The estimate includes an overall contingency component of 19.2 percent, based upon a line-item analysis as described in the Atomic Industrial Forum/National Environmental Studies Project Report AIF/NESP-036 "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates".

Q. WHAT WAS THE BASIS OF THE COST ESTIMATE IN THE 2019 DECOMMISSIONING STUDY?

A. The 2019 study was developed primarily using the technical database (inventory of the physical plant) from prior estimates for Palo Verde. This database was updated, as required, to include changes in the site inventory and for compatibility with the latest cost modeling software.

Decommissioning is a labor-intensive program. Accordingly, representative 2019 craft labor costs were provided by the site. Utility salaries, overhead and benefits, site operating costs, as well as corporate contributions were also provided by site and/or APS headquarters personnel for inclusion in the cost model.

Low-level radioactive waste, for purposes of this cost analysis, was assumed to be shipped to the Energy*Solutions* disposal site in Clive, Utah, with some higher-level radioactive waste assumed to be shipped to the Waste Control Specialists ("WCS") site in Andrews County, Texas. Costs for the disposal of the radioactive waste streams generated by decommissioning were based upon then-current contracts with the associated vendors, service providers, and/or published rates/tariffs.

The spent fuel management requirements identified by APS were also incorporated into the decommissioning program and reflected APS experience in the handling and storage of spent fuel and the available information on the development of a federal waste management system for fuel from commercial nuclear generators.

Q. WHAT IS THE NATURE OF THE CHANGES IN DECOMMISSIONING ESTIMATE OVER TIME?

A. Over time, there are three drivers that influence the decommissioning costs. The first is the general economic changes in the price of labor, cost of electricity, changes in property taxes, etc. These all tend to track with the general economic inflation as exemplified in the

U.S. Bureau of Labor Statistics Consumer Price Index. For this driver, a nuclear power plant decommissioning is no different from any other activity in the general economy.

The second driver which influences decommissioning costs is what could be described as changes in the work scope. Examples of such changes are included in the 2019 estimate for Palo Verde. These include additional security force requirements due to regulatory changes by the NRC; reductions in building demolition costs due to the availability of new technology; and should there be any other changes to the site configurations, such as the Flexible and Diverse Mitigation Strategies ("FLEX") building.

The third driver is waste disposal rates. The rates for disposal for various packages can be significantly different from that due to general economic inflation, see the discussion below. The variations in waste disposal rates have several causes. These fluctuations can be due to but not limited to the following, negotiated life of plant contracts or lack of life of plant agreements; new disposal facilities; and revised packaging requirements.

Q. HAS THE COST IDENTIFIED IN THIS STUDY INCREASED SINCE YOUR LAST STUDY CONDUCTED IN 2016?

A. Yes, there is an overall increase from 2016 to 2019 of approximately 8% from $2.74 billion to $2.96 billion. This represents an annual increase of 2.59% per year versus an annual CPI escalation rate of 2.76% per year. This shows that the actual increase from 2016 to 2019 is less than that expected by using the CPI rate. The cost for the decommissioning of the 3 units and common structures increased by approximately 9.2% or 2.98%/year. The cost for the decommissioning of the ISFSI increased by approximately 8.66% or 2.81%/year while the cost for Appendices G through K and M decreased approximately 6.32% or 2.15%/year. Table 1 provides a summary of this data.

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Table 1

Cost Category	2016, $s (thousands)	2019, $s (thousands)	% Change	Annual % Change
Units 1, 2, & 3 and Common	2,392,736	2,612,986	9.205	2.979
ISFSI (Appendix L)	134,365	145,994	8.655	2.806
Appendix G – K & M	212,000	198,607	-6.318	-2.152
Total	2,739,101	2,957,587	7.98	2.591

Q. WHAT CHANGED BETWEEN THE 2016 STUDY AND THE CURRENT 2019 STUDY?

A. The following is a description of the main factors responsible for the less than expected increase.

As seen above, the costs for Units 1, 2, 3 & Common increased slightly greater than the CPI rate while the cost for Appendix G – K & M decreased. The main reason for a decrease in Appendix G – K & M is the reduction of the Large Component Containerized Waste Rate. Another factor in the decrease is the 4% reduction in the craft labor rates. Both are explained below.

<u>Waste Disposal</u>

Primary Burial increased $56.8 million or 17% - The primary containerized waste rate increased by approximately 48%. This increase is offset by a decrease in large component waste disposal rate and class A resin disposal rate of 74% and 57%, respectively. Secondary burial costs decreased by approximately $6.1 million or 48%. This decrease was due to a decrease in the Bulk Class A rate and the DAW rate of 10% and 42%, respectively. In addition to the decrease in the DAW rate, there was a change in assumed DAW density from 10 lbs/cu ft to 20 lbs/cu ft, reducing the total volume. Table 2 provides a summary of the disposal rate changes.

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Table 2

Waste Category	2016		2019	
Large Component Containerized Class A Rate	310.00	$/ CF	79.20	$ / CF
Class A containerized	122.00	$/ CF	180.00	$ / CF
Bulk Class A	62.00	$/ CF	56.05	$ / CF
Class A Resin	53,125.00	$ / Cask	22,927.50	$ / Cask
DAW Processing	2.57	$ / LB	1.48	$ / LB

Utility Staff

The Utility staff costs increased $74 million or approximately 9%, 2.9%/year. There are a couple of reasons for this increase. TLG has made some revisions to the staff levels, in some of the periods, over the past three years to better reflect recent experience. Also, the average staff salaries, for positions used in the estimate, increased approximately 3.64% based on information supplied by APS. On the other hand, craft labor rates are approximately 4% lower than those used in the 2016 estimate. This again is based on the rate information provided by APS.

Security

Security costs increased by $60.6 million or approximately 36%. Security Staff levels decreased in 2019 anywhere from 10% to over 40% depending on the period. This decrease was offset by an increase in the average salary of 40% to 70% depending on the period. In addition to these changes, TLG has modified the security calculation since 2016, correcting some inconsistencies. The Units 2 & 3 security costs were misallocated over time relative to the Unit 1 costs. This has been corrected in the 2019 estimate.

Insurance

All insurance premiums currently in effect, as reported by APS, increased by approximately 10.2% overall from 2016 to 2019; however, not all of the insurance policies in effect during operations are assumed to be in effect during decommissioning. Of the property and liability insurance policies assumed to be in effect during decommissioning, the premiums increased approximately 52.7% and 142.2%, respectively, from 2016 to 2019, causing an overall increase of $15.6 million or 86% from 2016 to 2019.

Q. IS IT APPROPRIATE TO REFLECT THE 2019 DECOMMISSIONING COST STUDY IN EPE'S DETERMINATION OF DECOMMISSIONING FUNDING IN THIS CASE?

A. Yes. The 2019 estimate, Rev 1, for Palo Verde represents the best available cost estimate for the decommissioning of the Palo Verde facility.

V. Methodology for Estimating Decommissioning and Dismantling Costs

Q. WHAT METHODOLOGY WAS USED TO PREPARE THE COST ESTIMATE?

A. The methodology used to develop the cost estimate followed the basic approach presented in the AIF/NESP-036 study report, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates," and the DOE's "Decommissioning Handbook." The estimating techniques have been augmented, when appropriate, to reflect experience gained in decommissioning at several of the large commercial units over the past 30 years.

The two references describe a unit cost factor method for estimating decommissioning activity costs to standardize the estimating calculations. Unit cost factors for activities such as concrete removal ($/cubic yard), steel removal ($/ton), and cutting costs ($/inch) were developed from the labor information provided by the site. Material information was taken in large part from RSMeans, "Building Construction Cost Data 2019." The activity-dependent costs for decontamination, removal, packaging, shipping, and burial were estimated using the item quantity (cubic yards, tons, inches, etc.) originally developed from Palo Verde plant drawings and inventory documents. The activity duration critical path derived from such key activities, e.g., the disposition of the nuclear steam supply system ("NSSS"),[1] was used to determine the total decommissioning program schedule.

The program schedule is used to determine the period-dependent costs such as program management, administration, field engineering, equipment rental, quality assurance, and security. The salary and hourly rates are typical for personnel associated with period-dependent costs.

[1] The NSSS is the collection of equipment, including the reactor vessel, which produces the high-pressure steam used to drive the turbines. This equipment, together with supporting cleanup systems, is where most of the highly radioactive components reside.

The costs for conventional demolition of non-radioactive structures, materials, backfill, landscaping, and equipment rental were obtained from conventional demolition references.

In addition, collateral costs were included for heavy equipment rental or purchase, safety equipment and supplies, energy costs, permits, taxes, and insurance.

The activity-dependent, period-dependent, and collateral costs were added to develop the total decommissioning costs. An overall contingency was added to allow for the effects of unpredictable program problems.

One of the primary objectives of every decommissioning program is to protect public health and safety. The cost estimates for the Palo Verde decommissioning activities includes the necessary planning, engineering, and implementation to provide this protection to the public.

Q. HAS THE NRC APPROVED SITE-SPECIFIC COST ESTIMATES UTILIZING THE TLG COST ESTIMATING METHODOLOGY?

A. Yes. The NRC has reviewed TLG's cost estimating methodology. The NRC approved the decommissioning plan proposed by TLG for the Pathfinder Atomic Power Station. Funding provisions were based upon a site-specific estimate developed by TLG. TLG was also selected by the following utilities to prepare site-specific cost estimates for inclusion within the decommissioning plans or Post-Shutdown Decommissioning Activity Reports ("PSDAR") submitted to the NRC for the following nuclear units:

Long Island Lighting Company/Long Island Power Authority....... Shoreham
Sacramento Municipal Utility District..Rancho Seco
Portland General Electric...Trojan
Yankee Atomic Electric Company .... Rowe
Maine Yankee Atomic Power Company .... Maine Yankee
Pacific Gas & Electric...Humboldt Bay-3
Southern California Edison... San Onofre-1
Consumer Power Company .... Big Rock Point
Duke Energy Florida.. Crystal River Unit 3
Exelon Generation .... Oyster Creek

Entergy Nuclear .... Vermont Yankee
Entergy Nuclear .... Pilgrim
Omaha Public Power District... Fort Calhoun

Q. WHAT ARE THE FINANCIAL COMPONENTS OF THE COST MODEL?

A. The cost model considers three financial components. The first is the base cost estimate, calculated using the site-specific inventory, and labor, materials costs, equipment rental costs, radioactive waste disposal costs, and other costs consistent with the current site operations at Palo Verde.

The second financial component is the contingency values applied against each of the line items in the estimate; this is discussed later in my testimony.

A third component, financial risk, is discussed in the cost estimate report, but is not applied in the cost estimate. As discussed in the report, financial risk is addressed by performing frequent updates to the estimate to account for such changes as regulatory revisions, industry experience, changes in the availability of radioactive waste disposal facilities, and revised DOE performance schedules for pick-up of spent fuel from the site.

Q. HOW IS THE CONTINGENCY CALCULATED?

A. The purpose of the contingency is to allow for the costs of high probability program problems occurring in the field where the frequency, duration, and severity of such problems cannot be predicted accurately and have not been included in the basic estimate. The Association for the Advancement of Cost Engineering, International ("AACEI") (in their Cost Engineers' Notebook) defines contingency as follows:

> Contingency - 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.

Past decommissioning experience has shown that unforeseeable elements of cost are likely to occur in the field and may have a cumulative effect. In the AIF/NESP-036 Guidelines Study, TLG examined the major activity-related problems (decontamination, segmentation, equipment handling, packaging, shipping, and burial) with respect to reasons for contingency. Individual activity contingencies ranged from 10 percent to 75 percent of the related base cost, depending on the degree of difficulty judged to be appropriate from our actual decommissioning experience. The overall contingency, when applied to the appropriate components of all three generating units, and other site support features of the Palo Verde estimate, on a line item basis, results in an average of approximately 19.2 percent.

Q. IS IT FAIR TO VIEW CONTINGENCY AS A "SAFETY FACTOR" OR CUSHION AGAINST FUTURE PRICE INCREASES?

A. No. There is a general misconception on the use and role of contingency within decommissioning estimates, sometimes incorrectly viewed as a "safety factor." Safety factors provide additional security and address situations that may never occur. Contingency dollars are expected to be fully expended throughout the program. They also provide assurance that sufficient funding is available to accomplish the intended tasks. An estimate without contingency, or from which contingency has been removed or reduced, can disrupt the orderly progression of events and jeopardize a successful conclusion to the decommissioning process. Contingency, as used in these estimates, does not account for price escalation and inflation in the cost of decommissioning over the remaining operating life of the unit. Thus, the contingency is expected to be spent; however, since contingency dollars are intended to address complexities in the performance of the field decontamination and dismantling activities, it is difficult to identify today those activities most likely to be affected in the future.

Q. DOES THE ESTIMATED COST INCLUDE THE DISPOSAL OF SPENT NUCLEAR FUEL?

A. No. It is important to note that, although decommissioning of a site cannot be complete without the removal of all spent fuel, the final disposition of spent nuclear fuel is outside the scope of decommissioning. In accordance with the Nuclear Waste Policy Act, the DOE is required to enter into contracts with owners and/or generators of spent fuel, pursuant to which the DOE is contractually responsible for final disposition of spent fuel as high-level nuclear waste. Until recently, the disposal cost was financed by a one mill/kWh surcharge, based on net electrical generation, paid into the DOE's waste fund during operations. On November 19, 2013, the U.S. Court of Appeals for the D.C. Circuit ordered the Secretary of the DOE to suspend collecting annual fees for nuclear waste disposal from nuclear power plant operators until the DOE has conducted a legally adequate fee assessment. The disposal fee was formally set to 0.0 mill/kWh as of May 15, 2014. The 2019 estimate assumed that an equivalent charge would be reinstated sometime in the future, prior to final shutdown of Palo Verde, but only for determining the Greater than Class Costs ("GTCC") disposal charge that is expected to be imposed by the DOE.

Regardless of the disposal fee, the cost of disposal of spent fuel is accounted for separately and is specifically excluded from the decommissioning cost estimates.

VI. Decommissioning Processes

Q. WHAT IS THE PROCESS OF DECOMMISSIONING A NUCLEAR POWER REACTOR USING THE DECON ALTERNATIVE?

A. The conceptual approach that the NRC has identified in its amended regulations is to divide decommissioning into three phases. The initial phase commences with the effective date of permanent cessation of operations and involves the transition of both plant and licensee from reactor operations, i.e., power production to facility de-activation and closure. Phases II and III pertain to the activities involved in reactor decommissioning and license termination.

TLG's estimate for the Palo Verde site uses the DECON decommissioning method. This estimate addresses Phase I activities in Period 1. Phases II and III activities are included in Period 2. Period 3 and Post-Period 3 are added for site restoration and long-term spent fuel management; these activities are outside the scope of the NRC decommissioning requirements.

A. Period 1 – Planning and Engineering

This period begins upon shutdown of the facility and involves site preparations to initiate decommissioning. The reactor would be defueled with the fuel placed in the spent fuel pool until it is cooled sufficiently to be transferred to DOE or an alternative storage facility. Notification is provided to the NRC certifying the permanent cessation of operations and the removal of fuel from the reactor vessel; the licensee would then be prohibited from reactor operation. As noted earlier, transportation and disposal of spent fuel at a DOE facility is not considered part of decommissioning and no costs associated with these activities are included in the decommissioning estimates. (These expenses have been funded by the owner throughout the plant's operating life, payable to DOE for future rendering of these services.) However, the impact on the decommissioning schedule due to the presence of the spent fuel on site has been addressed in the study through the schedule. Wastes remaining from plant operations would be removed from the site and all systems nonessential to decommissioning would be isolated and drained.

Within two years of notification to cease reactor operations, the licensee is required to provide a Post-Shutdown Decommissioning Activities Report ("PSDAR"). This report would provide a description of the licensee's planned decommissioning activities, a corresponding schedule and an estimate of expected costs. The PSDAR would also address whether environmental impacts associated with the proposed decommissioning scenario have already been considered in a previously prepared environmental statement(s). Ninety days following the NRC's receipt of the PSDAR, the licensee can initiate certain decommissioning activities without specific NRC approval under a modified 10 C.F.R. § 50.59 review process. The rule permits the licensee to expend up to 3 percent of the generic decommissioning cost for planning, with an additional 20 percent available following the 90-day waiting period and certification of permanent defueling. Remaining funds would be available to the licensee with submittal of a detailed, site-specific cost estimate.

B. Period 2 - Decommissioning Operations

This period commences once the PSDAR has been submitted to the NRC for review and with the mobilization of the decontamination and dismantling workforce. This phase addresses the removal of radioactivity from the site and concludes with termination of the NRC's operating license. Activities include selective decontamination of contaminated systems, e.g., using aggressive chemical solvents to dissolve corrosion films holding radionuclides, thereby reducing radiation levels.

While effective, the on-site decontamination processes are not expected to reduce residual radioactivity to the levels necessary to release the material as clean scrap. Therefore, all contaminated components will have to be removed for controlled burial. However, decontamination will reduce personnel exposure and will permit workers to operate in the immediate vicinity of most components, cutting and removing them for controlled disposition at a low-level radioactive waste burial facility.

Contaminated piping to and from major components will be cut and removed. Selected major components such as the reactor coolant pumps, steam generators, pressurizers, and other large components will then be removed intact and sealed so that they may be transported off-site. Smaller components, such as sampling system pumps, filters, filter housings, strainers, etc., will be loaded into containers and shipped for controlled disposal.

The reactor vessel and its internals will be segmented and remotely loaded into steel liners for transport to the burial facility in heavily shielded shipping casks. The reactor vessel and internals will have sufficiently high radiation levels to require all cutting to be done underwater or behind heavy shields, using cutting tools operated by remote control to reduce radiation exposure to the workers.

Concrete immediately surrounding the reactor vessel is expected to be radioactive and will be removed by controlled blasting. This blasting process is well developed, safe, and is the most cost-effective way to remove the heavily-reinforced concrete from the structure.

Some surfaces of sections of interior floors within areas of the Containment and other buildings in the power block are expected to be contaminated from exposure to contaminated air/water as a result of plant operations. This contamination will be removed by scarification (surface removal) so that the remaining surfaces will be cleaned to release levels and will not require disposal as Class A radioactive waste.

Contaminated process equipment, pipe hangers, supports, and electrical components will be removed and routed for controlled disposal.

Finally, an extensive radiation survey will be performed to ensure all radioactive materials above the levels specified by the NRC have been removed from the site. With

NRC confirmation, the NRC license for most of the site (excluding the ISFSI) will be terminated.

C. Period 3 – Site Restoration

This period begins once license termination activities have concluded and involves the demolition of all remaining structures, typically to a depth of three feet below grade. Clean concrete rubble would be used on-site for fill and additional soil would be used to cover each subgrade structure. Excess rubble is trucked off-site for disposal.

D. Post Period 3 – Spent Fuel Storage

The ISFSI will continue to operate under a Part 50 license following the transfer of the spent fuel inventory from the Fuel Building. Transfer of spent fuel to a DOE or interim facility will be exclusively from the ISFSI once the fuel pools have been emptied and the structures released for decommissioning. Palo Verde will continue shipping spent fuel canisters to DOE through the year 2097.

At the conclusion of the spent fuel transfer process, the ISFSI will be decommissioned. TLG's estimate includes the cost to decommission the ISFSI. In the ISFSI, the spent fuel assemblies are contained within stainless steel canisters. On the ISFSI pad, these canisters are housed within reinforced concrete and steel shield cylinders known as overpacks. The canisters are assumed to be removed, shipped, and disposed of by the DOE. The steel overpack liners are assumed to have some level of neutron-induced activation as a result of the long-term storage of the fuel, i.e., to levels exceeding free-release limits. As an allowance, seven overpacks per unit (site total of 21) are assumed to require remediation, equivalent to the number of overpacks required to accommodate the final core offloads at Palo Verde (241 assemblies per unit for a site total of 723 assemblies). The cost of the disposition of this material, as well as the demolition of the ISFSI facility, is included in the estimate. The NRC will terminate the remaining license if it determines that site remediation has been performed in accordance with a license termination plan and the terminal radiation survey and associated documentation demonstrate that the facility meets the release criteria. Once the requirements are satisfied, the NRC can terminate the remaining license for the ISFSI.

The remaining reinforced concrete dry storage modules are then demolished, the concrete storage pad is removed, and the area graded and landscaped to conform to the surrounding environment.

Q. HOW DOES THE PRESENCE OF SPENT FUEL ON SITE AFTER PLANT SHUTDOWN AFFECT THE DECOMMISSIONING PROCESSES?

A. Although the study does not address the transport or disposal of spent fuel from the Palo Verde site, it does consider the constraint that the presence of spent fuel on the site can impose on other decommissioning activities. In particular, the decommissioning scheduling developed in support of the last four cycles of cost updates for the Palo Verde estimates incorporates an APS request for a six-year minimum cooling prerequisite for off-loading the fuel from the storage pools. As such, these spent fuel management activities will necessarily delay the final release of the power blocks for alternative/unrestricted use. This delay is reflected in the increased cost of the period-dependent activities. To the extent possible, the decommissioning estimates were structured around the spent fuel areas of the units and their availability for decontamination, such that delays in decommissioning other portions of the facility could be minimized. Decommissioning would proceed on the surrounding facilities and non-essential systems during the approximately six-year pool off-load period. The operating licenses can then be amended with the remaining fuel placed in dry storage.

Some small portion of the existing Palo Verde site will continue to be licensed by the NRC under the existing Part 50 license for the ISFSI. The endpoint of this storage period is estimated to be in 2097. Following this, the ISFSI will be decommissioned, the license terminated, and the concrete storage casks and pads crushed and removed.

Q. DOES THE PROCESS OF DECOMMISSIONING EXTEND BEYOND REMOVAL OF CONTAMINATED AND ACTIVATED MATERIAL FROM THE SITE?

A. Yes. There are additional activities beyond the removal of contaminated material that will be undertaken in the process of releasing the site for alternative use. This work includes costs for the remaining dismantling and grading operations and is generally referred to as site restoration.

Q. PLEASE DESCRIBE THE SITE RESTORATION ACTIVITIES.

A. These activities begin once license termination activities have concluded and involve the demolition of all remaining structures, typically to a depth of three feet below grade. Clean concrete rubble generated from the demolition of the Containment, Auxiliary, Fuel, Radwaste, and Turbine Buildings, etc., would be used on-site for fill and additional soil would be used to cover each subgrade structure. Excess rubble is trucked off-site for disposal. Either any below grade structures will be removed, or voids below grade, such as the 31-mile buried water line from Phoenix to the Water Reclamation Facility, will be filled with sand or concrete. The object is to prevent any future surface subsidence.

Once the below grade features of the site have been addressed, the surface of the site will be graded to conform to the surrounding environs. The evaporation and makeup water reservoir walls will be breached to prevent retaining water. At this point, the site is available for reuse, except for the footprint of the ISFSI.

Q. WHY WERE THE REMAINING STRUCTURES ON SITE ASSUMED TO BE DISMANTLED?

A. Efficient removal of the contaminated materials and verification that the radionuclide concentrations are below the stringent NRC limits will require substantial damage to many of the structures. Blasting, coring, drilling, scarification (surface removal), and the other decontamination work will damage power block structures including the Containment, Radwaste, Auxiliary, and Fuel Buildings. Verifying that subsurface radionuclide concentrations meet NRC site release requirements may require removal of grade slabs and lower floors, potentially weakening footings and structural supports.

It is also important to remember that the Palo Verde structures were custom designed and built to support a specific nuclear unit design that went into service in the 1980s. They would most likely be an impediment rather than a benefit to any potential future plant, if one were ever to be constructed at the site. Moreover, the facility's infrastructure degrades without continual maintenance. Unless the site is redeveloped shortly after release of its NRC license, the value in reusing plant facilities quickly diminishes.

As demonstrated by U.S. experience, dismantling is clearly the most appropriate and cost-effective option and should serve as the foundation for the decommissioning cost estimates. It is unreasonable to anticipate that these structures would be repaired and preserved after the radiological contamination is removed.

Q. WHAT ASSURANCE IS THERE THAT THE ESTIMATED COST FOR DECOMMISSIONING WILL REFLECT FUTURE DEVELOPMENTS AND INCREASES OR DECREASES IN COSTS?

A. The cost estimate prepared for Palo Verde is based on present technology, the current information available on decommissioning costs, and on existing federal regulations. No provision is made to include future costs or savings due to the uncertainties in improvements in technology, major regulatory changes, inflation factors, etc. It should be noted that the contingency, as used in the estimates, only covers uncertainties within the decommissioning schedule timeframe.

VII. Recommendations

Q. IS IT NECESSARY TO SELECT A SPECIFIC DECOMMISSIONING METHOD AT THIS TIME?

A. No. The actual method or combination of methods selected to decommission Palo Verde should be based on a detailed economic, engineering, and environmental evaluation of the alternatives considering the site and surroundings at the time of decommissioning and reflecting the latest experience in the decommissioning of similar nuclear power facilities. The owners of Palo Verde will make such evaluations near the time of final shutdown of the units.

Q. WHAT ARE YOUR RECOMMENDATIONS?

A. I recommend that, for planning purposes, the decommissioning cost funding be based upon removal of Palo Verde using the DECON alternative. This alternative provides the most reasonable means for amending/terminating the license for the site in the shortest possible time. Furthermore, this alternative avoids the long-term costs and commitments associated with the maintenance, surveillance and security requirements of the conventional delayed dismantling alternatives. Funding for DECON does not preclude using SAFSTOR in the future, but funding for SAFSTOR may remove DECON as an option due to funding limitations. The Commission has adopted the DECON alternative as a basis for funding nuclear plant decommissioning in every case in which a TLG witness has testified.

The DECON alternative also allows use of the plant's knowledgeable operating staff, a valuable asset to a well-managed, efficient decommissioning program. Equipment needed to support decommissioning operations such as cranes, ventilation systems, and radwaste processing equipment would be fully operational. In addition, the site would be available for other use in the near term, with the exception of the area immediately surrounding the plant's fuel storage facility.

VIII. Conclusion

Q. PLEASE SUMMARIZE YOUR TESTIMONY.

A. In 2019, TLG performed site-specific cost estimates for the decommissioning of Palo Verde. The total estimated cost for the decommissioning in 2019 dollars was $2,957.6 million. The study shows an increase of approximately $218 million dollars, or 8 percent, from the 2016 estimate. These amounts includes costs to remove all radioactive materials from the site which exceed the release criteria, terminate the NRC operating licenses, remove all structures above the three foot below grade elevation and backfill all below grade voids to the surface elevation, transfer all spent fuel from all three Fuel Buildings to the on-site ISFSI, operate this ISFSI until 2097 (excluding ISFSI security and operating staff and ISFSI operating expenses, which are assumed to be recovered from the DOE and therefore not included), and decommission the ISFSI following removal of all spent fuel and GTCC material by the DOE, currently estimated to occur in the year 2098.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes, it does.

RODERICK KNIGHT

Manager, Decommissioning

EDUCATION:

University of New Haven, BS Civil Engineering 1993
Magna Cum Laude, Selected to Chi Epsilon (Civil Engineering Honor Society)
University of Maine, BS Natural Resource Management 1981

SPECIAL QUALIFICATIONS:

- Cost Estimate development
- Report writing
- Client interaction
- Familiarity with Code of Federal Regulations
- CPM Scheduling analysis
- Ability to work through complex situations leading to defendable and realistic reports
- Computer proficiency, including the following: Microsoft Excel; Microsoft Word, Microsoft Project for Windows; several other spreadsheet / cost analysis programs

WORK EXPERIENCE:

TLG Services, LLC (an Entergy Company)

Manager, Decommissioning
2016 to present

- Manage cost estimating staff in the completion of various portions of the decommissioning cost estimates
- Listen to and respond to employee concerns and recommendations
- Verify all aspects of the decommissioning costs estimates adhere to TLG Services high quality standards
- Work with Clients to ensure they are receiving the best product available for their needs
- Maintain project schedules and budgets
- Ensure conformance to federal regulations

Knight Cost Engineering Services, LLC
President
2004 – 2016

- Worked on a contract basis as a Certified Cost Professional
- Cost estimating, planning and scheduling services
- Provided litigation and rate hearing support
- Developed decommissioning cost estimates for the nuclear industry, including utilities and research facilities

- Maintained extensive vendor contact in support of cost estimates
- Managed cost estimating staff in the completion of various portions of the decommissioning cost estimates
- Ensured conformance to federal regulations

Scientech, Inc.
1992 – 2004
Project Manager

- Developed decommissioning cost estimates for the nuclear industry
- Developed and meet project schedules and budgets
- Maintained extensive vendor contact in support of cost estimates
- Managed four to five engineers in the completion of various portions of the decommissioning cost estimates
- Maintained close client contact to ensure that their comments and concerns are incorporated into the project
- Ensured conformance to federal regulations
- Prepared cost estimates in support of rate hearings and litigation

Project Engineer

- Determined the extent of client-supplied technical information and verify that this information is adequate to support the project
- Investigated post-shutdown cost reduction methods
- Developed computer-generated models to standardize cost estimating methodologies
- Developed reports on decommissioning scheduling and cost analysis
- Support development of proposals for projects

TLG Engineering, Inc.
Project Engineer
1985 – 1992

- Coordinated all cost estimating components in preparation for a detailed cost estimate for nuclear power plant decommissioning
- Calculated structural design specifications
- Maintained the schedule and budget for the generation of cost estimates
- Contributed to the development of current methodology for accurate decommissioning cost estimates
- Developed a database for use within computer codes providing detailed cost estimates
- Instructed at conferences and hearings on nuclear power plant decommissioning

Industry Experience

- Acted as Project Manager for numerous TLG decommissioning cost studies from 2016 – 2020 for both United States and Canadian clients.
- Acted as project manager for several dismantling cost estimates for other power production facilities, including coal, gas, oil and wind.
- Assisted in the development of successful proposals to Utilities for developing decommissioning cost studies from 2016 - 2020.
- Prepared Asset Retirement Obligation (ARO) and Escalation Analysis reports for several clients from 2016 - 2020.
- Worked with TSSD developing and reviewing decommissioning cost estimates, 2016.
- Worked with Enercon Federal Services, Inc. in 2016 developing a decommissioning cost estimate for Electrobras Termonuclear S.A. in Brazil. This project was not finished when I joined Entergy.
- Worked as part of a team for a confidential client reviewing decommissioning cost estimates for facilities in Canada, 2015 and 2016.
- Presented at the 2014 Nuclear Energy Insider conference in Charlotte, North Carolina. Presentation was titled "How Utilities Can Prepare Accurate Decommissioning Cost Estimates."
- In 2014 worked with Radiation Safety & Control Services, LLC developing lesson plans and presenting lessons to personnel from Korean Hydro and Nuclear Power (KHNP) in South Korea.
- In 2014 worked as part of a team developing detailed site specific decommissioning cost estimates for the Vermont Yankee Nuclear Power
- Plant. The estimates included identification of labor costs, man-hours, duration hours, waste volumes, waste packaging and disposal costs.
- Participated in the Department of Energy Project Peer Review of the River Corridor Closure Project at the Hanford Site in Richland, WA. The purpose of the review was to assess the projects progress in the capital asset cleanup project.
- In 2012 and 2015 Developed decommissioning cost estimates for the Independent Spent Fuel Storage Installations at the Connecticut Yankee, Maine Yankee and Yankee Rowe sites.

- Developed Independent Cost Estimates (ICE) in support of reviews for DOE projects. One each in 2011, 2012, 2013, 2014 and 2015. These projects included both construction and decommissioning estimates.
- In 2011 and 2012 worked as part of a team developing decommissioning cost estimates for Atomic Energy of Canada Limited's (AECL) Chalk River Laboratories.
- From 2008 through 2014 developed decommissioning cost estimates for multiple facilities at Argonne National Laboratory in Argonne, IL including four buildings associated with the Intense Pulsed Neutron Source Complex; the Alpha Gamma Hot Cell Facility and Building 310.
- In 2006, 2009, 2012 and 2015 developed decommissioning cost estimates for Indiana Michigan Power Company's D. C. Cook Nuclear Power Plant. Cost estimates included numerous scenarios with various spent fuel shipping schedules and decommissioning methodologies.
- Developed spent fuel shipping schedules for various nuclear power plants based on various versions of the Department of Energy's Acceptance Priority Ranking (APR) and Annual Capacity Report (ACR).
- In summer of 2008 worked with Kiewit Federal Group developing a cost estimate for Northwest Energy's Columbia Generating Station main condenser replacement project.
- In fall of 2007 developed multiple project schedules for Environmental Power Company for various energy generation projects.
- From 2005 to present developed decommissioning cost estimates, project schedules, spent fuel disposition schedules and present value analysis for confidential clients (3 separate suits) in support of their claim against the United States Department of Energy for damages related to failure of the USDOE to take receipt of spent nuclear fuel beginning in 1998.
- In my career I have been responsible for the development of over 100 decommissioning cost estimates for the nuclear industry, including the analysis of spent fuel shipping schedules, effects of license extension on decommissioning and spent fuel storage costs, analyzed post-shutdown cost reduction methods and developed computer generated models to standardize cost estimating methodologies.
- In addition to developing decommissioning cost estimates for numerous commercial nuclear power plants, I have also been responsible for developing estimates for a variety of facilities. These estimates were developed for a number of reasons, including proposal support, owner estimates and project funding. This work includes the development of estimates at Los Alamos

National Laboratory, manufacturing facilities and research facilities. Most of these estimates included the remediation of both radiological and hazardous wastes.

- Performed numerous prudency reviews of cost estimates developed by others. In many cases these reviews were used by confidential clients in the determination whether to purchase nuclear power plants.
- One of eleven-member EM-6 expert Review Team for Department of Energy project at Brookhaven National Labs, Long Island, NY, April 3–7, 2000; Assessed cost, schedule, technical scope, management planning and control, and external factors for six DOE projects. These projects included both radiological and hazardous contamination requiring a variety of remedial action processes.

International Experience

- In the Fall of 2015 and Spring of 2016 worked for the IAEA in revising and developing new training material for decommissioning. Work is both home based and at the IAEA.
- In October of 2015 developed and presented information on developing decommissioning cost estimates as part of a decommissioning planning program at the IAEA. The program was in support of planning the decommissioning of research reactors in North Africa.
- In June of 2009 served as an expert in the review of the revised KRSKO Nuclear Power Plant Decommissioning Plan, jointly owned by Slovenia and Croatia. The Plan included revisions based on recommendations made in December of 2005. A detailed review was performed and included interviews with many of the authors. A detailed report was prepared and submitted to the IAEA.
- In December of 2006 served as an expert in the review of the revised BN-350 partial decommissioning cost estimate. The estimate is a detailed estimate of several areas of the facility and is based on the recommendations of the Experts from two earlier missions. This estimate is to be used as a template for estimating the remaining scope of work. A detailed review was performed and included interviews with many of the authors. A detailed report was prepared and submitted to the IAEA.
- In October of 2005 served as an expert in the review of the KRSKO Nuclear Power Plant Decommissioning Plan, jointly owned by Slovenia and Croatia. The Plan included revisions to the cost estimate based on recommendations made in December of 2003. This mission focused on the decommissioning cost estimate and included a presentation on the how to develop a decommissioning cost estimate that conforms to IAEA standards. A detailed review was performed and

included interviews with many of the authors. A detailed report was prepared and submitted to the IAEA.

- In the fall of 2004 worked as part of a Scientech team contracted by PA Government Services (PA) to assist in developing and promoting a seriesof reforms for the Armenian energy sector. Worked directly with PA's project office in Armenia. The main focus of the activities under this Agreement was to provide expertise on the Armenian Nuclear Power Plant (ANPP) decommissioning and nuclear safety issues. This work included reviewing the existing reports and studies on ANPP's decommissioning; developing a draft proposal for ANPP's decommissioning based on international experience; conducting a workshop for all stakeholders to present draft report on decommissioning the ANPP, report revision based on workshop feedback and finalizing report and plan for decommissioning.
- Served as an expert, in March of 2004, on an International Atomic Energy Agency (IAEA) mission to Vienna, Austria. The mission was to review the comments of the Peer Review held in 2003 (of which I served as an expert) and develop a plan which will lead to an internationally acceptable decommissioning plan for the BN-350 Nuclear Power Plant located in Aktau, Kazakhstan. A report was provided to the IAEA.
- Served as an expert on an International Atomic Energy Agency (IAEA) mission to Zagreb, Croatia, in December of 2003. The purpose of this mission was to provide technical support for the review of the decommissioning program for Krsko Nuclear Power Plant, jointly owned by Slovenia and Croatia. The mission consisted of the review of the Krsko NPP decommissioning cost estimate, to be used to establish a funding mechanism. A report of our findings was produced and submitted to the IAEA.
- Served as a member of a Peer Review Committee for the International Atomic Energy Agency (IAEA) in the summer of 2003. The purpose of this committee was to review the Decommissioning Plan for the BN-350 Nuclear Reactor in Kazakhstan and produce a report of our findings for the Kazakhstan Atomic Energy Committee. The mission included a site visit to the BN-350 reactor in Aktau, Kazakhstan.

Testimony/Deposition

- Provided Direct Written Testimony in 2020 in support of the decommissioning cost study prepared by TLG for the Palo Verde Generating Station on behalf of El Paso Electric Company.
- Provided Direct Written Testimony in support of the 2012, 2015 and 2018 D. C. Cook Decommissioning Cost Studies on behalf of Indiana Michigan Power Company.

- Testified in front of the Indiana Utility Regulatory Commission in May 2008 in support of the D. C. Cook Decommissioning Cost Study on behalf of Indiana Michigan Power Company.
- Provided Direct Written Testimony in support of the D. C. Cook Decommissioning Cost Study on behalf of Indiana Michigan Power Company in 2007.
- Provided cost estimates to a confidential client for litigation support in 2006. This work included providing deposition in the fall of 2006.
- In the winter of 2005 provided cost estimates to a confidential client for litigation support. Also provided deposition in May of 2005 in support of this work.
- Provided direct testimony as a material witness in the United States Court of Federal Claims in March of 2004 in support of their claim against the United States Department of Energy for damages due to failure of the USDOE to take receipt of spent nuclear fuel beginning in 1998.
- In December of 2003 provided deposition for a client in support of their claim against the United States Department of Energy for damages due to failure of the USDOE to take receipt of spent nuclear fuel beginning in 1998.

Additional

- Taught at decommissioning seminar in Newport, R.I. in Oct 1995
- Developed lesson plans and instructed at ANS Winter Meeting, 1999
- Passed Engineer in Training (EIT) exam in 1993

Publications

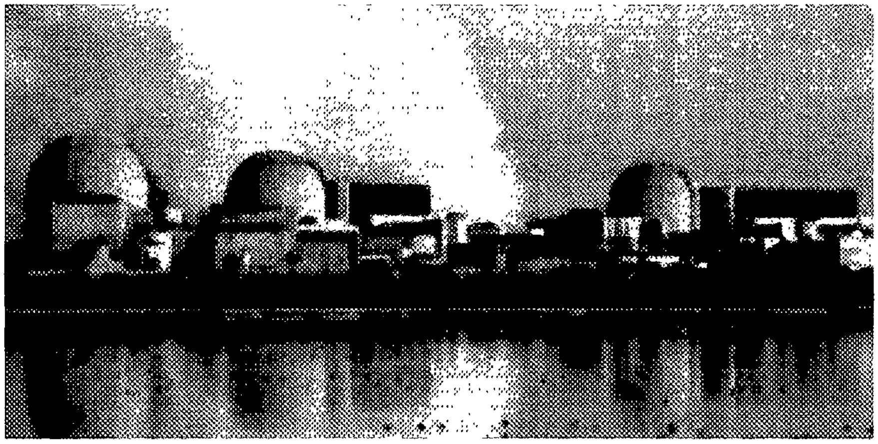
Presented a paper entitled "How Utilities Can Achieve More Accurate Decommissioning Cost Estimates" at American Nuclear Society Winter Meeting, Long Beach, CA, 1999. The paper was published in ANS Transactions, Volume 81, 1999

Document A04-1761-001, Rev. 1

2019 DECOMMISSIONING COST STUDY

for the

PALO VERDE NUCLEAR GENERATING STATION



Prepared for

Arizona Public Service Company

prepared by

TLG Services, Inc.
Bridgewater, Connecticut

July 2020

APPROVALS

Project Manager	Roderick W. Knight	7/28/2020
	Roderick W. Knight	**Date**
Project Engineer	Benjamin J. Stochmal	7/28/2020
	Benjamin J. Stochmal	**Date**
Technical Manager	Francis W. Seymore	7/28/2020
	Francis W. Seymore	**Date**

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APPENDICES

REVISION LOG

No.	Date	Item Revised	Reason for Revision
0	5/12/20		Original Issue
1	7/28/2019	Appendix N	Corrected Tables

ACRONYMS / DEFINITIONS

- AIF — Atomic Industrial Forum
- ALARA — As-Low-As-Reasonably Achievable
- CERCLA — Comprehensive Environmental Response, Compensation, and Liability Act
- CWS — Circulating Water System
- DAW — Dry Active Waste
- DOC — Decommissioning Operations Contractor
- DOE — Department of Energy
- DOT — Department of Transportation
- EPA — Environmental Protection Agency
- FA — Fuel assembly
- GTCC — Greater Than Class C
- IPs — Industrial Packages
- ISFSI — Independent Spent Fuel Storage Installation
- kW — Kilowatt
- LLRW — Low Level Radioactive Waste
- LTP — License Termination Plan
- LSA — Low Specific Activity
- MARSSIM — Multi-Agency Radiation Survey & Site Investigation Manual
- MOU — Memorandum of Understanding
- MSSS — Main Steam Supply System
- Mw — Megawatt
- NESP — National Environmental Studies Project
- NRC — Nuclear Regulatory Commission
- NSSS — Nuclear Steam Supply Systems
- NWPA — Nuclear Waste Policy Act
- OA — Operating Agent
- ORISE — Oak Ridge Institute for Science and Education
- P&IDs — Piping & Instrument Diagrams
- PERT — Program Evaluation and Review Technique
- PSDAR — Post-Shutdown Decommissioning Activities Report
- Palo Verde — Palo Verde Nuclear Generating Station
- RPV — Reactor Pressure Vessel
- SCO — Surface Contaminated Object
- TEDE — Total Effective Dose Equivalent
- TLG — TLG Services, Inc.
- UFSAR — Updated Final Safety Analysis Report

EXECUTIVE SUMMARY

This analysis, prepared for the Operating Agent (OA) of the Palo Verde Nuclear Generating Station (Palo Verde) by TLG Services, Inc. (TLG), evaluates the cost to decommission Palo Verde following the final cessation of plant operations. The total projected station cost for the DECON alternative is estimated at $2.96 billion, reported in 2019 dollars. The cost estimate includes the decommissioning of the three Palo Verde nuclear units, plus the decommissioning of the Water Reclamation Facility, the Water Reclamation Supply System Pipeline & Structures, the Evaporation Ponds, the Make-up Water Reservoirs, the Independent Spent Fuel Storage Facility (ISFSI), the Stored Steam Generators & Storage Facility (facility for storage of six retired steam generators), and the Stored Reactor Closure Heads & Storage Facility. The major cost contributors to the overall decommissioning cost are labor, radioactive waste disposal, and other removal-related activities (e.g. engineering, support equipment, capital expenditures for spent fuel containers). 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.

The costs to decommission Palo Verde are evaluated for the DECON decommissioning alternative. Regardless of the timing of the decommissioning activities, the estimates assume the eventual removal of all the contaminated and activated plant components and structural materials, such that the facility operator may then have unrestricted use of the site with no further requirement for an operating license.

This study provides estimates for decommissioning Palo Verde under current requirements and is based on present-day costs and available technology. Cost summaries for the various facilities are provided at the end of this section for the major cost components. In addition, the estimate includes the costs to transfer spent fuel from the spent fuel storage pools to the DOE and transfer fuel from the ISFSI to the DOE. This is consistent with the OA's assumption that most ISFSI / spent fuel related operational, maintenance and capital costs will be paid by reimbursements from the DOE.

The decommissioning scenario analyzed for the purpose of generating the estimate is described in Section 2. The assumptions are presented in Section 3. A decommissioning timeline and sequence of decommissioning activities are provided in Section 4 and Appendix D. The major cost contributors are identified in Section 6, and schedules of annual expenditures provided in Appendix B and Appendix N.

Detailed activity costs for each nuclear unit are provided in Appendix C. Detailed costs for the other facilities are provided in Appendices G, H, I, J, K, L, and M.

DECOMMISSIONING COST SUMMARY

	Cost, 2019$ 1 (thousands)	Schedule (years)
UNIT 1 (Appendix C-1) [2]		
PRE-SHUTDOWN [3]		
Early Planning Prior to Shutdown	1,858	3.0
Pre-Shutdown Planning	11,085	2.0
PREPARATIONS		
Post-Shutdown Transition	111,506	1.0
Decommissioning Preparations	78,061	0.5
DECOMMISSIONING		
NSSS Removal	272,278	2.0
Site Decontamination	230,738	2.5
Decontamination Following Wet Fuel	27,700	0.5
Delay Before License Termination	19,052	2.5
License Termination	23,677	0.8
SITE RESTORATION		
Site Restoration	44,943	1.9
GTCC shipping	32,486	0.04
Subtotal	853,384	16.7
UNIT 2 (Appendix C-2)		
PREPARATIONS		
Post-Shutdown Transition	89,055	0.7
Decommissioning Preparations	51,398	0.3
DECOMMISSIONING		
NSSS Removal	300,609	2.0
Site Decontamination	253,540	3.0
Decontamination Following Wet Fuel	27,604	0.5
Delay Before License Termination	12,377	1.6
License Termination	23,507	0.8
SITE RESTORATION		
Site Restoration	44,747	1.9
GTCC shipping	32,486	0.04
Subtotal	835,323	10.8

1 Columns may not add due to rounding
2 The appendix referenced in parenthesis provides the reference source for the data
3 Pre-shutdown planning activities are applicable to all three units but costs are assigned to Unit 1

DECOMMISSIONING COST SUMMARY (continued)

	Cost, 2019$ [1] (thousands)	Schedule (years)
Unit 3 (Appendix C-3) [2]		
PREPARATIONS		
Post-Shutdown Transition	88,911	0.7
Decommissioning Preparations	51,359	0.3
DECOMMISSIONING		
NSSS Removal	298,788	2.0
Site Decontamination	302,032	3.0
Decontamination Following Wet Fuel	34,373	0.5
License Termination	32,634	0.8
SITE RESTORATION		
Site Restoration	83,695	1.9
GTCC shipping	32,486	0.04
Subtotal	924,279	9.2
ISFSI (Appendix L)		
ISFSI Operations / Spent Fuel Transfer (Units 1, 2, & 3) Shutdown until End of Spent Fuel Transfer to DOE	121,440	n/a
ISFSI License Termination	15,848	n/a
ISFSI Demolition and Site Restoration	8,706	n/a
Subtotal	145,994	
OTHER FACILITIES		
Stored Steam Generators & Storage Facility (Appendix G)	57,074	n/a
Water Reclamation Facility (Appendix H)	11,027	n/a
Water Reclamation Supply System Pipeline & Structures (Appendix I)	54,024	n/a
Evaporation Ponds (Appendix J)	66,009	n/a
Make-up Water Reservoirs (Appendix K)	5,069	n/a
Stored Reactor Closure Heads & Storage Facility (Appendix M)	5,405	n/a
Subtotal	198,607	
STATION TOTAL	**2,957,587**	

1 Columns may not add due to rounding
2 The appendix referenced in parenthesis provides the reference source for the data

SUMMARY TABLE: LICENSE TERMINATION, SPENT FUEL MANAGEMENT AND NON-NUCLEAR COST

	License Termination		Spent Fuel Management		Site Restoration		Total Cost[1] (thousands)
Unit 1 (Appendix C-1)[2]	785,071	(92%)	13,902	(2%)	54,411	(6%)	853,384
Unit 2 (Appendix C-2)	769,585	(92%)	13,081	(2%)	52,657	(6%)	835,323
Unit 3 (Appendix C-3)	817,726	(88%)	11,620	(1%)	94,934	(10%)	924,279
Independent Spent Fuel Storage Facility (Appendix L)	-		145,994	(100%)	-		145,994
Stored Steam Generators and Storage Facility (Appendix G)	56,465	(99%)	-		609	(1%)	57,074
Water Reclamation Facility (Appendix H)	-		-		11,027	(100%)	11,027
Water Reclamation Supply System Pipeline & Structures (Appendix I)	-		-		54,024	(100%)	54,024
Evaporation Ponds (Appendix J)	-		-		66,009	(100%)	66,009
Make-up Water Reservoirs (Appendix K)	-		-		5,069	(100%)	5,069
Stored Reactor Closure Heads & Storage Facility (Appendix M)	5,288	(98%)	-		117	(2%)	5,405
Station Total	**2,434,134**	(82%)	**184,596**	(6%)	**338,856**	(11%)	**2,957,587**

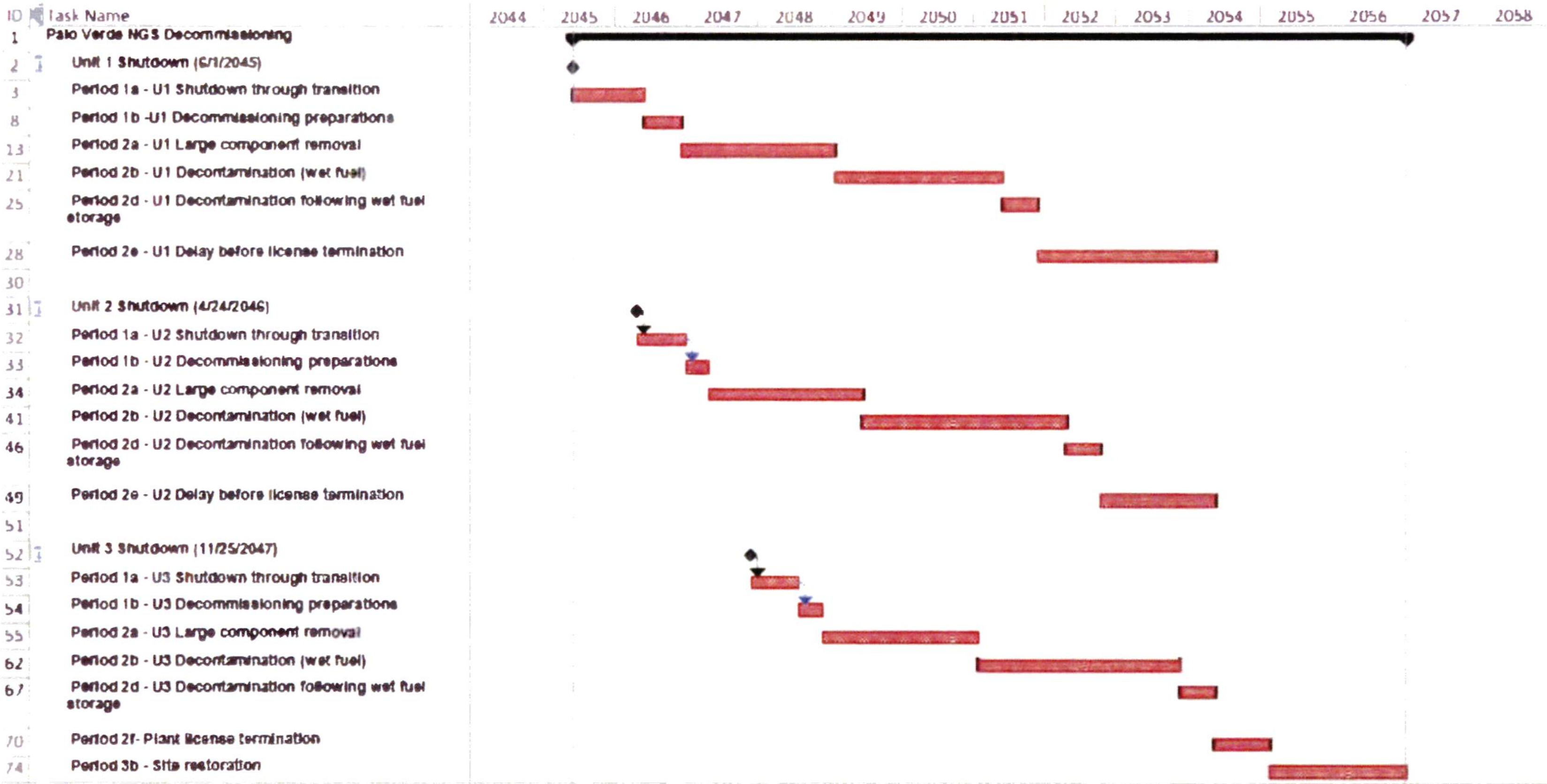
1 Columns may not add due to rounding
2 The appendix referenced in parenthesis provides the reference source for the data

2016 vs. 2019 DECOMMISSIONING COST ESTIMATE COMPARISON

	2016 Study Cost, 2016$ (thousands)	2016 Study Cost, 2019$ (thousands)[1]	2019 Study Cost, 2019$ (thousands)	Change '16-'19 (thousands)	% Chg.
Unit 1 (Appendix C-1) [2]					
Pre-shutdown	13,103	14,219	12,943	-1,276	-9%
Preparations	181,132	196,560	189,566	-6,994	-4%
Decommissioning	521,914	566,371	573,445	7,075	1%
Site Restoration	75,269	81,680	77,429	-4,251	-5%
Subtotal	791,417	858,831	853,384	-5,447	-1%
Unit 2 (Appendix C-2)					
Preparations	146,924	159,439	140,454	-18,986	-12%
Decommissioning	541,208	587,309	617,636	30,327	5%
Site Restoration	75,067	81,461	77,233	-4,228	-5%
Subtotal	763,200	828,209	835,323	7,113	1%
Unit 3 & Common Structures (Appendix C-3)					
Preparations	146,749	159,249	140,271	-18,978	-12%
Decommissioning	583,441	633,138	667,827	34,689	5%
Site Restoration	107,930	117,123	116,181	-942	-1%
Subtotal	838,119	909,510	924,279	14,769	1.6%
Subtotal Units 1, 2, & 3	2,392,736	2,596,550	2,612,986	16,435	1%
Independent Spent Fuel Storage Installation (Appendix L)	134,365	145,810	145,994	184	0%
Other Facilities					
Stored Steam Generators and Storage Facility (Appendix G)	74,071	80,380	57,074	-23,306	-29%
Water Reclamation Facility (Appendix H)	11,545	12,528	11,027	-1,502	-12%
Water Reclamation Supply System Pipeline & Structures (Appendix I)	52,421	56,886	54,024	-2,863	-5%
Evaporation Ponds (Appendix J)	60,732	65,905	66,009	104	0%
Make-up Water Reservoirs (Appendix K)	4,744	5,148	5,069	-79	-2%
Stored Reactor Closure Heads & Storage Facility (Appendix M)	8,487	9,210	5,405	-3,806	-41%
Subtotal	212,000	230,058	198,607	-31,451	-14%
Station Total [3]	**2,739,101**	**2,972,419**	**2,957,587**	**-14,832**	**0%**

1 Escalated using a 3-year composite index of 1.085 based upon BLS index "CPI Services"
2 The appendix referenced in parenthesis provides the reference source for the data
3 Columns may not add due to rounding

SUMMARY LEVEL MILESTONE SCHEDULE



Note: Removal of the Water Reclamation Facility, Water Reclamation Supply System Pipeline & Structures, Evaporation Ponds, Make-Up Water Reservoirs, Retired Steam Generators & Storage Facility, and the Stored Reactor Closure Heads & Storage Facility can begin any time after Unit 3 shutdown and must be completed by the end of the site license termination period for the nuclear units.

1. INTRODUCTION

This report presents estimates of the cost to decommission the Palo Verde Nuclear Generating Station (Palo Verde), for the DECON scenario described in Section 2, following a scheduled and permanent cessation of plant operations. The analysis is designed to provide the OA with sufficient information to assess its financial obligations as they pertain to the eventual decommissioning of the nuclear station. It is not a detailed engineering document, but a financial analysis prepared in advance of the detailed engineering that will be required to carry out the decommissioning.

This study incorporates two decommissioning cost reduction alternatives. These alternatives were initially evaluated as part of the 1998 decommissioning cost study, and they were subsequently included in the 2001, 2004, 2007, 2010, 2013 and 2016 decommissioning cost estimates. Appendix A is an excerpt from the 1998 study summarizing these alternatives. Two alternatives were approved by the OA for use in conjunction with the 1998 study: On-site disposal of clean fill, and OA to act as Decommissioning Operations Contractor (DOC). As DOC, the OA will provide contract management of the decommissioning labor force, including subcontractors, as well as direct all decontamination and dismantling activities.

Isolation of the spent fuel pool was also first incorporated into the 1998 base estimate, and has been retained in the subsequent studies. Section 2.2, Item 3, contains a further description of this activity. A complete discussion of the assumptions used in this estimate is presented in Section 3.

1.1 OBJECTIVES OF STUDY

The objective of this study is to prepare an estimate of the cost, schedule, and waste volume generated to decommission Palo Verde, including all common and supporting facilities. The study considered the integration of the three-unit dismantling, and the dismantling of the Water Reclamation Facility, the Water Reclamation Supply System Pipeline & Structures, the Evaporation Ponds, the Make-up Water Reservoirs, the Independent Spent Fuel Storage Installation (ISFSI), the Stored Steam Generators and Storage Facility, and the Stored Reactor Closure Heads & Storage Facility. However, the site's Transmission and Distribution System will remain in place and is not considered part of this decommissioning estimate.

Although essentially identical, the three units on the Palo Verde site were designed and constructed using the "slide along" concept, i.e., the second and third units followed along as the design of the first unit was finalized. The interconnection between the units was minimal since they were not built simultaneously. This schedule resulted in a differential in the start dates of commercial power operation, i.e., Unit No. 3 began commercial operation approximately two years after Unit No. 1. This differential is reflected in the dates for final shutdown and, correspondingly, the initiation of decommissioning activities. Since there are advantages to sequential decommissioning (e.g., a learning curve may increase the overall program efficiency), the offset in shutdown dates was retained in the decommissioning schedule. Consequently, the decommissioning sequence for the three units made use of this offset in integrating the dismantling program for the entire station.

Operating licenses were issued on December 31, 1984 for Unit 1; December 9, 1985 for Unit 2; and March 25, 1987 for Unit 3[1]*. Based upon the license renewal for all the units in 2011, for the purposes of this study the shutdown dates were taken as June 1, 2045 for Unit 1; April 24, 2046 for Unit 2; and November 25, 2047 for Unit 3. This time frame was used as an input to scheduling activities.

1.2 SITE DESCRIPTION

Palo Verde is located approximately 34 miles west of the nearest boundary of the city of Phoenix, in Maricopa County, Arizona. The three Nuclear Steam Supply Systems (NSSS) are standardized designs marketed by ABB/Combustion Engineering as "System 80s." A stretch power program to increase output has been implemented on all three units.

The NSSS of each unit consists of a pressurized water reactor with two independent primary coolant loops, each of which has two reactor coolant pumps and a steam generator. An electrically heated pressurizer and connecting piping complete the system. These systems are housed within seismic Category I reinforced concrete dry structures. Each such containment is a steel-lined, pre-stressed concrete cylinder with a hemispherical dome and a flat, reinforced concrete foundation mat. A welded stainless steel liner plate, anchored to the inside face of the containment, serves as a leak-tight membrane.

Heat produced in each reactor is converted to electrical energy by a Main Steam Supply System (MSSS). A turbine-generator system converts the thermal

* Annotated references for citations in Sections 1-6 are provided in Section 7.

energy of steam produced in the steam generators into mechanical shaft power and then into electrical energy. The plant's turbine-generators are each tandem compound, four-element units. They consist of one high-pressure double-flow and three low-pressure double-flow elements driving a direct-coupled generator at 1800 rpm. The turbines are operated in a closed feedwater cycle that condenses the steam; the heated feedwater is returned to the steam generators. Heat rejected in the main condensers is removed by the Circulating Water System (CWS).

The CWS 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. The circulating water pumps take suction from the intake structure and pump the circulating water through the main condensers. The cooling water is returned from the main condensers to the cooling towers.

1.3 REGULATORY GUIDANCE

The Nuclear Regulatory Commission (NRC or Commission) provided initial decommissioning requirements in its rule "General Requirements for Decommissioning Nuclear Facilities," issued in June 1988[2]. This rule set forth financial criteria for decommissioning licensed nuclear power facilities. The regulation addressed decommissioning planning needs, timing, funding methods, and environmental review requirements. The intent of the rule was to ensure that decommissioning would be accomplished in a safe and timely manner and that adequate 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," [3] which provided additional guidance to the licensees of nuclear facilities on the financial 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.

The rule defined three decommissioning alternatives as being acceptable to the NRC: DECON, SAFSTOR, and ENTOMB. The DECON alternative, the option evaluated for this analysis, assumes that any contaminated or activated portion of the plant's systems, structures, and facilities are removed or decontaminated to levels that permit the site to be released for unrestricted use shortly after the cessation of plant operations.

The rule also placed limits on the time allowed to complete the decommissioning process. For SAFSTOR, the process is restricted in overall duration to 60 years, unless it can be shown that a longer duration is necessary to protect public health and safety. The guidelines for ENTOMB are similar, providing the NRC with both sufficient leverage and flexibility to ensure that these deferred options are only used in situations where it is reasonable and consistent with the definition of decommissioning. At the conclusion of a 60-year dormancy period (or longer for ENTOMB if the NRC approves such a case), the site would still require significant remediation to meet the unrestricted release limits for license termination.

The 60-year restriction has limited the practicality for the ENTOMB alternative at commercial reactors that generate significant amounts of long-lived radioactive material. In 2017, the NRC's staff issued the regulatory basis for proposed new regulations on the decommissioning of commercial nuclear power reactors. In the regulatory basis, the NRC staff proposed removing any discussion of the ENTOMB option from existing guidance documents "since the method is not deemed practically feasible for current U.S. power reactors, and the timeframe for decommissioning completion using the ENTOMB method is generally inconsistent with current regulations."[4]

In 1996, the NRC published revisions to the general requirements for decommissioning nuclear power plants.[5] When the regulations were originally adopted in 1988, it was assumed that the majority of licensees would decommission at the end of the facility's operating licensed life. Since that time, several licensees permanently and prematurely ceased operations. Exemptions from certain operating requirements were required once the reactor was defueled to facilitate the decommissioning. Each case was handled individually, without clearly defined generic requirements. The NRC amended the decommissioning regulations in 1996 to clarify ambiguities and codify procedures and terminology as a means of enhancing efficiency and uniformity in the decommissioning process. The new amendments allow for greater public participation and better define the transition process from operations to decommissioning.

Under the revised regulations, licensees will submit written certification to the NRC within 30 days after the decision to cease operations. Certification will also be required once the fuel is permanently removed from the reactor vessel. Submittal of these notices will 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 a notice of permanent cessation of operations, the licensee is required to submit a Post-Shutdown Decommissioning Activities Report (PSDAR) to the NRC. The PSDAR describes the planned decommissioning activities, the associated sequence and schedule, and an estimate of expected costs. Prior to completing decommissioning, the licensee is required to submit an application to the NRC to terminate the license, which will include a License Termination Plan (LTP).

In 2011, the NRC published amended regulations to improve decommissioning planning and thereby reduce the likelihood that any current operating facility will become a legacy site.[6] The amended regulations require licensees to conduct their operations to minimize the introduction of residual radioactivity into the site, which includes the site's subsurface soil and groundwater. Licensees also may be required to perform site surveys to determine whether residual radioactivity is present in subsurface areas and to keep records of these surveys with records important for decommissioning. The amended regulations require licensees to report additional details in their decommissioning cost estimate as well as requiring additional financial reporting and assurances. These additional details, including an ISFSI decommissioning estimate, are included in this analysis.

1.3.1 High-Level Radioactive Waste Management

Congress passed the "Nuclear Waste Policy Act" [7] (NWPA) in 1982, assigning the federal government's long-standing responsibility for disposal of the spent nuclear fuel created by the commercial nuclear generating plants to the DOE. It was to begin accepting spent fuel by January 31, 1998; however, to date no progress in the removal of spent fuel from commercial generating sites has been made.

Today, the country is at an impasse on high-level waste disposal, even with the License Application for a geologic repository submitted by the DOE to the NRC in 2008. The Obama Administration cut the budget for the repository program while promising to "conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle ... and make recommendations for a new plan." Towards this goal, the Obama administration appointed a Blue Ribbon Commission on America's Nuclear Future (Blue Ribbon Commission) to make recommendations for a new plan for nuclear waste disposal. The Blue Ribbon Commission's charter includes a requirement that it consider "[o]ptions for safe storage of used nuclear fuel while final disposition pathways are selected and deployed."[8]

On January 26, 2012, the Blue Ribbon Commission issued its "Report to the Secretary of Energy" containing a number of recommendations on nuclear waste disposal. Two of the recommendations that may impact decommissioning planning are:

- "[T]he United States [should] establish a program that leads to the timely development of one or more consolidated storage facilities"
- "[T]he United States should undertake an integrated nuclear waste management program that leads to the timely development of one or more permanent deep geological facilities for the safe disposal of spent fuel and high-level nuclear waste"[9]

In January 2013, the DOE issued the "Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste," in response to the recommendations made by the Blue Ribbon Commission and as "a framework for moving toward a sustainable program to deploy an integrated system capable of transporting, storing, and disposing of used nuclear fuel."[10]

"With the appropriate authorizations from Congress, the Administration currently plans to implement a program over the next 10 years that:

- Sites, designs and licenses, constructs and begins operations of a pilot interim storage facility by 2021 with an initial focus on accepting used nuclear fuel from shut-down reactor sites;
- Advances toward the siting and licensing of a larger interim storage facility to be available by 2025 that will have sufficient capacity to provide flexibility in the waste management system and allows for acceptance of enough used nuclear fuel to reduce expected government liabilities; and
- Makes demonstrable progress on the siting and characterization of repository sites to facilitate the availability of a geologic repository by 2048."

The NRC's review of DOE's license application to construct a geologic repository at Yucca Mountain was suspended in 2011 when the Obama administration significantly reduced the budget for completing that work. However, the US Court of Appeals for the District of Columbia Circuit issued a writ of mandamus (in August 2013)[11] ordering NRC to comply with federal law and resume its review of DOE's Yucca Mountain repository license application to the extent of previously appropriated funding for the review. That review is now complete with the publication of the five-volume safety evaluation report. A supplement to DOE's environmental impact statement and an adjudicatory hearing on the contentions filed by interested parties must be completed before a licensing decision can be made.

Completion of the decommissioning process is dependent upon the DOE's ability to remove spent fuel from the site in a timely manner. DOE's repository program assumes that spent fuel allocations will be accepted for disposal from the nation's commercial nuclear plants, with limited exceptions, in the order (the "queue") in which it was discharged from the reactor. [12]

To achieve this objective, based upon the oldest fuel receiving the highest priority and an annual maximum rate of transfer of 3,000 metric tons of uranium, DOE would commence pickup of spent fuel from commercial generators no later than 2032, with fuel completely removed from the site by 2097. These dates were provided by the OA; different DOE acceptance schedules may result in different completion dates.

The NRC requires that licensees establish a program to manage and provide funding for the caretaking of all irradiated fuel at the reactor site until title of the fuel is transferred to the DOE.[13] Interim storage of the fuel, until the DOE has completed the transfer, will be at an on-site ISFSI.

An ISFSI, operated under a 10 CFR Part 50 General License (in accordance with 10 CFR 72, Subpart K [14]), has been constructed to support continued plant operations. The facility is assumed to be available to support future decommissioning operations. As such, following the final cessation of plant operations, the fuel from the wet storage pools, including the final cores, is either transferred to the DOE or packaged for interim storage at the ISFSI (depending upon the shutdown date assumed). Once the fuel handling buildings' wet storage pools are emptied, the buildings can be either decontaminated and dismantled or prepared for long-term storage.

For cost estimating purposes, the spent fuel storage scenario developed by the OA assumes that the existing ISFSI facility will be available to support decommissioning operations. The current OA spent fuel storage plan projects that spent fuel will be in dry storage at Palo Verde through the year 2097, but the OA believes that, with one exception, all costs to operate, and maintain the ISFSI will be paid by reimbursements from the DOE. The one item that the OA believes will not be reimbursable by the DOE is the final transfer of spent fuel, either from the spent fuel pool to the DOE or from the ISFSI dry storage facility to the DOE. Therefore, the costs for these activities are included in this estimate.

DOE has breached its obligations to remove fuel from reactor sites, and has also failed to provide the plant owners with information about how it will ultimately perform. DOE officials have stated that DOE does not have an obligation to accept already-canistered fuel without an amendment to DOE's contracts with plant licensees to remove the fuel (the "Standard Contract"), but DOE has not explained what any such amendment would involve. Consequently, the OA has no information or expectations on how DOE will remove fuel from the site in the future. In the absence of information about how DOE will perform, and for purposes of this analysis only, it is assumed that DOE will accept already-canistered fuel. If this assumption is incorrect, it is assumed that DOE will have liability for costs incurred to transfer the fuel to DOE-supplied containers.

1.3.2 <u>Low-Level Radioactive Waste Management</u>

The contaminated and activated material generated 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, [15] and its Amendments of 1985, [16] the states became ultimately responsible for the disposition of low-level radioactive waste generated within their own borders.

Arizona is a member of the Southwest Compact, which currently does not have an operational disposal site. For the purposes of the decommissioning estimate, the existing waste disposal options available for the Palo Verde site are used for this estimate.

With the exception of Texas, no new compact facilities have been successfully sited, licensed, and constructed. The Texas Compact disposal facility is now operational and waste is being accepted from generators within the Compact by the operator, Waste Control

Specialists (WCS). The facility is also able to accept limited volumes of non-Compact waste.

Disposition of the various waste streams produced by the decommissioning process considered all options and services currently available to Palo Verde. The majority of the low-level radioactive waste designated for direct disposal (Class A) [17] can be sent to Energy*Solutions'* facility in Clive, Utah. Therefore, disposal costs for Class A waste were based on Palo Verde's Life of Plant Agreement with Energy*Solutions*. This facility is not licensed to receive the higher activity portion (Classes B and C) of the decommissioning waste stream.

The WCS facility is able to receive the Class B and C waste. As such, for this analysis, Class B and C waste was assumed to be shipped to the WCS facility and disposal costs for the waste were based on current rates paid by Palo Verde, as well as publicly available pricing from WCS for irradiated hardware and for resin and filter packages for B and C wastes.

The dismantling of the components residing closest to the reactor core generates radioactive waste that may be considered unsuitable for shallow-land disposal (i.e., low-level radioactive waste with concentrations of radionuclides that exceed the limits established by the NRC for Class C radioactive waste (Greater-than Class C or GTCC)). The Low-Level Radioactive Waste Policy Amendments Act of 1985 assigned the federal government the responsibility for the disposal of this material. The Act also stated that the beneficiaries of the activities resulting in the generation of such radioactive waste bear all reasonable costs of disposing of such waste. However, to date, the federal government has not identified a cost, if any, for GTCC disposal or a schedule for acceptance.

For purposes of this analysis, the GTCC radioactive waste is assumed to be packaged and disposed of in a manner similar to high-level waste and at a cost equivalent to that envisioned for the spent fuel. The GTCC is packaged in the same canisters used for spent fuel and is assumed to be stored on site in the ISFSI and shipped to the DOE following completion of all spent fuel shipments.

1.3.3 Radiological Criteria for License Termination

In 1997, the NRC published Subpart E, "Radiological Criteria for License Termination [18] amending 10 CFR Part 20. This subpart provides radiological criteria for releasing a facility for unrestricted use. The regulation states that the site can be released for unrestricted use if radioactivity levels are such that the average member of a critical group would not receive a Total Effective Dose Equivalent (TEDE) in excess of 25 millirem per year, and provided that residual radioactivity has been reduced to levels that are As Low As Reasonably Achievable (ALARA). The decommissioning estimates for Palo Verde assume that the site will be remediated to a residual level consistent with the NRC-prescribed level for radioactive material.

It should be noted that the NRC and the Environmental Protection Agency (EPA) differ on the amount of residual radioactivity considered acceptable in site remediation. The EPA has two limits that apply to radioactive materials. An EPA limit of 15 millirem per year is derived from criteria established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or Superfund.[19] An additional limit of 4 millirem per year, as defined in 40 CFR Part 141.66, is applied to drinking water.[20]

On October 9, 2002, the NRC signed an agreement with the EPA on the radiological decommissioning and decontamination of NRC-licensed sites. The Memorandum of Understanding (MOU) [21] provides that the EPA will defer exercise of authority under the CERCLA for the majority of facilities decommissioned under NRC authority. The MOU also includes provisions for NRC and EPA consultation for certain sites when, at the time of license termination, (1) groundwater contamination exceeds EPA-permitted levels; (2) the NRC contemplates restricted release of the site; and/or (3) residual radioactive soil concentrations exceed levels defined in the MOU.

The MOU does not impose any new requirements on NRC licensees and should reduce the involvement of the EPA with NRC licensees who are decommissioning. Most sites are expected to meet the NRC criteria for unrestricted use, and the NRC believes that only a few sites will have groundwater or soil contamination in excess of the levels specified in the MOU that trigger consultation with the EPA.

However, if there are other hazardous materials on the site, the EPA may be involved in the cleanup. As such, the possibility of dual regulation remains for certain licensees. The present study does not include any costs for such an occurrence.

2. DECON DECOMMISSIONING ALTERNATIVE

Cost studies were developed to decommission the Palo Verde units for the NRC-approved DECON decommissioning alternative. This alternative deals with the immediate removal of all regulated radioactive material from the site and ultimate release of the site for unrestricted and/or alternative use. The following sections describe the basic activities associated with the DECON alternative. 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.

The DECON alternative, as defined by the NRC in the Code of Federal Regulations, is "the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations." This study does not address the cost to remove spent fuel from the site by the DOE; such costs will be funded through the surcharge on electrical generation (Please see Section 3.5.1 for more detail). However, the study does recognize the constraint imposed by the spent fuel residing on site during the decommissioning process, and also the costs associated with the final transfer of the spent fuel containers to the DOE after the shutdown of each of the units, as well as the decontamination and demolition of the ISFSI following removal of all spent fuel and GTCC material.

The conceptual approach that the NRC has described in its regulations divides decommissioning into three phases. The initial phase commences with the effective date of permanent cessation of operations and involves the transition of both plant and licensee from reactor operations (i.e., power production) to facility de-activation and closure. During the first phase, notification is to be provided to the NRC certifying the permanent cessation of operations and the removal of fuel from the reactor vessel. The licensee would then be prohibited from reactor operation.

The second phase encompasses activities during the storage period or during major decommissioning activities, or a combination of the two. The third phase pertains to the activities involved in license termination. The decommissioning estimate developed for Palo Verde is also divided into phases or periods; however, demarcation of the phases is based upon major milestones within the project or significant changes in the projected expenditures.

2.1 Period 0 – Pre-Shutdown

In anticipation of the cessation of plant operations, detailed preparations are undertaken to provide a smooth transition from plant operations to site decommissioning. Through implementation of a staffing transition plan, the organization required to manage the intended decommissioning activities is assembled from available plant staff and outside resources. Preparations include the planning for permanent defueling of the reactor, revision of technical specifications applicable to the operating conditions and requirements, a characterization of the facility and major components, and the development of the PSDAR.

In addition to the PSDAR, two additional documents will be required by the NRC in support of the decommissioning program. The first is a Site-Specific Decommissioning Cost Estimate, which will give in greater detail the expected expenditures and time frames for the various aspects of the decommissioning scenario selected by the Owners of Palo Verde. With the NRC acceptance of the Site-Specific DCE, the owners will have full access to their decommissioning trust funds. The second document is an Irradiated Spent Fuel Management Plan, which will detail the expected time table and costs for the caretaking and transfer of the spent fuel to the DOE.

The PSDAR, required within two years of the notice to cease operations, provides a description of the licensee's planned decommissioning activities, a timetable, and the associated financial requirements of the intended decommissioning program. Upon receipt of the PSDAR, the NRC will make the document available to the public for comment in a local hearing to be held in the vicinity of the reactor site. Ninety days following submittal and NRC receipt of the PSDAR, the licensee may begin to perform major decommissioning activities under a modified 10 CFR § 50.59 procedure, i.e., without specific NRC approval. Major activities are defined as any activity that results in permanent removal of major radioactive components, permanently modifies the structure of the containment, or results in dismantling components (for shipment) containing GTCC, in accordance with 10 CFR Part 61. Major components are further defined as comprising the reactor vessel and internals, large bore reactor recirculation system piping, and other large components that are radioactive. The NRC includes the following additional criteria for use of the 10 CFR § 50.59 process in decommissioning. The proposed activity must not:

- foreclose release of the site for possible unrestricted use,
- significantly increase decommissioning costs,

- cause any significant environmental impact, or
- violate the terms of the licensee's existing license.

Existing operational technical specifications are reviewed and modified to reflect plant conditions and the safety concerns associated with permanent cessation of operations. The environmental impact associated with the planned decommissioning activities is also considered. Typically, a licensee will not be allowed to proceed if the consequences of a particular decommissioning activity are greater than that bounded by previously evaluated environmental assessments or impact statements. In this instance, the licensee would have to submit a license amendment for the specific activity and update the environmental report.

The decommissioning program outlined in the PSDAR will be designed to accomplish the required tasks within the ALARA guidelines (as defined in 10 CFR Part 20) for protection of personnel from exposure to radiation hazards. It will also address the continued protection of the health and safety of the public and the environment during the dismantling activity. Consequently, with the development of the PSDAR, activity specifications, cost-benefit and safety analyses, work packages, and procedures would be assembled in support of the proposed decontamination and dismantling activities.

2.2 Period 1 – Preparations

The following activities are initiated following final plant shutdown and in preparation for actual decommissioning activities:

- Characterization of the site and surrounding environs. This includes radiation surveys of work areas, major components (including the reactor vessel and its internals), internal piping, and primary shield walls.
- Isolation of the spent fuel storage pools and fuel handling systems, such that decommissioning operations can commence on the balance of the plant. Decommissioning operations are scheduled around the fuel handling area to optimize the overall project schedule. The fuel is transferred to the DOE or the ISFSI as it decays to the point that it meets the minimum cooling time criteria of the canisters. Consequently, it is assumed that the fuel pools remain operational for approximately six years following the cessation of plant operations. The spent fuel pools are assumed to be emptied six years after that unit's final shutdown date.

- Specification of transport and disposal requirements for activated materials and/or hazardous materials, including shielding and waste stabilization.
- Development of procedures for occupational exposure control, control and release of liquid and gaseous effluent, processing of radwaste (including dry-active waste, resins, filter media, metallic and non-metallic components generated in decommissioning), site security and emergency programs, and industrial safety.

2.3 Period 2 – Decommissioning Operations

This period includes the physical decommissioning activities associated with the removal and disposal of contaminated and activated components and structures, including the successful termination of the 10 CFR Part 50 operating licenses. Significant decommissioning activities in this phase include:

- Construction of temporary facilities and/or modification of existing facilities to support dismantling activities. This may include a centralized processing area to facilitate equipment removal and component preparations for off-site disposal.
- Reconfiguration and modification of site structures and facilities as needed to support decommissioning operations. This may include the upgrading of roads (on- and off-site) as required to facilitate hauling and transport. Modifications may be required to the containment structure to facilitate access of large/heavy equipment. Modifications may also be required to the refueling area of the buildings to support the segmentation of the reactor vessel internals and component extraction.
- Design and fabrication of temporary and permanent shielding to support removal and transportation activities, construction of contamination control envelopes, and the procurement of specialty tooling.
- Procurement (lease or purchase) of shipping cask, cask liners, and industrial packages.
- Decontamination of components and piping systems as required to control (minimize) worker exposure.
- Removal of piping and components no longer essential to support decommissioning operations.

- Removal of control rod drive housings and the head service structure from reactor vessel head. Segmentation of the vessel closure head.
- Removal and segmentation of the upper internals assemblies. Segmentation will maximize the loading of the shielded transport casks, i.e., by weight and activity. The operations are conducted under water using remotely operated tooling and contamination controls.
- Disassembly and segmentation of the remaining reactor internals, including the core shroud and lower core support barrel. Some material is expected to exceed Class C disposal requirements. As such, the segments will be packaged in modified fuel storage canisters for geologic disposal.
- This study assumes that each unit has legacy GTCC material present in the spent fuel pool at final shutdown. Weight equivalent to the capacity of two GTCC storage canisters are assumed per unit. This material will be held on the ISFSI pad until the DOE removes all GTCC canisters from the site.
- Segmentation of the reactor vessel. A shielded platform is installed for segmentation as cutting operations are performed in-air using remotely operated equipment within a contamination control envelope. The water level is maintained just below the cut to minimize the working area dose rates. Segments are transferred in-air to containers that are stored under water, for example, in an isolated area of the refueling canal.
- Removal of the activated portions of the concrete biological shield and accessible contaminated concrete surfaces. If dictated by the steam generator and pressurizer removal scenarios, those portions of the associated steam generator cubicles necessary for access and component extraction are removed.
- Removal of the steam generators and pressurizer for material recovery and controlled disposal. These components can serve as their own burial containers provided that all penetrations are properly sealed and the internal contaminants are stabilized, e.g., with grout. Steel shielding will be added, as necessary, to those external areas of the package to meet transportation limits and regulations. Additional shielding is not required for the retired (stored) steam generators.
- Retired (stored) closure heads will be shipped intact by rail to the disposal site.
- Transfer of the spent fuel from the storage pools to the ISFSI for interim storage or DOE.

At least two years prior to the anticipated date of license termination, an LTP is required. Submitted as a supplement to the Updated Final Safety Analysis Report (UFSAR) or its equivalent, 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 the end use 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, make the plan available for public comment, and schedule a local hearing. LTP approval will be subject to any conditions and limitations as deemed appropriate by the Commission. The licensee may then commence with the final remediation of site facilities and services, including:

- Removal of remaining plant systems and associated components as they become nonessential to the decommissioning program or worker health and safety (e.g., waste collection and treatment systems, electrical power, and ventilation systems).
- Removal of the steel liners from the refueling canal, disposing of the activated and contaminated sections as radioactive waste. Removal of any activated/ contaminated concrete.
- Surveys of the decontaminated areas of the containment structures.
- Removal of the contaminated equipment and material from the auxiliary and fuel buildings, and any other contaminated facility. Use radiation and contamination control techniques until radiation surveys indicate that the structures and equipment can be released for unrestricted access and conventional demolition. This activity may necessitate the dismantling and disposition of most of the systems and components (both clean and contaminated) located within these buildings. This activity will facilitate surface decontamination and subsequent verification surveys required prior to obtaining release for demolition.
- Removal of the remaining components, equipment, and plant services in support of the area release survey(s).
- Routing of material removed in the decontamination and dismantling process to a central processing area. Material certified to be free of contamination is released for unrestricted disposition, e.g., as scrap, recycle, or general disposal. Contaminated material is characterized and segregated for additional off-site processing (disassembly, chemical cleaning, volume reduction, and waste treatment), and/or packaged for controlled disposal at a LLRW disposal facility.

Incorporated into the LTP is the Final Survey Plan. This plan identifies the radiological surveys to be performed once the decontamination activities are completed and is developed using the guidance provided in the "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)".[22] This document incorporates the statistical approaches to survey design and data interpretation used by the EPA. It also identifies state-of-the-art, commercially available instrumentation and procedures for conducting radiological surveys. Use of this guidance ensures that the surveys are conducted in a manner that provides a high degree of confidence that applicable NRC criteria are 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 amend the operating license(s) to reduce the licensed area to the ISFSI area if it determines that site remediation has been performed in accordance with the LTP, and that the terminal radiation survey and associated documentation demonstrate that the property (exclusive of the ISFSI) is suitable for release.

2.4 Period 3 – Site Restoration

Following completion of decommissioning operations, site restoration activities begin. Efficient removal of the contaminated materials and verification that residual radionuclide concentrations are below the NRC limits will result in substantial damage to many of the structures. Although performed in a controlled and safe manner, blasting, coring, drilling, scarification (surface removal), and the other decontamination activities will substantially degrade power block structures, including the reactor and auxiliary buildings. Under certain circumstances, verifying that subsurface radionuclide concentrations meet NRC site release requirements will require removal of grade slabs and lower floors, potentially weakening footings and structural supports. This removal activity will be necessary for those facilities and plant areas where historical records, when available, indicate the potential for radionuclides having been present in the soil indicate system failures, or where it is required to confirm that subsurface process and drain lines were not breached over the operating life of the station.

Dismantling of site structures following decommissioning is clearly the most appropriate and cost-effective option. It is unreasonable to anticipate that these structures would be repaired and preserved after the radiological contamination is removed. The effort to dismantle site structures with a work force already mobilized on site is more efficient than if the process were deferred. Site facilities quickly degrade without maintenance, adding additional expense and creating potential hazards to the public as well as to future workers. Abandonment creates a breeding ground for vermin infestation as well as other biological hazards.

This cost study presumes that non-essential structures and site facilities are dismantled as a continuation of the decommissioning activity. Foundations and exterior walls are removed to a nominal depth of three feet below grade. The three-foot depth allows for the placement of gravel for drainage, as well as topsoil, so that vegetation can be established for erosion control. Site areas affected by the dismantling activities are restored and the plant area graded as required to prevent ponding and inhibit the refloating of subsurface materials.

Non-contaminated concrete rubble produced by demolition activities is processed to remove reinforcing steel and miscellaneous embedments. The processed material is then used on site to backfill foundation voids. Excess materials are trucked to an on-site landfill.

2.5 ISFSI Operations and Decommissioning

Transfer of spent fuel to the DOE will be initially from the spent fuel pools and subsequently from the ISFSI once the fuel pools have been emptied and the structures released for decommissioning. This study only includes ISFSI-related costs after Unit 1 shutdown through the end of ISFSI fuel operations and the final decommissioning and dismantling costs of the ISFSI. The spent fuel costs included are limited to the loading and transfer of the canisters to the DOE from the spent fuel pool to a DOE transport vehicle, or transfers of spent fuel canisters from the ISFSI to the DOE transport vehicle. These costs are shown in Appendix L.

When all fuel and GTCC canisters from the ISFSI have been shipped to other locations, the ISFSI will be decommissioned. The Commission will terminate the 10 CFR Part 50 general license in accordance with an ISFSI license termination plan.

The assumed design for the ISFSI is based upon the use of a multi-purpose canister which contains the spent fuel assemblies, and a concrete overpack that the canister is placed within for pad storage. The overpack liners are assumed to have some level of neutron-induced activation, as a result of the long-term storage of the fuel, i.e., to levels exceeding free-release limits. As an allowance, seven overpacks per unit (site total of 21) are assumed to require remediation, equivalent to the number of overpacks required to accommodate the final core offloads at Palo Verde. The remaining overpacks, once the canisters containing the spent fuel assemblies have been removed, will be dismantled using conventional techniques for the demolition of reinforced concrete. The concrete storage pad will then be removed, and the area graded and landscaped to conform to the surrounding environment.

3. COST ESTIMATE

The cost analysis prepared for decommissioning Palo Verde consider the unique features of the site, including the NSSS, power generation systems, support services, site buildings, and ancillary facilities. The basis of the estimates, including the sources of information relied upon, the estimating methodology employed, site-specific considerations, and other pertinent assumptions, is described in this section.

3.1 BASIS OF ESTIMATE

A site-specific cost estimate was developed using drawings and plant documents provided by the OA. Components were inventoried from the mechanical and electrical Piping & Instrument Diagrams (P&IDs). 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 the OA 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. This study assumes that the OA will act as the DOC and provide direct management of the decommissioning operations for the project. As DOC, the OA will provide contract management of the decommissioning labor force, including subcontractors, as well as directing all decontamination and dismantling activities.

The utility staffing levels for this estimate reflect the same number of personnel as used in the 2016 estimate. Security however, was modified somewhat in consideration of recent decommissioning project experience and licensee feedback.

The revised security model is based on the existing operating levels as provided by Palo Verde. The operating staff levels are divided equally between all three units at Unit 1 shutdown. As spent fuel conditions progress from wet to dry and decommissioning activities are completed the staff is reduced accordingly. The staffing levels per unit will maintain access control, material control, and safeguard the spent fuel (in accordance with the requirements of 10 CFR Part 37, Part 72, and Part 73).

3.2 METHODOLOGY

The methodology used to develop the estimates follows the basic approach originally presented in the AIF/NESP-036 study report, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates" [23], and the DOE "Decommissioning Handbook" [24]. These documents present a unit factor method for estimating decommissioning activity costs, which simplifies the estimating calculations. Unit factors for concrete removal ($/cubic yard), steel removal ($/ton), and cutting costs ($/inch) were developed using local labor rates. The activity-dependent costs were estimated with the item quantities (cubic yards and tons), developed from plant drawings and inventory documents. Removal rates and material costs for the conventional disposition of components and structures relied upon information available in the industry publication, "Building Construction Cost Data," published by RSMeans [25].

This analysis reflects lessons learned from TLG's involvement in the Shippingport Station Decommissioning Project, completed in 1989, as well as the decommissioning of the Cintichem reactor, hot cells, and associated facilities, completed in 1997. In addition, the planning and engineering for the Rancho Seco, Trojan, Yankee Rowe, Big Rock Point, Maine Yankee, Humboldt Bay-3, Oyster Creek, Connecticut Yankee, Crystal River, Vermont Yankee, Fort Calhoun and Pilgrim nuclear units have provided additional insight into the process, the regulatory aspects, and the technical challenges of decommissioning commercial nuclear units.

The unit factor method provides a demonstrable basis for establishing reliable cost estimates. The detail provided in the unit factors, including activity duration, labor costs (by craft), and equipment and consumable costs, ensures that essential elements have not been omitted. Appendix E presents the detailed development of a typical unit factor. Appendix F provides the values contained within one set of factors developed for this analysis.

Regulatory Guide 1.184[26] Revision 1, issued in October 2013, describes the methods and procedures that are acceptable to the NRC staff for implementing the requirements that relate to the initial activities and the major phases of the decommissioning process. The costs and schedules presented in this analysis follow the general guidance and sequence in the regulations. The format and content of the estimates is also consistent with the recommendations of Regulatory Guide 1.202,[27] issued February 2005.

Work Difficulty Factors

TLG has historically applied work difficulty adjustment factors (WDFs) to account for the inefficiencies in working in a power plant environment. WDFs were assigned to each unique set of unit factors, commensurate with the inefficiencies associated with working in confined, hazardous environments. The ranges used for the WDFs are as follows:

• Access Factor	10% to 20%
• Respiratory Protection Factor	10% to 50%
• Radiation/ALARA Factor	10% to 40%
• Protective Clothing Factor	10% to 30%
• Work Break Factor	8.33%

The factors and their associated range of values were developed in conjunction with the AIF/NESP-036 study. The application of the factors is discussed in more detail in that publication.

Scheduling Program Durations

The unit factors, adjusted by the WDFs as described above, are applied against the inventory of materials to be removed in the radiologically controlled areas. The resulting man-hours, or crew-hours, are used in the development of the decommissioning program schedule, using resource loading and event sequencing considerations. The scheduling of conventional removal and dismantling activities are based upon productivity information available from the "Building Construction Cost Data" publication.

An activity duration critical path is used to determine the total decommissioning program schedule. The schedule is relied upon in calculating the carrying costs, which include program management, administration, field engineering, equipment rental, and support services such as quality control and security. This systematic approach for assembling decommissioning estimates ensures a high degree of confidence in the reliability of the resulting cost estimate.

3.3 IMPACT OF DECOMMISSIONING MULTIPLE REACTOR UNITS

In estimating the near simultaneous decommissioning of three co-located reactor units there can be opportunities to achieve economies of scale, by sharing costs between units, and coordinating the sequence of work activities. There will also be schedule constraints, particularly where there are requirements for specialty equipment and staff, or practical limitations on when final status surveys can take place. For purposes of the estimates, Units 1, 2 and 3 are assumed to be essentially identical. Common facilities have been assigned to Unit 3. A summary of the principal impacts is listed below.

- The sequence of work generally follows the principal that the work is done at Unit 1 first, followed by similar work at Units 2 and 3. This permits the experience gained at Unit 1 to be applied by the workforce at the later units. It should be noted however, that the estimates do not consider productivity improvements at the later units, since there is little documented experience with decommissioning multiple units simultaneously. The work associated with developing activity specifications and procedures can be considered essentially identical between the units, therefore the later units' costs are assumed to be a fraction of the first unit (~ 43%).
- Segmenting the reactor vessel and internals will require the use of special equipment. The decommissioning project will be scheduled such that later unit's reactor internals and vessel are segmented after the activities at Unit 1 have been completed.
- Some program management and support costs, particularly costs associated with the more senior positions, can be avoided with multiple reactors undergoing decommissioning simultaneously. As a result, the estimates are based on a "lead" unit that includes these senior positions, and an "additional" unit that excludes these positions. The designation as lead is based on the unit undertaking the most complex tasks (for instance vessel segmentation) or performing tasks for the first time.
- The final radiological survey schedule is also affected by a multi-unit decommissioning schedule. It would be considered impractical to try to complete the final status survey of Unit 1, while Units 2 and 3 still have ongoing radiological remediation work and waste handling in process. As such, the transfer of the spent fuel from the storage pools and subsequent decontamination of the fuel buildings is coordinated so as to synchronize the final status survey for the station.
- The final demolition of buildings at Units 1, 2 and 3 are considered to take place concurrently. This is considered a reasonable assumption since access to the buildings is considered good at the station.

- Unit 1, as the first unit to enter decommissioning, incurs the majority of site characterization costs.
- Shared systems and structures are generally assigned to Unit 3.
- Station costs such as emergency response fees, regulatory agency fees, corporate overhead, and insurance are generally allocated on an equal basis between the units.

3.4 FINANCIAL COMPONENTS OF THE COST MODEL

TLG's proprietary decommissioning cost model, DECCER, produces a number of distinct cost elements. These direct expenditures, however, do not comprise the total cost to accomplish the project goal, i.e., license termination and site restoration.

3.4.1 Contingency

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, and labor stoppages. 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 funds to cover these types of expenses.

The activity- and period-dependent costs are combined to develop the total decommissioning cost. 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 [27] 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 analysis 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 analysis, does not account for price escalation and inflation in the cost of decommissioning over the remaining operating life of the station.

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. 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.

For example, the most technologically challenging task in decommissioning a commercial nuclear station is the disposition of the reactor vessel and internal components, now highly radioactive after a lifetime of exposure to core activity. The disposition of these components forms the basis of 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 expected optimization, however, 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 the operation of highly specialized tooling, field conditions, and water clarity.

Contingency funds are an integral part of the total cost to complete the decommissioning process. Exclusion of this component puts at risk a successful completion of the intended tasks and, potentially, subsequent related activities. For this study, TLG examined the major activity-related problems (decontamination, segmentation, equipment handling, packaging, transport, and waste disposal) that necessitate a contingency. Individual activity contingencies ranged from 10% to 75%, depending on the degree of difficulty judged to be appropriate from TLG's actual decommissioning experience. The contingency values used in this study are as follows:

• Decontamination	50%
• Contaminated Component Removal	25%
• Contaminated Component Packaging	10%
• Contaminated Component Transport	15%
• Low-Level Radioactive Waste Disposal	25%
• Reactor Segmentation	75%
• NSSS Component Removal	25%
• Reactor Waste Packaging	25%
• Reactor Waste Transport	25%
• Reactor Vessel Component Disposal	50%
• GTCC Disposal	15%
• Non-Radioactive Component Removal	15%
• Heavy Equipment and Tooling	15%
• Supplies	25%
• Engineering	15%
• Energy	15%
• Characterization and Termination Surveys	30%
• Construction	15%
• Taxes and Fees	10%
• Insurance	10%
• Staffing	15%
• Spent Fuel Storage (Dry) Systems	15%
• Spent Fuel Transfer Costs	15%
• Operations and Maintenance Expenses	15%
• ISFSI Decommissioning	25%

The contingency values are applied to the appropriate components of the estimates on a line item basis. A composite value is then reported at the end of each estimate. For example, the composite contingency values are 19.3%, 19.6%, and 19.3% for Units 1, 2, and 3, respectively.

Table L of Appendix L, the ISFSI decommissioning calculation, uses a flat 25% contingency added at the end of the calculation.

Two of the owners of the Palo Verde station are regulated utilities that are based in states that have specific requirements for the application of contingency as it relates to nuclear power plant decommissioning cost estimates. The California Public Utilities Commission has expressed a desire for owners to conservatively establish an appropriate contingency factor for inclusion in the decommissioning revenue requirements. To that end, a document[28] was prepared by Pacific Gas and Electric Company to address the California commission's request. In addition to the contingency based on the AIF guidelines as identified above, additional contingency was added to the consolidated cash flows in Appendix O to accomplish this need. Additional contingency was added to reflect an overall project contingency of 25%. This contingency was incorporated on a line item basis, with each line item receiving a pro-rated share of the increase. The nominal increase in contingency to achieve an overall contingency rate of 25% is a multiplier of 1.288 as a site average; each Appendix has a separate calculation to arrive at a 25% value.

The Public Utility Commission of Texas has issued regulations regarding contingency within nuclear decommissioning cost estimates. [30] The Commission's Substantive Rule §25.231(b)(1)(F)(i) requires use of a contingency of 10% of the cost of decommissioning. As a modification to the contingency based on the AIF guidelines as identified above, an administrative reduction was incorporated in the overall contingency on the cash flows in Appendix P to fulfill this requirement. This contingency reduction was incorporated on a line item basis, with each line item receiving a pro-rated share of the decrease. The nominal decrease in contingency to achieve an overall contingency rate of 10% is a multiplier of 0.515 as a site average; each Appendix has a separate calculation to arrive at a 10% value.

3.4.2 Financial Risk

In addition to the routine uncertainties addressed by contingency, another cost element that is sometimes necessary to consider when bounding decommissioning costs relates to uncertainty, or risk. Examples can include changes in work scope, pricing, job performance, and other variations that could conceivably, but not necessarily, occur. Consideration is sometimes necessary to generate a level of confidence in the estimate, within a range of probabilities. TLG considers these types of costs under the broad term "financial risk." Included within the category of financial risk are:

- Delays in approval of the decommissioning plan due to intervention, public participation in local community meetings, legal challenges, and national and local hearings.
- 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 national commitments, e.g., in the ability to accommodate certain waste forms for disposition or in the timetable for such, e.g., the start and rate of acceptance of spent fuel by the DOE.
- Pricing changes for basic inputs such as labor, energy, materials, and disposal. Items subject to widespread price competition (such as materials) may not show significant variation; however, others such as waste disposal could exhibit large pricing uncertainties, particularly in markets where limited access to services is available.

This cost study does not add any additional costs to the estimate for financial risk, since there is insufficient historical data from which to project future liabilities. Consequently, the areas of uncertainty or risk are revisited periodically and addressed through repeated revisions or updates of the base estimate.

3.5 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 impacts of these considerations are identified in this section.

3.5.1 Spent Fuel Disposition

The cost to dispose of spent fuel generated from plant operations is not reflected within the estimates to decommission Palo Verde. Ultimate disposition of the spent fuel is within the province of the DOE's Waste Management System, as defined by the Nuclear Waste Policy Act. Any delay in the transfer of spent fuel may increase the on-site management costs. As such, the disposal cost was financed by a 1 mill/kWhr surcharge paid into the DOE's waste fund during operations. On November 19, 2013, the U.S. Court of Appeals for the D.C. Circuit ordered the Secretary of the Department of Energy to suspend collecting annual fees for nuclear waste disposal from nuclear power plant operators until the DOE has conducted a legally adequate fee assessment.

The NRC does, however, require licensees to establish a program to manage and provide funding for the management of all irradiated fuel at the reactor site until title of the fuel is transferred to the Secretary of Energy. This requirement is prepared for through inclusion of transfer costs for the spent fuel containers to the DOE within the estimates, as described below.

For the basis of this cost study, it is assumed the existing Palo Verde ISFSI will continue storing spent fuel throughout the decommissioning of Palo Verde, with the OA providing operation and maintenance of the facility through the license termination and site restoration of the ISFSI in 2098. This study assumes no transfer of fuel among the three Palo Verde units. Table 3.1 provides details regarding the spent fuel disposition assumptions used in this analysis. Upon each unit's shutdown, it is assumed that the operation and maintenance cost of the spent fuel pools is a decommissioning cost. The decommissioning organization is expected to assume management responsibilities for all fuel bundles in the fuel pools at each unit's shutdown. Each unit includes the continued cost of wet storage of the spent fuel until each cycle has decayed for six years from reactor core discharge date.

Within six years of each unit's shut down, some spent fuel will be transferred from the pools to the DOE and the remainder will be relocated to the ISFSI until such time that transfer to a DOE permanent or interim storage facility can be completed. The spent fuel pools are assumed to be emptied six years after that unit's final shutdown date. The cost estimate assumes that the spent fuel storage facility and support systems are isolated from the balance of the systems to allow more flexibility in dismantling and cost savings.

The decommissioning scenario has been constructed to permit continued operation of the Fuel Building of each unit. Once the spent fuel assemblies have been placed in dry storage or transferred to the DOE, each unit's wet spent fuel storage and handling facilities will be available for decommissioning.

The ISFSI is currently licensed to operate under a 10 CFR Part 50 general license (in accordance with 10 CFR 72, Subpart K [14]). The estimate assumes that as decommissioning progresses, the 10 CFR Part 50 license will be reduced to the ISFSI, such that the ISFSI will remain under the General License.

It is assumed that spent fuel will be shipped either to the DOE's geological repository or to an interim spent fuel storage facility during the operational period of the ISFSI facility. The estimate only includes ISFSI costs that the OA expects to not be reimbursed by the DOE. Once all spent fuel and GTCC canisters have been removed from the site, the dry storage facility will be removed.

This estimate does not include certain ISFSI-related costs that are assumed to be reimbursable by the DOE. These costs are:

- Capital costs for spent fuel canisters and overpacks
- Construction of an ISFSI shield wall
- Installation of an ISFSI crane and cask handling equipment
- Operation and maintenance costs of the ISFSI (including property taxes)
- ISFSI staffing costs
- ISFSI security costs

The post-shutdown costs to transfer spent fuel from each spent fuel pool to the DOE and the costs to transfer casks from the ISFSI to the DOE are reflected within the decommissioning estimate for dry fuel storage as outlined in Appendix L.

3.5.2 Reactor Vessel and Internal Components

The reactor vessel, steam generators, pressurizer, coolant pumps, and piping will be chemically decontaminated prior to any dismantling work. The reactor pressure vessel and its 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.

TABLE 3.1
PALO VERDE
SPENT FUEL AND GTCC DISPOSITION

Canisters Prior to Shutdown	Pool to DOE	Pool to ISFSI 24 FA[1]	Pool to ISFSI 37 FA	ISFSI to DOE 31FA (avg)	GTCC/ Legacy[2]	Total Casks to ISFSI	Total Casks to DOE
Unit 1	24	51	35	-	-	86	24
Unit 2	15	53	42	-	-	95	15
Unit 3	32	48	40	-	-	88	32
Total	71	152	117	-	-	269	71

Canisters After Shutdown through 2057	Pool to DOE	Pool to ISFSI 24 FA	Pool to ISFSI 37 FA	ISFSI to DOE 31FA (avg)	GTCC/ Legacy	Total Casks to ISFSI	Total Casks to DOE
Unit 1	19	-	16	14.0	10	16	33
Unit 2	24	-	13	7.0	10	16	31
Unit 3	30	-	6	7.0	10	6	37
Total	73	-	35	28.0	30	38	101

Canisters 2058 through 2098	Pool to DOE	Pool to ISFSI 24 FA	Pool to ISFSI 37 FA	ISFSI to DOE 31FA (avg)	GTCC/ Legacy	Total Casks to ISFSI	Total Casks to DOE
Unit 1	-	-	-	87.7	-	-	87.7
Unit 2	-	-	-	101.9	-	-	101.9
Unit 3	-	-	-	86.4	-	-	86.4
Total	-	-	-	276.0	-	-	276.0

Total assemblies discharged	12,151
Assemblies accepted by DOE from the ISFSI	9,196
Total 24 assembly casks required	152
Total 37 assembly casks required	152
Total fuel casks loaded to ISFSI	304
Assemblies accepted by DOE from the pool	2,955
21 assembly casks accepted by DOE from the pool	144

Total Casks

Unit 1 to ISFSI	102.0
Unit 1 to DOE	144.7
Unit 2 to ISFSI	111.0
Unit 2 to DOE	147.9
Unit 3 to ISFSI	94.0
Unit 3 to DOE	155.4
GTCC/Legacy Waste	30.0
Total Casks (spent fuel & GTCC)	478.0

Notes: [1] Fuel Assemblies
[2] Legacy GTCC waste includes an allowance of 2 canisters per unit remaining from plant operations in spent fuel pool; the remaining 8 canisters per unit hold the GTCC resulting from vessel internals segmentation operations.

The dismantling of reactor internals at Palo Verde will generate GTCC radioactive waste generally unsuitable for shallow land disposal. Although the material is not classified as high-level waste, the DOE has indicated it will accept title to this waste for disposal at the future high-level waste repository. However, the DOE has not yet established acceptance criteria or a disposition schedule for this material, and numerous questions remain as to the ultimate disposal cost and waste form requirements. As such, for purposes of this study, the GTCC waste resulting from reactor vessel internals segmentation is assumed to be packaged and disposed of in the same manner as high-level waste, at a cost equivalent to that envisioned for the 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 for disposal.

3.5.3 Steam Generators and Other NSSS Components

The recommended method of removal for the steam generators is to extract the steam generators through the existing containment equipment hatch. This approach is the same as the one used to replace the original steam generators.

The containment polar crane will be modified to support the removal. The generators will then be rigged for removal, disconnected from the surrounding piping, 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 slowly roll outside of the Reactor Building as it is being lowered. Once the steam generator has been lowered to the horizontal position, it will be lowered onto a prime mover and moved to an on-site storage area to await transport to the disposal facility. The second steam generator will be removed using the same technique.

Once at the storage area, the secondary side of the generator (steam dome, separator, and dryer portions above the u-bends) will be removed, segmented, and packaged for disposal. The primary section (tube section and lower channel head) will be cut into smaller sections which allow unrestricted rail shipment. The generator sections will then be loaded onto a prime mover and moved to an on-site railhead where they will be transported to the Energy*Solutions*' facility in Clive, Utah. The pressurizer on each unit will be removed using the same techniques and shipped intact.

Palo Verde Units 1, 2, and 3 has already replaced their original sets of steam generators; they are currently stored on site within a concrete protective structure and will remain there until final plant decommissioning. The costs for transportation and disposal of these original sets of steam generators have been included in this analysis.

3.5.4 Main Turbine and Condenser

The main turbine will be dismantled using conventional maintenance procedures. The turbine rotors and shafts will be removed to a laydown area. The lower turbine casings will be removed from their anchors by controlled demolition. The main condensers will also be disassembled and moved to a laydown area. Turbine components are assumed to be clean and will be surveyed and free-released. The condensers for all units are assumed to be contaminated and they will be sent for disposal to the Energy*Solutions*' Utah disposal facility. Components will be packaged and readied for transport in accordance with the intended disposition.

3.5.5 Transportation Methods

Contaminated piping, components, and structural material other than the highly activated reactor vessel and internal components will qualify as Low Specific Activity (LSA)- II or III, Type A, or Surface Contaminated Object, SCO-I or II, as described in Title 49 of the Code of Federal Regulations.[31] The contaminated material will be packaged in general design packages, as defined in 49 CFR 173.410 in Industrial Packages (IP I, II, or III, as defined in subpart 10 CFR 173.411) or Type A packages as defined in 49 CFR 173.465 for transport unless demonstrated to qualify as their own shipping containers. The reactor vessel and internal components are expected to be transported in accordance with 10 CFR Part 71, as a Type B waste container. It is conceivable that the reactor, due to its limited specific activity, could qualify as LSA II or III. However, the high radiation levels on the outer surface would require that additional shielding be incorporated within the packaging so as to attenuate the dose to levels acceptable for transport.

Transport of the highly activated metal, produced in the segmentation of the reactor vessel and internal components, will be by shielded truck cask. Cask shipments may exceed 95,000 pounds, including vessel segment(s), supplementary shielding, cask tie-downs, and tractor-trailer. The maximum level of activity per shipment assumed permissible was based upon the license limits of the available shielded transport casks. The segmentation scheme for the vessel and internal segments is designed to meet these limits.

The transport of large intact components, e.g., large heat exchangers and other oversized components will be by a combination of truck, rail, and/or multi-wheeled transporter.

The low-level radioactive waste requiring controlled disposal will be sent to disposal facilities in Utah and Texas. Transportation costs are estimated using published tariffs from Tri-State Motor Transit. [32] Truck transport assumes a maximum normal road weight limit of 80,000 pounds for all shipments, with the exception of the overweight shielded casks and non-divisible large components.

3.5.6 Low-Level Radioactive Waste Disposal

A majority of LLRW generated in the decontamination and dismantling of Palo Verde is disposed of at the Energy*Solutio*Utah facility. This site will receive contaminated material such as steam generator primary side material, pressurizer, and reactor coolant piping, packaged system components and piping, contaminated concrete, and concrete rubble. DAW is assumed to be sent to a facility in Oak Ridge, Tennessee for incineration/compaction or direct to the Energy*Solutions* Utah disposal facility. Class B and C waste (principally reactor pressure vessel (RPV) internals) are assumed to be buried at the Waste Control Specialists (WCS) facility in Andrews County, Texas. Clean metallic scrap material primarily from the Turbine Building will be surveyed prior to release.

Based upon current disposal rates for metallic waste, volume reduction and waste processing is not considered economical.

3.5.7 Stored Steam Generators and Storage Facility

This study includes the disposal costs of six retired steam generators (two per unit). They are assumed to be stored in the on-site storage facility until the time of the decommissioning. All activities associated with the stored steam generators and storage facility are considered non-critical and will not affect the overall decommissioning schedule. These generators are assumed to be packaged and transported in the same manner as the steam generators extracted from the Reactor Buildings. The stored steam generators are not expected to require any substantial decontamination or shielding prior to shipment for disposal. Appendix G summarizes the retired steam generator disposal and the facility decommissioning costs.

3.5.8 Water Reclamation Facility

All activities associated with the water reclamation facility are considered non-critical and will not affect the overall decommissioning schedule. No program management or heavy equipment period-dependent costs have been allocated to this facility. Staff and equipment assigned to the unit activities can support this work since the task can be started and interrupted when critical path activities allow for usage of equipment and manpower. Assuming all release criteria is met; the building structures can be removed in an orderly fashion using acceptable controlled demolition techniques. The use of soil remediation technologies will not be required since it is assumed hazardous and radiological release criteria will also be met.

The buildings will be removed to a nominal depth of three feet below grade level. Concrete will be processed (crushed) prior to use as backfill. Holes will be drilled in the foundation base mat to allow for natural drainage. Building and structure sub grade voids will be backfilled with clean demolition debris and graded. Underground piping will be excavated and all voids backfilled. Appendix H summarizes the facility decommissioning costs.

3.5.9 Water Reclamation Supply System Pipeline & Structures

All activities associated with the water reclamation supply system pipeline and structures are considered non-critical and will not affect the overall decommissioning schedule. There are no specific program management or heavy equipment period-dependent costs assigned since the task can be started and interrupted when critical path activities allow for usage of equipment and manpower.

These activities include the removal of the 91st Avenue Wastewater Treatment Plant Interface Structure, Buckeye Irrigation Company Interface, and the Hassayampa Pumping Station. The buildings will be demolished to a nominal depth of three feet below grade level. Concrete will be processed (crushed) prior to use as backfill. Holes will be drilled in the foundation base mat to allow for natural drainage. All piping up to three feet below grade will be excavated and removed. All piping below three feet below grade will be left in place and filled with concrete slurry to prevent any future collapse. Appendix I summarizes the decommissioning costs.

3.5.10 Evaporation Ponds

The study includes the removal, restoration and closure of all three evaporation ponds. All activities associated with the Evaporation Ponds are considered non-critical and will not affect the overall decommissioning schedule. There are no program management or heavy equipment period-dependent costs assigned since the task can be started and interrupted when critical path activities allow for usage of equipment and manpower.

Based upon plant operations and radiological survey information, trace levels of radioactive materials were detected in the two older Evaporation Ponds. Beginning in 1996 and at least annually thereafter samples have been obtained from both Evaporation Ponds and dose calculations each year have indicated that the highest dose from residual radioactivity is less than 1 mRem/year TEDE. Consequently, no allowance has been provided for remediation of the Evaporation Ponds.

The costs for the site restoration and closure (including development of a Subpart D Permitted landfill in accordance with Arizona statutes) were provided by APS for inclusion in this report. These costs include complete removal of the sediment, liners and drainage system and regrade and revegetation of the surrounding area. The study also includes the cost to develop an onsite Subpart D Permitted landfill which will contain the sediment from the three evaporation ponds. Appendix J summarizes these costs.

3.5.11 Make-up Water Reservoirs

The study includes the removal, site restoration, and closure costs for both make-up water reservoirs. All activities associated with the two Make-up Water Reservoirs are considered non-critical and will not affect the overall decommissioning schedule. There are no program management or heavy equipment period-dependent costs assigned since the task can be started and interrupted when critical path activities allow for usage of equipment and manpower.

The costs for the site restoration and closure in accordance with Arizona statutes were provided by APS for inclusion in this report. These costs include complete removal of the sediment, liners and drainage system and regrade and revegetation of the surrounding area. Appendix K summarizes the facility decommissioning costs.

3.5.12 ISFSI

The OA has completed development of an ISFSI and the facility is currently operational. This facility is assumed to have sufficient capacity to accommodate operational and decommissioning fuel storage requirements. Incremental capital costs related to the utilization of the ISFSI during the decommissioning period have been excluded from the estimate since they are assumed to be fully reimbursable from the DOE. The excluded costs include: purchase of canisters and overpacks, transfer of the Unit 1 fuel building crane to the ISFSI, instrumentation of ISFSI pads, purchase ISFSI transfer equipment, and construction of a radiation shield wall along one side of the ISFSI.

Palo Verde will use the NAC International Universal MPC (Multi-Purpose Canister) System with a maximum loading of 24 assemblies per canister through the year 2018. Beginning in 2020 Palo Verde will use the NAC International Magnastor system with a maximum loading of 37 assembly per canister system for the storage and transportation of spent fuel. See Table 3.1 for details regarding spent fuel assumptions regarding quantities of dry fuel storage and GTCC canisters. Canisters provided by the DOE for transfer from the fuel pool to the DOE are assumed to be provided at no cost; plant personnel will still perform the loading and transfer of these canisters, and transfer of the canisters from the ISFSI to the DOE at the same rate of $280 thousand per canister.

The estimate excludes ISFSI security and operating staff and ISFSI operating expenses.

The overpack liners are assumed to have some level of neutron-induced activation, as a result of the long-term storage of the fuel, i.e., to levels exceeding free-release limits. As an allowance, seven overpacks per unit (site total of 21) are assumed to require remediation, equivalent to the number of overpacks required to accommodate the final core offloads at Palo Verde (241 assemblies per unit for a site total of 723 assemblies). The cost of the disposition of this material, as well as the demolition of the ISFSI facility, is included in the estimate.

Considering the use of a 37 assembly canister system, the current ISFSI facility will have adequate capacity to store the GTCC waste. There is no cost included in this estimate for the construction of an additional storage pad.

It is assumed that on-site landfill facilities may be reopened for the disposal of ISFSI demolition debris, if required. The ISFSI decommissioning and demolition will occur (in 2098) immediately following the completion of fuel transfer to the DOE (2097). This is based upon the assumed date that the U.S. DOE begins receipt of spent fuel from the utilities, Palo Verde's priority in the queue, and an assumed rate of shipment from the site to DOE beyond the published DOE queue. Aside from direct canister closure and transfer costs from the pool or ISFSI to a DOE transport vehicle, ISFSI operations and maintenance costs for the ISFSI are not included in this estimate, but are assumed to be paid from reimbursements by the DOE. Appendix L summarizes the ISFSI facility fuel transfer and decommissioning costs.

3.5.13 Stored Reactor Closure Heads & Storage Facility

This study includes the disposal costs of three retired reactor closure heads (one per unit). They are assumed to be stored in the on-site storage facility until the time of the decommissioning. All activities associated with the stored closure heads and storage facility are considered non-critical and will not affect the overall decommissioning schedule. These components are assumed to be packaged and transported intact to the disposal site. The stored reactor closure heads are not expected to require any substantial decontamination or shielding prior to shipment for disposal. Appendix M summarizes the retired closure head disposal and the facility decommissioning costs.

3.5.14 On-Site Clean Fill Disposal

Construction debris resulting from the decommissioning project is considered suitable for on-site disposal. This saves some of the transportation costs and the tipping fee at a commercial disposal facility. An existing landfill may be expanded for the disposal of this construction debris, or existing voids (excluding the evaporation ponds) may be utilized for this purpose.

3.5.15 Site Conditions Following Decommissioning

Following the decommissioning effort, the structures and remaining systems will meet the site release limit that will be specified in the Palo Verde NRC license termination plan. The NRC involvement in the decommissioning process typically will end at this point. Local building codes, state environmental regulations, and the OA's 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 except the switchyard and site drainage facilities. These non-radiological costs are a part of this study.

3.5.16 Utility Staffing

This estimate assumes that the OA will act as its own DOC (Decommissioning Operations Contractor) for the project. As such, some contractor management, supervisory and professional positions will be eliminated. Staffing levels are assigned for each unit by sub-period and functional area. Economies of a multi-unit decommissioning are recognized by establishing a primary and a secondary staff level. The unit assigned the primary staff will include common supervisory positions and positions that may be shared across all units. The types of positions and staffing levels are adjusted based upon the type of activity occurring in each sub-period. The staffing model allows for sharing of resources with other OA operating units and other corporate functions and assignments.

Staffing costs include direct salary as well as an allowance for overheads. A profile of the staffing level for the three-unit decommissioning, including contractors and craft, is provided in Figure 3.1 (at the end of Section 3). The graph shows minimal staff during the pre-shutdown planning phase, which starts five years before the shutdown of Unit 1. Since the shutdowns of the three units are fairly close together, the utility and craft staffing levels will increase rapidly during the first three years of the decommissioning. Utility staffing levels will gradually decrease after completing the removal of physical systems at each of the three units.

Staffing levels and management support will vary based upon the amount and type of decommissioning work. Craft manpower levels decrease after systems removal and structures decontamination and drop substantially during the delay period and the license termination survey period. However, craft staff levels increase again during the site restoration period due to the work associated with structures demolition.

ISFSI support staff levels during license termination and demolition in 2098 are also included. The ISFSI staffing levels for operation, maintenance and security of the ISFSI are not included since the costs are not included.

3.5.17 Miscellaneous Structures Demolition

Appendix C, Table C-3, activity index 3b.1.1.27 "Miscellaneous Structures & Foundations" includes the cost to remove many of the smaller common buildings at the site. The facilities included within this line item are listed below.

Blowdown Demineralizer Area
Concrete Block Barriers
Condensate Demineralizer Transfer Pump Area
Diesel Generator Rework Shop
Demineralized Water Storage
Electrical Equipment Facilities
Electrical Battery Storage Building
Emergency Diesel Generator Buildings
Fire Protection Storage Shed
General Maintenance Shop
Large Motor Storage Sheds

LSR Waste Holdup Tank Area
Lube Oil Tank Area
Metrology Tower Building
Miscellaneous Yard Foundations
Miscellaneous Yard Foundations - All Units
New Fuel Depot Underground Storage Tanks
New Protected Area Security Extension Facility
New Vehicle Maintenance Facility
Pop-Up Barriers
Reactor Makeup Tank Area
Resin Storage Shed
Sally-Port (West Side)
Single Point Vehicle Access
Spray Pond Pumphouse
Sub-Synchronous Resonance Equipment Building
Startup Transformer Yard
Sulfuric Acid Tank Area
Training Mockup Facility
Turbine Building Tank Storage Area
Welding Combination Shop

3.5.18 New Structures

No new structures were added to the site inventory for the 2019 estimate.

3.6 ASSUMPTIONS

The following are the major assumptions made in the development of the cost analysis for decommissioning Palo Verde.

3.6.1 Estimating Basis

1. The estimate is performed in accordance with the methodology described in the AIF/NESP-036 study.
2. Decommissioning costs are reported in the year of projected expenditure; however, the values are provided in 2019 dollars for the current estimate. Costs are not inflated, escalated, or discounted over the period of performance.
3. Plant drawings, equipment, and structural specifications used in the estimate were provided by the OA.

4. All units are assumed to be essentially identical except for common structures and systems. Common systems and structures are assigned to and incorporated within the estimate for Unit 3.

5. Additional decommissioning costs for secondary side systems contamination caused by the Unit 2 steam generator tube rupture are included in the estimate. The turbines have been treated as clean components in the estimate. The condensers have been treated as contaminated components for all three units in this estimate.

3.6.2 <u>Labor Costs</u>

1. The craft labor required to decontaminate and dismantle the nuclear units will be acquired through standard site contracting practices. The current rates for labor at the site (fully loaded) are used as an estimating basis.

2. Utility staffing requirements will vary with the level of effort associated with the various phases of the project. Once the decommissioning program commences, the operations staff will be reduced to only those staff positions necessary to support the decommissioning program and ISFSI activities. Staff transition costs from plant operations to decommissioning are included in this study. The total transition costs are calculated for the site, and divided equally between the three units. Employee labor cost data and craft labor rates for site administration, operations, construction, and maintenance personnel were provided by the OA for positions identified by TLG.

3. Site security, radiological controls, and overall site administration during decommissioning and dismantling will be provided by the OA. There is a significant nuclear security presence at each reactor until the spent fuel has been removed from the spent fuel pool to the ISFSI. The spent fuel pools are assumed to be emptied six years after that unit's final shutdown date, at which time the nuclear security force for that unit is significantly reduced.

4. Engineering services for such items as writing activity specifications and detailed work procedures will be provided by outside contractors with the appropriate expertise.

5. All work (except vessel and internals removal activities) will be performed on an 8-hour per day, 5-day per week basis, with no

overtime. There are 11 paid holidays per year. Vessel and internal removal activities will be performed using two shifts, with an additional charge for back shift activities.

3.6.3 Design Conditions

1. Any fuel cladding failure that 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., ^{137}Cs, ^{90}Sr, or transuranics) has been prevented from reaching levels exceeding those which permit the major NSSS components to be shipped under current DOT regulations, and to be buried within the requirements of 10 CFR Part 61.
2. The estimated curie content of the vessel and internal components were derived from those listed in NUREG/CR-3474.[33] Actual estimates were derived from the Ci/gram values in NUREG/CR-3474 and adjusted for the different mass of the Palo Verde components, operating life, and periods of decay. Additional short-lived isotopes were derived from NUREG/CR-0130[34] and NUREG/CR-0672[35] and benchmarked to the long-lived values from NUREG/CR-3474.
3. Segmentation of the reactor vessel internal components will produce a limited quantity of activated material with radionuclide inventories exceeding Class C quantities, as defined in 10 CFR Part 61. The GTCC material is generally not suitable for shallow land disposal and will most likely be disposed of as high-level waste in the DOE's geological repository (unless the NRC approves an alternative solution). The cost of disposal, unlike that for the spent fuel, is not addressed by the DOE's 1 mill/kWhr surcharge on plant electrical generation. As such, the disposal cost for GTCC presumes the packaging of this material in canisters similar to those used for spent fuel disposal, at an equivalent cost in dollars per cubic foot to what the DOE is charging for the disposal of spent fuel using the 1 mill/kWhr surcharge.
4. The only neutron-activated concrete expected to be above release levels is the bioshield, adjacent to and surrounding the reactor vessel. Aside from this, and material resulting from the scarifying of some concrete surfaces, the bulk of concrete in the Reactor Building and other buildings on site is assumed to meet NRC release limits for on-site disposal of material.

5. Control elements will be removed and disposed of along with the spent fuel, i.e., there is no additional cost provided for their disposal.

3.6.4 General

1. The existing plant equipment is considered obsolete and suitable for scrap as deadweight quantities only. The OA will make economically reasonable efforts to salvage equipment following final plant shutdown. 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 the OA may realize based upon those efforts. It is difficult to predict whether the market for used equipment will be stronger or weaker than it is today. For these reasons, no equipment salvage value was included in the estimate.

2. Scrap generated during decommissioning is not included as a credit in this study for two reasons: (1) the relatively low market value of scrap; and (2) the relatively high cost of releasing the material from the site, i.e., the time and expense associated with "contamination-free" certification. It is assumed, for purposes of this estimate, that any value received from the sale of the material would be more than offset by the on-site processing costs.

3. The concrete debris resulting from building demolition activities is crushed on site to reduce the size of the debris. The resulting crushed concrete is used to backfill below grade voids. The rebar removed from the concrete crushing process is disposed of as scrap steel in a similar fashion as other scrap metal as discussed previously.

4. The OA will provide for the on-site electrical power required to decommission the plant. For estimating purposes, the plant is assumed to be de-energized, with decommissioning activities relying on temporary power connections.

5. Current plant staffing will remove all items of furniture, tools, mobile equipment (such as forklifts, trucks, bulldozers, and other similar mobile equipment), and other such items of personal property owned by the OA that can be easily removed without the use of special equipment at no cost or credit to the project.

6. Existing warehouses will be cleared of non-essential material and remain for use by the OA and its subcontractors. The warehouses may be dismantled as they become unnecessary to the decommissioning program.

7. The current OA staffing perform the following activities at no cost or credit to the project during the first six months of the planning period:

    - Fuel oil tanks will be emptied and cleaned by flushing or steam cleaning prior to disposal.
    - Acid and caustic tanks will be emptied.
    - Lubricating and transformer oils will be drained and removed from site by a waste disposal vendor.
    - All hazardous and legacy radioactive material will be removed and disposed of.

8. The decommissioning activities will be performed in accordance with the current regulations assumed to be in place at the time of decommissioning. This includes the ability to dispose of demolition debris on-site. Changes in current regulations may have a cost impact on decommissioning.

9. Material and equipment costs for conventional demolition and/or construction activities were taken from RSMeans Construction Cost Data.

10. The 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, and the use of respiratory protection and personnel protective clothing. These items lengthen a task's duration, which increases the costs and lengthens the overall 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.

11. FEMA and state fees associated with emergency planning are assumed to continue for approximately 18 months following the cessation of operations. At this time, the FEMA fees are discontinued. The timing is based upon the anticipated condition of the spent fuel (i.e., the hottest spent fuel assemblies are assumed to be cool enough that no substantial Zircaloy oxidation

and off-site event would occur with the loss of spent fuel pool water). State and local fees are continued until all spent fuel is transferred to dry storage cask.

12. Nuclear liability insurance provides coverage for damage or injuries due to radiation exposure from equipment, material, etc., used during decommissioning. Nuclear liability insurance is phased out upon final decontamination of the site. Nuclear property insurance will cease upon termination of the 10 CFR Part 50 or Part 72 license(s). Insurance costs in the estimate are based on premium information for required policies identified by the OA following cessation of plant operations and during decommissioning activities. Premium discounts are in accordance with NRC guidelines.

13. A one million dollar annual property tax allowance is included in the estimate. This cost is shared equally among the three units and is applied from final shutdown until the end of site restoration in January 2057. Sales tax will be included at the local rates for purchased material.

14. This estimate assumes that processed water which meets state and federal release limits can be disposed of without additional cost.

15. The perimeter fence and in-plant security barriers will be moved as appropriate to conform to the Security Plan in force during the various stages in the project.

16. The concrete circulating water piping will be abandoned by accessing the underground piping and permanently backfilling the voids. Contaminated underground concrete pipe will be removed entirely or decontaminated and abandoned. Underground steel pipe will be removed completely. Electrical manholes will be backfilled with suitable earthen material and abandoned. The Water Reclamation & Supply System concrete piping (35 miles of piping from Palo Verde to Phoenix) will be filled with concrete.

17. All site vestiges will be removed to a nominal depth of three feet below ground, with non-contaminated subgrade foundations remaining in place below this level. Holes will be drilled in each of the foundation basemats to allow for natural drainage. Building and structures subgrade voids will be backfilled with clean demolition fill. The site will be graded and landscaped.

18. The existing electrical switchyard will remain after decommissioning in support of the utility's electrical transmission and distribution system.
19. Most railroad tracks on site will be removed; an active spur connecting the ISFSI to the main line will remain to support rail shipments of spent fuel.
20. Road and parking areas with asphalt or concrete surfacing will be broken up and the material used as backfill on site. All gravel road and parking areas will remain in place and be covered with fill. Culverts, head walls, and stone riprap will remain in place to allow natural drainage.
21. The OA will have some existing scaffolding quantities available from plant operations to support the decommissioning project. Therefore, only costs associated with the remaining required scaffolding are included.
22. No significant quantities of asbestos, industrial solvents, chromated water, lead, or mercury are expected to be present on site at the time of decommissioning. Therefore, remediation costs for these types of materials are not included in the study.
23. This study has assumed that the Arizona Revised Statues, specifically 49-762.01 through 49-762.08 and 49-701.01, all regarding the definition and handling of solid waste, do not interfere with the on-site disposal of concrete rubble; nor do they create any requirement for the removal of below grade clean or decontaminated structures, which this study assumes are abandoned in place. The establishment of a solid waste disposal facility on site will create a long-term liability for the management and caretaking of the disposal facility. Any costs for this ongoing management and caretaking are not included in this estimate.

3.7 COST ESTIMATE SUMMARY

Summaries of the radiological decommissioning costs and annual expenditures are provided in Appendices B, C, G, and H through P. Table 6.1 provides a breakdown of these 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 cost tables in Appendices C, G, H, I, J, K, L, M and N. Note that Appendix N represents a consolidation of the cash flows from Appendices B, C, G, H, I, J, K, L and M; it folds all site costs into the three Palo Verde unit costs. Appendices O and P represent consolidated cash flows with contingencies of 25% and 10%, respectively. 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, Other (spent fuel, insurance, staffing, fees, etc.) and Contingency.
- The subtotal reported for the major cost categories does not include contingency, which is reported in a separate column.
- "Other" includes different types of costs, which are not easily categorized (such as characterization contract services, license termination survey, contract sources, plant preparation costs, etc.).

Appendices C, G, H, I, J, K, L, M and N provide the supporting, detailed costs elements. The cost elements are assigned to one of three subcategories: "License Termination," "Spent Fuel Management," and "Site Restoration." The subcategory "License Termination" is used to accumulate costs that are consistent with "decommissioning" as defined by the NRC (i.e., 10 CFR § 50.2). The cost reported for this subcategory is generally sufficient to terminate the unit's operating license, recognizing that there may be some additional cost impact from spent fuel management. Costs are included in the years 2040 through 2043 for Unit 1 pre-planning; these costs are shown in Appendix C, Table C-1 in subperiod 0.

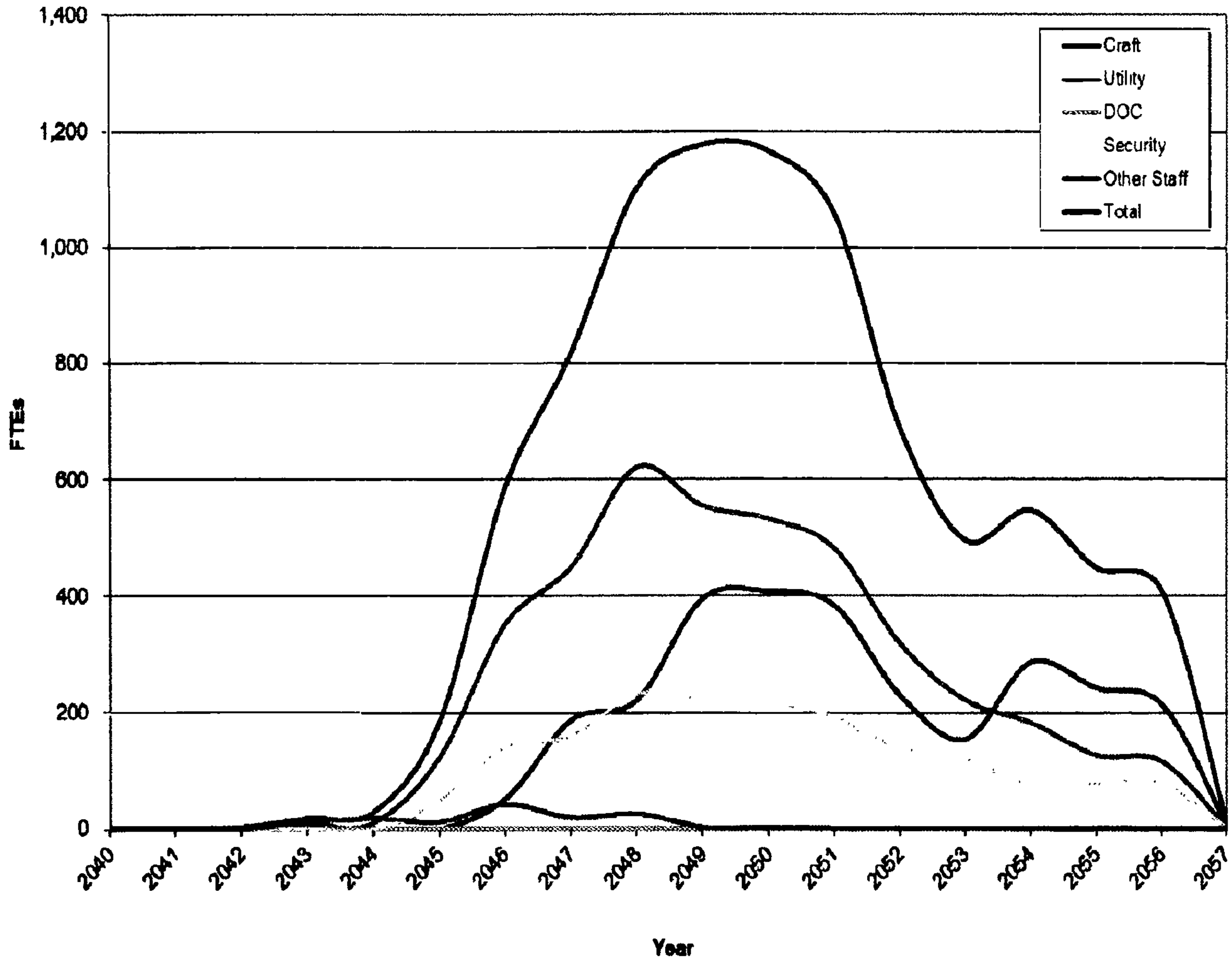
The "Spent Fuel Management" subcategory contains costs associated with the transfer of spent fuel from the spent fuel pools to the DOE, or from the ISFSI to the DOE.

"Site Restoration" is used to capture costs associated with the dismantling and demolition of buildings and facilities demonstrated to be free from contamination. This includes structures never exposed to radioactive materials, as well as those facilities that have been decontaminated to appropriate levels. Structures are removed to a depth of three feet and backfilled to conform to local grade.
The cost of GTCC disposal is included in the "Nuclear Steam Supply System Removal" cost element. While designated for disposal at a federal facility along with the spent fuel, GTCC waste is still classified as low-level

radioactive waste and, as such, included as a "License Termination" expense.

Decommissioning costs are reported in 2019 dollars. Costs are not inflated, escalated, or discounted over the period of expenditure (or remaining lifetime of the plant).

FIGURE 3.1
PALO VERDE MANPOWER LEVELS



Notes:

1) Manpower for fuel transfers from ISFSI to DOE after 2057, for GTCC canister transfers to DOE in 2097, and for decommissioning and demolition of the ISFSI in 2098 not shown

2) The labor hour basis of this chart was taken from Appendices C, G, H, I, J, K, L, M and N; however not all line items in these appendices have labor hour values available (e.g. spent fuel canister transfers to the DOE)

4. SCHEDULE ESTIMATE

The schedules for the decommissioning scenarios considered in this study follow 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 plans described in Section 3.5.1.

A timeline for the decommissioning of Units 1, 2, 3 and the ISFSI is presented in Figure 4.1. Appendix D presents a more detailed schedule of decommissioning activities for each unit. The scheduling sequence assumes that fuel is removed from the spent fuel pool within the first six years after operations cease. The key activities listed in the schedule do not reflect a one-to-one correspondence with those activities in the cost tables, but reflect dividing some activities for clarity and combining others for convenience. The schedule was prepared using "Microsoft Project. [36]

4.1 SCHEDULE ESTIMATE ASSUMPTIONS

The schedule 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 work activity durations used in the precedence network reflect the actual man-hour estimates from the cost tables, 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:

- Planning of decommissioning activities starts approximately three years prior to permanent shutdown of Unit 1. During the pre-shutdown planning period a staff of project and technical personnel are dedicated to the project.
- The Fuel Buildings are isolated until such time that all spent fuel has been discharged from the spent fuel pools to the DOE or to the ISFSI. Decontamination and dismantling of the storage pools is initiated once the transfer of spent fuel to the ISFSI or DOE is complete.
- Period 2 decommissioning activities for Unit 1 will begin immediately following the 18-month Period 1 preparation phase after the cessation of plant operations. Period 2 activities for Units 2 and 3 will begin following a 12-month Period 1 preparation phase. Sequencing the integrated decommissioning of Palo Verde is intended to maintain an even level of staff resources.

- All work (except vessel and internals removal) is performed during an 8-hour workday, 5 days per week, with no overtime. There are eleven paid holidays per year.
- Reactor 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. The number of cask shipments out of the Reactor Building is expected to average three every two weeks. Non-cask shipments will be limited to 10 per week.
- 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.
- Dismantlement and demolition of the miscellaneous non-radioactive facilities are assumed to be performed off the overall critical path schedule. Such activities start after Unit 1 shutdown and are assumed to be complete prior to the start of the site restoration phase (Period 3).

4.2 PROJECT SCHEDULE

The period-dependent costs presented in the Appendix C detailed cost tables are based upon the durations developed in the schedule. 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 period-dependent costs. A second critical path is also shown for the spent fuel cooling period, which determines the release of the fuel buildings for final decontamination.

Project timelines are provided in Figures 4.1. Milestone dates are based on shutdown dates of June 1, 2045, April 24, 2046, and November 25, 2047 for Units 1, 2, and 3, respectively.

The OA also provided the assumed completion date for transfer of Palo Verde fuel from the ISFSI to the DOE, i.e. by the end of 2097. The schedule and timeline for the ISFSI therefore shows ISFSI decontamination and demolition in 2098, following the completion of transfer of the spent fuel and GTCC canisters from the ISFSI to the DOE.

FIGURE 4.1
DECOMMISSIONING TIMELINES
(not to scale)

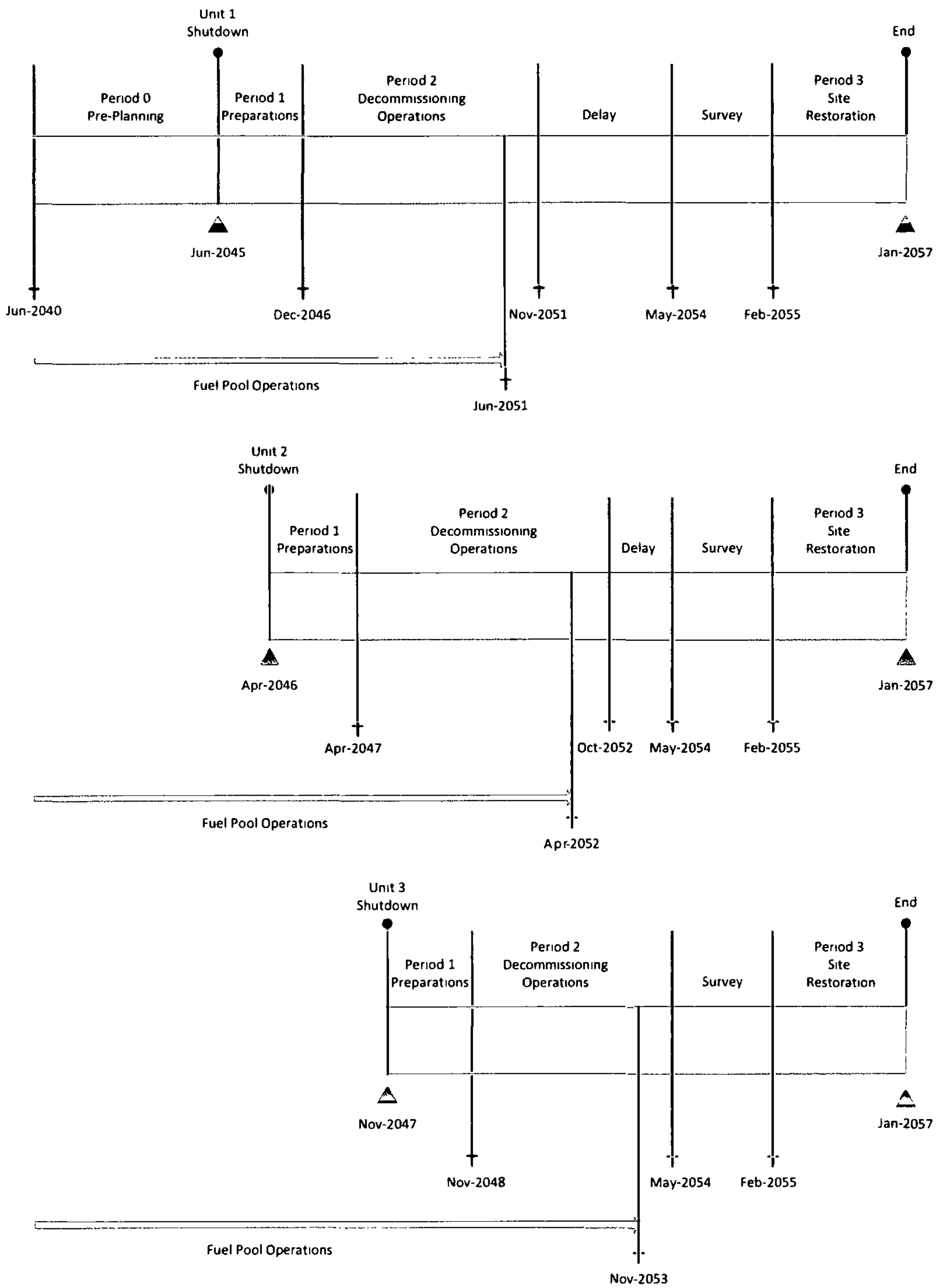
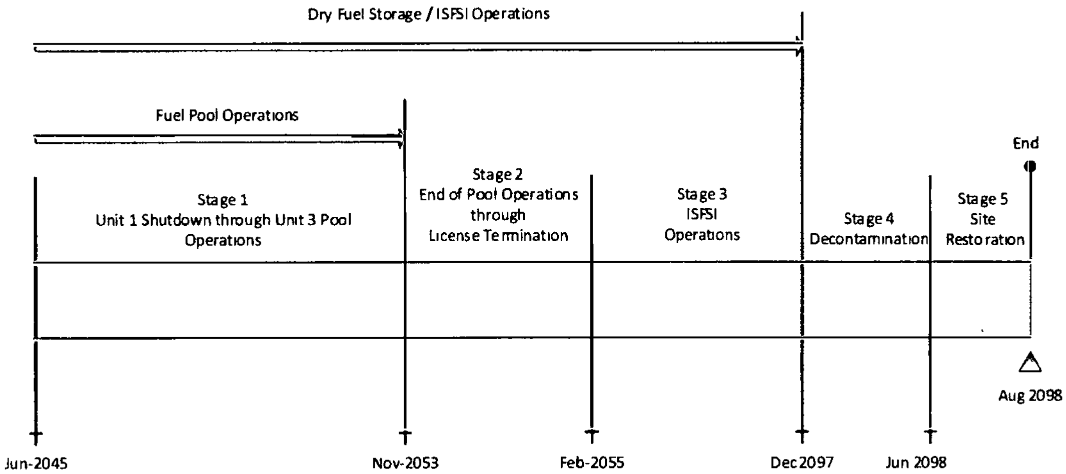


FIGURE 4.1 (continued)
DECOMMISSIONING TIMELINES
(not to scale)



5. RADIOACTIVE WASTES

The objectives of the decommissioning process are the removal of all radioactive material from the site that would restrict its future use and the termination of the NRC license(s). This currently requires the remediation of all radioactive material at the site in excess of applicable legal limits. Under the Atomic Energy Act [36] 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, 10 CFR Part 71 defines radioactive material for the purpose of transportation and 10 CFR Part 61 specifies its disposition.

Title 49 of the Code of Federal Regulations is the principle set of rules and regulations (sometimes called administrative law) issued by the Departments of Transportation and Homeland Security, federal agencies of the United States regarding transportation and transportation related security. Most of the materials being transported for controlled burial are categorized as LSA or SCO materials containing Type A quantities, as defined in 49 CFR Parts 173-178. Shipping containers are required to be Industrial Packages (IP-1, IP-2 or IP-3, as defined in § 173.411) or Type A packages (§ 173.465). 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, and penetrations.

The volumes of radioactive waste generated during the various decommissioning activities at the site are shown on a line-item basis in Appendix C and summarized in Tables 5.1. The quantified waste volume summaries shown in these tables are consistent with 10 CFR Part 61 classifications. The volumes are calculated based on the exterior dimensions for containerized material and on the displaced volume of components serving as their own waste containers.

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 (greater than Type A quantity waste), where high concentrations of gamma-emitting radionuclides limit the capacity of the shipping containers.

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 over the time period during which the decommissioning is accomplished, 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 material generated in the decontamination and dismantling of Palo Verde is primarily generated during Period 2. Material that is contaminated or potentially contaminated will be removed and sent to the Energy*Solutions* facility in Clive, Utah. The current metallic waste disposal rate is less than the cost for waste processing and volume reduction and is therefore considered uneconomical.

For purposes of constructing the estimates, the current cost for disposal at the Energy*Solutions* facility was used for a majority of the radioactive waste produced from the decommissioning activities. Separate rates were used for containerized waste and large components. Demolition debris including miscellaneous steel, scaffolding, and concrete was disposed of at a bulk rate. The decommissioning waste stream also included resins and dry active waste.

Class A waste is disposed of at Energy*Solutions'* facility in Clive, Utah. Metallic waste is buried at a cost of $202 per cubic foot (based upon an average waste density of 65 pounds per cubic foot), and large component waste burial is at a cost of $83 per cubic foot. Concrete, soil, asbestos and other bulk debris are disposed of at a rate of $59 per cubic foot (based upon an average waste density of 88 pounds per cubic foot). Dry active wastes, e.g., cloth, paper and plastics, are disposed of at $30 per cubic foot, with an assumed density of 20 pounds per cubic foot.

Since Energy*Solutions* is not currently able to receive the more highly radioactive components generated in the decontamination and dismantling of the reactor, disposal costs for the Class B and C irradiated hardware material were based upon existing Palo Verde agreements with WCS for the Andrews County, Texas disposal facility, and publicly available pricing from WCS for irradiated hardware. Class B waste from liquid waste processing was based upon Barnwell, S.C. disposal rates as a proxy.

Class B resin and filter waste is disposed of at $4,761 per cubic foot at the Waste Control Specialists facility in Andrews County, Texas. Classes B and C wastes resultant from irradiated reactor hardware are disposed of at an average of $5,700 and $7,500 per cubic foot, respectively.

GTCC waste is disposed of at a rate of $5,700 per cubic foot, as packaged in a spent fuel canister. GTCC waste is stored on site at the ISFSI until the DOE is ready to receive the shipments; this is assumed to occur in 2097. All disposal unit rates do not include contingency dollars applied against burial costs.

TABLE 5.1
PALO VERDE
DECOMMISSIONING WASTE SUMMARY [1, 2]

Unit	Waste Category	Volume (cubic feet)	Weight (pounds)
1	Class A Bulk (concrete, metal siding)	33,214	1,568,943
	Class A Metallic (containerized waste and large components)	430,143	28,121,485
	Class A DAW	19,999	399,971
	Class A (low-activity resins and filters)	6,550	533,855
	Class B (irradiated vessel internals and higher-activity resin and filters)	2,002	243,294
	Class C (irradiated vessel internals)	224	34,938
	GTCC (irradiated vessel internals and legacy waste)	4,433	905,513
	Waste Processing (not used in 2019 estimate)	0	0
	Scrap Metal (non-contaminated)		122,687,000
2	Class A Bulk (concrete, metal siding)	33,109	1,563,987
	Class A Metallic (containerized waste and large components)	506,853	33,022,370
	Class A DAW	21,310	426,206
	Class A (low-activity resins and filters)	6,634	538,880
	Class B (irradiated vessel internals and higher-activity resin and filters)	2,002	243,294
	Class C (irradiated vessel internals)	224	34,938
	GTCC (irradiated vessel internals and legacy waste)	4,433	905,513
	Waste Processing (not used in 2019 estimate)	0	0
	Scrap Metal (non-contaminated)		118,091,000
3	Class A Bulk (concrete, metal siding)	41,264	1,949,229
	Class A Metallic (containerized waste and large components)	528,322	34,364,125
	Class A DAW	21,922	438,440
	Class A (low-activity resins and filters)	7,007	575,655
	Class B (irradiated vessel internals and higher-activity resin and filters)	2,002	243,294
	Class C (irradiated vessel internals)	224	34,938
	GTCC (irradiated vessel internals and legacy waste)	4,433	905,513
	Waste Processing (not used in 2019 estimate)	0	0
	Scrap Metal (non-contaminated)		155,317,000

TABLE 5.1
(continued)
PALO VERDE
DECOMMISSIONING WASTE SUMMARY [1,2]

Unit	Waste Category	Volume (cubic feet)	Weight (pounds)
Steam Gen.	Class A Metallic (containerized waste and large components)	146,958	13,246,071
RPV Heads	Class A Metallic (containerized waste and large components)	15,216	924,428
ISFSI	Class A Metallic (containerized waste and large components)	38,624	4,150,679
Other	Subpart D Waste (Evaporation Ponds)	67,500,000	
Totals	Class A Bulk (concrete, metal siding)	107,587	5,082,160
	Class A Metallic (containerized waste and large components)	1,666,116	113,829,158
	Class A DAW	63,231	1,264,616
	Class A (low-activity resins and filters)	20,192	1,648,389
	Class B (irradiated vessel internals and higher-activity resin and filters)	6,007	729,882
	Class C (irradiated vessel internals)	673	104,814
	GTCC (irradiated vessel internals and legacy waste)	13,300	2,716,539
	Subpart D Waste	67,500,000	
	Scrap Metal (non-contaminated)		396,095,000

1 Waste is classified according to the requirements as delineated in Title 10 CFR, Part 61.55
2 Columns may not add due to rounding

FIGURE 5.1
RADIOACTIVE WASTE DISPOSITION

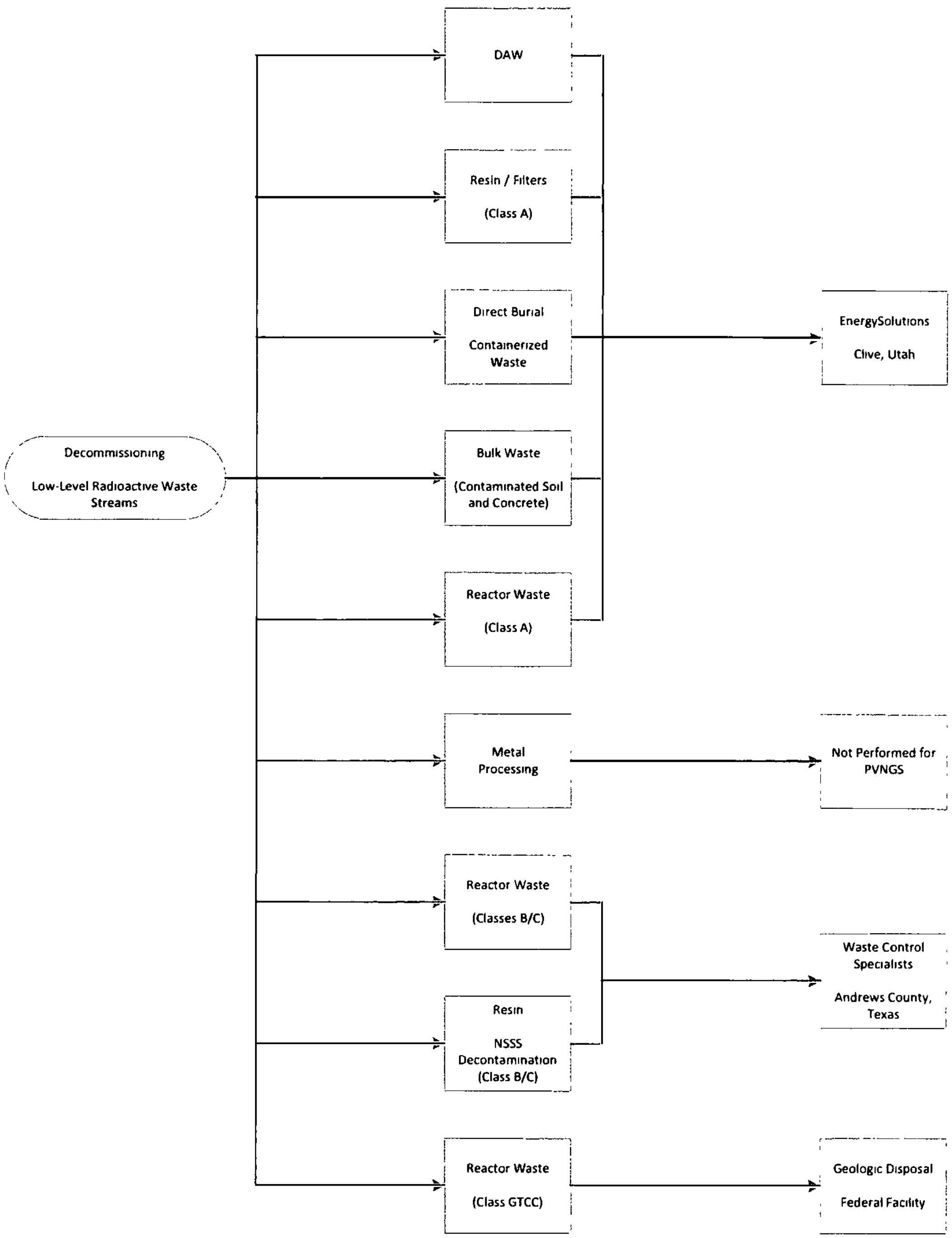


FIGURE 5.2
DECOMMISSIONING WASTE DESTINATIONS
RADIOLOGICAL