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REPORT SUMMARY

During the past two decades the NRC regulated nuclear industry has encountered and dealt with a diverse range of political, financial and technological challenges while decommissioning its nuclear facilities. During that time, the decommissioning of nuclear facilities has evolved into a mature industry in the United States with a number of large power reactors successfully decommissioned and their NRC licenses terminated. One of the challenges discussed in this report is site release standards, required by state regulators that are more stringent than NRC regulations that have resulted in increased decommissioning costs. To control costs from previously unexpected conditions, power reactor licensee and contractors developed many innovative dismantling and decontamination approaches that both simplified performance of the work and reduced the costs.

Background

Over the last ten years, several nuclear power plants have detected small quantities of radioactivity in groundwater from inadvertent releases of licensed material. An NRC task force, established in 2006 to investigate these detections concluded that, “Although there have been a number of industry events where radioactive liquid was released to the environment in an unplanned and unmonitored fashion, based on the data available, the task force did not identify any instances where the health of the public was impacted.”

The nuclear power industry, in response to these detections, has entered into a voluntary initiative to implement groundwater monitoring programs at all sites in order to assure local stakeholders that the public health and safety are being protected.

Objective

To discuss experiences with decommissioning cost estimates and the factors that impacted the actual cost of decommissioning projects.

Approach

This report discusses the experiences with decommissioning cost estimates and the factors that impacted the actual cost of the decommissioning projects. The measures used at to manage costs and reduce the impact of unexpected regulatory developments and site conditions are also discussed. As it is the subject of currently proposed NRC regulation, the measures used to manage and fund the cost of the characterization, remediation and disposal of waste removed from a site to reduce groundwater contamination levels is also included. Lastly, the measures

taken by the nuclear power industry to incorporate the lessons learned from the prior decommissioning experiences into planning future decommissioning and design of new plants is presented.

Results

Based on the experiences presented in this report, the nuclear industry has proven that it has the technology and ability to decommission its nuclear reactors. Recent experience has shown that power reactor facilities can be successfully decommissioned to unrestricted use criteria at costs that are, in most cases, close to estimates developed prior to the start of physical decommissioning work, even with the occurrence of previously unidentified conditions. Some key points that support this conclusion are the following:

- Decommissioning of nuclear facilities in the United States has evolved into a mature industry that has benefited from lessons learned and is well equipped to estimate and manage cost.
- All power reactor sites have been successfully decommissioned to unrestricted use.
- Groundwater remediation has been a small fraction of decommissioning cost and is not likely to be a large contributor to decommissioning cost.
- Complete characterization of subsurface conditions during the operating lifetime of a nuclear facility is an unreasonable expectation.
- The NEI Groundwater Protection Initiative will have a positive impact on future decommissioning by causing groundwater issues to be identified and effectively dealt with on a timely basis.

The experience presented in this report illustrates that the nuclear power industry can effectively manage and fund plant decommissioning within the existing regulations and by incorporating the lessons learned from the recent decommissioning experience. The proposed regulatory changes offered by NRC offer no significant benefit in reducing the likelihood of legacy sites for power reactors.

Applications, Values, and Use

The Electric Power Research Institute (EPRI) has documented the industry’s decommissioning experiences and lessons learned in a series of Experiences Report covering entire decommissioning projects and specialized decommissioning tasks and technologies. Utilities and other organizations responsible for the decommissioning of nuclear power plants can use lessons learned and experiences from recent decommissioning projects as basis and optimization of future decommissioning planning and cost estimation.

Keywords

Decommissioning
Groundwater Monitoring
Groundwater Remediation

EXECUTIVE SUMMARY

During the past two decades the NRC regulated nuclear industry has encountered and dealt with a diverse range of political, financial and technological challenges while decommissioning its nuclear facilities. During that time, the decommissioning of nuclear facilities has evolved into a mature industry in the United States with a number of large power reactors successfully decommissioned and their NRC licenses terminated. One of the challenges discussed in this report is site release standards, required by state regulators that are more stringent than NRC regulations that have resulted in increased decommissioning costs. To control costs from previously unexpected conditions, power reactor licensee and contractors developed many innovative dismantling and decontamination approaches that both simplified performance of the work and reduced the costs.

Over the last ten years, several nuclear power plants have detected small quantities of radioactivity in groundwater from inadvertent releases of licensed material. An NRC task force, established in 2006 to investigate these detections concluded that, “Although there have been a number of industry events where radioactive liquid was released to the environment in an unplanned and unmonitored fashion, based on the data available, the task force did not identify any instances where the health of the public was impacted.” (Reference 95).

The nuclear power industry, in response to these detections, has entered into a voluntary initiative to implement groundwater monitoring programs at all sites in order to assure local stakeholders that the public health and safety are being protected.

This report discusses the experiences with decommissioning cost estimates and the factors that impacted the actual cost of the decommissioning projects. The measures used at to manage costs and reduce the impact of unexpected regulatory developments and site conditions are also discussed. As it is the subject of currently proposed NRC regulation, the measures used to manage and fund the cost of the characterization, remediation and disposal of waste removed from a site to reduce groundwater contamination levels is also included. Lastly, the measures taken by the nuclear power industry to incorporate the lessons learned from the prior decommissioning experiences into planning future decommissioning and design of new plants is presented.

Summary Conclusions

Based on the experiences presented in this report, the nuclear industry has proven that it has the technology and ability to decommission its nuclear reactors. The lessons learned in completing recent decommissioning have been captured by the industry and will serve as a basis for future decommissioning planning and cost estimation. The Electric Power Research Institute (EPRI) has documented the industry’s decommissioning experiences and lessons learned in a series of

Experiences Report (References 1 to 93) covering entire decommissioning projects and specialized decommissioning tasks and technologies. Recent experience has shown that power reactor facilities can be successfully decommissioned to unrestricted use criteria at costs that are, in most cases, close to estimates developed prior to the start of physical decommissioning work, even with the occurrence of previously unidentified conditions. Some key points that support this conclusion are the following:

- <u>Decommissioning of nuclear facilities in the United States has evolved into a mature industry that has benefited from lessons learned and is well equipped to estimate and manage cost</u>.

  As a result of lessons learned, future decommissioning projects can be performed at reduced costs. As all the decommissionings begun to date have been successfully completed or have not identified impediments to their completion, there is little or no potential for power plants site to become legacy sites. As discussed in the body of this report, in the late 1990s a number of large power reactors were successfully decommissioned. These power reactors included Trojan, Big Rock Point, Maine Yankee, Yankee Rowe, and Connecticut Yankee. To control costs resulting from unexpected conditions encountered during decommissioning, power reactor licensees and contractors have developed many innovative dismantling and decontamination approaches during the course of performing their decommissioning projects. These innovations both simplified performance of the work and reduced the costs. While many of these innovations arose as a reaction to unanticipated conditions, their use during future decommissioning projects will reap significant savings when they can be incorporated into planning before the work starts. Some of the industry developments and innovative methods that have been used to reduce decommissioning costs include the following:

  - **Adoption of Bulk Removal Approach:** The availability of the Envirocare (now Energy Solutions) disposal facility in Clive, Utah for Part 50 licensed material starting in the mid-1990s reduced waste disposal rates and modified decommissioning from a time consuming and costly on-site decontamination with a subsequent final status survey approach, to a more aggressive approach of shipping contaminated material off-site for disposal. The availability of a cost-effective off-site disposal option for contaminated materials has resulted in shorter decommissioning project schedules. Properly implemented, aggressive removal of contaminated material will have the effect of reducing labor and overhead costs for future decommissioning projects.

    - This bulk removal approach has allowed for the reduction of final survey costs. Complete removal of structures as assumed radioactive waste has been found to be much less expensive than the time and labor intensive process of performing final status surveys.
    - Use of large re-usable waste shipping containers has allowed for bulk removal, packaging and disposal of contaminated soil and rubble. Decreased packaging and material handling costs have been demonstrated using this method. Additionally, this approach is likely to accelerate the rate at which decommissioning work can be accomplished.
    - Use of bulk demolition techniques, such as explosives and ram hoes has been demonstrated and reduces project durations and labor costs.

    - The free release of materials from a site being decommissioned or the use of specialty off-site facilities for decontamination and free-release of materials has allowed waste to be removed from project sites much more rapidly. Many sites have demonstrated that structures, including some where decontamination has been performed, can be free released and the demolition debris sent to a local landfill. The additional option is to ship removed system and structures off-site for decontamination or survey and release to a controlled landfill such as those in Tennessee. This has the effect of shortening schedules and reducing project labor costs, as well as decreasing costs associated with waste disposal. Expansion of this waste treatment option can further decrease future decommissioning costs.

  - **Improved Primary System Decontamination:** Advances in primary system decontamination and the ensuing radiation dose rate reductions have demonstrated the feasibility of using simpler, less expensive, and faster hands-on dismantling techniques, rather than reliance on expensive and slow robotics and remote tooling techniques.
  - **Improved Contracting Practices:** Experience has resulted in successful contracting techniques which has improved cost performance. An example of this is contracting incentives, such as cost-plus incentive fees have been used to reduce bid costs by reducing potential financial risk that are inherent in fixed-price contracts. This technique reduces the effects of cascading inclusion of inflated contingencies.
  - **Improved Removal Techniques for Large Components:** One-piece removal of large components, such as reactor pressure vessels and steam generators, in lieu of segmentation, has been demonstrated to reduce costs and shorten schedules. This has also reduced waste disposal, packaging and transportation costs through averaging of radioactivity over a large single mass, thereby allowing components to be disposed of as less expensive Class A waste and transported as their own containers.

- <u>All power reactor sites have been successfully decommissioned to unrestricted use</u>.

  A subset of the challenges encountered in recent decommissioning is the detection of radionuclide contamination in groundwater. At certain nuclear power plant sites being decommissioned starting in the late 1990's, this has led to increased groundwater monitoring and in one case, at the Connecticut Yankee (CY) site, significant soil remediation. In all cases where groundwater contamination has been detected, groundwater monitoring or in the case of CY, post-remediation monitoring has shown the levels of radioactivity in groundwater to be below NRC site release limits. For all of these sites, the NRC license has been terminated allowing unrestricted use of the site by members of the public.

- Groundwater remediation has been a small fraction of decommissioning cost and is not likely to be a large contributor to decommissioning cost.

  Experience has shown that the cost of groundwater remediation during decommissioning, even under extreme conditions, has been a small fraction of the total cost of the decommissioning. At Connecticut Yankee, remediation cost related to reducing groundwater contamination were less than 9% of the total decommissioning costs. Of that cost, only two-thirds was driven by NRC regulations.

  All increases in required decommission funds at CY were approved by the Federal Energy Regulatory Commission (FERC). It was never in question as to whether the required groundwater remediation would be completed, just how it would be paid for (i.e. decommissioning funds approved by FERC or electric utility assets). Although electric utility assets were not allocated for use in paying for groundwater remediation costs, this would have been required to complete the decommissioning had FERC not approved these cost along with the other cost increases identified.

  The nuclear power plants that are Independent Power Producers will also need to perform and pay for all work that is necessary to complete the decommissioning. Most of these plants are owned and operated by large ongoing nuclear business and therefore the risk of default is extremely low.

- Complete characterization of subsurface conditions during the operating lifetime of a nuclear facility is an unreasonable expectation.

  The requirement in the proposed NRC regulations for extensive subsurface soil characterization (or remediation for that matter) during an operating facility's lifetime will not result in improved estimates of the quantity of soil remediation required during a future decommissioning. It is not possible to perform meaningful subsurface characterization without disrupting the operation essential equipment, risking the breeching of barriers that contain radioactivity, or exacerbating the migration of contaminants already in the environment. Based on industry decommissioning experience, the majority of subsurface contamination (by volume and concentration) would likely be located directly under operating systems, structures, and components (SSCs), which would inhibit safe or adequate access for characterization purposes. It is therefore unlikely that the proposed subsurface characterization requirements could be implemented so as to produce data that would enhance decommissioning cost estimates prior to plant shutdown.

- The NEI Groundwater Protection Initiative will have a positive impact on future decommissioning by causing groundwater issues to be identified and effectively dealt with on a timely basis.

  The nuclear power industry as a whole has incorporated the lessons learned from the decommissioning as well as operating sites where contamination has been detected in groundwater. All nuclear plant sites have committed to and implemented the Nuclear Energy Institute Groundwater Protection Initiative (NEI GWPI) that calls for the monitoring of groundwater at all power plants sites and the assessment of the potential of leaks to occur that could contaminate groundwater. This industry initiative is supported by technical guidelines developed by EPRI and industry experts (References 74 and 88). NEI will soon issue additional guidance that is based on the GWPI, NRC Regulatory Guide 4.21 and 10 CFR 20.1406. This guidance (NEI 08-08, “Generic FSAR Template Guidance for Life Cycle Minimization of Contamination”) provides guidelines for future plants that incorporate lessons learned from groundwater contamination experience.

The experience presented in this report illustrates that the nuclear power industry can effectively manage and fund plant decommissioning within the existing regulations and by incorporating the lessons learned from the recent decommissioning experience. The proposed regulatory changes offered by NRC offer no significant benefit in reducing the likelihood of legacy sites for power reactors.

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INTRODUCTION

Over the past ten years EPRI has developed and published a number of lessons learned documents and workshop proceedings related to decommissioning (References 1 to 93). Many of these experience reports and workshops were developed in conjunction with U.S. nuclear plants currently in different phases of decommissioning. These documents provide a sound reference base for reactor facilities that will eventually undergo decommissioning.

The ultimate goal of the decommissioning of a reactor site is to release the site for future use. One of the aspects of that release is the removal of the power plant site from the obligations of the NRC license. In the U.S., this release is primarily governed by the U.S. Nuclear Regulatory Commission (NRC) through the License Termination Rule (LTR) (Reference 94) which instituted dose based release standards (more commonly known as the 25 mrem/yr criteria) in 1996. Additionally, the states where a number of sites that have been decommissioned are located have required more stringent limits on allowable contamination levels than those allowed by the NRC.

The nuclear industry in the United States has gained a wealth of decommissioning experience over the past two decades. Large scale reactor decommissioning started in the United States in the 1980's with the decommissioning of DOE's Shippingport Atomic Power Station, the worlds first nuclear power plant to produce electricity. Experience gained from that project was used as the basis for preparing many power reactors decommissioning cost estimates in the 1990's.

The experience gained from the Shippingport decommissioning project also set the stage for planning and implementing the decommissioning of many small demonstration and isotope production reactors during the 1990s. Many of these facilities had complex issues, such as Transuranic radionuclide contamination or leaks to ground water which resulted in large volumes of contaminated soil and bedrock. These experiences showed that these issues in all cases could be successfully managed and the NRC licenses at the sites terminated (e.g., the Saxton and Cintichem reactors).

In the late 1990s, a number of large power reactor decommissioning projects were initiated. As of the present, most of these reactors have been successfully decommissioned to unrestricted use criteria resulting in termination of their NRC licenses. Examples include Trojan, Big Rock Point, Maine Yankee, Yankee Rowe and Connecticut Yankee.

Over the last ten years, several nuclear power plants, including both operating and decommissioning plants, have detected small quantities of radioactivity in groundwater from inadvertent releases of licensed material. An NRC task force, established in 2006 to investigate these detections concluded that, "Although there have been a number of industry events where radioactive liquid was released to the environment in an unplanned and unmonitored fashion, based on the data available, the task force did not identify any instances where the health of the public was impacted." (Reference 95)**.**

Experience at a number of decommissioning commercial nuclear power stations has positively identified unintentional releases of small quantities of radionuclides from plant systems and structures during the operations of these plants. Any one or a combination of component, system, and structural integrity failures has ultimately led to unmonitored activity being released to areas of these the sites. The released radionuclides that were not retained in the soil at the leak location traveled downward to the groundwater below the site. The groundwater radionuclide concentrations were below site release limits at most sites. However, at the Connecticut Yankee site significant soil and bedrock remediation was needed to bring groundwater concentrations down to the release standards for all regulatory authorities.

The goal of this report is to discuss:

- The actual costs of decommissioning at power plant sites compared to the pre-shutdown decommissioning cost estimates
- The measures taken during actual site decommissioning to control cost through innovative decommissioning techniques.
- The ability of nuclear power plant owners to fund decommissioning including post-shutdown cost increases
- Actual experience with groundwater contamination at the sites during the decommissioning process and the magnitude of groundwater related cost relative to total decommissioning costs.
- The measures taken by the nuclear power industry to incorporate the lessons learned from the decommissioning experiences into planning future decommissioning and into the design of future power plants.

2

SITE RELEASE REGULATORY REQUIREMENTS

2.1 Overview and Background

There are a number of regulatory agencies and other interested parties that have a stake in the release of a nuclear power plant site for future non-regulated use. This chapter describes how multiple regulatory agencies may be involved in the decommissioning of power plant sites, and discusses how imposition of clean-up criteria by these agencies has affected release of certain sites during the last 10 years.

Many entities including the NRC, state regulators, the EPA and local stakeholders are a part of establishing the release criteria for a site. Meeting the site release limits for groundwater required by certain states has resulted in much lower cleanup levels for soil than those determined based on NRC requirements alone. At the Connecticut Yankee plant, significantly more soil remediation was required due to these lower allowable concentrations.

2.2 Radiological Release Criteria

The following are examples of how the requirements imposed by different agencies have affected the termination of licenses at decommissioned sites.

2.2.1 Connecticut Yankee

The determination of the radiological release criteria for sites can require the involvement of various stakeholders. As an example of these types of interactions, the CY experience will be discussed in detail followed by variations in experience for other plants.

2.2.1.1 NRC

The NRC License Termination Rule (Reference 94) defines the standard for unrestricted release of a site. This regulation requires that no average member of the critical group receive a post closure dose of more then 25 mrem/yr Total Effective Dose Equivalent (TEDE) from all dose pathways (i.e. contaminated soil, concrete and groundwater). There is an additional requirement that residual radioactivity be reduced to levels that are as low as reasonably achievable (ALARA).

To define how Connecticut Yankee Atomic Power Company (CYAPCO) was to meet this regulation for the decommissioning of CY, a License Termination Plan (LTP) was written and submitted to the NRC in July of 2000. This plan included the results of calculations for the remediation limits that needed to be achieved in order to meet the NRC 25 mrem/yr standard. Following a review and comments resolution period, the CY LTP was approved in November of 2002. The key soil and groundwater concentration limits determined by this process are shown in Table 2-1.

2.2.1.2 State of Connecticut

As CY planned to convey most of the site property to a different owner at the end of decommissioning, the State of Connecticut Property Transfer Act (PTA) would need to be met at the time of the transfer. The Connecticut Department of Environmental Protection (CT DEP) developed standards based on the applicable state regulations that corresponded to a release standard of 19 mrem/yr TEDE to an average member of the critical group. Compliance with the CT DEP risk based criteria would be shown using the same methodology as required by the CY LTP except to the lower dose standard.

The CT DEP regulations contain additional remediation standards for groundwater. The CY site is classified as residential by the State of Connecticut. Under the applicable state standards, additional polluting substances such as radionuclides are not allowed, in an aquifer under sites classified like CY, at levels above background. Through discussions between CY and the CT DEP it was agreed that the US EPA published Maximum Contaminant Levels (MCLs, a.k.a. Drinking Water Standards) would be an adequate standard for compliance even though the goal would remain as “no measurable concentrations over background”. For each radionuclide, the MCL is the concentration in water that if consumed for a year at “average“ drinking water rate of 2 gallons per day, would result in a dose to the target organ (most susceptible organ) of 4 mrem/year. The methodology used to perform this calculation is based on an International Council on Radiation Protection publication ICRP-2 published 1975. More recent dose assessment methodology published by the ICRP and utilized by the NRC is based on the TEDE dose (all doses normalized to a whole body dose) basis rather than an organ dose methodology. Using the more current methodology, the TEDE dose calculated using the slightly lower intake rate published in NRC guidance (and used in the CY LTP) would be approximately 1 mrem/yr each for the two primary radionuclides present in groundwater at CY, Tritium (H-3) and Strontium 90 (Sr-90), at the MCL concentrations. As will be discussed later in this chapter and in Section 4.2.1.2, this factor led to a considerable increase in the amount of soil and bedrock that required remediation that needed at Connecticut Yankee.

2.2.1.3 EPA/NRC MOU

The EPA and NRC entered into a memorandum of understanding (MOU) concerning radionuclide remediation standards on October 9, 2002 (Reference 96). The purpose of the MOU was to identify the interactions between the NRC and EPA for the decommissioning and decontamination of NRC-licensed sites and to indicate the way in which those interactions would take place. The MOU was largely limited to the coordination between EPA, when acting under its Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) authority, and the NRC, when an NRC-licensed facility was undergoing decommissioning, or when the facility had completed decommissioning and the NRC had terminated its license. The MOU defined radionuclide concentrations which, if present at the time of license termination of NRC licensed facility, would initiate consultation between NRC and EPA. The MOU included trigger concentrations for soil, based on residential and industrial future use of the site. Soil screening concentrations for some of the key radionuclides normally encountered at nuclear plant sites, measured in elevated concentrations in soil and/or have been detected in groundwater are given in Table 2-1. The MOU also contains trigger concentrations for groundwater. These correspond to the EPA Maximum Contaminant Levels. MCL values for the key radionuclides that have been measured in groundwater at nuclear power plants are shown in Table 2-1.

2.2.1.4 Comparison of Release Criteria/Multiple Regulation

Table 2-1 is a listing of the radionuclide release limits for the different regulatory agencies for some of the key radionuclides present at CY. The CY LTP values were determined using NRC recognized dose modeling code (RESRAD developed by Argonne National Laboratories) and input parameters from NRC guidance. The key concentrations to which remediation needs to be performed to meet all of the regulations are highlighted.

Table 2-1
Comparison of Site Release Limits for Different Regulatory Agencies

Media: Radionuclide	**NRC 25 mrem/yr (CY LTP)**	**State of CT Regulations (19 mrem/yr)**	**EPA/NRC MOU: Residential Soil Levels**	**CY Soil Screening Concentration to Achieve MCLs in the Groundwater**
Soil : Co-60	3.81 pCi/g[1]	2.9 pCi/g	4 pCi/g	3.5 pCi/g
Soil : Cs-137	7.91 pCi/g	6 pCi/g	6 pCi/g	3.3 pCi/g
Soil : Sr-90	1.55 pCi/g	1.18 pCi/g	23 pCi/g	0.065 pCi/g
Soil: H-3	412 pCi/g	313 pCi/g	228 pCi/g	3.3 pCi/g
Water: Co-60	1,140 pCi/L[2]	100 pCi/L	100 pCi/L	N/A
Water: Cs-137	431 pCi/L	200 pCi/L	200 pCi/L	N/A
Water: Sr-90	251 pCi/L	8 pCi/L	8 pCi/L	N/A
Water: H-3	652,000 pCi/L	20,000 pCi/L	20,000 pCi/L	N/A

As can be seen from Table 2-1, the State of Connecticut requirements are the most restrictive standards for both soil and groundwater for essentially all of the key radionuclides listed (although the EPA/NRC MOU soil screening concentration for H-3 is lower than the state limit, remediation was driven by the CY soil screening concentrations shown in the last column). In some cases, the EPA/NRC MOU criteria are the same as that of the State of Connecticut. Further review of Table 2-1 shows that the most restrictive soil concentrations listed (to meet the CT

DEP regulations) are not greatly lower than those defined by the CY LTP. Therefore, the CT DEP standards for soil did not greatly affect the quantity of soil remediated.

Contrary to the criteria for soil, the State of Connecticut's release limits for groundwater and the groundwater consultation trigger in the EPA/NRC MOU are much lower then that determined in the CY LTP. Meeting these lower concentrations for groundwater resulted in significantly more soil remediation at CY than would have been required to meet the LTP criteria alone due to the following:

Certain radionuclides can be released from soil due to groundwater or precipitation passing through the soil. An equilibrium exists between the contaminated soil and the groundwater. If a radionuclide is easily mobilized, soil containing that radionuclide in sufficient concentrations can cause groundwater levels to exceed the groundwater criteria. This proved to be the case for Tritium (H-3) and Strontium-90 (Sr-90) at CY as can be seen in the last column of Table 2-1 Tritium needed to be remediated to a level approximately 95 times lower and Sr-90 to a level approximately 18 times lower then the CT DEP dose based soil criteria in order to meet the MCL levels with the site in it's final state. The reduction factors determined by comparing to the MOU triggers are 69 for H-3 and 354 for Sr-90. The effect on remediation of the mobility of CSCs-137 is less as the soil remediation concentration is only 45 % less then that required to meet the CT DEP 19 mrem/yr criteria.

As is discussed in Section 4.2.1.2.3 of this report, in order to meet the MCLs at time of site release at CY, 55 % more soil required removal and disposal of as radioactive waste than would have been required to meet only the NRC regulations. The estimated cost due to the additional remediation, waste disposal and the additional monitoring required by the State of Connecticut is $25M which corresponds to approximately 3% of the total decommissioning costs for CY.

2.2.2 Other Plant Sites with Additional State Release Criteria

In most states the NRC release criteria is used for the release of the site (i.e., the state agencies involved agree that the NRC standards meet their requirements). However other states in which decommissioning plants were located have imposed their own more stringent limits on the plant licensees (as was discussed in the last section for CY). The following are a few examples where additional state release criteria came into effect: Although the state standards do not affect the ability of the site to be released from it's NRC license, it is more cost effective for a site to remediate to the most stringent standards rather then have to perform more remediation at a later time to meet state standards.

2.2.2.1 Maine Yankee

Many of the requirements for release of the Maine Yankee (MY) site were the results of negotiations with and/or legislation by stakeholders for the site. This included the establishment of a Technical Resolutions Panel consisting of 2 members representing the State of Maine and 2 members from Maine Yankee. At the time that MY was initially setting their release criteria, 1999 to 2000, the following regulations and other guidance were in place:

- NRC – 25 mrem/yr TEDE plus ALARA as previously discussed.
- EPA – 15 mrem/yr TEDE with the additional requirement of dose due to the groundwater pathway being no more then 4 mrem/yr to the target organ. The concentrations in groundwater that corresponded to the 4 mrem/yr criteria are those defined by the EPA as the Maximum Contaminant Levels (MCLs as discussed above).

In light of the above, MY proposed a release criteria of 10 mrem/yr TEDE from all pathways including no more than 4 mrem/yr TEDE from the groundwater dose pathway. The MY proposed criteria were subsequently made law by the State of Maine legislature and implemented by MY.

Maine Yankee chose to make these limits a part of their NRC approved License Termination Plan (LTP). Due to this, the NRC performed their inspections to ensure compliance to these lower dose limits in releasing MY from it’s NRC license.

2.2.2.2 Yankee Rowe

The Yankee Rowe site had similar criteria to that for Maine Yankee (i.e., 10 mrem/yr TEDE and no more then 4 mrem/yr organ dose) that was required by the State of Massachusetts Department of Public Health (DPH). Agreement between Yankee Rowe and the MA DPH on the release criteria was reached in the 2005-2006 time frame.

2.2.3 Plants without Additional State Imposed Release Criteria

The following plants met the NRC and state limits by using the NRC LTR criteria of 25 mrem/yr TEDE from all pathways to a member of the criteria group. Where additional criteria were used they are discussed in the following:

- Trojan Plant
- Big Rock Point Plant
- Saxton – Volunteered to comply with the 4 mrem/yr organ dose drinking water standard (EPA MCLs)
- Rancho Seco Plant

3

EXPERIENCES AND COSTS OF POWER REACTOR DECOMMISSIONING

3.1 Overview

This chapter discusses the overall experiences at recent power reactor sites and how the costs of those decommissionings compare with their pre-shutdown Decommissioning Cost Estimates (DCE). Also discussed in this chapter is how the decommissioning of nuclear power plants has become a mature industry through the experiences of these recent decommissioning experiences.

3.2 Background

As discussed in Chapter 1, the nuclear industry in the United States has gained a wealth of decommissioning experience over the past two decades. This decommissioning experience can be used to enhance the preparation of future decommissioning cost estimates. Experience from these projects demonstrates the accuracy of DCEs that have been prepared for these projects. Two examples sited, for very recent projects, Big Rock Point and Maine Yankee, had actual costs of decommissioning that where within 6% and 8.8% respectively, of the of the pre-shutdown estimated costs (Reference 97). This level of accuracy was achieved by MY despite significant challenges that were encountered during the project. Through diligent project management MY was able to control costs, even when state regulatory mandates invoked a much more restrictive cleanup criteria than anticipated (10 mrem/yr versus NRC’s 25 mrem/yr criterion as discussed in Chapter 2), and after the decommissioning contractor defaulted resulting in the owner self-managing the project.

Connecticut Yankee, the most challenging of all the full scale power reactor decommissioning projects to date, experienced a relatively large increase in actual costs versus the pre-shutdown estimates (a 99% increase from $427M to $850M). As is discussed later in this chapter, the CY decommissioning was fully funded and successfully completed. As is discussed in Section 4.2.1.4, a small fraction of the cost increases were related to groundwater contamination and the soil remediation required to meet site release limits. The large majority of the cost increase (more than 82 %) was due to other factors such as:

- Termination of the contract with the major decommissioning contractor
- Concrete contamination resulting in the total removal of a number of site building and disposal of the resulting radioactive waste
- Difficulties encountered and project cost overruns in segmenting the Reactor Vessel Internals

- The relatively high ratio of Transuranic radionuclides to the easy to detect beta/gamma radionuclides in contamination on structures and inside systems compared to other power plants. This factor made removals radiologically difficult and greatly slowed the work.

The Association for the Advancement of Cost Engineering International (AACEI), which was founded as a resource for general cost estimating methodology (not specific to decommissioning) and a certifier of cost estimators, defines the most accurate type of cost estimate that can be expected, a “Definitive Estimate”, as having an expected accuracy of -5% to +15% (Reference 3-2). Clearly, the nuclear power industry has demonstrated the capability to accurately estimate within industry standards, the cost of decommissioning in most cases.

3.3 Lessons Learned During Power Reactor Decommissioning

During the past two decades the NRC regulated nuclear industry has encountered and dealt with a diverse range of political, financial and technological challenges while decommissioning its nuclear facilities. These factors in certain cases have led to increases in scheduled durations and cost due to public intervention, weather delays, regulatory approvals and contracting disputes during actual decommissioning work. Now that the industry has experienced these challenges, future decommissioning projects will be able to benefit from the lessons that have been learned. This will allow licensees to plan and implement future decommissioning projects in a more cost effective manner. Some of the challenges which resulted in lessons learned include:

- Uncertainty of scope has arisen on decommissioning projects due to inability to fully characterize facilities during initial planning stages. Radiological and physical conditions have been found to constrain access and ability to fully characterize subsurface conditions early in the project. However, these constraining conditions are continuously altered by decommissioning work, permitting subsequent access to conduct full subsurface characterizations (i.e. characterization performed after overlying structures have been removed has found contamination not identified during extensive characterization efforts performed prior to the start of decommissioning). Prior to the industry gaining the benefits of the lessons-learned we now have, it was believed that full characterization could be performed as a single phase prior to the start of decommissioning work. As a result of that belief, it was assumed and that the full scope of the decommissioning work would be known, and could be planned (and contracted out) all at once. Experience has shown that this not the case for a reactor undergoing decommissioning. As an example, it was learned that subsurface soil contamination tends be narrowly distributed in the unsaturated zone along preferential anthropogenic flow paths. The areas where subsurface contamination may occur usually cannot be adequately accessed for characterization until late in the decommissioning process, after the structures, systems and components with higher levels of contaminants sources have been removed. Experience has shown that subsurface characterization efforts at early stages tend to miss these subsurface conditions. The early characterization approach led to contracting disputes when scope changes were encountered and extensive re-planning efforts were spent when the approach being followed was deemed ineffective by new information. This is one of the most important lessons learned, that characterization and the ensuing D&D work planning needs to be performed on a continuous basis throughout a decommissioning project. Future decommissioning projects will be able to better plan and control costs by breaking the projects into smaller individual projects to avoid wasted up front efforts and mid-stream approach changes.

- Projects shifting from turn-key contracting to self-manage/self-perform has occurred due to decommissioning contractor defaults or terminations:. During these first large scale decommissioning projects, that were planned and implemented without the benefit of prior industry experience, many innovative decommissioning approaches were attempted in an effort to control costs. Some of these approaches were found to be beneficial, while others had an opposite effect and contributed to the challenges cited. One approach that had unintended consequences was the use of rigid fixed-price contracts at MY and CY, where decommissioning contractors signed up to perform the entire decommissioning work scope. As previously discussed, it is not possible to fully characterize and entirely plan the decommissioning before the work starts. This less than certain work scope coupled with fixed-price do-it-all contracts led to disputes and approach changes that caused delays in those projects. The industry has learned that a more flexible contracting and planning approach would avoid these problems and contribute to better cost control lowering cost.
- Regulatory uncertainty on application of release criteria has led to project delays and increased costs. Use of the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) was new and had to be learned by both licensees and regulators. States' jurisdiction for imposing lower release criteria and alternate dose pathway assumptions was a development that often resulted in multi-party protracted negotiations during the course of performing decommissioning work. This uncertainty led to additional costs for Derived Concentration Guideline Level (DCGL) development re-work and increased project durations where decommissioning approaches had to change in response to differing end-point objectives. With many of these uncertainties now resolved, future decommissioning costs can be better projected and controlled.

As previously discussed, in the late 1990s a number of large power reactors were successfully decommissioned, such as Trojan, Big Rock Point, Maine Yankee, Yankee Rowe, and Connecticut Yankee. To control costs from unexpected conditions encountered during decommissioning, power reactor licensee and contractors developed many innovative dismantling and decontamination approaches during the course of performing their decommissioning projects. These innovative approaches simplified performance of the work and reduced the costs. Planned use of these innovative D&D approaches on future decommissioning projects will reap significant savings, when they can be incorporated into planning before the work starts. Some of the industry developments and innovative methods that have been used to reduce decommissioning costs include the following:

- The reduced radwaste disposal cost that occurred with the advent of the Envirocare (now Energy Solutions) disposal facility in Clive, Utah being able to accept Part 50 licensed material starting in the mid-1990s shifted decommissioning approaches towards aggressive removal of contaminated material, instead of the more time consuming and costly on-site decontamination and free-release approach. This has allowed for shorter project schedules, reducing overall project labor and overhead costs.

- This bulk removal approach has also reduced final survey costs, where the complete removal of structures (as assumed radioactive waste) has been found to be much less expensive than the time and labor intensive process of performing final status surveys.
- Use of large re-usable shipping containers has allowed for bulk removal, packaging and disposal of contaminated soil and rubble. This has decreased packaging and material handling costs, and accelerated the rate at which decommissioning work can be accomplished.
- The use of specialty off-site facilities for decontamination and free-release of materials to controlled landfills such as those in Tennessee has allowed waste materials to be removed from project sites much more rapidly, thereby shortening schedules and reducing project labor.
- Many site shave demonstrated that structures, including those where decontamination has been performed, can be free released and the demolition debris sent to a local landfill. As with the last bullet, this has allowed waste materials to be removed from project sites much more rapidly, thereby shortening schedules and reducing project labor.
- Advances in primary system decontamination, and the ensuing radiation dose rate reductions has allowed the use less expensive and faster hands-on dismantling techniques, rather that reliance on expensive and slow robotics and remote tooling techniques.
- Use of bulk demolition techniques, such as explosives and ram hoes has reduced project durations and labor costs.
- Contracting incentives, such as cost-plus incentive fees have been used to reduce bid costs, by reducing potential financial risk that are inherent in fixed-price contracts, thereby reducing the effects of cascading inclusion of inflated contingencies.
- One-piece removal of large components, such as reactor pressure vessels and steam generators, in lieu of segmentation, has reduced labor costs and shortened schedules. This has also reduced waste disposal, packaging and transportation costs through averaging of radioactivity over a large single mass, thereby allowing components to be disposed of as less expensive Class A waste, and transported as their own containers.

These developments and innovative techniques have helped the nuclear power industry show that nuclear power plants can be decommissioned within the required regulations

3.4 Summary of Lessons Learned at Decommissioning Plants

Based on this experience, the nuclear industry has proven that it has the technology and ability to decommission its nuclear reactors. Recent experience has shown that power reactor facilities can be successfully decommissioned to unrestricted use criteria at costs generally close to that estimated prior to the start of physical decommissioning work, even with the occurrence of the challenges.

The lessons learned in completing recent decommissioning have been captured by the industry, including EPRI in decommissioning experience reports that will serve as a basis for future decommissioning planning and cost estimating.

Some of the sites, where groundwater contamination has been detected have needed to include the increased cost of monitoring and remediation in rate cases that increase the funds available for the decommissioning. The increases due to groundwater contamination to met NRC limits have, in even the worst case, been less than 12% of the increase requested. In all cases, the utility has been able to obtain approval to pass the increased decommissioning costs onto the rate payers. Nuclear power plants that are Independent Power Producers are a part of ongoing nuclear business by those utilities and therefore the risk of default is extremely low.

As all the decommissionings begun to date have been successfully completed or have not identified impediments to their completion, there is little or no potential for power plants site to become legacy sites. The proposed regulatory changes offered by NRC no significant benefits in reducing the likelihood of legacy sites for power reactors and as such the existing NRC regulatory structure provides adequate assurance based on the decommissioning experiences described in this report.

4

EXPERIENCES RELATED TO GROUNDWATER CONTAMINATION

4.1 Overview

This chapter discusses how specific site experiences addressing groundwater contamination have affected decommissioning costs. Significant remediation to meet the groundwater related release criteria discussed in the Chapter 2 has only been required at one nuclear power plant site.

4.2 Decommissioning Case Studies

This section will focus on sites where significant radiological groundwater contamination was detected and the impact that this contamination had on:

- The ability of the site to achieve unrestricted release from its NRC license
- The affect of addressing the cost of groundwater contamination in relation to total decommissioning costs.
- The ability of the plant owner to fund any increases to decommissioning costs

4.2.1 Connecticut Yankee Experience

Remediation of soil and bedrock at Connecticut Yankee (CY) in order to meet the site release criteria discussed in the last chapter proved to be substantial. How the site met the various regulatory requirements to address groundwater contamination at CY is described in this section based on information obtained in a number of EPRI Reports and Guidelines (References 74, 81, 91 and 93).

4.2.1.1 Site Characterization

Based upon site characterization, CY installed groundwater monitoring wells in various areas of the site and began groundwater monitoring in late 1997. The results of these early sample rounds showed significant levels of tritium in the plant’s industrial area. Levels as high as 152,000 in 1997 pCi/L were measured in one well located hydraulically downgradient of the tank farm located outside of the Auxiliary Building. Additional quarterly well sampling showed that levels of tritium, after 6 months, had dropped quickly to near to or below the EPA Maximum Contaminant Levels MCL (20,000 pCi/L). This was consistent with the draining of the tank suspected of being the source of the leakage. Detectable levels of Cesium-137 (Cs-137) were also measured in the vicinity of the outside tank farm adjacent to the Primary Auxiliary Building but were a fraction of the EPA MCL concentration of 200 pCi/l.

An expanded monitoring plan begun in 2001 included analysis of groundwater samples for all 20 radionuclides of concern identified as potentially present at the CY site. The analysis results of the first round of groundwater sampling under the detailed characterization plan showed significant levels of Strontium-90 (Sr-90), as high as 200 pCi/l, in some of the wells near to and hydraulically downgradient to the tank farm previously mentioned. Although the highest levels were 25 times higher than the EPA MCL for Sr-90 (8 pCi/l), the concentrations were only approximately 2 times higher than would be acceptable using the TEDE whole body dose methodology utilized by the NRC. This dose, due to groundwater contamination under NRC methodology, allowed a sufficient portion of the 25 mrem/yr post closure dose limit to be designated to other dose pathways (i.e., soil and concrete contamination).. Additionally there were detections of H-3 consistent with previous sampling.

Unlike the rapid drop of H-3 concentrations from their historical highs, the pre-remediation trend of Sr-90 concentrations in groundwater was more erratic. A more detailed analysis of the Sr-90 trend showed a correlation of the increases in Sr-90 groundwater concentrations with increasing water table levels. This fact indicated that a continuing inventory of Sr-90 existed at some locations on the site and that this inventory was being contacted during periods of high water table (generally springtime periods of snow melt and precipitation). It was postulated that as the water table rose, it came in contact with contaminated soil that was above the average water table level. This contact would result in the dissolution of the Sr-90 from the soil due to the chemical equilibrium of water and soil. This mobilized Sr-90 would then move through the groundwater and be detected in the samples taken from wells downgradient of the contaminated soil inventory.

To provide further definition, an extensive soil characterization program was initiated. Approximately 200 sample locations generating approximately 1000 samples, primarily in the tank farm and downgradient areas, were chosen. Soil samples from other areas of the plant were also analyzed to determine if this situation existed elsewhere. Figure 4-2 shows the locations of the soil samples and the locations where remediation below the water table was necessary to meet the bounding State of Connecticut regulations. Many sample locations were outside buildings, but for certain buildings the soil under the building was sampled by boring through floors. The results of this campaign indicated the highest levels of radionuclides were present under the tank farm adjacent to the Auxiliary Building. In addition to high levels of Sr-90, significant levels of most of the other radionuclides of concern at CY were present in the soil below the tank farm. This information confirmed the movement of Sr-90 in groundwater as discussed above.

4.2.1.2 Soil Remediation

4.2.1.2.1 PAB Excavation

- As discussed in detail in Section 2.2.1.4, although less soil and no bedrock remediation was needed to meet the NRC approved release criteria in the CY LTP, additional remediation was required to meet the State of Connecticut regulations. This was done to avoid the need for additional remediation at a later time to meet state regulations. As can be seen from Figure 4-1, the required soil removal was centrally located to the industrial area. The structures in the tank farm area and the PAB were removed in their entirety (See Figure 4-1) to prevent future impact on groundwater from the contaminated concrete in basements of these structures when the infiltration of groundwater into the remediated area was allowed.

Figure 4-1
PAB Excavation at CY

The results of the post-remediation assessment of the PAB excavation was that the post remediation groundwater concentrations would be below the EPA MCL and meeting the bounding State of Connecticut site release criteria.

4.2.1.2.2 Tank Farm Excavation

The remediation of the Tank Farm Excavation proved to be more difficult than the downgradient areas. Due to blasting during plant construction, the bedrock in this area was more fractured than in other areas of the PAB excavation. As the Tank Farm area was where the majority of the leakage events affecting groundwater had occurred, soil in this area had the highest radionuclide concentrations measured on site. More radionuclides were detected in this area as the soil radionuclide retention properties stopped movement of most of the radionuclides away from the leakage areas.

The same remediation techniques used for the remainder of the PAB excavation was also used in this area. After the soil had been vacuumed from the area directly below the tank farm, radioactivity could be detected in bedrock fractures. The results of the comprehensive survey was that an area of bedrock approximately 25 feet square and up to 16 feet deep needed to be removed to ensure that groundwater concentrations would not exceed the EPA MCLs after the remediation. It should be noted that this bedrock remediation would not have been necessary to meet only the NRC site release criteria.

A post remediation survey was performed on this additional area of remediation and no readings over background were found. The results of a post remediation radiological assessment were that projected groundwater concentrations would be well below the EPA MCLs.

4.2.1.2.3 Other Soil Remediations

To determine if groundwater conveyed contamination had spread to other areas of the site industrial area and to investigate the affect of other contamination incidents, 12 additional areas were sampled. The results of this sampling identified the need for 7 additional excavations. Although these areas generally had much lower levels of soil contamination than the tank farm, remediation was needed to achieve projected post remediation groundwater concentrations that were below the MCLs. The sample results were compared to the limits stated in Table 2-1 and remediation requirements were determined. Figure 4-2 shows all the soil and bedrock remediation areas where removals were made below the water table**.**

Post-remediation groundwater monitoring confirmed the radiological assessments performed after remediation was completed in the excavations. Measured groundwater concentrations were below the NRC limits and the triggers of the EPA/NRC MOU allowing release of the CY site from its NRC license. Additional groundwater monitoring is required at CY through 2010 to meet CT DEP regulations.

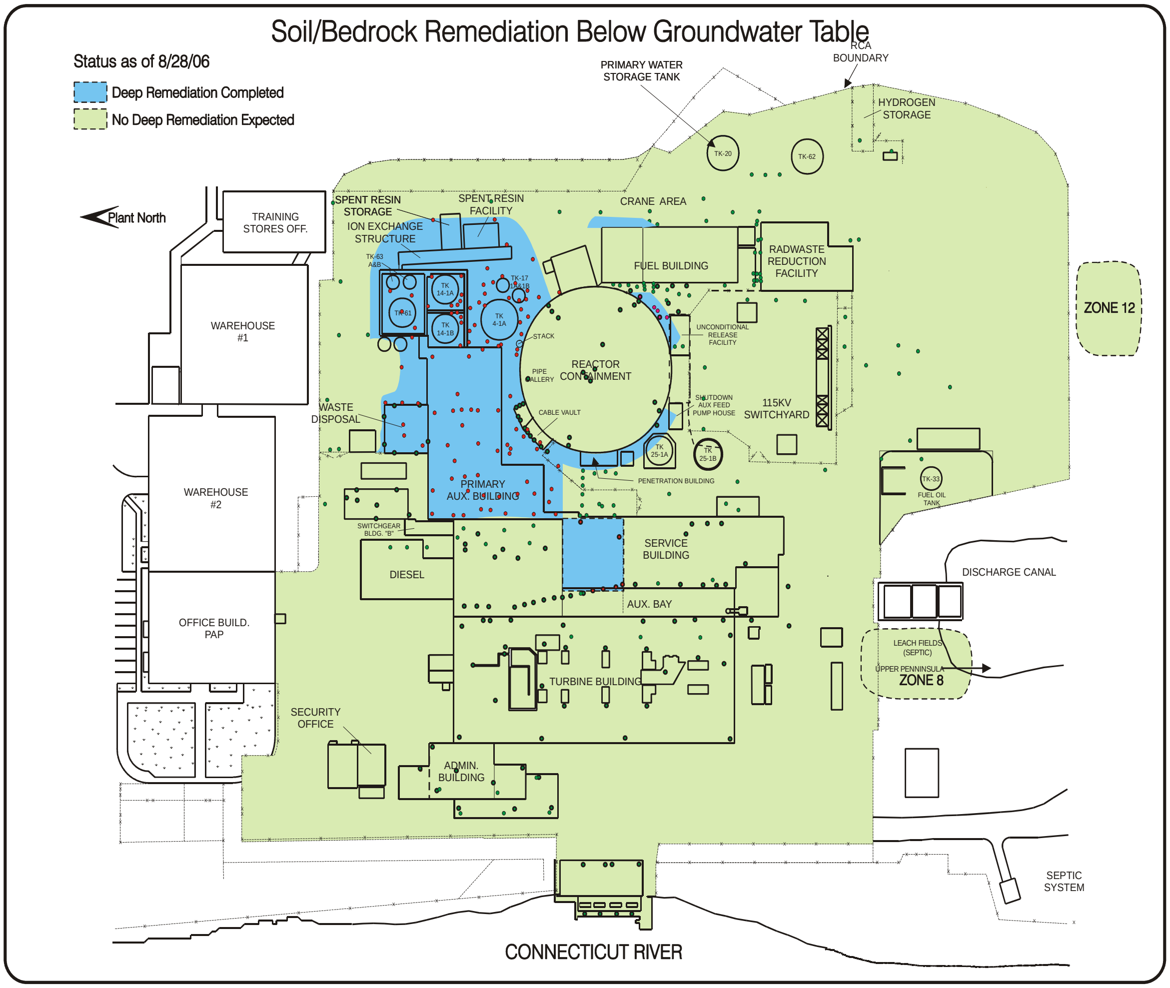

Figure 4-2
Remediation Areas Located below the Water Table at CY

A total 1.17 million ft^3 of soil and bedrock required removal and disposal as radioactive waste due to facility leaks and spills, and subsequent conveyance of the contamination by groundwater to other areas of the CY industrial area. Using an assumed soil density of 75 lbs/ft^3 the total weight of the additional remediations was 87.5 million pounds, the total cost of the transportation and disposal of this material is approximately $35 million at a unit price for transportation and disposal of $0.40/lb (approximate rates applying volume discounts available at the time). Additional cost, above that for transportation and disposal including costs for remediation and packaging of the waste and the cost of the engineered soil needed to backfill the excavation, added more than $20 million. When the cost of groundwater monitoring of $20M was added the total cost related to addressing groundwater contamination at CY was $75M. Table 4-1 provides a comparison of the groundwater related costs for CY, Maine Yankee and Yankee Rowe to their respective total decommissioning costs. The portion of the total volume of remediated soil and bedrock that did not require removal to meet NRC limits but was removed to meet the MCLs at time of site release (per the discussion in Section 2.2.1.4) was 412,000 ft^3 for a total weight of 31 million pounds. This additional quantity is a 55% increase of what would have been required in meeting the NRC regulations. The total cost of the transportation and disposal of this material is approximately $12.4 M at above stated unit prices. Additional remediation and packaging costs were approximately $7 million. When the portion of the groundwater monitoring cost driven by State of Connecticut requirements is included, the total portion of groundwater related costs attributable to State of Connecticut requirements is approximately $25M or 33 % of all groundwater related decommissioning costs and 3 % of all CY decommissioning costs.

Table 4-1
Groundwater Related Costs Compared to Total Decommissioning Cost

Plant Site	Total Decommissioning Cost	Cost Related to Groundwater Contamination	Percentage of Total Cost Due to Groundwater	Groundwater Cost Due to State Regulation	State Driven Cost as a % of Total Decommissioning Cost
Conn. Yankee	$ 850 M	$ 75 M (Remediation and Monitoring)	9 %	$ 25 M	3 %
Maine Yankee	$ 500 M	$ 10 M (Monitoring Only)	2 %	None	N/A
Yankee Rowe	$ 750 M	$ 15 M (Monitoring Only)	2 %	None	N/A

4.2.1.3 Funding for Groundwater Related Costs

Connecticut Yankee needed to request additional funds as the decommissioning proceeded to cover a number of unexpected costs. The total cost of the CY decommissioning increased from the pre-shutdown estimate of $427M to the completed project total of $850M (this value does not include the cost of long term on-site storage of spent fuel).

All increases in required decommission funds at CY were approved by the Federal Energy Regulatory Commission (FERC). It was never in question as to whether the required groundwater remediation would be completed, just how it would be paid for (i.e. decommissioning funds approved by FERC or electric utility assets). Although electric utility assets were not allocated for use in paying for groundwater remediation costs, this would have been required to complete the decommissioning had FERC not approved these cost along with the other cost increases identified.

The nuclear power plants that are Independent Power Producers will also need to perform and pay for all work that is necessary to complete the decommissioning. Most of these plants are owned and operated by large ongoing nuclear business and therefore the risk of default is extremely low

It is noteworthy that the groundwater contamination related cost at CY were less than 9% of the total decommissioning costs and approximately 18 % of the decommissioning cost increases from the pre-shutdown estimates. When only the groundwater contamination related cost driven by NRC regulation are used, the percent of total decommissioning cost is less than 6 % and less than 12 % of the decommissioning cost increases. The groundwater related costs at CY, the worst case site in terms of groundwater contamination, are small fractions of the total decommissioning costs and the post-shutdown increases to decommissioning cost estimates.

4.2.2 Yankee Rowe

Groundwater monitoring was also conducted during the decommissioning of the Yankee Rowe, located in western Massachusetts. The tritium concentrations detected at Yankee Rowe the concentrations were much lower than at CY.

4.2.2.1 Groundwater Characterization Results

The highest concentrations detected during the Yankee Rowe decommissioning were slightly higher than the EPA MCLs for tritium of 20,000 pCi/l. The location where the groundwater concentration exceeded the MCLs was fairly deep below the site in localized, relatively small "sand lenses." It was determined by analysis that if a well was placed so as to draw water for use by a resident on the site after license termination, the concentration of the pumped water could not exceed a tritium concentration that exceeded the MCLs. This is due to fact that the tritium in the sand lenses would not be transferred to the groundwater due to the physical properties of the sand.

As Yankee Rowe had committed to achieve the Groundwater MCL, the post closure TEDE dose that needed to be allocated for the "existing" groundwater was 0.77 mrem/yr corresponding to the dose from 20,000 pCi/L of H-3 in groundwater. This dose was calculated assuming the Resident Farmer Scenario and using the RESRAD dose modeling code developed for NRC and other agencies by Argonne National Laboratories.

As Yankee Rowe had committed to the State of Massachusetts DPH (MA DPH) criteria 10 mrem/yr site, release limits for soil had to first be ratioed down from values determined by RESRAD at a dose of 25 mrem/yr. The 10 mrem/yr also needed to take into account the calculated dose from radionuclides that leach from subsurface structure (0.5 mrem/year) and the groundwater doses of 0.77 mrem/yr discussed in the last paragraph. This left 8.73 mrem/year to be used for soil in the industrial area**.** An adjustment factor of 0.873 was applied to the 10 mrem/yr site release limits for soil.

Application of the release limits discussed in the last paragraph resulted in soil remediation due to achieving the dose limits from the soil pathway that were only slightly reduced due to groundwater from the 10 mrem/yr total MA DPH limit. The very limited impact of groundwater contamination was due to the following:

- Groundwater samples from relatively shallow depth show concentrations below the EPA MCLs, therefore not requiring remediation to achieve a standard that was much more stringent than the NRC site release criteria.
- As discussed above, the higher groundwater concentrations in the sand lenses did not require remediation as they could not produce well water in excess of the EPA MCLs.

4.2.2.2 Groundwater Related Costs

As discussed in the last section, no soil remediation costs at Yankee Rowe were directly due to groundwater contamination. Therefore the only groundwater related costs are from groundwater monitoring activities for tasks such as the following:

- Installation of groundwater monitoring wells
- Sampling of the wells and analysis of the samples
- Modeling of the groundwater flow to predict flow paths

It is estimated that the total of these activities at Yankee Rowe was approximately 2 % of the total decommissioning costs (See Table 4-1) at the site of $750M (this value does not include the cost of long term on-site storage of spent fuel) and less than 5% of increase $330 M in total decommissioning cost from the pre-shutdown Decommissioning Cost Estimate. Yankee Rowe requested and received approval from FERC for the increase in decommissioning funds. This example illustrates the situation at most sites being decommissioned where the cost due to groundwater is a very small fraction of the total decommissioning costs.

4.2.3 Maine Yankee

The Maine Yankee plant also observed elevated levels of tritium in on-site groundwater monitoring wells. Although most wells had levels well below the EPA MCL, one well showed tritium concentrations as high as 58,000 pCi/l at the end of the Maine Yankee decommissioning.

As discussed in Chapter 2, the release limits for Maine Yankee allowed up to 4 mrem/yr TEDE dose from groundwater. A separate calculation was developed for existing groundwater using the RESRAD based on unit concentrations of each nuclide. The groundwater dose calculated from the highest individual groundwater sample result from site monitoring wells was well below the 4 mrem/yr limit.

Because the worst case groundwater concentrations were below the site release limits, no soil remediation was needed that was attributable to groundwater contamination. There were significant groundwater monitoring costs such as those incurred at Yankee Rowe for monitoring wells, sampling, sample analysis and groundwater flow modeling. These costs totaled were less than 2 percent of the total decommissioning costs (See Table 4-1) for Maine Yankee of $500 M (this value does not include the cost of long term on-site storage of spent fuel). This is another example of groundwater related costs being a very small fraction of total decommissioning costs.

4.3 Summary of Experiences Related to Groundwater Contamination

In cases where the decommissioning cost increases have been substantial, the portions of those cost increases that are attributable to groundwater contamination are a small fraction of the total. Even at Connecticut Yankee (CY), where the groundwater contamination observed was the most significant, total remediation, waste disposal and groundwater monitoring cost to meet NRC site release requirements was less than 6% of the total decommissioning cost (not including spent fuel storage costs).

Some of the sites where groundwater contamination has been detected have needed to include the increased cost of monitoring and remediation in rate cases that increase the available funds for the decommissioning. The increases due to groundwater contamination to met NRC limits have, in the highest case at CY, been less than 12% of the increase requested. In all cases, the utility has been able to obtain approval to pass the increased decommissioning costs onto the rate payers. This philosophy also applies at nuclear power plants that are Independent Power Producers. These plants are part of an ongoing nuclear business by those utilities and therefore the risk of default is extremely low.

As is illustrated by the CY experience, the overlying structures need to be removed to adequately characterize the soil beneath them. The requirement in the proposed NRC regulations for extensive subsurface soil characterization (or remediation for that matter) during an operating facility's lifetime will not result improved estimates of the quantity of soil remediation required during a future decommissioning due to the obstructions present. It is not feasible to perform meaningful subsurface characterization without disrupting the operation essential equipment, risking the breeching of barriers that contain radioactivity, or exacerbating the migration of contaminants already in the environment. Based on industry decommissioning experience, the majority of subsurface contamination (by volume and concentration) would likely be located directly under operating systems, structures, and components (SSCs), which would inhibit safe or adequate access for characterization purposes. It is therefore unlikely that the proposed subsurface characterization requirements could be implemented so as to produce data that would enhance decommissioning cost estimates prior to plant shutdown.

5

USING LESSONS LEARNED FROM GROUNDWATER CONTAMINATION EXPERIENCES

5.1 Overview

As a result of the lessons learned during the power plant decommissioning, the nuclear power industry has proactively taken steps to incorporate the lessons learned into the planning for future decommissionings. This section describes these measures.

5.2 NEI Groundwater Protection Initiative

The Nuclear Energy Institute (NEI) Groundwater Protection Initiative (GPI) (NEI 07-07, Reference 99) was developed to identify actions to improve utilities' management and response to instances where the inadvertent release of radioactive substances may result in low but detectible levels of plant-related materials in subsurface soils and water. The inadvertent releases addressed by this initiative fall outside the current requirements of the Nuclear Regulatory Commission (NRC) and are well below the NRC's limits that ensure protection of public health and safety. Planned liquid and airborne releases performed in accordance with NRC's regulations are not included in the scope of the initiative. The initiative also includes guidance on how the utilities should communicate with their stakeholders about those instances.

The Ground Water Protection Initiative identifies those actions necessary for implementation of a timely and effective ground water protection program. In addition, objectives are specified to accomplish each action and the acceptance criteria to demonstrate that the objectives have been met.

The NEI Groundwater Protection Initiative applies to all Nuclear Generating Plants including:

- Operating Nuclear Plants
- Decommissioning Pants
- New Plants Prior to Fuel Receipt

The key requirements of the NEI GPI are:

- To assess the hydrogeology and geology at the nuclear site
- Perform a risk assessment is which systems may leak and where as well as an assessment of work practices that involve licensed material and for which there is a credible mechanism for the licensed material to reach groundwater.
- Perform monitoring for leaks and record any detected in the sites incident file for use in decommissioning planning (per 10 CFR 50.75(g))
- Communication of leaks and spills to regulators and local authorities (detectable concentrations greater than 100 gallons that are not remediated by the end of the next business day)
- Communication of any exceedances of REMP limits (generally the same as MCLs) "on site" or "off site"
- Oversight consisting of self assessments and industry assessments to ensure implementation

By the end of 2007 US nuclear power plants had developed and implemented their action plans that:

- Evaluated Site Hydrology
- Installed Initial Groundwater Monitoring Wells as committed in the action plans.
- Implemented other aspects of their action plans including development of protocols for communicating with stakeholders and recording contamination incidents in their site's 10 CRF 50.75 (g) file.
- NEI 07-07 "Industry Groundwater Protection Initiative-Final Guidance Document" was issued on August 31, 2007. A one year period was provided to accomplish full implementation of the new guidance provided.

5.3 NEI Guidance for New Plants

NEI will soon issue NEI 08-08 Generic FSAR Template Guidance for Life Cycle Minimization of Contamination that will incorporate the lessons learned from recent groundwater contamination experience into the design of new nuclear plants. The primary content of this document is to incorporate the key provisions of NEI 07-07 and the regulatory guidance from NRC's Regulatory Guide 4.21 (Reference 100) (10 CFR 20.1406). This is an ongoing activity at this time involving NRCs Office of New Reactors and the reactor supply vendors. EPRI provided technical support and participated in the development of industry recommendations for Reg Guide 4.21 and continues to be a participant in the new plant work.

5.4 Chapter Summary

The NEI Groundwater Protection Initiative has had a positive impact on future decommissioning by causing groundwater issues to be identified and dealt with on a more timely basis. The nuclear power industry has proactively taken steps to incorporate the lessons learned into the planning for future decommissionings and the design of new power plants.

6

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