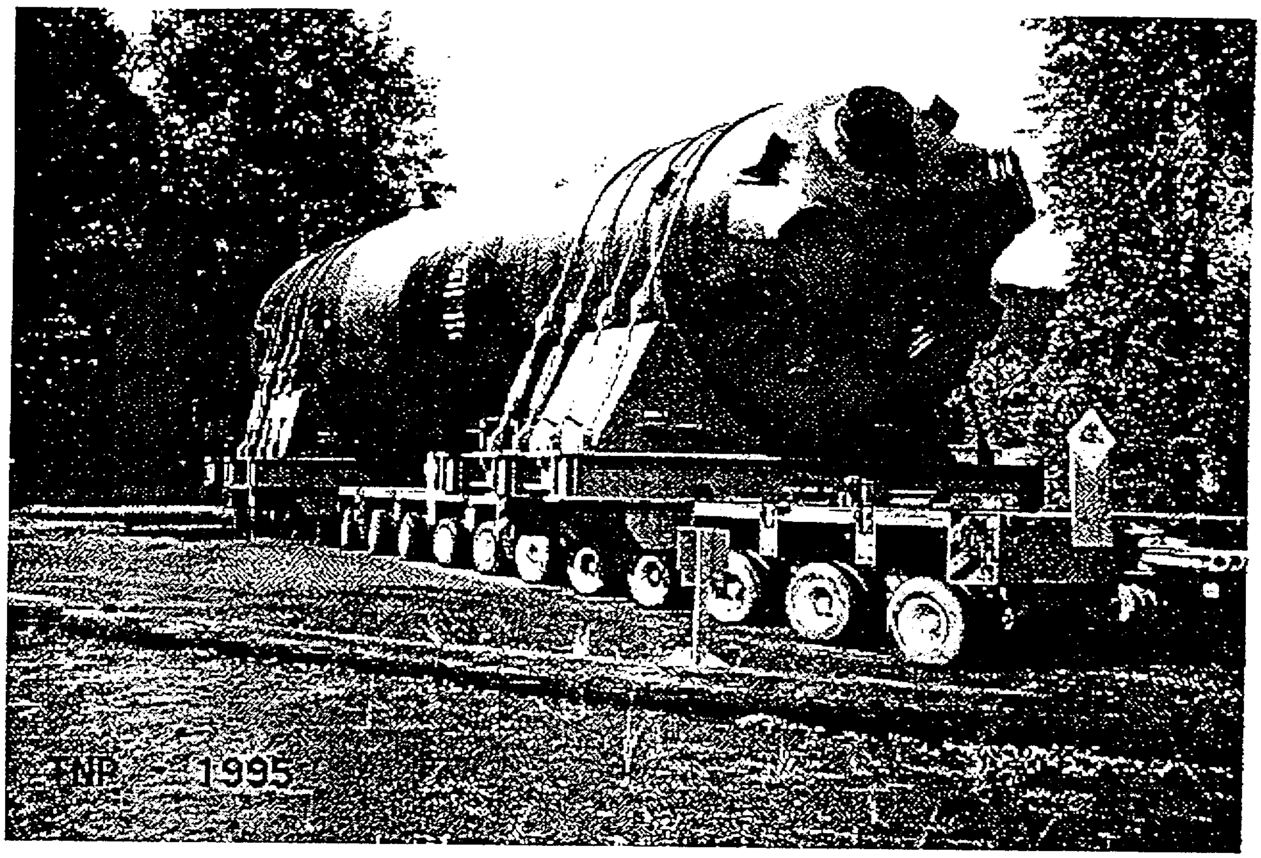
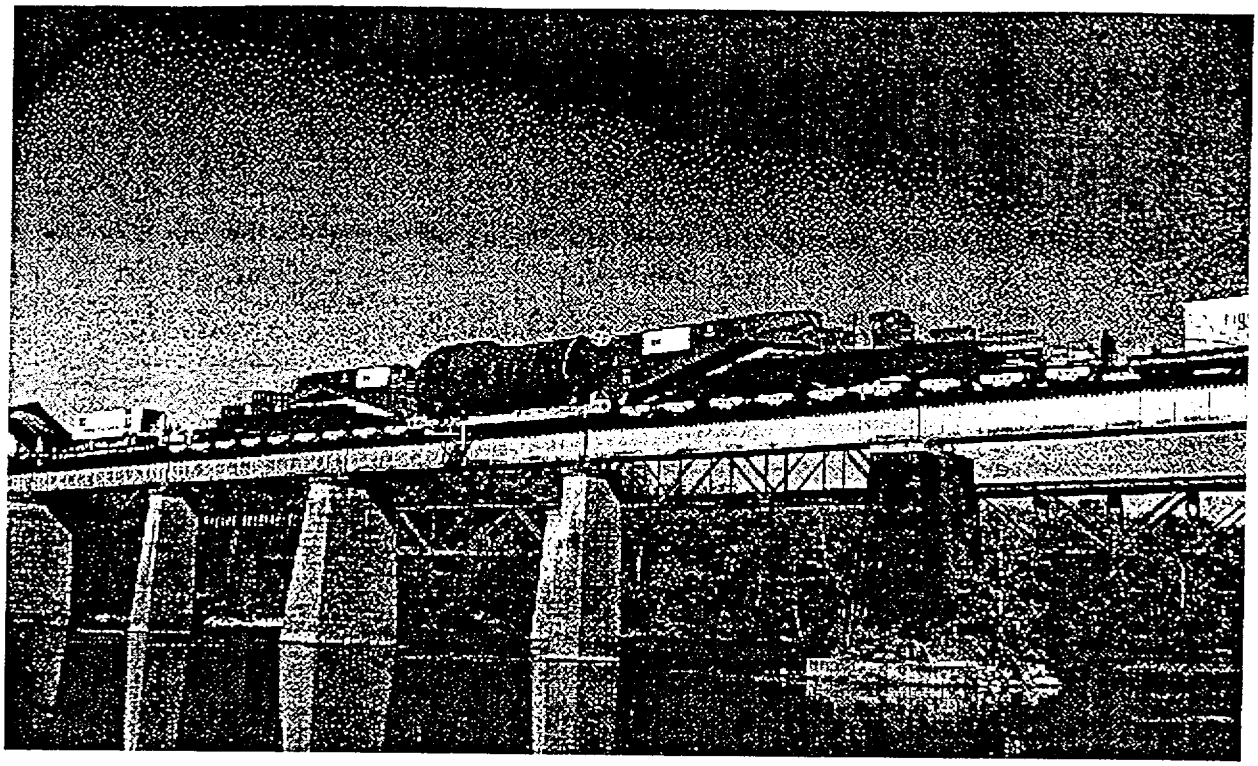


FIGURE 4.4

Rail Transport of Steam Generator



4.5 ASSUMPTIONS

The following are the major assumptions made in the development of the cost estimates for decommissioning the Zion Station.

1. Costs are calculated in 1996 dollars. A present-value economic analysis is not included, nor is escalation or general inflation reflected within the costs reported.
2. Both units are assumed to be identical except for common structures and systems. Common systems and structures are assigned to, and incorporated within, the estimate for Unit 2 as being required to support decommissioning operations.
3. Plant drawings, equipment and structural specifications, including construction details, were provided by ComEd.
4. Employee salary and craft labor rates for site administration, operations, construction, and maintenance personnel were provided by ComEd for positions identified by TLG.
5. ComEd provides for any necessary electrical power to be brought on site required to decommission the plant. Energy costs are included in the estimate.
6. Material and heavy equipment rental and operating costs were taken from R.S. Means Building Construction Cost Data.
7. Radioactive contamination while mostly restricted to the primary side of the steam cycle, has traveled to the secondary side of the plant. This will result in the removal and shipment of large quantities of secondary side systems, piping and equipment for off-site survey, processing, and possible burial.
8. Radioactively contaminated piping, components, and structures other than the reactor vessel and internals are assumed to meet DOT limits for LSA material. For transportation calculations, the distance from the plant site to the Central Midwest Compact or Envirocare is 385 miles and 1,635 miles, respectively. Rates for shipping radioactive wastes were provided by Tri-State Motor Transit in published tariffs for this cargo (Ref. 14).
9. The reactor vessel and internals' disposal costs were based on remote in-place segmentation, packaging in shielded casks, and shipping by truck to the burial ground. A maximum normal road weight limit of 80,000 pounds is assumed for all truck shipments with the exception of several overweight cask shipments. Cask shipments may exceed 95,000 pounds,

including vessel segment(s), supplementary shielding, cask tie-downs and tractor trailer. The maximum curies per shipment assumed permissible is based upon the license limits of available shielded shipping casks. The number and curie content of vessel segments were selected to meet these limits.

10. The number of cask shipments out of the Reactor Building is expected to average three every two weeks.

11. Reactor vessel and internals packages' conditions:

    Any fuel cladding failure which occurred during the lifetime of the plant is assumed to have released fission products at sufficiently low levels that the buildup of quantities of long-lived isotopes (e.g. cesium-137, strontium-90, or transuranics) has been prevented from reaching levels exceeding those which permit the major primary coolant system components to be shipped as LSA waste and to be buried within the requirements of 10 CFR Part 61 or the regional burial ground.

12. The estimated curie content of the vessel and internals at final shutdown was derived from those listed in NUREG/CR-3474 (Ref. 15). Actual estimates will be derived from the curie per gram values in NUREG/CR-3474 and adjusted for the different mass of components and projected operating life, as well as for different periods of decay. Additional short-lived isotopes were derived from NUREG/CR-0130 (Ref. 16) and NUREG/CR-0672 (Ref. 17), and benchmarked to the long-lived values from NUREG/CR-3474.

13. This study estimates that there will be some radioactive waste which is greater than 10 CFR Part 61 Class C quantities (GTCC), resulting from disposal of the highly activated sections of the reactor vessel internals. The cost of disposal, has been estimated from equivalent disposal costs for spent nuclear fuel.

14. Control elements will be removed and disposed of along with the spent fuel assemblies.

15. Greater than Class "C" waste remaining after segmentation of the reactor vessel internals will be packaged in fuel bundle containers for storage. If the DOE were to default on its obligations to accept spent fuel and GTCC material, decommissioning costs would almost certainly increase.

16. This study does not address the cost for the transportation and disposal of spent fuel from the site. Ultimate disposition of the spent fuel is the province of DOE's Waste Management System, as defined by the Nuclear Waste Policy Act and funded through the 1 mill per kilowatt-

hour electrical generation surcharge. If DOE were to delay its obligations to accept spent fuel starting after 2010, decommissioning costs would increase.

17. The final reactor core discharge has been transferred to the fuel handling building where it will remain until transferred to the DOE.

18. Scrap generated during decommissioning is not included as a salvage credit line item in this study for two reasons: (1) the scrap value merely offsets the associated site removal and scrap processing costs, and (2) a relatively low value of scrap exists in the market. Scrap processing and site removal costs are not included in the estimate.

19. ComEd will make economically reasonable efforts to salvage equipment during decommissioning. Nonetheless, because placing a salvage value on this machinery and equipment would be speculative, and the value would be small in comparison to overall decommissioning expenses, this estimate does not attempt to quantify the value that ComEd may realize based upon those efforts. While decommissioning are presently scheduled to begin in 2013, it may occur earlier or later, depending on a variety of economic and regulatory factors. Additionally, because of ComEd's life cycle management of equipment, a program designed to optimize equipment performance through preventive maintenance, it is difficult to predict the remaining life of the equipment that will be on site when decommissioning begins. Finally, it is difficult to predict whether the market for used equipment will be stronger or weaker than it is today. For these reasons, it is not possible to provide an estimate of the salvage value of the equipment at the plant. Moreover, any salvage value would be small when compared to total decommissioning expenses.

20. The ComEd staffing requirements during decommissioning vary with the level of effort associated with the various phases of the project. Once the decommissioning program commences, only those staff positions necessary to support the decommissioning program are included.

21. This study assumes that ComEd will contract with a Decommissioning Operations Contractor (DOC) for the decontamination and dismantling of Zion Station. ComEd will provide sufficient staff to perform the preparatory planning and scheduling, and oversee the dismantling. Site security, radiological controls, quality assurance and overall site administration during decommissioning will also be provided by ComEd.

22. Engineering services for such items as writing activity specifications, detailed procedures, detailed activation analyses, and structural modifications, etc. are assumed to be provided by the DOC staff.

23. ComEd will remove items of personal property owned by ComEd that can be removed without the use of special equipment.

24. ComEd has sufficient scaffolding to support the decommissioning project. No costs associated with the purchase or rental of scaffolding are included in the estimate.

25. Existing warehouses will remain for use by ComEd and its subcontractors. Those warehouses scheduled for removal will be dismantled as they are no longer needed to support the decommissioning program; others may remain for alternate use.

26. ComEd will perform the following activities at no cost or credit to the project:

    - Fuel oil tanks will be emptied. Tanks will be cleaned by flushing or steam cleaning as required prior to disposal.
    - Acid and caustic tanks will be emptied through normal usage; any excess acid or caustic removed to support disposal of the storage container(s) is returned to the vendor.
    - Lubricating and transformer oils will be drained and removed from site by a waste disposal vendor.

27. The decommissioning activities will be performed in accordance with the current regulations, which are assumed to still be in place at the time of decommissioning. Changes in current regulations may have a cost impact on decommissioning.

28. This study follows the principles of ALARA through the use of work duration adjustment factors which incorporate such items as radiological protection instruction, mock-up training, the use of respiratory protection, and personnel protective clothing. These items lengthen a task's duration, which increase the costs and lengthens the schedule. ALARA planning is considered in the costs for engineering and planning, and in the development of activity specifications and detailed procedures. Changes to 10 CFR Part 20 worker exposure limits may impact the decommissioning cost and project schedule.

29. This study was performed in accordance with the published study from the Guidelines document. The contents of the guidelines were prepared under the review of a task force consisting of representatives from utilities, state regulatory commissions, architect/engineering firms, the Federal Energy Regulatory Commission, the NRC, and the National Association of Regulatory Utility Commissioners.

30. Nuclear property and liability insurance carried by ComEd for the site will continue throughout the decommissioning period at a rate discounted pursuant to the NRC proposed rule, "Financial Protection Requirements for Permanently Shutdown Nuclear Power Reactors", issued for comment in the Federal Register on October 30, 1997 (FR 58690).
31. Only existing site structures and those presently planned will be considered in the decommissioning cost.
32. The perimeter fence and in-plant security barriers will be moved as appropriate to conform with the Site Security Plan in force at the various stages in the project.
33. The existing electrical switchyard will remain after decommissioning in support of the utility's electrical transmission and distribution system.
34. Underground metal and concrete piping and tunnels will either be surveyed in place and released, or excavated and removed for survey. Any piping that exceeds the site release criteria will be removed.
35. A flat annual property tax payment for the Zion Station was provided by ComEd.

4.6 COST ESTIMATE SUMMARY

A summary of the radiological decommissioning costs and annual expenditures is provided in Tables 4.1 and 4.2. Table 8.1 provides breakdowns of those same radiological costs into the components of decontamination, removal, packaging, transportation, waste disposal, project management (staffing), and other cost categories. The costs were extracted from the detailed reports in Appendix C. The Appendix shows the detailed listings and costs of major activities for the decommissioning scenario. The following should be considered when reviewing these tables:

- "Decon" as used in the headings of these tables, refers to decontamination activities, as opposed to the NRC term DECON, which refers to the prompt removal decommissioning scenario.
- "Total" as used in the headings of these tables, is the sum of Decon, Remove, Pack, Ship, Bury, and Contingency, as well as other miscellaneous items not listed (such as engineering and preparations).
- The subtotal for the aforementioned major cost categories does not include contingency, which is reported in a separate column.

- "Other" includes different types of costs, which vary by the associated line item and do not readily fall into one of the other categories. For instance, in systems removal and structures decontamination, the "Other" cost consists of the off-site recycling costs for low-level radioactive waste. In most of the engineering preparatory activities the "Other" cost is strictly engineering labor. However, "Other" also includes the utility staffing, taxes, insurance, plant energy budgets, and regulatory fees.

TABLE 4.1
ZION NUCLEAR STATION - UNIT 1
SUMMARY OF DELAYED-DECON DECOMMISSIONING COSTS
(1996 Dollars)

Year	Period 1 Dormancy Prep	Period 2 Wet Storage	Period 3 Operations	Period 4a Dismantling	Period 4b Dormancy	Period 4c Final Site Survey	Totals
1998	29,650,000						29,650,000
1999	24,676,000						24,676,000
2000	10,661,000	2,278,853					12,939,853
2001		4,520,551					4,520,551
2002		4,520,551					4,520,551
2003		4,520,551					4,520,551
2004		4,532,936					4,532,936
2005		4,520,551					4,520,551
2006		4,520,551					4,520,551
2007		4,520,551					4,520,551
2008		4,532,936					4,532,936
2009		4,520,551					4,520,551
2010		4,520,551					4,520,551
2011		4,520,551					4,520,551
2012		4,532,936					4,532,936
2013		3,901,298	4,678,830				8,580,127
2014			37,507,212				37,507,212
2015			14,250,959	49,581,492			63,832,450
2016				75,647,500			75,647,500
2017				60,131,982	546,014		60,677,996
2018					3,690,648		3,690,648
2019					3,690,648		3,690,648
2020					3,700,760		3,700,760
2021					3,690,648		3,690,648
2022					3,690,648		3,690,648
2023					3,690,648		3,690,648
2024					3,700,760		3,700,760
2025					3,063,744	8,578,000	11,641,744
2026						1,289,000	1,289,000
	64,987,000	60,463,921	56,437,000	185,360,974	29,464,517	9,867,000	406,580,412

Note: Period 4a consists of clean dismantling costs in support of decontamination

TABLE 4.2
ZION NUCLEAR STATION - UNIT 2
SUMMARY OF DELAYED-DECON DECOMMISSIONING COSTS
(1996 Dollars)

Year	Period 1 Dormancy Prep	Period 2 Wet Storage	Period 3 Operations	Period 4a Dismantling	Period 4b Dormancy	Period 4c Final Site Survey	Totals
1998	29,650,000						29,650,000
1999	24,677,000						24,677,000
2000	10,659,000	2,323,422					12,982,422
2001		4,608,962					4,608,962
2002		4,608,962					4,608,962
2003		4,608,962					4,608,962
2004		4,621,589					4,621,589
2005		4,608,962					4,608,962
2006		4,608,962					4,608,962
2007		4,608,962					4,608,962
2008		4,621,589					4,621,589
2009		4,608,962					4,608,962
2010		4,608,962					4,608,962
2011		4,608,962					4,608,962
2012		4,621,589					4,621,589
2013		4,608,962					4,608,962
2014		4,608,962					4,608,962
2015		858,656	31,665,056				32,523,712
2016			26,741,167	26,736,460			53,477,627
2017				84,859,199			84,859,199
2018				84,979,149			84,979,149
2019				32,387,192	2,395,508		34,782,700
2020					3,879,451		3,879,451
2021					5,248,851		5,248,851
2022					7,288,691		7,288,691
2023					7,288,691		7,288,691
2024					7,299,291		7,299,291
2025					6,204,036	7,745,309	13,949,345
2026						30,231,691	30,231,691
	64,986,000	67,745,427	58,406,223	228,962,000	39,604,518	37,977,000	497,681,168

Note: Period 4a consists of clean dismantling costs in support of decontamination.

5. SCHEDULE ESTIMATE

The schedule for the decommissioning scenarios considered in this study follows the sequence presented in the AIF/NESP-036 study, with minor changes to reflect recent experience and site-specific constraints. In addition, the scheduling has been revised to reflect the spent fuel management plan outlined for the Zion Station.

Figure 5.1 presents a schedule for the prompt decommissioning alternative; the assumptions supporting this schedule are listed in Section 5.1. The key activities listed in the schedule do not reflect a one-to-one correspondence with those activities in the Appendix C cost tables, but reflect dividing some activities for clarity and combining others for convenience. A legend defining the schedule nomenclature and depictions is also included. The schedule was prepared using the "Microsoft Project for Windows" computer software (Ref. 18).

5.1 SCHEDULE ESTIMATE ASSUMPTIONS

The schedule estimate reflects the results of a precedence network developed for the site decommissioning activities, i.e., a PERT (Program Evaluation and Review Technique) Software Package. The durations used in the precedence network reflect the actual man-hour estimates from the cost tables in Appendix C, adjusted by stretching certain activities over their slack range and shifting the start and end dates of others. The following assumptions were made in the development of the decommissioning schedule.

- 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.

- The fuel handling facilities located in the Fuel Handling Building will be isolated and serve as an interim wet fuel storage facility until such time that all spent fuel has been discharged from the spent fuel. The site will then be decommissioned around the Fuel Handling Building. Decontamination and dismantling of the Fuel Handling Building is initiated once the transfer of spent fuel to the DOE high-level waste repository is complete in 2025.

- 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.

- For plant systems removal, the systems with the longest removal durations in areas on the critical path are considered to determine the duration of the activity.

- The vessel segmentation activities for Unit 1 and Unit 2 will essentially be conducted in series.

5.2 PROJECT SCHEDULE

The period-dependent costs presented in the cost tables in Appendix C are based upon the durations developed in the schedule for each decommissioning alternative. Durations are established between several milestones in each project period; these durations are used to establish a critical path for the entire project. In turn, the critical path duration for each period is used as the basis for determining the total costs for these period-dependent items.

A Project timeline for the three decommissioning alternative is included in this section as Figure 5.2. Milestone dates are based on actual operating and shutdown dates as well as the planning dates provided by ComEd for the start of decommissioning activities, and the dates for first and last spent fuel shipments.

FIGURE 5.1

DELAYED-DECON ACTIVITY SCHEDULE

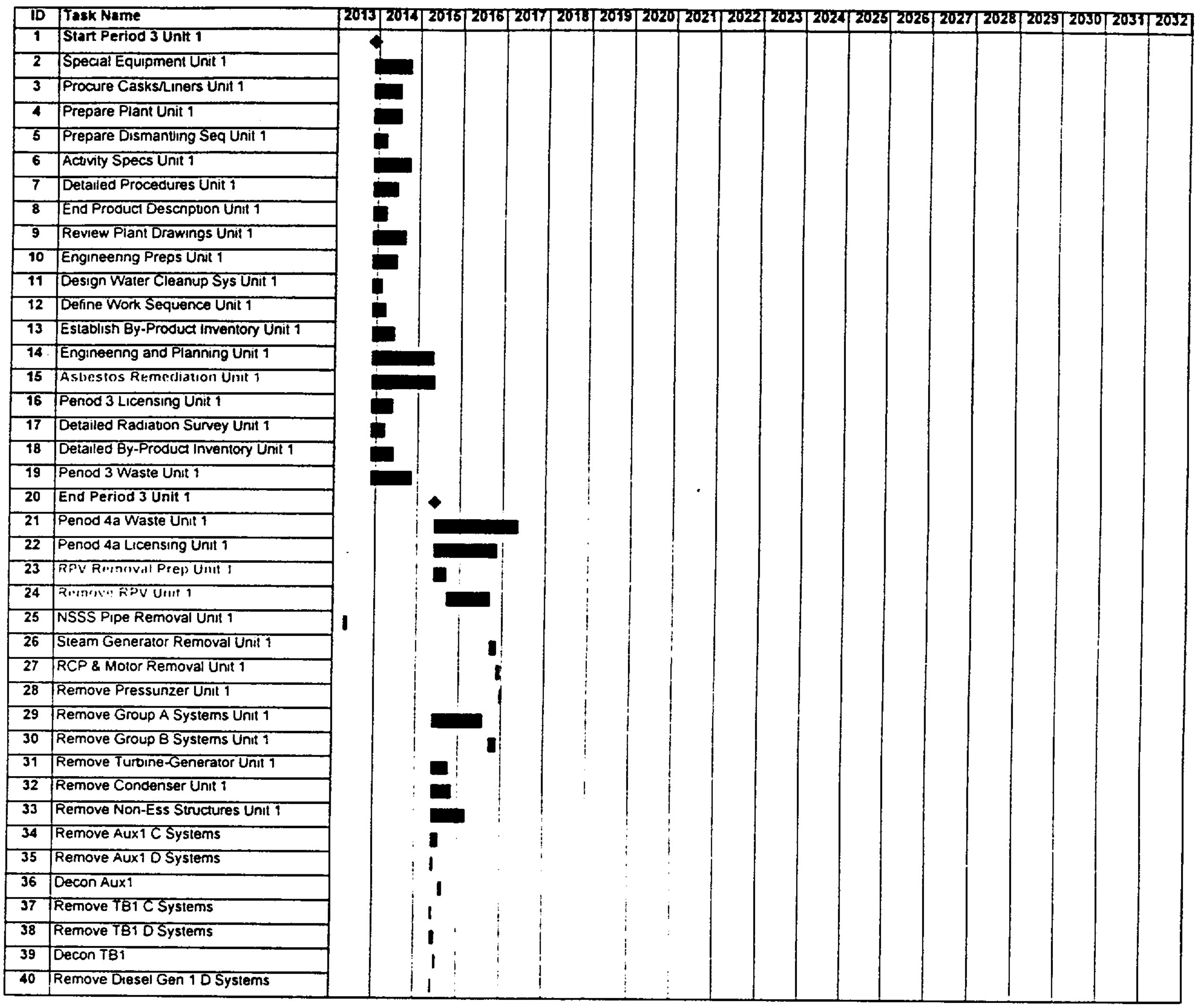


FIGURE 5.1

DELAYED-DECON ACTIVITY SCHEDULE

(Continued)

ID	Task Name
41	Other Bldgs 1 C Systems
42	Other Bldgs 1 D Systems
43	Remove RB1 C Systems
44	Remove RB1 D Systems
45	Decon RB1
46	End Period 4a Unit 1
47	Start Period 3 Unit 2
48	Special Equipment Unit 2
49	Procure Casks/Liners Unit 2
50	Prepare Plant Unit 2
51	Prepare Dismantling Seq Unit 2
52	Activity Specs Unit 2
53	Detailed Procedures Unit 2
54	End Product Description Unit 2
55	Review Plant Drawings Unit 2
56	Engineering Preps Unit 2
57	Design Water Cleanup Sys Unit 2
58	Define Work Sequence Unit 2
59	Engineering and Planning Unit 2
60	Asbestos Remediation Unit 2
61	Establish By-Product Inventory Unit 2
62	Period 3 Licensing Unit 2
63	Detailed Radiation Survey Unit 2
64	Detailed By-Product Inventory Unit 2
65	Period 3 Waste Unit 2
66	End Period 3 Unit 2
67	Revise Activity Specs Unit 2
68	Revise Detailed Procedures Unit 2
69	Period 2 Waste Unit 2
70	Licensing Period 2 Unit 2
71	Transfer Vessel Cutting Equipment
72	RPV Removal Prep Unit 2
73	RPV Removal Unit 2
74	NSSS Pipe Removal Unit 2
75	Steam Generator Removal Unit 2
76	RCP & Motor Removal Unit 2
77	Remove Pressurizer Unit 2
78	Remove Group B Systems Unit 2
79	Remove Group A Systems Unit 2
80	Remove Turbine-Generator Unit 2

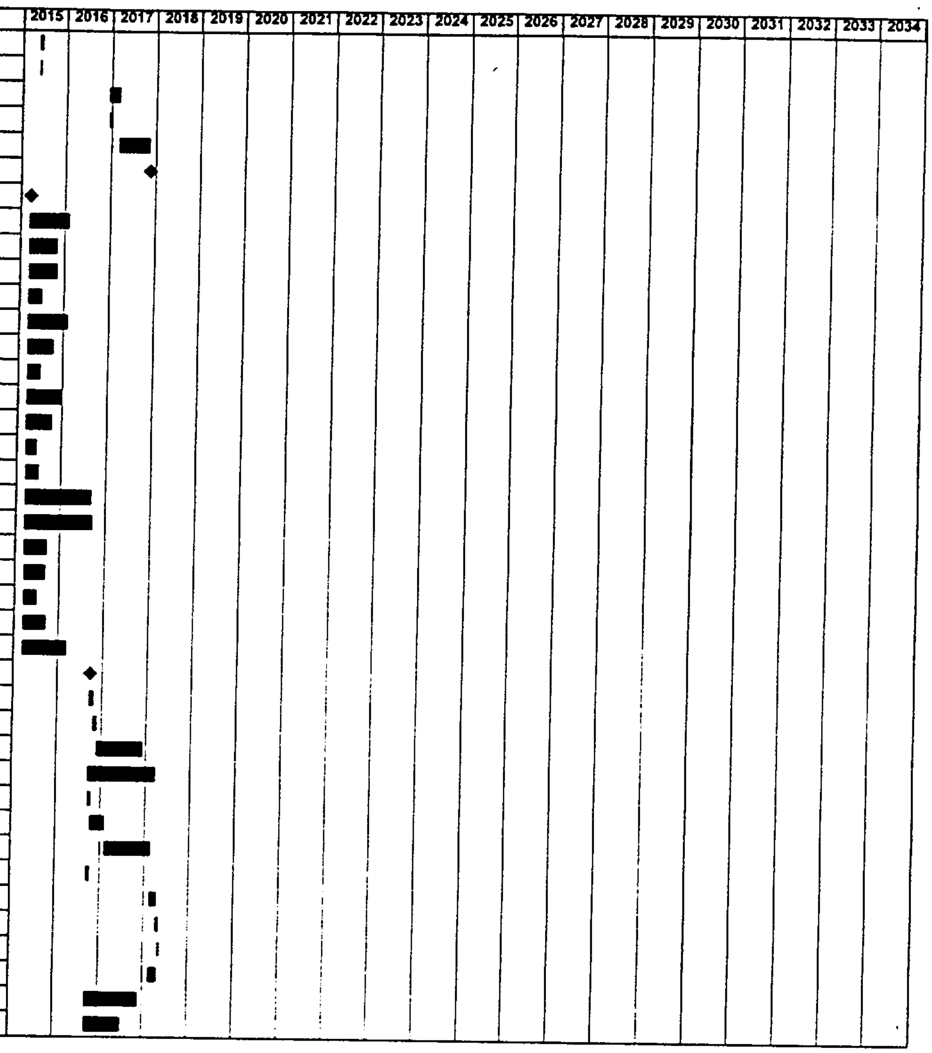


FIGURE 5.1

DELAYED-DECON ACTIVITY SCHEDULE

(Continued)

ID	Task Name
81	Remove Condenser Unit 2
82	Remove Non-Ess Structures Unit 2
83	Remove TB2 C Systems
84	Remove TB2 D Systems
85	Decon TB2
86	Remove Service D Systems
87	Remove Diesel Gen 2 D Systems
88	Remove RB2 C Systems
89	Decon RB2
90	Remove Aux2 C Systems
91	Remove Aux2 D Systems
92	Decon Aux2
93	End Period 4a Unit 2
94	Period 4b Unit 1 Dormancy
95	Period 4b Unit 2 Dormancy
96	Period 4c Final Survey Unit 1
97	Fuel Support Systems
98	Remove Fuel Pool Racks
99	FHB Decon
100	Period 4c Final Survey Unit 2
101	End Decommissioning

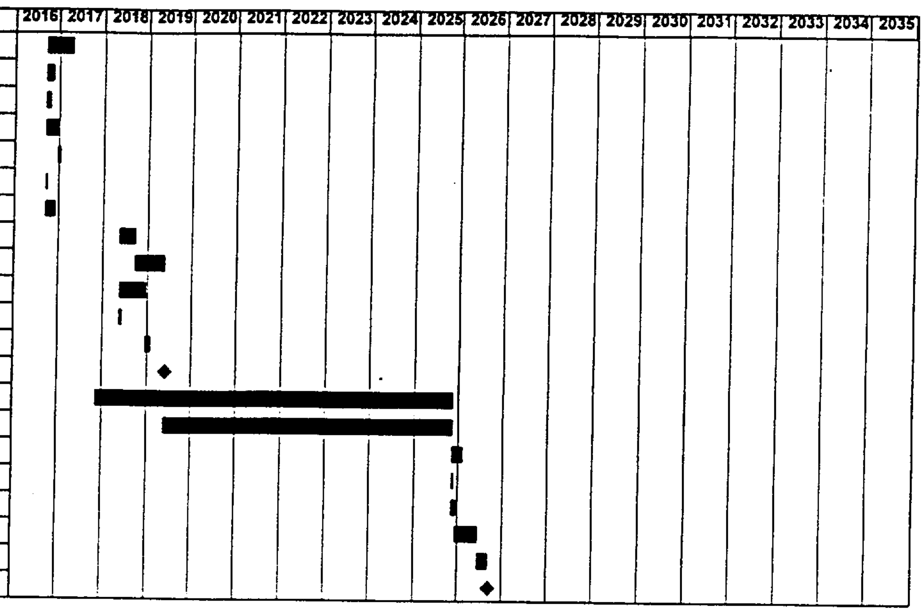
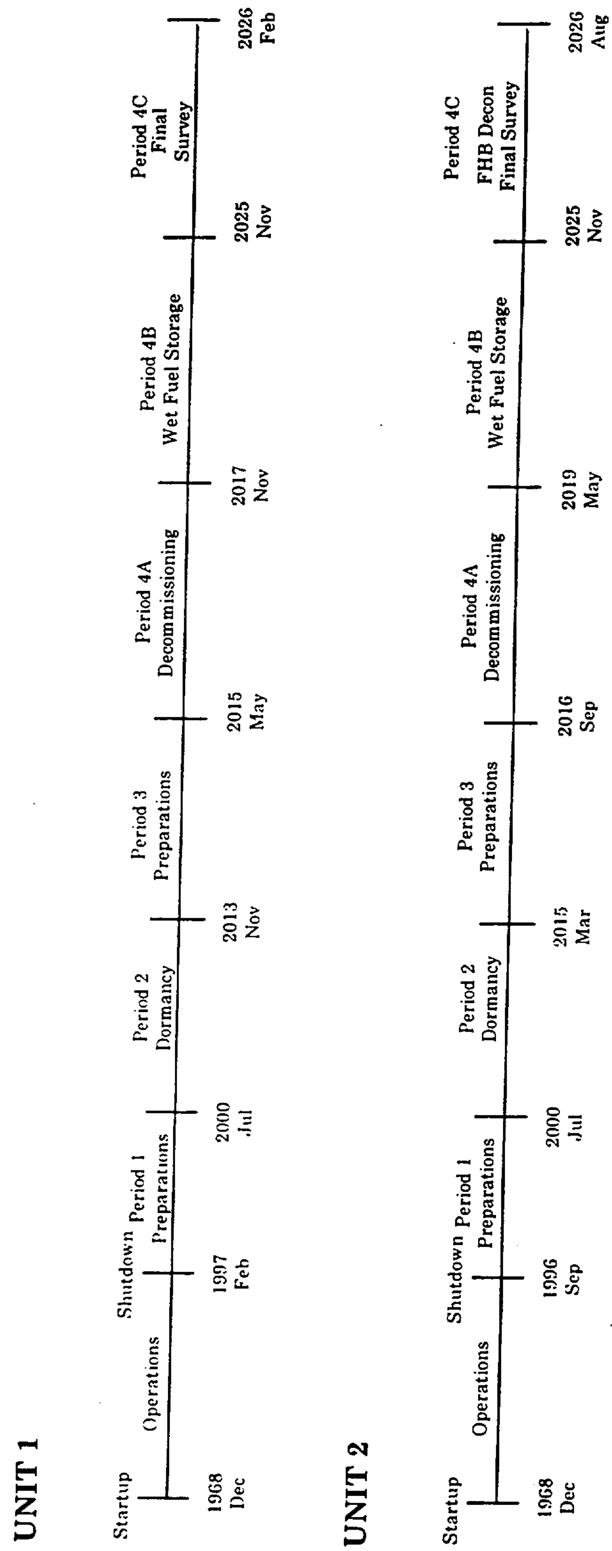


FIGURE 5.2A

DELAYED-DECON
DECOMMISSIONING TIMELINES



NOT TO SCALE

6. RADIOACTIVE WASTES

The goal of the decommissioning program is the removal of all radioactive material from the site which would restrict its future use and termination of the NRC license for the site. This currently requires the remediation of all radioactive material at the site in excess of applicable legal limits. Under the Atomic Energy Act (Ref. 19), the NRC is responsible for protecting the public from sources of ionizing radiation. Title 10 of the Code of Federal Regulations delineates the production, utilization, and disposal of radioactive materials and processes. In particular, Part 61 controls the burial of low-level radioactive material and Part 71 defines radioactive material.

The radioactive waste volumes generated during the various decommissioning activities at the site are shown by line activity in the cost tables in Appendix C. Waste volume summaries, shown in Table 6.1, are quantified consistent with Part 61 classifications. The volumes are calculated based on the gross container dimensions or, for components serving as their own waste container, the volume is calculated based upon the displaced volume of the component, i.e., steam generators and pressurizer.

Most of the materials being transported for controlled burial are categorized as LSA material containing Type A quantities, as defined in 49 CFR Parts 173-178 (Ref. 20). Containers are required to be strong, tight packages. For this study, commercially available steel containers are presumed to be used for the disposal of piping, small components, and concrete. Larger components can serve as their own containers with proper closure of all openings, access ways, penetrations, etc.

The reactor vessel and internals are categorized as large quantity shipments and, accordingly, will be shipped in reusable shielded truck casks with disposable liners. In calculating disposal costs, the burial fees are applied against the liner volume, as well as the special handling requirements of the payload. Packaging efficiencies are lower for the highly-activated materials (than those for Type A quantity waste) where high concentrations of gamma-emitting radionuclides limit the capacity of the shipping containers.

The steam generators are presumed to be shipped intact for disposal. The components are assumed to be grouted with low-density cellular concrete for stabilization of the internal contaminants. While the grout will also provide some shielding, additional steel is assumed necessary to meet transportation criteria.

No process system containing / handling radioactive substances at shutdown is presumed to meet material release criteria by decay alone, i.e., systems radioactive at shutdown will still be radioactive in a deferred decommissioning alternative due to the presence of long-lived radionuclides. While the dose rates decrease with time, radionuclides such as ^{137}Cs will still control the disposition requirements.

The waste volume generated in the decontamination and dismantling of the nuclear units is primarily generated during Period 4A. Contaminated and activated material will be characterized on site with a significant volume routed for additional processing. Components with low levels of removable surface contamination will be decontaminated on site, to the maximum extent possible. Components with low levels of internal contamination will be shipped to a waste recycling center for disassembly, decontamination, volume reduction, and/or repackaging. Heavily contaminated components and activated materials are generally routed for controlled disposal after on-site volume reduction.

Low-level radioactive waste is destined for final disposal at the future Central Midwest Compact facility to be located in Illinois. For cost estimating purposes, this facility was assumed to be located within 385 miles of the site. Disposal costs at this facility were calculated with a base burial fee of approximately $364 per cubic foot. This value was developed by Vance & Associates, as an estimate of regional disposal costs. Special handling charges as well as curie and weight surcharges were added, as applicable, using the current schedule of rates in effect at Barnwell. Some low-level radioactive waste may meet the disposal criteria for the Envirocare facility in Clive, Utah. This estimate assumed that all concrete scabble dust would be disposed of at the Envirocare facility at a disposal rate of $87 per cubic foot.

Noncompactable (metallic) radioactive waste generated from removal of the primary system plant equipment is assumed to be sent to an off-site vendor for recycling as a means of reducing the ultimate disposal volume. Considering typical plant conditions and industry experience, the inventory of contaminated material at the Zion Station was segregated based on the likelihood of volume reduction and decontamination for radiological free release. The burial volumes reported in Table 6.1 reflect the savings resulting from reprocessing and recycling. Off-site processing of non-compactable metallic waste was estimated to cost approximately $177 per cubic foot, based on industry experience, and appears as an "other" cost in the detailed decommissioning cost tables in Appendix C.

The estimate recognizes that secondary side systems including the Main Steam, Condensate, Feedwater, along with connecting system and equipment may contain some radioactive contamination. For purposes of this estimate these systems were assumed to be sent to an outside vendor that specializes in the survey and reprocessing of LLW. A cost of $1.29 per pound was used as an industry average for this material. While some of this material will ultimately be sent for disposal by the off-site vendor, the $1.29 per pound rate is an all inclusive rate for all material, and no burial volumes are reported. This cost appears as an "other" cost in the detailed decommissioning cost tables in Appendix C.

TABLE 6.1

DECOMMISSIONING RADIOACTIVE WASTE BURIAL VOLUMES

	Waste Class[1]	Volume[2] (Cubic feet)
Unit 1	A	123,460
	B	7,531
	C	884
	>C	230
Total		**132,105**
Unit 2 & Common	A	196,700
	B	9,423
	C	884
	>C	230
Total		**207,237**

1 Waste is classified according to the requrements as delineated in Title 10 of the Code of Federal Regulations, Section 61.55

2 Columns may not add due to rounding.

7. OCCUPATIONAL EXPOSURE

Estimates of occupational radiation exposure were developed by TLG from the hours expended removing contaminated components and in the decontamination of site structures. These estimates are scoping in nature and are performed to provide an upper boundary to the exposure limits for comparison with NRC maximum dose limitations. Changes in the total occupational exposure estimates do not impact the cost model used by TLG. The estimates are used to determine where exposure reduction or control efforts are most effective.

Worker dose is calculated as the product of the direct personnel hours expended in radiation fields and the average area dose rate estimated for each decommissioning task. The calculation assumes that:

- Only those personnel directly involved in the decontamination, removal, and packaging activities, as well as associated health physics personnel, are considered in the exposure calculation. Casual exposures to the supervisory and plant staff are not included in the estimate.

- Personnel exposure to radiation is minimized by utilizing shielding and remote handling techniques and avoiding higher radiation fields when personnel presence is not necessary.

- 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.

- Exposures as the result of spent fuel storage activities are expected to be minimal, and therefore are not included.

- Cobalt-60 and Cesium-137 (current ratio is approximately 60/40) are the primary contributors to radiation exposure.

It should be noted that the calculation of occupational exposure shown in Appendix C is based upon typical work area dose rates and conservative residence times for decommissioning personnel. Actual incurred exposure is expected to be less than estimated based upon current field experience. The magnitude of the reduction will depend upon the potential for modifying the working environment (e.g., through the use of selective decontamination and personnel shielding) as well as the effectiveness of task planning, worker training and ALARA tools (e.g., simulations, mockups) to minimize exposure.

8. RESULTS

The projected costs to decommission the station, presuming the use of the DECON alternative, including the approximate 25 year operation of the Fuel Handling Building fuel storage pool as an interim wet fuel storage facility, is estimated to be $904,261,580 in 1996 dollars. The costs reflect the site-specific features of the Zion Station, the local cost of labor, the DOE's schedule for spent fuel receipt, and a projected cost for low-level radioactive waste disposal at the regional compact site. Analyses of the major activities contributing to the total cost for each of the decommissioning alternatives are provided in Table 8.1.

Staffing, including management, security, and health physics combine with the removal labor cost to represent the majority of the costs to decommission a nuclear station. This is a direct result of the labor-intensive nature of the decommissioning process, as well as the management controls required to ensure a safe and successful program. Low-level radioactive waste disposal (burial) represents the next largest cost component. These costs are indicative of the expense incurred in siting, developing, and licensing new disposal facilities. Packaging and transportation costs are most sensitive to the waste volume generated in the decontamination and dismantling process, the volume reduction achieved, transport regulations for low-level radioactive waste, and the final destination (i.e., distance to the disposal site). "Other" costs include off-site waste reprocessing expenses which can also be considered as "decontamination" expenditures, as well as true incidentals such as property taxes, engineering costs, insurance, and fees.

The construction of barriers and the general decontamination of plant areas in preparation for long-term storage does not alleviate the need for continued surveillance. The structural integrity of facilities must be maintained to support eventual decontamination and dismantling activities.

It is expected that a full-time preventive and corrective maintenance staff will be needed to maintain essential site services and prevent the deterioration of the site facilities. Peripheral structures will have to be maintained or remediated where asbestos and other hazardous and toxic material could enter the environment through degradation, weathering, or insufficient maintenance of site structures.

This study provides an estimate for decommissioning the site under current requirements based on present-day costs and available technology. Individual costs associated with decommissioning activities have increased at rates greater than general inflation. For example, there has been significant volatility in the issues and policies surrounding waste disposal, i.e., access and cost of low-level radioactive waste disposal has been unpredictable and has escalated at rates historically greater than inflation (over the past ten years). The government's spent fuel disposal program has experienced a series of delays which have impeded the prompt decommissioning of the commercial reactors retired to date. Waste disposal has become the primary driver in the escalation of decommissioning costs. It is therefore appropriate that this cost estimate be reviewed periodically.

TABLE 8.1

SUMMARY OF DELAYED-DECON DECOMMISSIONING COSTS

Work Category	Costs 96$ (thousands)[1]	Percent of Total Costs[1]
DECON		
Unit 1		
1998/1999 Costs	54,326	13.36
Decontamination	5,760	1.42
Removal	58,406	14.37
Packaging	7,097	1.75
Shipping	2,024	0.50
Burial (Off-Site)	64,918	15.97
Utility Staffing	92,923	22.85
Other[2]	121,127	29.79
Subtotal	**$406,580**	**100.00**
Unit 2 & Common		
1998/1999 Costs	54,327	10.92
Decontamination	9,185	1.85
Removal	90,250	18.13
Packaging	8,149	1.64
Shipping	2,466	0.50
Burial (Off-Site)	91,360	18.36
Utility Staffing	101,999	20.49
Other[2]	139,946	28.12
Subtotal	**$497,681**	**100.00**
Station Total (with contingency)	**$905,013**	

1. Columns may not add due to rounding.
2. Other includes engineering & preparations, undistributed costs, off-site LLW recycling costs, NRC fees, EP fees and maintenance costs, etc.

9. REFERENCES

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2. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.159, "Assuring the Availability of Funds for Decommissioning Nuclear Reactors," February, 1995.

3. U.S. Code of Federal Regulations, Title 10, Parts 2, 50 and 51, "Decommissioning of Nuclear Power Reactors," Nuclear Regulatory Commission, Federal Register Volume 61 (p39278+), July 29, 1996.

4. "Nuclear Waste Policy Act of 1982 and Amendments," U.S. Department of Energy's Office of Civilian Radioactive Management, 1982.

5. "Low-Level Radioactive Waste Policy Amendments Act of 1985," Public Law 99-240, January 15, 1986.

6. Vance & Associates, Low-Level Radioactive Waste Disposal Projection for the Central Midwest Regional Disposal Facility, 1996.

7. T.S. LaGuardia et al., "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates," AIF/NESP-036, May, 1986.

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9. "Building Construction Cost Data 1996," Robert Snow Means Company, Inc., Kingston, Massachusetts.

10. Project and Cost Engineers' Handbook, Second Edition, p. 239, American Association of Cost Engineers, Marcel Dekker, Inc., New York, New York.

9. REFERENCES
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11. "@Risk Users Manual" Version 3.1, Palisade Corporation, Newfield, NY 1995.

12. Public Law 99240, "Low-Level Policy Act". January 15, 1986, Title 1, Section 3(1)D.

13. Chem-Nuclear Services, Inc., Low-Level Radioactive Waste Management Facility, Barnwell, SC.

14. Tri-State Motor Transit Company, published tariffs, Interstate Commerce Commission (ICC), Docket No. MC-109397 and Supplements, 1996.

15. J.C. Evans et al., "Long-Lived Activation Products in Reactor Materials," NUREG/CR-3474, Pacific Northwest Laboratory for the Nuclear Regulatory Commission, August, 1984.

16. R.I. Smith, G.J. Konzek, W.E. Kennedy, Jr., "Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station," NUREG/CR-0130 and addenda, Pacific Northwest Laboratory for the Nuclear Regulatory Commission, June, 1978.

17. H.D. Oak, et al., "Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station," NUREG/CR-0672 and addenda, Pacific Northwest Laboratory for the Nuclear Regulatory Commission, June, 1980.

18. "Microsoft Project for Windows," Version 3.0, Microsoft Corporation, Redmond, WA, 1993.

19. "Atomic Energy Act" of 1954," (68 Stat. 919).

20. U.S. Department of Transportation, Section 49 of the Code of Federal Regulations, "Transportation," Parts 173 through 178, 1996.

APPENDIX A

UNIT COST FACTOR DEVELOPMENT

APPENDIX A
UNIT COST FACTOR DEVELOPMENT

Example: Unit Factor for Removal of Contaminated Heat Exchanger < 3,000 lbs.

1. SCOPE

Heat exchangers weighing < 3,000 lbs. will be removed in one piece using a crane or small hoist. They will be disconnected from the inlet and outlet piping. The heat exchanger will be sent to the packing area.

2. CALCULATIONS

Act ID	Activity Description	Activity Duration	Critical Duration
a	Remove insulation	60	(b)
b	Mount pipe cutters	60	60
c	Install contamination controls	20	(b)
d	Disconnect inlet and outlet lines	60	60
e	Cap openings	20	(d)
f	Rig for removal	30	30
g	Unbolt from mounts	30	30
h	Remove contamination controls	15	15
i	Remove, wrap in plastic, send to packing area	60	60
	Totals (Activity/Critical)	355	255

Duration adjustment(s):	
+ Respiratory protection adjustment (50% of critical duration)	128
+ Radiation/ALARA adjustment (16.04167% of critical duration)	41
Adjusted work duration	424
+ Protective clothing adjustment (30% of adjusted duration)	127
Productive work duration	551
+ Work break adjustment (8.33 % of productive duration)	46
Total work duration min	597 min

***** Total duration = 9.950 hr *****

APPENDIX A
(continued)

3. LABOR REQUIRED

Crew	Number	Duration (hr)	Rate ($/hr)	Cost
Laborers	3.00	9.950	$38.91	$1,161.46
Craftsmen	2.00	9.950	$49.11	$977.29
Foreman	1.00	9.950	$51.98	$517.20
General Foreman	0.25	9.950	$53.65	$133.45
Fire Watch	0.05	9.950	$38.91	$19.36
Health Physics Technician	1.00	9.950	$34.14	$339.69
Total labor cost				$3,148.45

4. EQUIPMENT & CONSUMABLES COSTS

Equipment Costs	none
Consumables/Materials Costs	
-Blotting paper 50 square feet @ $0.56 per square foot {2}	$28.00
-Plastic sheets/bags 50 square feet @ $0.06 per square foot {3}	$3.00
-Gas torch consumables 1 @ $6.57 per hour x 1 hour {1}	$6.57
Subtotal cost of equipment and materials	$37.57
Overhead & profit on equipment and materials @ 16.250%	$6.11
Total costs, equipment & material	$43.68
TOTAL COST Removal of contaminated heat exchanger <3000 pounds:	**$3,192.13**
Total labor cost:	$3,148.45
Total equipment/material costs:	$43.68
Total adjusted exposure man-hours incurred:	41.022
Total craft labor man-hours required per unit:	72.635

APPENDIX A
(continued)

5. NOTES AND REFERENCES

1. Durations are shown in minutes. The integrated duration accounts for those activities that can be performed in conjunction with other activities, indicated by the alpha designator of the concurrent activity. This results in an overall decrease in the sequenced duration.

2. Work difficulty factors were developed in conjunction with the AIF program to standardize decommissioning cost studies and are delineated in the "Guidelines" study (Ref. 7, Vol. 1, Chapter 5).

3. Adjusted for regional material costs for Chicago, IL.

4. References:

   1. R.S. Means (1996) Division 016 Section 420-6360 page19
   2. McMaster-Carr Ed. 101
   3. R.S. Means (1996) Division 015 Section 602-0200 page13

APPENDIX B

UNIT COST FACTOR LISTING
(Power Block Structures Only)

APPENDIX B

UNIT COST FACTOR LISTING
(Power Block Structures Only)

Unit Cost Factor	Cost/Unit($)
Removal of clean instrument and sampling tubing, $/linear foot	$0.42
Removal of clean pipe 0.25 to 2 inches diameter, $/linear foot	$5.28
Removal of clean pipe >2 to 4 inches diameter, $/linear foot	$6.41
Removal of clean pipe >4 to 8 inches diameter, $/linear foot	$12.44
Removal of clean pipe >8 to 14 inches diameter, $/linear foot	$24.12
Removal of clean pipe >14 to 20 inches diameter, $/linear foot	$31.26
Removal of clean pipe >20 to 36 inches diameter, $/linear foot	$46.02
Removal of clean pipe >36 inches diameter, $/linear foot	$54.73
Removal of clean valves >2 to 4 inches	$65.42
Removal of clean valves >4 to 8 inches	$124.43
Removal of clean valves >8 to 14 inches	$241.22
Removal of clean valves >14 to 20 inches	$312.65
Removal of clean valves >20 to 36 inches	$460.25
Removal of clean valves >36 inches	$547.26
Removal of clean pipe hangers for small bore piping	$26.68
Removal of clean pipe hangers for large bore piping	$ 98.30
Removal of clean pumps, <300 pound	$206.62
Removal of clean pumps, 300-1000 pound	$574.97
Removal of clean pumps, 1000-10,000 pound	$2,293.43
Removal of clean pumps, >10,000 pound	$4,420.60
Removal of clean pump motors, 300-1000 pound	$243.60
Removal of clean pump motors, 1000-10,000 pound	$957.74
Removal of clean pump motors, >10,000 pound	$2,154.91
Removal of clean turbine-driven pumps < 10,000 pound	$2,647.13
Removal of clean turbine-driven pumps > 10,000 pounds	$5,921.18

APPENDIX B
(continued)

Unit Cost Factor	Cost/Unit($)
Removal of clean PWR turbine-generator	$140,573.16
Removal of clean heat exchanger <3000 pound	$1,230.80
Removal of clean heat exchanger >3000 pound	$3,088.59
Removal of clean feedwater heater/deaerator	$8,726.30
Removal of clean moisture separator/reheater	$17,766.44
Removal of clean PWR main condenser	$386,291.31
Removal of clean tanks, <300 gallons	$267.67
Removal of clean tanks, 300-3000 gallon	$847.81
Removal of clean tanks, >3000 gallons, $/square foot surface area	$7.06
Removal of clean electrical equipment, <300 pound	$114.45
Removal of clean electrical equipment, 300-1000 pound	$396.60
Removal of clean electrical equipment, 1000-10,000 pound	$793.20
Removal of clean electrical equipment, >10,000 pound	$1,883.18
Removal of clean electrical transformers < 30 tons	$1,307.85
Removal of clean electrical transformers > 30 tons	$3,766.35
Removal of clean standby diesel-generator, <100 kW	$1,335.85
Removal of clean standby diesel-generator, 100 kW to 1 MW	$2,981.69
Removal of clean standby diesel-generator, >1 MW	$6,172.70
Removal of clean electrical cable tray, $/linear foot	$10.63
Removal of clean electrical conduit, $/linear foot	$4.64
Removal of clean mechanical equipment, <300 pound	$114.45
Removal of clean mechanical equipment, 300-1000 pound	$396.60
Removal of clean mechanical equipment, 1000-10,000 pound	$793.20
Removal of clean mechanical equipment, >10,000 pound	$1,883.18
Removal of clean HVAC equipment, <300 pound	$114.45

APPENDIX B
(continued)

Unit Cost Factor	Cost/Unit($)
Removal of clean HVAC equipment, 300-1000 pound	$396.60
Removal of clean HVAC equipment, 1000-10,000 pound	$793.20
Removal of clean HVAC equipment, >10,000 pound	$1,883.18
Removal of clean HVAC ductwork, $/pound	$0.83
Removal of contaminated instrument and sampling tubing, $/linear foot	$1.12
Removal of contaminated pipe 0.25 to 2 inches diameter, $/linear foot	$28.17
Removal of contaminated pipe >2 to 4 inches diameter, $/linear foot	$50.75
Removal of contaminated pipe >4 to 8 inches diameter, $/linear foot	$80.21
Removal of contaminated pipe >8 to 14 inches diameter, $/linear foot	$161.39
Removal of contaminated pipe >14 to 20 inches diameter, $/linear foot	$196.08
Removal of contaminated pipe >20 to 36 inches diameter, $/linear foot	$274.39
Removal of contaminated pipe >36 inches diameter, $/linear foot	$326.00
Removal of contaminated valves >2 to 4 inches	$240.80
Removal of contaminated valves >4 to 8 inches	$390.39
Removal of contaminated valves >8 to 14 inches	$806.95
Removal of contaminated valves >14 to 20 inches	$1,031.10
Removal of contaminated valves >20 to 36 inches	$1,371.94
Removal of contaminated valves >36 inches	$1,630.02
Removal of contaminated pipe hangers for small bore piping	$72.33
Removal of contaminated pipe hangers for large bore piping	$242.82
Removal of contaminated pumps, <300 pound	$683.79
Removal of contaminated pumps, 300-1000 pound	$1,604.75
Removal of contaminated pumps, 1000-10,000 pound	$5,371.10
Removal of contaminated pumps, >10,000 pound	$13,058.37
Removal of contaminated pump motors, 300-1000 pound	$683.39

APPENDIX B
(continued)

Unit Cost Factor	Cost/Unit($)
Removal of contaminated pump motors, 1000-10,000 pound	$2,178.36
Removal of contaminated pump motors, >10,000 pound	$4,904.86
Removal of contaminated turbine-driven pumps < 10,000 pounds	$6,538.91
Removal of contaminated turbine-driven pumps > 10,000 pounds	$14,908.12
Removal of contaminated heat exchanger <3000 pound	$3,192.13
Removal of contaminated heat exchanger >3000 pound	$9,228.79
Removal of contaminated tanks, <300 gallons	$1,142.53
Removal of contaminated tanks, >300 gallons, $/square foot	$22.91
Removal of contaminated electrical equipment, <300 pound	$531.30
Removal of contaminated electrical equipment, 300-1000 pound	$1,290.09
Removal of contaminated electrical equipment, 1000-10,000 pound	$2,479.14
Removal of contaminated electrical equipment, >10,000 pound	$4,907.81
Removal of contaminated electrical cable tray, $/linear foot	$38.52
Removal of contaminated electrical conduit, $/linear foot	$48.74
Removal of contaminated mechanical equipment, <300 pound	$592.73
Removal of contaminated mechanical equipment, 300-1000 pound	$1,444.07
Removal of contaminated mechanical equipment, 1000-10,000 pound	$2,770.61
Removal of contaminated mechanical equipment, >10,000 pound	$4,907.81
Removal of contaminated HVAC equipment, <300 pound	$592.73
Removal of contaminated HVAC equipment, 300-1000 pound	$1,444.07
Removal of contaminated HVAC equipment, 1000-10,000 pound	$2,770.61
Removal of contaminated HVAC equipment, >10,000 pound	$4,907.81
Removal of contaminated HVAC ductwork, $/pound	$2.49
Removal/plasma arc cut of contaminated thin metal components, $/linear in.	$2.89
Additional decontamination of surface by washing, $/square foot	$6.06

APPENDIX B
(continued)

Unit Cost Factor	Cost/Unit($)
Additional decontamination of surfaces by hydrolasing, $/square foot	$26.19
Decontamination rig hook-up and flush	$5,076.67
Chemical flush of components/systems, $/gallon	$7.28
Removal of clean standard reinforced concrete, $/cubic yard	$308.91
Removal of grade slab concrete, $/cubic yard	$181.83
Removal of clean concrete floors, $/cubic yard	$247.22
Removal of sections of clean concrete floors, $/cubic yard	$790.37
Removal of clean heavily rein concrete w/#9 rebar, $/cubic yard	$179.45
Removal of contaminated heavily rein concrete w/#9 rebar, $/cubic yard	$1,494.77
Removal of clean heavily rein concrete w/#18 rebar, $/cubic yard	$227.87
Removal of contaminated heavily rein concrete w/#18 rebar, $/cubic yard	$1,980.63
Removal heavily rein concrete w/#18 rebar & steel embedments, $/cu yd	$349.21
Removal of below-grade suspended floors, $/square foot	$247.22
Removal of clean monolithic concrete structures, $/cubic yard	$708.70
Removal of contaminated monolithic concrete structures, $/cu yd	$1,496.58
Removal of clean foundation concrete, $/cubic yard	$553.59
Removal of contaminated foundation concrete, $/cubic yard	$1,392.76
Explosive demolition of bulk concrete, $/cubic yard	$25.75
Removal of clean hollow masonry block wall, $/cubic yard	$66.71
Removal of contaminated hollow masonry block wall, $/cubic yard	$189.47
Removal of clean solid masonry block wall, $/cubic yard	$66.71
Removal of contaminated solid masonry block wall, $/cubic yard	$189.47
Backfill of below-grade voids, $/cubic yard	$14.53
Removal of subterranean tunnels/voids, $/linear foot	$128.72
Placement of concrete for below-grade voids, $/cubic yard	$71.62

APPENDIX B
(continued)

Unit Cost Factor	Cost/Unit($)
Excavation of clean material, $/cubic yard	$2.72
Excavation of contaminated material, $/cubic yard	$6.22
Excavation of submerged concrete rubble, $/cubic yard	$10.74
Removal of clean concrete rubble, $/cubic yard	$56.66
Removal of contaminated concrete rubble, $/cubic yard	$23.09
Removal of building by volume, $/cubic foot	$0.22
Removal of clean building metal siding, $/square foot	$1.30
Removal of contaminated building metal siding, $/square foot	$3.54
Removal of standard asphalt roofing, $/square foot	$1.99
Removal of transite panels, $/square foot	$1.78
Scarifying contaminated concrete surfaces (drill & spall)	$9.61
Scabbling contaminated concrete floors, $/square foot	$1.47
Scabbling contaminated concrete walls, $/square foot	$5.77
Scabbling contaminated ceilings, $/square foot	$57.68
Scabbling structural steel, $/square foot	$4.91
Removal of clean overhead cranes/monorails < 10 ton capacity	$551.95
Removal of contaminated overhead cranes/monorails < 10 ton capacity	$1,335.98
Removal of clean overhead cranes/monorails >10-50 ton capacity	$1,324.65
Removal of contaminated overhead cranes/monorails >10-50 ton capacity	$3,209.00
Removal of polar cranes > 50 ton capacity, each	$5,528.86
Removal of gantry cranes > 50 ton capacity, each	$23,539.67
Removal of structural steel, $/pound	$0.30
Removal of clean steel floor grating, $/square foot	$2.94
Removal of contaminated steel floor grating, $/square foot	$7.63
Removal of clean free-standing steel liner, $/square foot	$10.58

APPENDIX B
(continued)

Unit Cost Factor	Cost/Unit($)
Removal of contaminated free-standing steel liner, $/square foot	$26.40
Removal of clean concrete-anchored steel liner, $/square foot	$5.29
Removal of contaminated concrete-anchored steel liner, $/square foot	$30.79
Placement of scaffolding in clean areas, $/square foot	$10.08
Placement of scaffolding in contaminated areas, $/square foot	$16.16
Landscaping w/o topsoil, $/acre	$2,818.07
Cost of CPC B-88 LSA box & preparation for use	$707.72
Cost of CPC B-25 LSA box & preparation for use	$780.47
Cost of CPC B-12V 12 gauge LSA box & preparation for use	$610.70
Cost of CPC B-144 LSA box & preparation for use	$2,644.33
Cost of LSA drum & preparation for use	$97.12
Cost of cask liner for CNSI 14-195 cask	$7,094.95
Cost of cask liner for CNSI 8-120A cask (resins)	$7,413.63
Cost of cask liner for CNSI 8-120A cask (filters)	$7,413.63
Decontamination of surfaces with vacuuming, $/square foot	$0.58

APPENDIX C

DELAYED-DECON
DECOMMISSIONING COST ESTIMATE UNITS 1 & 2

TABLE C-1
ZION NUCLEAR POWER STATION - UNIT 1
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
PERIOD 1														
1998 Decommissioning Expenditures								29650						
1999 Projected Decommissioning Expenditures								24676						
Period 1 Undistributed Costs														
1 Insurance						206	21	227						
2 Property taxes						274	27	302						
3 Plant energy budget						400	60	460						
4 NRC Fees						89	9	97						
5 Site Security Cost						217	33	250						
6 NEI Fees						46	5	51						
7 Site O&M Costs						287	29	316						
Subtotal Undistributed Costs Period 1						1520	183	1702						
Utility Staff Cost						7790	1168	8958						
TOTAL PERIOD 1						9309	1351	64987						
PERIOD 2														
1 Quarterly Inspection							a							
2 Semi-annual environmental survey							a							
3 Prepare reports							a							
4 Insurance						412	41	454						
5 Property taxes						548	55	603						
6 Disposal of contaminated solid waste			0.7	0.2	39		10	50	102				28	0.02
7 Plant energy budget						48	7	56						
8 NRC Fees						135	14	149						
9 Site Security Cost						143	21	164						
10 IDNS Fees						25	2	27						
11 Site O&M Costs						574	57	631						
12 NEI Fees						92	9	102						
13 Site maintenance staff						1990	298	2288						
PERIOD 2 ANNUAL TOTALS			0.7	0.2	39	3968	516	4524	102				28	0.02

MAINTENANCE COSTS FOR 13.365 YEARS OF WET FUEL STORAGE $ 60,463,921

TABLE C-1
ZION NUCLEAR POWER STATION - UNIT 1
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
PERIOD 3														
1 Site characterization survey						685	103	788						
2 Review plant dwgs & specs						460	69	529						
3 Perform detailed rad survey							a							
4 End product description						100	15	115						
5 Detailed by-product inventory						130	20	150						
6 Define major work sequence						750	113	863						
7 Perform SER and EA						310	47	357						
8 Perform Site-Specific Cost Study						500	75	575						
9 Prepare/submit License Termination Plan						410	61	471						
10 Receive NRC approval of termination plan							a							
Activity Specifications														
11.1 Re-activate plant & temporary facilities						663	99	763						
11.2 Plant systems						375	56	431						
11.3 Reactor internals						710	107	817						
11.4 Reactor vessel						650	98	748						
11.5 Biological shield						50	8	58						
11.6 Steam generators						312	47	359						
11.7 Reinforced concrete						80	12	92						
11.8 Turbine & condenser						80	12	92						
11.9 Plant structures & buildings						156	23	179						
11.10 Waste management						460	69	529						
11.11 Facility & site closeout						45	7	52						
11 Total						3581	537	4118						
Planning & Site Preparations														
12 Prepare dismantling sequence						240	36	276						
13 Plant prep. & temp. svces						1719	258	1977						
14 Design water clean-up system						140	21	161						
15 Rigging/CCEs/tooling/etc.						1455	218	1674						
16 Procure casks/liners & containers						123	18	141						

TABLE C-1
ZION NUCLEAR POWER STATION - UNIT 1
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
Detailed Work Procedures														
17.1 Plant systems						426	64	490						
17.2 Vessel head						250	38	288						
17.3 Reactor internals						250	38	288						
17.4 Remaining buildings						34	5	39						
17.5 CRD cooling assembly						100	15	115						
17.6 CRD housings & ICI tubes						100	15	115						
17.7 Incore instrumentation						100	15	115						
17.8 Reactor vessel						363	54	417						
17.9 Facility closeout						60	9	69						
17.10 Missile shields						45	7	52						
17.11 Biological shield						120	18	138						
17.12 Steam generators						460	69	529						
17.13 Reinforced concrete						50	8	58						
17.14 Turbine & condensers						312	47	359						
17.15 Auxiliary building						246	37	283						
17.16 Reactor building						246	37	283						
17 Total						3161	474	3635						
Period 3 Additional Costs														
18 Asbestos removal program		5611	944	43	7548		3391	17537	20471				129829	6
19 PCB Remediation								none at this time						
Subtotal Period 3 Activity Costs		5611	944	43	7548	13765	5455	33366	20471				129829	6
Period 3 Undistributed Costs														
1 DOC staff relocation expenses		753					113	866						
2 Insurance						618	62	680						
3 Property taxes						823	82	905						
4 Health physics supplies		534					134	668						
5 Heavy equipment rental		376					56	432						
6 Disposal of DAW generated			339	18	292		110	758	3354				9123	8
7 Plant energy budget						855	128	984						
8 NRC Fees						266	27	292						
9 Site Security Cost						652	98	750						
10 NEI Fees						139	14	152						
11 Site O&M Costs						861	86	947						
Subtotal Undistributed Costs Period 3		1663	339	18	292	4214	909	7435	3354				9123	8
DOC Staff Cost						4588	688	5276						
Utility Staff Cost						9008	1351	10360						

TABLE C-1
ZION NUCLEAR POWER STATION - UNIT 1
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
TOTAL PERIOD 3		7274	1284	60	7840	31575	8404	56437	23825				138952	14
PERIOD 4A														
Nuclear Steam Supply System Removal														
20.1 Reactor Coolant Piping	156	229	19	16	986		386	1792	2513				8720	35
20.2 Pressurizer Relief Tank	23	123	4	3	242		104	500	621				3322	16
20.3 Reactor Coolant Pumps & Motors	77	72	37	14	1513		440	2153	3839				3566	17
20.4 Pressurizer	32	49	5	5	888		252	1232	2321				1744	7
20.5 Steam Generators	258	1412	311	433	12298		3652	18362	32608				4858	19
20.6 CRDMs/ICIs/Service Structure Removal	69	59	43	8	1081		325	1585	2835				2814	17
20.7 Reactor Vessel Internals	105	1938	1675	309	8058		6031	18115	1834	529	884	230	15842	13
20.8 Reactor Vessel	195	4796	1427	277	2922		5582	15199	4716	2096			25743	20
20 Totals	914	8678	3521	1066	27987		16771	58938	51288	2625	884	230	66608	145
Removal of Major Equipment														
21 Main Turbine/Generator		357				6618	1082	8058					7919	3
22 Main Condensers		786				4239	832	5858					17531	39
Disposal of Plant Systems														
23.1 Aux Building Vents & Drains		27	0.2	0.1	13	9	11	61	34				610	0.07
23.2 Auxiliary Steam		30				20	10	60					733	
23.3 Auxiliary Steam-RCA		6				3	2	11					142	
23.4 Chemical Feed		7					1	9					176	
23.5 Chemical and Volume Control		1841	38	19	2015	1149	1143	6204	5225				42140	29
23.6 Component Cooling		435				532	189	1156					10600	
23.7 Condensate		873				3033	673	4580					20692	
23.8 Containment Air Monitoring		7				3	2	12					156	
23.9 Containment Spray		315				654	177	1146					7624	
23.10 Demineralized Water		3				2	1	6					66	
23.11 Electrical - Contaminated		2361	5	2	239	2190	979	5777	617				55887	9
23.12 Electrical - RCA		360					90	450					8068	
23.13 Extraction Steam		144				382	93	619					3484	
23.14 Extraction Steam - RCA		153				356	92	600					3712	
23.15 Feedwater		375				868	224	1467					9032	
23.16 Feedwater - RCA		89				124	41	253					2162	
23.17 Fire Protection - RCA		87				64	31	182					2118	
23.18 Gland Steam		40				26	14	80					975	
23.19 HVAC-Auxiliary Building		319	0.6	0.3	29	270	128	747	76				6301	1.2
23.20 HVAC-Containment Building		1088	7	3	358	1293	557	3306	920				22248	4

TABLE C-1
ZION NUCLEAR POWER STATION - UNIT 1
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
Disposal of Plant Systems (continued)														
23.21 Heater Drains		487				1607	363	2457					11291	
23.22 Hydrogen/Carbon Dioxide		23				13	8	44					574	
23.23 Instrument Air - RCA		44				10	12	66					1077	
23.24 Main Steam		766				2671	592	4030					18388	
23.25 Main Steam - RCA		90				164	47	301					2183	
23.26 Miscellaneous Heater Drains		81				63	30	173					1960	
23.27 Nitrogen		17				54	12	84					413	
23.28 Nuclear Sampling		128	1	0.5	58	68	57	312	148				2975	0.4
23.29 Off Gas		439	4	2	213	250	201	1109	546				10075	2.5
23.30 Penetration Pressurization		19				17	7	44					458	
23.31 Primary Water		149	3	1	145	241	110	649	380				3422	1.2
23.32 Radioactive Waste Disposal		25	0.6	0.3	30	13	16	85	77				583	0.2
23.33 Reactor Coolant		514	6	3	318	27	213	1080	808				11769	13
23.34 Residual Heat Removal		354	18	8	927	732	433	2473	2379				8204	6
23.35 Safety Injection		822	14	7	710	618	478	2649	1826				18990	8
23.36 Service Air - RCA		4				0.4	1	5					90	
23.37 Service Water		291				856	201	1349					7019	
23.38 Service Water - RCA		278				409	131	818					6752	
23.39 Station Heating		42				7	12	60					1035	
23.40 Turbine Bldg Vents & Drains		16				25	8	48					356	
23.41 Waste Drains		124	2	0.8	91	20	57	295	232				2843	1.6
23.42 Waste Gas		30	0.6	0.3	30	55	23	140	80				685	0.4
23 Totals		13304	100	48	5176	18896	7471	44995	13348				308071	77
24 Erect scaffolding for systems removal		3919	0.7	0.3	40	186	1018	5163	105				40141	
Decontamination of Site Buildings														
25.1 * Reactor Building	992	761	57	31	2486	563	1403	6294	6949				38796	
25.2 Auxiliary Building	621	275	19	22	211	138	458	1744	2288				19690	
25.3 Contaminated Soil		4	139	164	1474		408	2188	16941				556	0.0003
25.4 Service Building & Addition	82		0.3	0.3	3		42	128	33				1855	
25.5 Turbine Building	103		3	4	32		60	202	372				2276	
25 Totals	1799	1040	218	221	4206	701	2371	10556	26582				63172	0.0003
Period 4A Additional Costs														
26 RCRA Soil Remediation		1				234	24	258					13	

TABLE C-1
ZION NUCLEAR POWER STATION - UNIT 1
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
Subtotal Period 4A Activity Costs	2713	28086	3840	1334	37409	30874	29569	133826	91323	2625	884	230	503454	265
Period 4A Undistributed Costs														
1 Decon equipment	534						80	614						
2 Decon supplies	480						120	600						
3 DOC staff relocation expenses		753					113	866						
4 Process liquid waste	114		322	277	2942		866	4521		4906			252	2.0
5 Insurance						1026	103	1129						
6 Property taxes						1229	123	1351						
7 Health physics supplies		2005					501	2507						
8 Heavy equipment rental		3727					559	4287						
9 Small tool allowance		352					53	405						
10 Pipe cutting equipment		680					102	782						
11 Disposal of DAW generated			563	29	484		182	1258	5566				15139	13
12 Decommissioning Equipment Disposition			5	2	221	480	56	764	572				778	0.6
13 Plant energy budget						1205	181	1386						
14 NRC Fees						556	56	612						
15 Site Security Cost						1842	276	2118						
16 NEI Fees						230	23	253						
17 Radwaste Processing Skids						896	134	1030						
18 Site O&M Costs						1429	143	1572						
Subtotal Undistributed Costs Period 4A	1127	7517	890	309	3647	8893	3671	26054	6138	4906			16169	15

TABLE C-1
ZION NUCLEAR POWER STATION - UNIT 1
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
DOC Staff Cost						10138	1521	11659	26582				63172	0
Utility Staff Cost						10866	1630	12496						
TOTAL PERIOD 4A	3840	35603	4730	1643	41056	60771	36390	184034	97460	7531	884	230	519623	280
PERIOD 4B														
1 Quarterly Inspection														
2 Semi-annual environmental surveys														
3 Prepare reports														
4 Insurance						381	38	419						
5 Property taxes						506	51	557						
6 Disposal of contaminated solid waste			1	0 2	39		10	50	102				28	0.02
7 Plant energy budget						48	7	56						
8 NRC Fees						128	13	141						
9 Site Security Cost						157	24	180						
10 NEI Fees						85	9	94						
11 Site O&M Costs						530	53	583						
12 Site maintenance staff						1403	210	1614						
PERIOD 4B ANNUAL MAINTENANCE TOTALS			0.7	0.2	39	3239	414	3693	102				28	0.02

MAINTENANCE COSTS FOR 7.978 YEARS OF DORMANCY $ 29,464,517

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
PERIOD 4C														
27 License Termination Survey Cost						6891	1723	8614					98805	
Period 4C Undistributed Costs														
4 Insurance						27	3	29						
5 Property taxes						140	14	154						
12 NRC Fees						39	4	43						
13 Site Security Cost						130	19	149						
5 Site O&M Costs						146	15	161						
Subtotal Undistributed Costs Period 4						481	55	536						
Utility Staff Cost						623	93	717						

TABLE C-1
ZION NUCLEAR POWER STATION - UNIT 1
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
TOTAL PERIOD 4C						7996	1871	9867					98805	
PERIOD 4A (Clean)														
Demolition of Remaining Site Buildings in Support of License Termination														
28.1 * Reactor Building		692					104	796					10014	
28.2 Auxiliary Building		304					46	349					3733	
28.3 Service Building & Addition		159					24	183					2439	
28 Totals		1154					173	1328					16186	
Subtotal Period 4A Activity Costs		1154					173	1328					16186	
TOTAL PERIOD 4A (Clean)		1154					173	1328					16186	
TOTAL COST TO DECOMMISSION	3840	44031	6029	1709	49738	194997	58388	406580	123460	7531	884	230	774157	294

TOTAL COST TO DECOMMISSION WITH	**19.87% Contingency: $**	**406,580,412**
TOTAL RADWASTE VOLUME BURIED:		**132,104 Cubic Feet**
TOTAL CRAFT LABOR REQUIREMENTS:		**774,157 Man-hours**
TOTAL PERSONNEL RADIATION EXPOSURE:		**294 Man-Rem**

TABLE C-2
ZION NUCLEAR POWER STATION - UNIT 2
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
PERIOD 1														
1998 Decommissioning Expenditures								29650						
1999 Decommissioning Expenditures								24677						
Period 1 Undistributed Costs														
1 Insurance						206	21	227						
2 Property Taxes						274	27	302						
3 Plant energy budget						399	60	458						
4 NRC Fees						89	9	97						
5 Site Security Cost						217	33	250						
6 NEI Fees						46	5	51						
7 Site O&M Costs						287	29	316						
Subtotal Undistributed Costs Period 1						1518	183	1701						
Utility Staff Cost						7790	1168	8958						
TOTAL PERIOD 1						9308	1351	64986						
PERIOD 2														
1 Quarterly Inspection							a							
2 Semi-annual environmental survey							a							
3 Prepare reports							a							
4 Insurance						412	41	453						
5 Property Taxes						548	55	603						
6 Disposal of contaminated solid waste			0.7	0.2	39		10	50	102				28	0.01
7 Plant energy budget						48	7	56						
8 NRC Fees						74	7	81						
9 Site Security Cost						155	23	178						
10 IDNS Fees						22	2	24						
11 Site O&M Costs						574	57	631						
12 NEI Fees						92	9	102						
13 Site maintenance staff						1983	297	2281						
PERIOD 2 ANNUAL TOTAL			0.7	0.2	39	3909	510	4460	102				28	0.01

MAINTENANCE COSTS FOR 15.19 YEARS OF WET FUEL STORAGE $ 67,745,427

TABLE C-2
ZION NUCLEAR POWER STATION - UNIT 2
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
PERIOD 3														
1 Site characterization survey						685	103	788						
2 Review plant dwgs & specs						197	30	226						
3 Perform detailed rad survey							a							
4 End product description						43	6	49						
5 Detailed by-product inventory						56	8	64						
6 Define major work sequence						321	48	369						
7 Perform SER and EA						133	20	152						
8 Perform Site-Specific Cost Study						214	32	246						
9 Prepare/submit License Termination Plan						175	26	201						
10 Receive NRC approval of termination plan a														
Activity Specifications														
11.1 Re-activate plant and temporary facilities						315	47	362						
11.2 Plant systems						160	24	184						
11.3 Reactor internals						304	46	349						
11.4 Reactor vessel						278	42	320						
11.5 Biological shield						21	3	25						
11.6 Steam generators						133	20	153						
11.7 Reinforced concrete						34	5	39						
11.8 Turbine & condenser						34	5	39						
11.9 Plant structures & buildings						67	10	77						
11.10 Waste management						197	30	226						
11.11 Facility & site closeout						19	3	22						
11 Total						1563	234	1797						
Planning & Site Preparations														
12 Prepare dismantling sequence						103	15	118						
13 Plant prep. & temp. svces						1719	258	1977						
14 Design water clean-up system						60	9	69						
15 Rigging/CCEs/tooling/etc.						1455	218	1674						
16 Procure casks/liners & containers						53	8	60						

TABLE C-2
ZION NUCLEAR POWER STATION - UNIT 2
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
Detailed Work Procedures														
17.1 Plant systems						182	27	209						
17.2 Vessel head						107	16	123						
17.3 Reactor internals						107	16	123						
17.4 Remaining buildings						14	2	17						
17.5 CRD cooling assembly						43	6	49						
17.6 CRD housings & ICI tubes						43	6	49						
17.7 Incore instrumentation						43	6	49						
17.8 Reactor vessel						155	23	179						
17.9 Facility closeout						26	4	30						
17.10 Missile shields						19	3	22						
17.11 Biological shield						51	8	59						
17.12 Steam generators						197	30	226						
17.13 Reinforced concrete						21	3	25						
17.14 Turbine & condensers						133	20	153						
17.15 Auxiliary building						105	16	121						
17.16 Reactor building						105	16	121						
17 Total						1352	202	1555						
Period 3 Additional Costs														
18 Asbestos removal program		7117	1198	66	13303		5235	26919	36231				164691	11
19 PCB Remediation							none at this time							
20 Stored LSA Waste Disposal			5	6	6130		1534	7675	15785	640				
Subtotal Period 3 Activity costs		7117	1203	72	19432	8126	7987	43940	52016	640			164691	11
Period 3 Undistributed Costs														
1 DOC staff relocation expenses		753					113	866						
1 Insurance						618	62	680						
2 Property Taxes						823	82	905						
3 Health physics supplies		624					156	780						
4 Heavy equipment rental		376					56	432						
5 Disposal of DAW generated			339	18	292		110	758	3354				9123	7
6 Plant energy budget						842	126	969						
7 NRC Fees						266	27	292						
8 Site Security Cost						416	62	479						
9 NEI Fees						139	14	152						
10 Site O&M Costs						861	86	947						
Subtotal Undistributed Costs Period 3		1753	339	18	292	3965	894	7261	3354				9123	7
DOC Staff Cost						3046	457	3503						
Utility Staff Cost						3219	483	3702						

TABLE C-2
ZION NUCLEAR POWER STATION - UNIT 2
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
TOTAL PERIOD 3		8870	1542	90	19724	18357	9821	58406	55370	640			173814	18
PERIOD 4A														
Nuclear Steam Supply System Removal														
21.1 Reactor Coolant Piping	175	258	20	18	1079		426	1975	2749				9789	37
21.2 Pressurizer Relief Tank	23	123	4	3	241		103	497	618				3307	15
21.3 Reactor Coolant Pumps & Motors	77	72	37	14	1513		440	2153	3839				3566	16
21.4 Pressurizer	32	49	5	5	888		252	1232	2321				1744	7
21.5 Steam Generators	258	1412	311	433	12298		3652	18362	32608				4858	19
21.6 CRDMs/ICIs/Service Structure Removal	69	59	43	8	1081		325	1585	2835				2814	16
21.7 Reactor Vessel Internals	105	1938	1675	309	8058		6031	18115	1834	529	884	230	15842	12
21.8 Reactor Vessel	195	4796	1427	227	2922		5569	15136	4716	2096			25743	19
21 Totals	933	8706	3523	1017	28079		16799	59057	51521	2625	884	230	67662	141
Removal of Major Equipment														
22 Main Turbine/Generator		357				6618	1189	8165					7919	3
23 Main Condensers		786				4239	636	5661					17531	37
Disposal of Plant Systems														
24.1 Auxiliary Bldg Vents & Drain		145	1	0.5	54		50	251	139				3341	0.4
24.2 Auxiliary Steam		289				314	119	722					7007	
24.3 Auxiliary Steam - RCA		36				29	13	77					868	
24.4 Chemical Feed - RCA		8				4	3	15					189	
24.5 Chemical and Volume Control		2807	54	27	2887		1433	7207	7473				64140	40
24.6 Component Cooling		647				1495	386	2528					15671	
24.7 Condensate		1033				3409	770	5213					24577	
24.8 Containment Air Monitoring		7				4	2	13					156	
24.9 Containment Spray		385				769	212	1366					9323	
24.10 Demineralized Water		9				7	3	19					225	
24.11 Demineralized Water - RCA		15				9	5	30					379	
24.12 Electrical - Contaminated		5365	9	4	440	4040	2059	11918	1138				127007	20
24.13 Electrical - RCA		1362				1047	161	2570					32231	
24.14 Extraction Steam		194				465	118	778					4714	
24.15 Extraction Steam - RCA		219				435	120	774					5327	
24.16 Feedwater		436				970	255	1661					10507	
24.17 Feedwater - RCA		94				134	43	271					2277	

TABLE C-2
ZION NUCLEAR POWER STATION - UNIT 2
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
Disposal of Plant Systems (continued)														
24.18 Fire Protection - RCA		217				189	83	489					5289	
24.19 Fuel Oil/Diesel Oil - RCA		8				4	3	15					189	
24.20 Gland Steam		56				38	20	114					1367	
24.21 HVAC-Auxiliary Building		614	1	1	57		168	840	146				12104	2
24.22 HVAC-Containment Building		1103	7	3.2	354		366	1833	912				22596	4.0
24.23 HVAC-DAW Building		53	0.1	0.04	5	45	21	124	13				1078	0.2
24.24 Heater Drains		874				1745	480	3099					21149	
24.25 Hydrogen/Carbon Dioxide		33				34	5	72					776	
24.26 Instrument Air - RCA		110				46	16	172					2690	
24.27 Main Steam		865				2828	640	4333					20767	
24.28 Main Steam - RCA		117				218	62	397					2850	
24.29 Make-up Demineralizer		626				701	262	1589					15069	
24.30 Make-up Demineralizer - RCA		46				35	17	99					1130	
24.31 Miscellaneous Heater Drains		119				86	43	248					2893	
24.32 Nitrogen		11				32	8	51					273	
24.33 Nuclear Sampling		147	1	0.6	67	75	65	356	170				3409	0.4
24.34 Off Gas		951	9	4	473	604	448	2488	1210				21873	5.4
24.35 Penetration Pressurization		22				25	9	56					523	
24.36 Primary Water		214	4	2	186		101	505	484				4880	1
24.37 Radioactive Waste Disposal		2168	44	21	2338	1141	1305	7018	6035				49531	18
24.38 Reactor Coolant		671	7	4	420	32	279	1413	1067				15353	16
24.39 Residual Heat Removal		423	20	9	989	785	474	2700	2537				9797	7
24.40 Safety Injection		1003	16	7	808	680	557	3071	2077				23112	9
24.41 Service Air - RCA		4				0.4	1	5					90	
24.42 Service Water		526				1350	334	2210					12714	
24.43 Service Water - RCA		477				678	221	1376					11583	
24.44 Station Heating		59				52	22	133					1426	
24.45 Station Heating - RCA		17				8	5	30					406	
24.46 Turbine Bldg Vents & Drains		61				57	24	142					1468	
24.47 Waste Drains		142	2	1	103	20	65	332	262				3239	2
24.48 Waste Gas		40	2	1	85	106	47	281	222				911	0.5
24.49 Wastewater Treatment		53				40	19	113					1284	
24 Totals		24878	177	85	9266	24790	11922	71117	23884				579756	127
25 Erect scaffolding for systems removal		3159	1	0.3	50	233	837	4280	131				36589	

TABLE C-2
ZION NUCLEAR POWER STATION - UNIT 2
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
Decontamination of Site Buildings														
26.1 Reactor Building	992	761	57	31	2486	563	1403	6294	6949				38796	
26.2 Auxiliary Building	621	275	19	22	211	138	458	1744	2288				19690	
26.3 Contaminated Soil		8	318	376	3378		935	5015	38823				1274	0.01
26.4 IDNS Ragems Facility	0 1		0.03	0.03	0 3		0.1	0.6	3				2	
26.5 IRSF	62	5	2.8	3 3	30.0	3	41	146	342				1441	
26.6 Miscellaneous Site Structures	2		0.3	0.3	3		2	8	34				52	
26.7 Training Center Addition	1		0.2	0.3	3		1	6	30				23	
26.8 Turbine Building	103		3	4	32		60	202	372				2276	
26.9 Wastewater Treatment Building	9		0.7	0 8	7		6	24	85				176	
26 Totals	1791	1049	401	438	6150	704	2906	13439	48926				63729	0.01
Period 4A Additional Costs														
27 RCRA Soil Remediation		3				913	92	1008					49	
Subtotal Period 4A Activity Costs	2724	38939	4102	1540	43544	37497	34381	162727	124462	2625	884	230	773235	308
Period 4A Undistributed Costs														
1 Decon equipment	534						80	614						
2 Decon supplies	501						125	626						
3 DOC Staff relocation expenses		753					113	866						
4 Process Liquid waste	298		400	391	3613		1151	5852		6158			498	1
5 Insurance						1111	111	1222						
6 Property Taxes						1330	133	1463						
7 Health physics supplies		2927					732	3659						
8 Heavy equipment rental		4034					605	4640						
9 Small tool allowance		542					81	623						
10 Pipe cutting equipment		680					102	782						
11 Disposal of DAW generated			609	32	524		197	1362	6024				16386	4
12 Decommissioning Equipment Disposition			5	2	221	480	56	764	572				778	0.2
13 Plant energy budget						1287	193	1480						
14 NRC Fees						602	60	662						
15 Site Security Cost						2326	349	2675						
16 NEI Fees						249	25	274						
17 Radwaste Processing Skids						970	145	1115					619	5
18 Site O&M Costs						1547	155	1701						
Subtotal Undistributed Costs Period 4A	1333	8936	1014	425	4358	9901	4413	30381	6596	6158			18281	10

TABLE C-2
ZION NUCLEAR POWER STATION - UNIT 2
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
Utility staff cost						16686	2503	19189						
DOC staff cost						13145	1972	15117						
TOTAL PERIOD 4A	4056	47875	5116	1965	47902	77230	43269	227414	131058	8783	884	230	791516	318
PERIOD 4B														
1 Quarterly Inspection							a							
2 Semi-annual environmental surveys							a							
3 Prepare reports							a							
4 Insurance						412	41	454						
5 Property taxes						548	55	603						
6 Disposal of contaminated solid waste			1	0.2	39		10	50	102				28	0.02
7 Plant energy budget						48	7	56						
8 NRC Fees						135	14	149						
9 Site Security Cost						143	21	164						
10 NEI Fees						92	9	102						
11 Site O&M Costs						574	57	632						
12 Site maintenance staff						1446	217	1663						
PERIOD 4B ANNUAL MAINTENANCE TOTALS			0.7	0.2	39	3400	432	3872	102				28	0.02
Period 4B Additional cost														
Spent Fuel Canister Loading						13252		13252						
Fuel Building Crane Upgrade						1200	180	1380						

COSTS FOR 6.45 YEARS OF WET FUEL STORAGE & FUEL TRANSFER $ 39,604,638

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
PERIOD 4C														
28 Remove spent fuel racks	767	84	98	16	1439	6911	1813	11129	3892				19525	2
Disposal of Plant Systems														
29 Spent Fuel Systems		135	5	2	235	119	111	606	605				3080	0.8
30 Erect scaffolding for systems removal		240	0.12	0.05	7	32	66	345	18				3499	

TABLE C-2
ZION NUCLEAR POWER STATION - UNIT 2
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
Decontamination of Site Buildings														
31 Fuel Building	673	680	20	9	570	334	703	2989	1691				30092	
32 License Termination Survey Costs		8339					2085	10424					121191	
Subtotal Period 4C Activity Costs	1440	9478	123	28	2251	7396	4778	25493	6205				177387	3
Period 4C Undistributed Costs														
1 Decon equipment	534						80	614						
2 Decon supplies	93						23	116						
3 DOC stafff relocation expenses		251					38	289						
4 Insurance						343	34	377						
5 Property taxes						456	46	502						
6 Health physics supplies		264					66	330						
7 Heavy equipment rental		1385					208	1593						
8 Small tool allowance		38					6	43						
9 Disposal of DAW generated			188	10	162		61	421	1861				5063	4
10 Plant energy budget						442	66	508						
11 NRC Fees						142	14	156						
12 Site Security Cost						735	110	845						
13 Site O&M Costs						478	48	526						
Subtotal Undistributed Costs Period 4 C	626	1938	188	10	162	2596	800	6321	1861				5063	4
Utility staff cost						2623	393	3016						
DOC staff cost						2737	411	3148						
TOTAL PERIOD 4 C	2066	11416	311	38	2413	15352	6382	37977	8067				182450	7
PERIOD 4A (Clean)														
Demolition of Remaining Site Buildings in Support of License Termination														
33.1 * Reactor Building		692					104	796					10014	
33.2 Auxiliary Building		304					46	349					3733	
33.3 Fuel Building		229					34	263					3300	
33.4 IRSF		121					18	140					1855	
33		1346					202	1548					18902	
Subtotal Period 4A Activity Costs		1346					202	1548					18902	

TABLE C-2
ZION NUCLEAR POWER STATION - UNIT 2
DECOMMISSIONING COST ESTIMATE
(Thousands of 1996 Dollars)

Activity	Decon	Remove	Pack	Ship	Bury	Other	Cntgcy	Total	A CF	B CF	C CF	>C CF	M-Hrs	M-Rem
TOTAL PERIOD 4A (Clean)		1346					202	1548					18902	
TOTAL COST TO DECOMMISSION	6123	69506	6985	2098	70892	216009	71741	497681	196700	9423	884	230	1167281	343

TOTAL COST TO DECOMMISSION WITH 20.02% Contingency:	$ 497,681,168	
TOTAL RADWASTE VOLUME BURIED:	207,237	Cubic Feet
TOTAL CRAFT LABOR REQUIREMENTS:	1,167,281	Man-hours
TOTAL PERSONNEL RADIATION EXPOSURE:	343	Man-Rem