LIQUID RADIOACTIVE RELEASE

LESSONS LEARNED TASK FORCE

FINAL REPORT

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EXECUTIVE SUMMARY

The Liquid Radioactive Release Lessons Learned Task Force (LLTF) was established by the NRC Executive Director for Operations on March 10, 2006, in response to incidents at Braidwood, Indian Point, Byron, and Dresden related to unplanned, unmonitored releases of radioactive liquids into the environment. The scope of the task force work included reviews of industry experience, associated public health impacts (if any), the NRC regulatory framework, related NRC inspection and enforcement programs, industry reporting requirements, past industry actions following significant inadvertent releases, international perspectives, and NRC communications with public stakeholders.

The task force included representatives from all four regional offices: the Office of Nuclear Reactor Regulation (NRR), the Office of Nuclear Materials Safety and Safeguards (NMSS), the Office of Nuclear Regulatory Research (RES), the Office of Public Affairs (OPA), the Office of the Executive Director for Operations (OEDO), and a representative from the State of Illinois.

The focus of the task force was on releases of radioactive liquids that were neither planned nor monitored. An understanding of the routine discharge of radioactive materials from a nuclear power plant is necessary to gain a perspective on the unplanned releases.

Virtually all commercial nuclear power plants routinely release radioactive materials to the environment in liquids and gases. These releases are planned, monitored, and documented. NRC regulations in 10 CFR Part 20 and in 10 CFR Part 50 place limits on these releases to ensure the impact on public health is very low. On an annual basis, NRC guidelines require that the release of radioactive material in a liquid form from a nuclear power plant must not result in a radiation dose of greater than 3 millirem to any individual in an unrestricted area. All licensees routinely report to the NRC that they are well within this limit.

To place 3 millirem of radiation in perspective, the average member of the public in the United States receives a radiation dose of about 360 millirem per year, primarily from natural sources such as radon in the soil and cosmic radiation, and from medical sources such as diagnostic X-rays. A passenger on a single cross country airplane flight receives a radiation dose of about 3 millirem due to the flight occurring at a high altitude, resulting in a reduction in shielding of cosmic radiation by the earth's atmosphere.

In accordance with NRC regulations, nuclear power plant operators are required to submit an annual report to the NRC detailing the amount of radioactive material released to the environment during the past year. This report estimates the public health impact of the releases. Nuclear power plant operators are also required by NRC regulations to monitor the environment in the vicinity of the nuclear power plant to assess the cumulative impact of the radioactive material that has been released. On an annual basis, the results of the environmental monitoring program are submitted to the NRC. Both of these reports for all nuclear power plants regulated by the NRC are available to the public via the NRC website.

Most of the events that have recently received increased attention from the NRC have involved tritium, which is a radioactive isotope of hydrogen. However, the task force did not limit its review to tritium related events. Other radioactive isotopes have been inadvertently released into the environment. An example is leakage from spent fuel pools, particularly where the pool contains fuel with degraded outer cladding material, thereby allowing fission products to be released from the fuel into the pool water.

The most significant conclusion of the task force regarded public health impacts. 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 task force did identify that under the existing regulatory requirements the potential exists for unplanned and unmonitored releases of radioactive liquids to migrate offsite into the public domain undetected. The following elements collectively contribute to this conclusion:

- Some of the power plant components that contain radioactive fluids that have leaked were constructed to commercial standards, in contrast to plant safety systems that are typically fabricated to more stringent requirements. The result is a lower level of assurance that these types of components will be leak proof over the life of the plant.

- Some of the components that have leaked were not subject to surveillance, maintenance, or inspection activities by NRC requirements. This increases the likelihood that leakage in such components can go undetected. Additionally, relatively low leakage rates may not be detected by plant operators, even over an extended period of time.

- Portions of some components or structures are physically not visible to operators, thereby reducing the likelihood that leakage will be identified. Examples of such components include buried pipes and spent fuel pool.

- Leakage that enters the ground below the plant may be undetected because there are generally no NRC requirements to monitor the groundwater onsite for radioactive contamination.

- Contamination in groundwater onsite may migrate offsite undetected. Although the power plant operator is required by NRC regulations to perform offsite environmental monitoring, the sampling locations are typically mostly in the vicinity of the point of release of the normal discharge flow path. For example, at Braidwood, most of the environment water samples were being taken near where the discharge pipe empties into the river, a distance of about 5 miles from the plant.

Furthermore, if groundwater contamination is detected, it may be difficult to monitor and to predict the movement of the contamination in the groundwater. The flow of groundwater can be influenced by a variety of factors and can be quite complex.

Another aspect of inadvertent releases of radioactive material to the environment that was illuminated by the Braidwood and Indian Point events was the level of public concern that can result. At both sites, media coverage was wide-spread. Concerns were expressed by Members of Congress, as well as by State and local officials. The Braidwood event led to the State of Illinois enacting legislation requiring reporting of events at a threshold well below that presently required by the NRC. Senator Obama of Illinois has introduced legislation in the United States Senate that would require additional reporting on a nationwide basis. Public meetings in the vicinity of the plants were widely attended, and the opinion expressed by the audiences was generally negative toward both the plant operator and the NRC. The events also led to the submission of a petition to the NRC in accordance with the provisions of 10 CFR 2.206. This petition was co-sponsored by 28 different public groups or individuals, and requested that the NRC take certain actions that the petitioners believed was warranted to protect public health.

When considering recommendations to be made as the result of the task force review, the task force members were challenged to weigh the likely benefit of implementing recommendations against the cost. The task force concluded that the relative potential benefit to protection of public health would generally be low, because the realistic potential for long term undetected radioactive leakage resulting in a more than minor radiation dose to members of the public is low. However, as illustrated by the Braidwood and Indian Point events, the task force concluded that the positive benefit to the NRC's goal of openness could be significant. The recommendations contained in the report reflect this judgement.

The task force recommendations generally address enhanced regulations or regulatory guidance for unplanned, unmonitored releases; additional reviews in the areas of decommissioning funding and license renewal; and enhanced public communications.

The nuclear industry has collectively responded to these events. Under the auspices of the Nuclear Energy Institute (NEI), the industry launched the "Industry Initiative on Groundwater Protection." This initiative is voluntary. Industry representatives have met with the NRC staff in meetings open to the public to inform the staff and the public of the industry actions. The initiative was unanimously approved by the industry chief nuclear officers, and required that each nuclear power plant site have a site-specific plan in place by July 31, 2006. The intent of the plans is to improve management of inadvertent radiological releases to the groundwater, prevent migration of licensed radioactive materials offsite, quantify the impacts on decommissioning, and enhance the trust and confidence of the local communities, the States, and the NRC. The initiative also provides for enhanced reporting of events, benchmarking of industry best practices, and possibly standardizing some practices. The actions described by the industry were generally viewed positively by members of the task force. However, because of the voluntary and preliminary nature of the actions, the task force did not weigh the industry actions heavily when considering recommendations.

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LIST OF ACRONYMS

ADAMS	Agencywide Documents Access and Management System
AEA	Atomic Energy Act
ALARA	As Low As Reasonably Achievable
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
BNL	Brookhaven National Laboratory
BTP	Branch Technical Position
BWR	Boiling Water Reactor
CNSC	Canadian Nuclear Safety Commission
CST	Condensate Storage Tank
Ci	Curie
DOE	United States Department of Energy
EDO	Executive Director for Operations
EPA	United States Environmental Protection Agency
EPRI	Electric Power Research Institute
FHB	Fuel Handling Building
FP&L	Florida Power and Light
FSAR	Final Safety Analysis Report
GALL	General Aging Lessons Learned
GDC	General Design Criteria
HFBR	High Flux Beam Reactor
HPCI	High Pressure Coolant Injection
IAEA	International Atomic Energy Agency
IMC	Inspection Manual Chapter
IP	Inspection Procedure
ISFSI	Independent Spent Fuel Storage Installation
LER	Licensee Event Report
LLD	Lower Limit of Detection
LTP	License Termination Plan
MCL	Maximum Contaminant Level
mrem	Millirem
mSv	Millisievert
NEI	Nuclear Energy Institute
NJDEP	New Jersey Department of Environmental Protection
NMSS	Office of Nuclear Material Safety and Safeguards
NOUE	Notification of Unusual Event
NPDES	National Pollutant Discharge Elimination System
NPP	Nuclear Power Plant
NRC	United States Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation
NYSDEC	New York Department of Environmental Conservation
ODCM	Offsite Dose Calculation Manual
OSTP	Office of State and Tribal Programs
OPA	Office of Public Affairs
PHG	Public Health Goal
PI	Performance Indicator
pCi/L	Picocurie per Liter
PWR	Pressurized Water Reactor
QA	Quality Assurance
RCA	Radiologically Controlled Area
RG	Regulatory Guide
REMP	Radiological Environmental Monitoring Program
RETS	Radiological Effluent Release Technical Specifications
ROP	Reactor Oversight Process

RWST	Refueling Water Storage Tank
SDP	Significance Determination Process
SFP	Spent Fuel Pool
SGBD	Steam Generator Blowdown Demineralizer
SSCs	Structures, Systems and Components
SRP	Standard Review Plan
TEDE	Total Effective Dose Equivalent
TLD	Thermoluminescent Dosimeter
UFSAR	Updated Final Safety Analysis Report
U.S.	United States
VOCs	Volatile Organic Compounds

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1.0 INTRODUCTION

1.1 Objective and Scope

Following reports earlier this year of inadvertent releases of radioactive liquids to the environment from nuclear power plants, the Nuclear Regulatory Commission's (NRC) Executive Director for Operations chartered a Task Force to conduct a lessons-learned review of these incidents. The levels of tritium and other radionuclides measured thus far do not present a health hazard to the public. Nonetheless, the task force members, (comprised of representatives from all four regional offices, the Office of Nuclear Reactor Regulation (NRR), the Office of Nuclear Material Safety and Safeguards, the Office of Nuclear Regulatory Research (RES), the Office of Public Affairs (OPA), the Office of the Executive Director of Operations (OEDO) and a representative from the State of Illinois), were instructed to identify and recommend areas for improvement applicable to the NRC and to industry. The Task Force reviewed and evaluated the following: industry experience; health impacts; regulatory framework; NRC inspection, enforcement and reporting aspects; industry actions; international perspectives; and communications with external stakeholders.

Consistent with its charter, the Task Force assessed: historical data on inadvertent releases of radioactive liquid; the possible health impact of these releases; existing regulations; NRC inspection program requirements, including enforcement; industry actions in response to these events; public communications; implications for decommissioning; and Department of Energy (DOE) Facility lessons learned. During its review, members of the Task Force participated in several public meetings related to this topic, which were attended by industry representatives and other public stakeholders. The Task Force also examined the following documentation: (1) inspection reports; (2) licensee event reports; (3) enforcement actions; (4) technical guidance documents from industry and the International Atomic Energy Agency (IAEA); (5) NRC policy and procedural documentation; (6) applicable industry codes; and (7) other pertinent documentation.

1.2 Background

As part of the normal operation of nuclear power plants, small amounts of radioactive gases and liquids are typically released to the environment. The discharge of radioactive gases and liquids, or effluents, can have environmental impacts on man and the environment. The NRC addresses this by specific regulations which limit these releases, and by verifying, both during the licensing process and throughout the operation of the nuclear power plant, that facility operation does not significantly impact plant workers, members of the public, and the environment. The NRC's regulations require releases of radioactive effluents beyond a plant's boundaries to be As Low As is Reasonably Achievable (ALARA). For radioactive liquids, the ALARA criterion is 3 mrem [0.03 millisievert (mSV)] per year (about 1 percent of the average annual radiation dose for a U.S. citizen).

One of the radionuclides released from nuclear power plants is tritium. Tritium is a weakly radioactive isotope of hydrogen with a half-life of 12.5 years that decays by emitting a low energy beta particle (or electron). Tritium is produced in nuclear reactors, but also occurs naturally in the environment due to cosmic rays interacting with atmospheric gases. The most common form of tritium is in water, since both tritium and non-radioactive hydrogen react in the same way with oxygen to produce water. Tritiated water is colorless and odorless. Tritium can also be found in such everyday self-illuminating devices as watches and exit signs.

The NRC requires that organizations that operate nuclear power plants (referred to as licensees) control, monitor, and report the results of environmental monitoring around their plants to ensure that potential impacts are detected and reviewed. Licensees accomplish this, in part, through their Radiological Environmental Monitoring Program (REMP). The REMP requires various off-site samples to be taken. The location and type of sample is usually selected based on the mechanisms in which radionuclides can reach the public, typically referred to as environmental pathways. These pathways include airborne and waterborne mechanisms, as well as ingestion, typically of milk and fish. Samples must be taken at required intervals, which are analyzed for the presence of specified radiological constituents. Each plant's REMP specifies reporting levels for radioactivity concentrations in environmental samples, including reporting levels for tritium in water.

If the reporting levels in the REMP are exceeded, the licensee must prepare and submit a report to the NRC that identifies the event and defines the corrective actions taken. The problem must also be reported to the NRC in the licensee's Annual Radiological Environmental Operating Report. In addition, the NRC inspects each licensee's effluent and environmental monitoring programs once every two years, to ensure NRC requirements are met. The status of licensee programs is documented by the NRC in inspection reports that are available to the public. Each licensee's Annual Radiological Environmental Operating Report is also available to the public.

The regulations that provide the limits on radioactive effluent releases and their associated radiation doses have been periodically revised over the years as new standards were developed. In 1975, the NRC amended its regulations (in 10 CFR Parts 50.34a and 50.36a, and Appendix I to 10 CFR Part 50) to provide numerical guides for design objectives and limiting conditions for operation to meet the ALARA radiation dose criterion. Adoption of these ALARA regulations required that power plant releases be kept to doses well below the radiation exposure limits for the public in 10 CFR Part 20, which is 100 mrem (1.0 mSv). In the decades following this amendment, the amount of routine radioactive effluents released from nuclear power plants decreased significantly, a direct result of the addition of improved radioactive waste treatment systems and improved fuel performance.

Almost all of the radioactive liquid released from nuclear power plants is discharged to the environment in a planned and monitored manner via systems and programs designed for that purpose. However, many licensees have experienced radioactive liquid releases that were inadvertent and not monitored. They have been caused by both human error, and by equipment failure or degradation. In some instances, the release of radioactive liquid was not recognized by the licensee until well after the release apparently started. It is the unplanned, unmonitored releases that are the focus of this report. If such a release is identified by the licensee, existing NRC regulations do not require routine onsite ground-water monitoring in the Restricted Area during facility operations, however, licensees will typically establish onsite ground-water monitoring and sampling programs once the source of the contamination is attributed to identified structure, system, or component leakage. These efforts ensure the licensee meets the requirements of 10 CFR 50.75(g)(1) which require, in part, that licensees keep a record of spills or other unusual occurrences involving the spread of contamination in and around the facility and site for decommissioning purposes. Onsite (and offsite) monitoring and sampling programs also ensure that the licensee meets 10 CFR 20.1501 requirements to conduct reasonable surveys under the circumstances in order to evaluate the concentrations or quantities of radioactive material and the potential radiological hazards present at the site.

NRC follow-up to an event where the licensee contaminated an area of their property can include routine inspection of the licensee's radiological effluent and environmental monitoring programs, or a radiation protection specialist from an NRC Regional Office may be sent to the site sooner, if the NRC concludes the event warrants a reactive inspection. If no radiation dose limits are exceeded, which is typically the case, the licensee has the option of remediating the contamination, or waiting until the plant is decommissioned to address the issue.

2.0 INDUSTRY EXPERIENCE REVIEW

2.1 Scope and Criteria

This section provides an overview of known inadvertent releases of radioactive liquid to the environment from power reactors, primarily from 1996 to the present.

The events described below do not constitute a complete list of all events that may have occurred during this time period. In order to complete a comprehensive review for lessons learned in a timely manner, the Task Force focused on identifying a cross-section of events that represented different causes, pathways of liquid release, impacts to the environment, and corrective actions to remediate. Events that received notable public attention were also included.

In addition to reviewing the known inadvertent releases of radioactive liquid to the environment at power reactor sites over the last 10 years, the Task Force also reviewed an event that occurred in 1986 at the Hatch facility. The Task Force reviewed this event because a notice of violation and proposed imposition of a civil penalty resulted. In addition, the volume of water released was substantial.

The Task Force identified three main areas of components which have leaked: spent fuel pools, underground piping, and valves on effluent discharge lines. In addition to the leakage of components, operator actions have also been the cause of several inadvertent releases.

2.2 Detailed Discussion of Review

Braidwood

In March 2005, the Illinois Environmental Protection Agency notified the licensee of reports of tritium in wells in a nearby community. The licensee began monitoring ground-water between the community of Godley, Illinois, and the Braidwood Nuclear Power Plant (Braidwood). The licensee measured tritium in a drainage ditch near the plant access road, but contaminated ground water was not identified at that time.

On November 30, 2005, Exelon informed the NRC that elevated levels of tritium had been measured in shallow, ground-water monitoring wells at Braidwood. At that time, the licensee had measured levels as high as 58,000 picocuries per liter (pCi/L). The licensee attributed the contamination to historical leakage of vacuum breaker valves along the circulating water blowdown line. Subsequently, the licensee suspended all further releases of liquid radioactive material. The circulating water blowdown line is routinely used for radioactive liquid releases to the Kankakee River. At Braidwood, the circulating water blowdown line is about 5 miles long and contains 11 vacuum breaker valves, spaced along the length of the line.

The licensee’s investigation found that significant unplanned radioactive releases from three of the 11 vacuum breaker valves occurred during 1996, 1998, and 2000. Additional minor releases were also identified between 1996 and 2005. The 1996 event resulted in the leakage of approximately 250,000 gallons of water. The 1998 and 2000 events each resulted in a release of approximately 3,000,000 gallons of water. Each leak occurred during a period coincident with ongoing, liquid radioactive releases through the blowdown line, resulting in tritium entering the ground-water system in the vicinity of the leaking vacuum breaker valve.

Between March 2005 and March 2006, Exelon sampled the water in drinking water wells of several nearby homeowners. The licensee identified tritium levels between 1,400 and 1,600 pCi/L in one residential drinking water well. The United States Environmental Protection Agency (EPA) drinking water standard for tritium is 20,000 pCi/L. This standard is also referred to as the Maximum Contaminant Level (MCL). The remaining residential well samples had no measurable tritium above normal background levels. In addition to the nearby homeowner's wells, the licensee sampled the ground water onsite and offsite, and found tritium levels as high as 225,000 to 250,000 pCi/L.

On April 6, 2006, a drain cooler relief valve in the feedwater system lifted and remained open, resulting in secondary plant steam being released to the environment through a vent in the turbine building wall. Approximately 114,000 gallons of feedwater was released as steam and most of the steam condensed on plant property. The system containing the feedwater was known to contain tritium as a result of past leakage from the liquid radioactive waste processing system. The licensee sampled on-site locations for tritium contamination, which indicated concentrations of up to 46,000 pCi/L of tritium. Based on the information provided, there is no indication that NRC effluent release limits have been exceeded, and the release does not present a health and safety hazard to plant personnel or to the public.

Exelon has undertaken remediation activities to reduce the levels of the tritium in the ground water at the Braidwood site. The Braidwood ground water tritium interim remediation plan is available through the NRC's electronic document database, ADAMS, under accession number ML061020107. ADAMS can be accessed via the NRC website. Due to intense public interest from local officials and residents, the licensee has held three public information forums: a public information meeting was sponsored by the village of Godley, IL; a public meeting was sponsored by U. S. Senator Richard Durbin; and a meeting with local officials was organized by U.S. Representative Jerry Weller.

Byron

On February 10, 2006, Exelon informed the NRC that elevated levels of tritium had been detected in several vacuum breaker valve vaults at Byron Station, near Rockford, Illinois. Subsequently, the licensee suspended releases of liquid radioactive effluents. The vacuum breaker valve vaults are located along approximately 2.5 miles of the circulating water blowdown line. In a manner similar to Braidwood, the line is normally used to carry non-radioactive water to the Rock River. It is also used for planned liquid radioactive effluent releases. The licensee installed additional monitoring wells to characterize the extent of the contamination and inspect the line for leaks. Two out of six monitoring wells near the vacuum breaker valve vaults showed low levels of tritium. One monitoring well had a tritium concentration of about 3,800 pCi/L and the other had a concentration of about 450 pCi/L. On March 31, 2006, Exelon notified the NRC of slightly elevated concentrations of tritium in the ground water on licensee property close to the blowdown line.

The licensee is currently monitoring the ground water, but has not taken any remediation actions. The licensee has responded to the State of Illinois Environmental Protection Agency denying violations of state regulations and indicated that they would submit an investigation report to the agency that documents the contamination and demonstrates that it will not migrate off the property at concentrations above 200 pCi/L. The licensee has not discussed plans for future remediation with the NRC staff.

Callaway

On June 14, 2006, Union Electric Company notified the NRC of elevated tritium levels along the blowdown discharge pipeline at the Callaway Plant, near Fulton, Missouri. The radioactive material is believed to have leaked from air-relief valves during routine radiological releases through the discharge pipeline. Tritium samples ranged from 20,000 to 200,000 pCi/L. Radioactive cobalt and cesium were detected in the surface soil inside the manholes where the valves are located. Positive sample locations were on the licensee's property. In addition, there is no evidence of radioactive contamination in drinking water based on the licensee's sampling and analysis of water in the wells.

Dresden

In August 2004, Exelon identified contaminated ground water in onsite monitoring wells at Dresden Nuclear Power Station (Dresden), near Morris, Illinois. The monitoring wells had been installed due to historical leaks related to the condensate storage tank that had occurred in the 1990's. The 2004 identification of contaminated water was due to a leaking underground pipe connected to the condensate storage tank. Subsequent onsite sampling identified tritium levels consistent with those present in the condensate storage tank of about 8,000,000 pCi/L. The licensee isolated the leaking pipe and replaced the faulty section of piping.

On January 3 and 19, 2006, onsite well samples indicated an increase in tritium concentration. The licensee increased the well's sampling frequency. On February 11, 2006, Exelon measured a well sample indicating 486,000 pCi/L of tritium present and determined that there was a potential leak in the underground, non-safety, high pressure coolant injection system suction and return piping, which is connected to the condensate storage tank. Sample results were as high as 680,000 pCi/L, measured on February 13, 2006. The licensee isolated the piping and realigned the system from the condensate storage tanks to the torus. Although the leak has not been fully identified by the licensee, Exelon had actions in progress to replace the piping and continue its evaluation.

Hatch

On December 3, 1986, Hatch released an estimated 141,500 gallons of water from the spent fuel pool (SFP) to a gap between the two reactor buildings and subsequently to other onsite buildings and the surrounding environment. Operational/configurational control errors resulted in the deflation of SFP seals and the resultant release. Based on estimates from recovery activities, approximately 124,000 gallons of liquid containing 0.20 curies (Ci) of tritium and 0.373 Ci of mixed fission products were released to a swamp located within the owner controlled area but which ultimately drains to the Altamaha River. Results of initial environmental surveys conducted by the licensee staff and independently by the State of Georgia, Department of Natural Resources verified that both the tritium and fission products released to the swamp and subsequently to the river posed no immediate danger to downstream water users (if any), or to nearby residents. The long-term onsite and offsite radiological impacts are assessed entirely through continuing monitoring of the contaminated area and adjacent off-site pathways. Specifically, in response to the event, the licensee established and maintained a long-term augmented environmental monitoring program. Periodic reports submitted to the NRC indicate a general reduction in activity in the swamp area resulting from radioactive decay and weathering and the potential erosion and migration of the radionuclides within the originally contaminated area.

Indian Point

Indian Point is located near Buchanan, New York. In August 2005, the licensee (Entergy) was excavating the ground near the Indian Point Unit 2 Fuel Storage Building Loading Bay, which is adjacent to the south wall of the spent fuel pool. On August 22, 2005, a hairline crack with moisture was discovered along the south wall of the spent fuel pool. Initial samples did not detect any radioactivity and spent fuel pool leakage was not suspected. On September 1, 2005, contamination was first detected on a sample from the crack. A second crack was discovered two weeks later and a temporary collection device was installed to capture leaking liquid. Analyses of the moisture indicated that the material had the same radiological and chemical properties as spent fuel pool water. The primary radioactive constituent was identified as tritium. The leak from the crack increased following the first measurable sample of 12 milliliters, which was collected on September 12, 2005. The leakage increased to a maximum of 1-2 liters per day and remained stable. It declined to a minimal amount by late December 2005.

On September 29, 2005, the licensee sampled water from an existing monitoring well in the

Unit 2 Transformer Yard. On October 5, 2005, the results from the sample were reported and indicated an unexpected concentration of tritium in onsite ground water. Prior to the September 2005 sample, the well was last analyzed for tritium in 2000 and none was detected. As Entergy continued its investigation into the source of the contamination, hydrological information and sample analyses of monitoring wells led to the conclusion that some contaminated ground water likely will, or has migrated to the Hudson River. Note, however, that the Hudson River is the discharge point for normal planned and monitored releases.

In an effort to reduce Unit 2 spent fuel pool leakage, Entergy has conducted Unit 2 spent fuel pool liner inspections. Accessible areas of the pool above the fuel racks were inspected and six suspect areas coated with epoxy. The licensee is also inspecting the walls adjacent to the fuel racks.

In addition to the detection of tritium, the radionuclides nickel-63, cesium-137, strontium-90, and cobalt-60 have been detected onsite at Indian Point. It is suspected that these isotopes are a result of leakage from the Unit 1 spent fuel pool which resulted in the contamination of some groundwater in the vicinity. Even though Unit 1 has been permanently shut down since 1974, its spent fuel pool still contains expended fuel and radioactive water. A curtain drain groundwater collection system surrounding the facility was expected to capture the contaminated groundwater, however, it is likely that some portion may be bypassing the drain system. Currently, the licensee operates a filter/demineralizer system in the spent fuel pool to reduce the concentration of radioactive material that may continue to leak from the Unit 1 facility until the fuel is removed in 2008.

Oyster Creek

On September 17 and 18, 1996, Oyster Creek Nuclear Generating Station, near Toms River, New Jersey, inadvertently discharged approximately 133,000 gallons of radioactively contaminated water to the environment from the condensate transfer system. The water was discharged to the canal, which eventually discharges to Barnegat Bay, from the circulating water discharge tunnel via the fire protection system and a portion of the service water system. The cause of the discharge was attributed to an operator opening an incorrect valve when placing a temporary system in service. The highest concentration of tritium measured was 16,000 pCi/L at the discharge point to the discharge canal, which is below the EPA drinking water standard.

Palo Verde

On March 1, 2006, a water sample collected from a test hole by Arizona Public Service Company at the Palo Verde Nuclear Generating Station Unit 3, near Phoenix, Arizona, identified tritium levels of 71,400 pCi/L. An environmental consultant, contracted by the licensee to determine the apparent cause, reported that tritiated water was found in Units 2 and 3 subsurface soils, but only Unit 3 indicated tritium levels above the EPA drinking water standard. Plant staff concluded that most of the elevated onsite tritium contamination was due to past operational practices during boric acid concentrator system (evaporator system) releases, resulting in rain deposition and washdown of roof drains. Prior to the mid-1990s, the licensee allowed evaporator system batch releases to occur during rainy days. During those releases, gaseous tritiated vapors were condensed by rain, and the resulting water runoff on the site was absorbed into the ground and also ran into the storm drain system.

It was determined that: (1) the tritiated water at elevated levels was confined onsite; (2) no elevated levels have been found in wells located outside the protected area; (3) there was no evidence of an offsite release of the radioactive water.

The licensee plans to install new monitoring wells in August 2006 and has agreed with the State of Arizona to pump sections of tritiated water from the ground subsurface based on data gathered from the wells. The licensee continues to evaluate and monitor the issue.

Perry

On March 28, 2006, a quarterly sample from a manhole in the underdrain system at the Perry Nuclear Power Plant, near Painesville, Ohio, operated by FirstEnergy Nuclear Operating Company, was collected and analyzed for tritium and gamma-producing isotopes. The underdrain system provides a means of controlling ground water level in the plant area. About 60,000 pCi/L of tritium was detected in the manhole. No gamma-producing isotopes were detected. Samples taken at other points in the underdrain system indicate lower levels of tritium. The licensee attributes the tritium to leakage from a flange in the feedwater system venturi. The leakage migrated through two elevations, through gaps, cracks, and spaces between structures, and into the underdrain system. The leaking flange has been repaired and tritium concentrations have decreased.

The licensee's assessment of this event is that the underdrain system captured the tritiated water, preventing ground-water contamination. Ground-water flow is mostly directed to the underdrain system. Initial measurements for tritium have confirmed the ground water is not contaminated. The licensee plans to install additional ground-water wells to confirm this conclusion.

Point Beach

In 1999, tritium and other radionuclides were identified near a retention pond at the Point Beach Nuclear Power Plant, near Manitowoc, Wisconsin. The retention pond was surrounded by a fence and was located outside the protected area, but within the owner controlled area. The retention pond was taken out of service in September 2002. It was subsequently remediated, capped, and abandoned. The characterization report assessed the contamination and determined that there was no health or safety impact to the public.

The contamination was apparently the result of a steam generator tube leak in 1975 and leakage from a buried pipe in 1997.

As part of the retention pond closure project, a subsurface ground-water survey was conducted in the immediate vicinity of the pond by digging seven trenches to a depth of approximately twelve feet, or to the depth of the impermeable clay layer. Tritium concentration in sand lenses in the top twelve feet of soil around the former retention pond ranged from 177 to 14,250 pCi/L. Based on those results, Point Beach has no plans to install special monitoring wells to sample surface ground water.

Currently, Point Beach conducts additional sampling to monitor ground water, monthly samples from the subsurface drainage system, and storm water runoff drains which empty into the beach area. The licensee also performs monthly sampling of intermittent streams on the east and west sides of the former retention pond. Tritium has been detected in these streams in concentrations ranging from the minimum detectable activity levels of about 200 pCi/L up to 400 pCi/L. The tritium in these streams came from leakage and discharges from the former retention pond which was constructed in 1968. It has been determined that the tritium is restricted to the area around the former retention pond and south-eastward in its drainage path to Lake Michigan.

Salem

On September 18, 2002, Salem Nuclear Station, near Wilmington, Delaware, operated by PSEG Nuclear, LLC, found evidence of contaminated water leakage through a wall into the

Unit 1 Auxiliary Building Mechanical Penetration Room. The licensee initiated an investigation and determined that the contamination was due to Unit 1 Spent Fuel Pool water that had leaked into a narrow seismic gap between the Unit 1 Auxiliary Building and Unit 1 Fuel Handling Building, and entered the Mechanical Penetration Room. Further licensee reviews determined that the tell-tale drain system for the Unit 1 spent fuel pool had become obstructed, which caused a build up of water between the spent fuel pool liner and concrete structure. The water then migrated through a wall and penetrations. The licensee cleaned the tell-tale drain system, which cleared the water buildup and stopped the leakage.

The licensee also initiated actions to evaluate possible migration of spent fuel pool water to the ground water because the seismic gap was ultimately connected with the ground water. The licensee initiated drilling wells. On February 6, 2003, the licensee identified tritium contamination in non-potable ground water near the Unit 1 fuel handling building. The licensee subsequently initiated an extensive ground-water sampling program to fully characterize the contamination. Maximum tritium levels of 15,000,000 pCi/L were identified in the ground water near the seismic gap. The licensee established, in conjunction with the State of New Jersey, an extensive ground-water remediation program. Which includes ongoing remediation of the seismic gap. As of December 2005, the licensee extracted about 1.6 curies of tritium with approximately 2 – 4 curies remaining to be extracted.

PSEG's evaluations did not identify any immediate health and safety consequences to onsite workers or members of the public. No contamination is believed to have migrated to the unrestricted area. The remediation efforts have created an in-gradient of water causing the water to flow toward the plant instead of offsite. No other plant related radionuclides were identified in the ground water.

Seabrook

In June 1999, the Seabrook power plant, operated by FPL Energy, near Seabrook, N.H., measured elevated tritium concentrations in the sump during routine monitoring of a discharge from the Steam Generator Blowdown Demineralizer (SGBD) sump. The sump is monitored as part of Seabrook's REMP. The licensee's investigation identified that the tritium activity was associated with an input to the sump from the Containment Annulus. Seabrook's investigation identified the source of the tritium leakage to be from a defect in the liner of the cask loading pool, which is connected to the fuel transfer canal in the Fuel Handling Building.

Seabrook initiated ground-water sampling in 2000 and detected a maximum tritium concentration of about 750,000 pCi/L in a sample of non-potable water collected from the annulus sump in close proximity to the location of the leak. The licensee subsequently installed ground-water dewatering wells to pump the water from areas of highest tritium concentrations and provide for its controlled discharge.

Seabrook installed additional monitoring wells as the result of a hydrology study, to identify the extent of the ground-water contamination. Seabrook's study did not identify any migration of radioactive contaminated water to the unrestricted area. Currently, ground water tritium levels are at or near background levels. The licensee continues to monitor the ground water on a routine, periodic basis to identify any changes.

Three Mile Island

On May 17, 2006, personnel at the Three Mile Island nuclear power plant, near Harrisburg, Pennsylvania, identified water coming from a utility access manway in the owner controlled parking lot. The licensee initially determined the source of the water to be a leak in a domestic water line since it was the only known source of water in the area. The licensee subsequently pumped out about 2000 gallons of water to parking lot asphalt during the period May 17- 20, 2006. Review by the licensee identified the manway to be an access port to underground telephone cables and initiated actions to identify the source of the leakage. On May 27, plant personnel again identified water coming from the location. The licensee pumped out another 2000 gallons to the parking lot asphalt.

On June 1, 2006, the licensee sampled and analyzed the water from the manway and identified elevated concentrations of tritium. The water contained a tritium concentration of 45,000 pCi/L. However, samples taken from four nearby ground-water monitoring wells indicated no elevated tritium in the surrounding ground water. Well samples taken in the vicinity of this manway indicate levels of 200 pCi/L which is the background lower limit of detection.

The licensee identified that the water had come from the condensate system and had reached the parking lot via an underground telephone cable conduit run. The water had entered a below floor grade telephone cable raceway which allowed the contaminated water to flow into the cable conduit run. Engineers identified the source of the tritium water leak to be an underground four inch de-icing line, within the protected area, from the condensate system to the condensate storage tank. The four inch pipe was excavated and temporarily patched to stop the leak. The licensee team continued enhanced monitoring of ground-water wells and also verified no tritium water had left the owner controlled area (island) via the underground cable conduit runs.

Watts Bar

Readily detectable concentrations of tritium have been identified in recently established onsite ground water monitoring wells at the Watts Bar Nuclear plant site. These wells were established as supplemental Radiological Environmental Monitoring Program requirements associated with Unit 1 modifications for upcoming production of tritium for DOE. Based on the establishment of additional onsite groundwater monitoring wells and evaluation of current onsite hydrology, a complex scenario of groundwater contamination resulting from two separate onsite systems/structures were identified. The first source included small leaks in a radioactive liquid effluent line which resulted in a dual branch plume of tritium. The leaks resulted in elevated levels of radionuclide contamination near the degraded piping and subsequent migration of the tritium into the ground water. The second source was determined to be leakage through the fuel transfer tube sleeve into the Shield Building annulus of the abandoned Unit 2 facilities with the tritium migrating into the ground water adjacent to the shield building. The licensee has developed and implemented corrective actions to prevent further leakage from the identified sources, and to mitigate contamination were possible, e.g., decontamination of soils associated with the radioactive liquid effluent waste line break. Current trends in onsite groundwater well tritium concentrations appear to indicate that the corrective actions have been successful and that fluctuations in onsite ground water sample results are attributable to migration of the tritium contaminated groundwater plumes. On two occasions in calender year 2005, tritium concentrations measured within REMP groundwater wells within the owner controlled areas exceeded the Offsite Dose Calculation Manual reporting levels (quarterly average concentration exceeding 30,000 pCi/L). Supplemental wells established to monitor tritium levels within the protected area also indicated elevated tritium levels. However, no tritium or other radionuclides have been detected at levels exceeding background concentrations from water samples collected from off-site wells, public drinking water, or the Tennessee River.

Wolf Creek

The circumstances at Wolf Creek are not related to an event, but are discussed here to illustrate an issue that is likely generic and should be addressed by the NRC staff. The plant discharges its routine radioactive liquid effluent into an onsite lake in accordance with its license, the ODCM, and within NRC ALARA criteria. The REMP sample data shows levels of tritium in the water, but below any reporting criteria. The average tritium concentration in the lake is about 13,000 pCi/L. The licensee uses the lake water for the plant fire protection system. Periodically they purge out the fire protection system and drain the water onto the plant property.

The issue is that the licensee is taking water from a known source of discharged licensed material and have sample data which supports that there is detectable levels of licensed radioactive material in the water introduced into the fire protection system. The licensee does not perform any radiological surveys of the water that is taken into the fire protection system. They also do not perform any radiological surveys of the discharged water, or environmental monitoring to see if the water discharged onsite is adversely impacting the environment.

The staff believes there are other licensees with similar circumstances. Given the available information, the staff does not consider the situation to be a health risk for either the public or for workers onsite.

2.3 Recommendation

(1) The staff should review and develop a position to address using lake water that contains licensed radioactive material for other site purposes, such as for use in the fire protection system.

The following table summarizes the plant events described above:

Nuclear Power Plant	Date of Release Discovery	Source of Release	Radionuclides Detected
Braidwood	March 2005	Vacuum breaker valves on the circulating water blowdown line	Tritium
Byron	February 2006	Vacuum breaker valves on the circulating water blowdown line	Tritium
Callaway	June 2006	Vacuum breaker valves on the circulating water blowdown line	Tritium, cobalt-58, cobalt-60, cesium-134, cesium-137
Dresden	August 2004, January 2006	Non-safety related HPCI suction and return line	Tritium
Hatch	December 1986	Fuel transfer canal due to operator action	Tritium
Indian Point	August 2005 - Unit 1 leakage predates August 2005	Unit 1 and Unit 2 spent fuel pools	Tritium, nickel-63, cesium-137, strontium-90, and cobalt-60
Oyster Creek	September 1996	Condensate transfer system due to operator action	Tritium
Palo Verde	March 2006	Rain condensing onto property after a gaseous release	Tritium
Perry	March 2006	Feedwater venturi	Tritium
Point Beach	1999	Retention pond	Tritium, cesium-137
Seabrook	June 1999	Spent fuel pool	Tritium
Salem	September 2002	Spent fuel pool	Tritium
Three Mile Island	May 2006	Condensate storage tank	Tritium
Watts Bar	August 2002	Effluent release pipe and SFP transfer tube sleeve	Tritium and mixed fission products

Table 1 Summary of Inadvertent Releases of Radioactive Liquids at NPPs

3.0 REVIEW RESULTS AND RECOMMENDATIONS

3.1 Public Health and Environmental Impacts of Inadvertent Releases

3.1.1 Scope and Criteria

Possible public health and environmental impacts from inadvertent releases of radioactive liquid from NRC-licensed operating facilities depend on many factors. These can include the types and quantities of isotopes in a release (the source term), their transport through and/or accumulation in environmental pathways and components (such as soil, water, plants or animals), and factors that reflect how different age groups can be exposed to a maximum dose (maximally exposed person) over time. For routine monitored liquid effluent releases, the maximally exposed person's dose is calculated based on an accurate source term, appropriate transport models for known environmental pathways, appropriate dose factors as detailed in Regulatory Guide (RG) 1.109, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I, and knowledge of the general population near the plant as specified in applicable licensing documents such as the Offsite Dose Calculation Manual (ODCM). Further, these routine liquid releases are usually discharged directly to a large body of surface water such as a lake, river or the ocean, to enhance additional dilution and dispersal of the radionuclide contaminants. Contrary to the process for routine effluents, the inadvertent/abnormal liquid releases to surface water and/or ground water documented in Section 2.2 encompass both monitored and unmonitored source terms subsequently discharged through unanalyzed environmental pathways and thus have the potential to affect doses to the offsite population and areas not previously addressed in applicable licensing documents.

To effectively assess the potential impact of these inadvertent releases, the review focused on those abnormal events at current operating power reactors with the potential for a measurable dose impact on members of the public and/or the offsite environment as a result of source strength and the potential for movement offsite. The events included releases which could exceed the liquid effluent concentration values listed in Table 2 of Appendix B to 10 CFR Part 20. These concentration values are considered safe for release. The table also explains how the values are derived. Examples of events addressed in this section include the inadvertent releases of liquids from spent fuel pool (SFP) or condensate storage tank (CST) structures and/or associated equipment. The review also included routine liquid releases initially prepared and monitored in accordance with applicable licensee approved ODCM guidance, but which were discharged to an unanalyzed environmental pathway as a result of degraded radioactive waste (radwaste) equipment or piping.

The offsite dose impacts from these inadvertent liquid releases were evaluated against established 10 CFR Part 20 dose limits for members of the public; ALARA design criteria for effluents detailed in 10 CFR Part 50; and the EPA drinking water maximum contaminant level (MCL) values. For operating reactor facilities, 10 CFR 20.1301(a) states that plant operation cannot expose a member of the public to more than 100 millirem (mrem) total effective dose equivalent in a year. Plants show they comply with this annual limit by measuring or calculating the dose for the maximally exposed individual; or by demonstrating that (i) the annual average concentrations of radioactive material released in gaseous and liquid effluents at the boundary of the unrestricted area do not exceed the values specified in Table 2 of Appendix B to 10 CFR Part 20; and (ii) for an individual continuously present in an unrestricted area, the dose from external sources would not exceed 2 mrem in an hour and 50 mrem in a year. In addition, 10 CFR 20.1301(e) requires licensees to meet an EPA annual exposure standard of 25 mrem from operations of the nuclear fuel cycle for all activities promulgated in 40 CFR 190. Additionally, the ALARA design objectives documented in Appendix I to 10 CFR Part 50 specify that all radioactive liquid releases above background from each light-water reactor to unrestricted areas may not lead to annual doses to any individual in an unrestricted area from all exposure pathways exceeding three mrem to the total body or 10 mrem to any organ. These design objectives, incorporated as controls for liquid effluents in ODCM documents as detailed in NUREG-1301 and NUREG-1302, also have been used in evaluating abnormal releases.

Although not an NRC requirement, the actual or potential offsite impact of these inadvertent liquid releases have been assessed against EPA drinking water MCL values established in 40 CFR 141.66. These concentration values can be related to calculated doses assuming chronic ingestion of the radionuclide. For example, the EPA concludes that drinking 2 liters per day of water with tritium at the drinking water MCL standard of 20,000 pCi/L would result in approximately four mrem per year total effective dose.

3.1.2 Detailed Discussion of Review

Based on currently available data for sites with detailed evaluations or monitoring, the inadvertent releases of radioactive liquids to surface and/or to ground-water pathways had a negligible impact on public radiation doses. For many of the identified sites, the lack of a public dose impact resulted from the radioactive contamination remaining within owner controlled areas. For the few events which resulted in detectable radionuclide concentrations in the surface and/or ground-water samples collected outside of the owner controlled area, dose impacts on members of the public still were determined to be negligible. However, several of the reviewed abnormal release event scenarios did, or potentially could, impact ground-water sources relative to established EPA drinking water standards.

Currently, the NRC lacks regulatory guidance for monitoring and evaluating both the immediate and long-term offsite dose or environmental impact of these inadvertent releases. Many of the releases reviewed varied significantly in methods for estimating and/or monitoring the source term in surface or ground water, predicting or monitoring the distribution of the radionuclide concentrations in the environment through time, and subsequently evaluating current and future dose impacts to the general public or offsite areas. The presence of tritium can indicate the existence of other radionuclides moving away from the release point in accordance with the site's surface or ground-water flow patterns. Based on solubility and transport factors, the other radionuclides may migrate away from the release point more slowly than tritium. Several licensee events initial evaluations, e.g., Indian Point and Watts Bar releases from the SFP equipment/facilities, required additional ground-water sampling wells and supplemental analyses for hard-to detect radionuclides (such as strontium-89/90 and nickel-63) to adequately determine the offsite dose impact, either through extensive ground-water monitoring or through detailed bounding dose calculations to conservatively estimate the possible radiation dose to members of the public. The types and quantities of isotopes in these releases can be difficult to pinpoint, based on operating conditions at the time of the release. For example, in the 1996 Hatch SFP release, the licensee used historical SFP water radionuclide concentration data from samples collected prior to the event to evaluate the release. A subsequent engineering evaluation of the release found that the leakage and subsequent refills of the pool would have disturbed corrosion buildup on the spent fuel, increasing radionuclide concentrations of the SFP water. In other cases, many of the release events reviewed occurred over an extended period of time and the use of current source term data may not reflect actual conditions at the time of the release. However, for the majority of events where concerns regarding the adequacy of monitoring or evaluation of source terms were addressed, the immediate dose impacts to members of the public and to the environment were found to be negligible. The uncertainties discussed above would not change this conclusion.

For many of the identified sites, the contaminated material shows no indication of moving to offsite areas, and thus, near-term effects on offsite doses are predicted to be negligible. For example, monitoring wells tracking tritium contamination identified beneath the Seabrook plant have verified that the contaminated ground-water plume has not migrated offsite. Nonetheless, such sites generally warrant continued monitoring.

For the Braidwood and Watts Bar sites where extensive migration of ground-water tritium has been identified, the source of the contamination was the inadvertent discharge of previously monitored liquid effluents through unanalyzed environmental pathways. If released through their normal discharge pathways, these releases would have been expected to meet both NRC offsite dose requirements and EPA drinking water standards. At the Braidwood facility, tritium has been identified in surface water and shallow ground-water monitoring well samples collected both within and beyond the site boundary. The ground-water tritium, with some on- and off-site sample results indicating concentrations in excess of the EPA MCL of 20,000 pCi/L, has migrated approximately 2000 to 2500 feet north of the site boundary and has resulted in detectable tritium concentrations, approximately 1500 pCi/L, in samples collected from a single offsite residential drinking water well. Flooding associated with the inadvertent releases resulted in minor soil surface contamination with gamma-emitting radionuclides providing the potential for external exposures to personnel within and adjacent to the site boundary. Conservative assumptions called bounding calculations, which assume maximum exposure, estimated doses to be small fractions of the 10 CFR Part 20 limits. The estimated maximum annual dose to a child ingesting contaminated well water would be 0.16 mrem, and the dose to an adult ingesting fish and contaminated water would be 0.07 mrem. For the Watts Bar facility, the plume of contaminated ground water is located entirely within the owner-controlled area. Tritium concentrations from onsite samples show maximum values of approximately 500,000 pCi/L, which exceeds the EPA limit for drinking water. The site's conceptual exposure models and samples of additional onsite and offsite ground water monitoring wells, public drinking water supplies, and the Tennessee River, confirm that the plume remains within the owner-controlled area and has no current means of causing offsite exposure. Additional analysis suggests the preferential migration (300 ft/yr) of the contaminated ground water follows permeable bedding material which surrounds the original subsurface piping to the Tennessee River. For these scenarios, maximum tritium concentrations released to the river site are not expected to exceed concentration values detailed in 10 CFR Part 20 effluent concentration; dose-based limits; or the MCL standards.

The Hatch event involved an acute unmonitored release of large volumes of contaminated liquids to onsite ground surfaces and surface waters. This event provides an example of long-term monitoring that was developed and implemented for a significant contamination event. In 1986, Hatch released 124,500 gallons of SFP water containing approximately 0.20 Ci of tritium and 0.373 Ci of mixed fission products to a swamp located within the owner-controlled area, but which ultimately drains to the Altamaha River. The licensee elected not to calculate maximum possible offsite doses. The evaluation of the onsite and offsite impacts were assessed entirely through immediate detailed surveys and the long-term monitoring of the contaminated area and adjacent off-site pathways. Results of initial environmental surveys conducted by the licensee staff and independently by the State of Georgia's Department of Natural Resources verified that both the tritium and fission products released to the swamp posed no immediate danger to downstream water users (if any), or to nearby residents. The licensee's on-going augmented environmental monitoring program indicates a general reduction in activity resulting from radioactive decay, and by erosion and weathering processes. The data also indicates potential movement of the radionuclides within the contaminated area after more than 20 years justifying the need for long-term monitoring.

Contrary to the acute release at Hatch, the Indian Point 2 release event involved the release of low volumes of SFP liquids, over an extended period. Monitoring results for this event demonstrate the importance of analyzing monitoring wells for multiple isotopes. In addition to tritium, nickle-63 and strontium-90 were detected in some onsite wells. Initial bounding calculations indicate offsite doses to be significantly below NRC established limits for the maximally exposed individual.

3.1.3 Conclusions

The review of the public health and environmental impact of liquid radioactive effluent releases, as described above, leads to the following conclusions:

(1) Based on bounding dose calculations and/or actual measurements, the near-term public health impacts have been negligible for the events at NRC-licensed operating power facilities discussed in this report. These events released radioactively contaminated liquids to the onsite/offsite environment in an unplanned, unmonitored manner.

(2) The offsite environmental impact from abnormal releases to the groundwater such as those discussed in this report cannot be readily monitored and evaluated based on the current groundwater monitoring requirements. For the abnormal release events reviewed, the determination of negligible health and environmental impacts required (was based on) the establishment of new ground and/or surface water monitoring to evaluate current and potential movement of the released material; additional radionuclide analyses to define the actual source term radionuclides and their quantities; and supplemental bounding dose calculations or long-term environmental monitoring programs.

3.1.4 Recommendations

The following recommendation addresses the above conclusions on the public health and environmental impact of inadvertent releases:

(1) The NRC should develop guidance to the industry for detecting, evaluating, and monitoring releases from operating facilities via unmonitored pathways.

<u>3.2 Existing Regulatory Framework</u>

3.2.1 Health Physics Requirements

3.2.1.1 Scope and Criteria

This section identifies the NRC regulatory requirements for radiological effluent and environmental monitoring programs, and public radiation dose limits for protection against radiation.

3.2.1.2 Detailed Discussion of Review

Regulatory Requirements Overview

There are numerous NRC regulations and regulatory guidance in place to ensure that licensees maintain adequate control over radioactive effluent discharges. The most notable regulations are 10 CFR Part 20, “Standards for Protection Against Radiation” and Appendix I to 10 CFR Part 50, “Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion ‘As Low As Is Reasonably Achievable’ for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents.” These standards contain the criteria for controlling radioactive material to limit radiation exposure to occupational workers and members of the public, and to limit the impact to the environment.

10 CFR Part 20 establishes standards for protection against ionizing radiation resulting from activities conducted by NRC licensees. These regulations control the receipt, possession, use, transfer, and disposal of licensed material to ensure that the standards of radiation protection are not exceeded. Numerous sections of 10 CFR Part 20 specifically deal with the controls for radioactive liquids.

10 CFR 20.1301 requires licensees to operate their facility so that the total effective dose equivalent (TEDE) to a member of the public does not exceed 0.1 rem (100 mrem) in a year. This dose limit is based on the impact from all radioactive gaseous and liquid effluents and any direct radiation from the plant or on-site storage facilities and tanks containing radioactive fluids. In addition to this generic dose limit, 10 CFR 20.1301(e) requires nuclear power reactors to comply with the EPA's radiation protection standard in 40 CFR Part 190. This standard limits the annual dose to a member of the public to less than or equal to 25 mrem to the total body or any organ, except the thyroid, which shall be limited to less than or equal to 75 mrem.

In order to demonstrate compliance with the public dose limits in 10 CFR Part 20, there are requirements for the performance of radiation surveys and monitoring. 10 CFR 20.1501 requires that "each licensee shall make or cause to be made, surveys that: (1) May be necessary for the licensee to comply with the regulations; and (2) Are reasonable under the circumstances to evaluate:

(I) The magnitude and extent of radiation levels; and
(ii) Concentrations or quantities of radioactive material; and
(iii) The potential radiological hazards.

This means a licensee is responsible for performing radiation surveys at its facility to look for radioactive materials that have the potential to impact workers and members of the public. Surveys are performed based on known historical plant information, as well as for areas that have a potential to be impacted by licensed radioactive material. For on-site spills and leaks which have the potential to contain licensed radioactive material, 10 CFR 20.1501 requires a licensee to conduct appropriate radiation surveys and monitoring to determine the radiological hazard (i.e, dose assessment) to workers and if there is a viable pathway to the unrestricted area, to members of the public. The surveys and monitoring can continue over a period of time or become an on-going monitoring program in order for the licensee to adequately characterize the extent and source of the contamination from the spills or leak.

For radiological effluent and environmental monitoring at nuclear power plants, the principal regulatory basis is contained in General Design Criteria 60, 61, and 64 of Appendix A of 10 CFR Part 50, and in Section IV.B of Appendix I of 10 CFR Part 50. Section IV.B of Appendix I of 10 CFR Part 50 states that:

"The licensee shall establish an appropriate surveillance and monitoring program to:

1. Provide data on quantities of radioactive material released in liquid and gaseous effluents...;

2. Provide data on measurable levels of radiation and radioactive materials in the environment to evaluate the relationship between quantities of radioactive material released in effluents and resultant radiation doses to individuals from principal pathways of exposure; and

3. Identify changes in the use of unrestricted areas (e.g., for agricultural purposes) to permit modifications in monitoring programs for evaluating doses to individuals from principal pathways of exposure."

The NRC's regulatory requirements and guidance to licensees to maintain radioactive effluents ALARA have been in place since the mid 1970s and have remained stable. Nuclear power plants, during the licensing process, are required by 10 CFR 50.34a to submit a description of the equipment and procedures for the control of radioactive effluents and for the maintenance and use of equipment installed in radioactive waste systems. The objective of this requirement is for licensees' routine operations to include the use of radioactive waste systems to keep levels of radioactive material in effluents ALARA. In addition, 10 CFR 50.36a requires licensees to have technical specifications (i.e., license conditions) which both comply with the public dose limits in 10 CFR Part 20 and require the use of operating procedures and radioactive waste systems to maintain radioactive effluents ALARA. The radioactive effluent controls program at nuclear power plants has remained a relatively constant and routine program.

The discussion that follows will describe the above regulatory requirements in more detail.

Radioactive Effluent Controls Program

For the release of radioactive liquid effluents, the NRC imposes specific requirements contained in 10 CFR 50.36a and detailed in Appendix I of 10 CFR 50. These requirements are structured to maintain the dose to members of the public from all radioactive effluent releases to levels that are ALARA. The NRC regulates radioactive effluents from nuclear power plants based on the calculated doses to members of the public from the effluents, not specifically on the total volume or type of radioactive material discharged. This type of criteria allows licensees the flexibility to control liquid effluents in an effective and efficient manner based on their plant specific radionuclide waste stream (i.e., focus their radioactive waste treatment systems on those radionuclides which could lead to the largest dose). The NRC requires licensees to have radiological effluent release technical specifications (RETS) that contain the ALARA dose criteria from Appendix I, which controls the dose to a hypothetical maximally exposed member of the public living near a nuclear power plant. The liquid radioactive effluent annual and quarterly dose controls are as follows:

1. Liquid effluents shall not produce doses to any member of the public of more than 3 mrem to the total body or 10 mrems to any organ in a year.

2. Liquid effluents; during any calendar quarter, the dose shall be limited to less than or equal to 1.5 mrems to the total body and to less than or equal to 5 mrems to any organ.

Radiological Environmental Monitoring Program

Prior to licensing a nuclear power plant, the NRC staff reviews the applicant's proposed radiological environmental monitoring program. The applicant is required to conduct a pre-operational program at least two years prior to initial criticality of the reactor. The pre-operational program documents the background levels of direct radiation and concentrations of radionuclides that exist in the environment. It also establishes the specific environmental pathways that will be sampled and evaluated during the life of the reactor. An environmental pathway is the connection between the radioactive releases from the nuclear power plant and a member of the public. For example, liquid radioactive effluent discharges into a river can impact the fish which in turn can impact people who catch and eat the fish. Discharges into the river can also impact the quality of drinking water, if the river is used as a source of drinking water. For these reasons, the NRC requires that environmental pathways be sampled and evaluated for the potential impacts on the environment and members of the public.

A licensee's pre-operational environmental monitoring program is reviewed by NRC staff in regard to the criteria contained in the NRC's Radiological Assessment Branch Technical Position, Revision 1, November 1979, "An Acceptable Radiological Environmental Monitoring Program," as revised and contained in NUREG-1301 and NUREG-1302. The Branch Technical Position (BTP) contains an example of an acceptable minimum radiological monitoring program for the environment outside a nuclear power plant. Highlights of the BTP include: (1) monitoring of air at the offsite locations where the highest concentrations of radionuclides are expected; (2) placement of dosimeters in two concentric rings; one ring outside the plant boundary and another ring four to five miles from the site boundary; (3) off site water samples (i.e., surface, ground, and drinking) upstream and downstream of the point of release to the environment; (4) milk samples at locations where the highest doses are expected; (5) and various vegetation and aquatic food samples. The BTP specifies the acceptable lower limits of detection for the principle radionuclides of concern and the various types of sample material that are to be analyzed.

The operational radiological environmental monitoring program (REMP) is essentially a continuation of the pre-operational program. The requirements of the program are specified in the licensee's RETS or the offsite dose calculation manual. The licensee must submit: (1) an annual radiological environmental monitoring report which assesses the impact of radiological effluent releases into the environment; and if necessary (2) a Special Report within 30 days of discovery of an event which resulted in a radioactive release which exceeded predetermined regulatory limits. The NRC also requires that the licensee participate in an Interlaboratory Comparison Program to ensure the accuracy and precision of the licensee's data. The initial REMP should be conducted for the first three years of commercial operation. Following this period, changes to the REMP may be made based on operational experience. Based on information gathered during NRC inspections, many licensees have reduced the scope and content of the REMP based on historical data (i.e, environmental samples with no detectable radioactive material of plant origin).

The results of each licensee's radiological environmental monitoring and effluent controls programs are required to be reported annually to the NRC, and are available to the public via the NRC's Agencywide Documents Access and Management System (ADAMS) document control program.

The BTP focuses on the public environment beyond the plant property. It does not require ground water monitoring within the licensee's site for general detection and monitoring purposes. Ground water monitoring within the licensee's site is only required if the ground water is tapped for drinking or irrigation purposes. In the offsite environment, ground water monitoring is required only of sources that are likely to be affected by the operation of the nuclear power plant.

The results of the REMP are intended to supplement the results of the radiological effluent controls program by verifying that any measurable concentrations of licensed radioactive material and levels of radiation in the environment are not higher than expected on the basis of the effluent measurements and modeling of the exposure pathways. Thus, the REMP criteria in the BTP provide for measurements of radiation and of radioactive material in those exposure pathways and for those radionuclides which lead to the highest potential radiation exposures of individuals resulting from plant operation. Areas in the vicinity of the plant that are assumed to have a low probability of receiving radioactive effluents from the plant have less or no environmental sampling stations.

The radiation detection capabilities specified in the BTP are 1970s state-of-the-art for routine environmental measurements in laboratories. More sensitive radiation detection capability exists today, but there is no regulatory requirement for plants to have this equipment. As a practical matter, many licensees do have the enhanced detection capability and routinely analyze environmental samples at much lower radioactivity detection levels than required by the regulatory guidance and license conditions. This capability has provided increased precision in quantifying the typically small doses attributed to any abnormal releases. The guidance primarily focuses on gamma isotopic analysis of environmental material and on tritium in water samples. There are minimal requirements for analyzing environmental samples for beta- and alpha-emitting radionuclides.

The regulatory guidance allows for deviations from the environmental sampling and analysis regime if samples are unobtainable due to hazardous conditions, seasonal unavailability, malfunction of automatic sampling equipment, and other legitimate reasons. If samples are unobtainable due to sampling equipment malfunction, the guidance states that every effort shall be made to complete corrective action prior to the end of the next sampling period. All deviations from the sampling schedule are required to be documented in the annual radiological environmental monitoring report.

The regulatory guidance provides built-in flexibility in the scope of the REMP. It provides a generic minimum program and also states that individual sites may have special local characteristics which have to be addressed on a site specific basis. It also allows licensees to reduce the scope and frequency of the sampling program, without NRC approval, based on historical data. What NRC inspectors have typically seen is that if a licensee's environmental samples have not detected licensed radioactive material in several years, then the licensee typically reduces the scope and sample frequency of the associated environmental pathway. The guidance is designed to allow the REMP to focus its sampling protocol on the more dose significant pathways and to drop sampling in those areas that result in the lowest dose. NRC inspections have observed reductions in the scope and frequency of licensee programs, but in all cases the minimum required sampling of the required pathways continues.

Reporting Requirements

As discussed above, there are no specific regulatory requirements for licensees to conduct routine on-site environmental surveys and monitoring for potential abnormal spills and leaks of radioactive liquids. However, 10 CFR 50.75(g) requires that licensees keep records of information important to the safe and effective decommissioning of the facility. These records include information on known spills or other unusual occurrences involving the spread of contamination in and around the facility or site. These records may be limited to instances when significant contamination remains after any cleanup procedures or when there is reasonable likelihood that contamination may have spread to inaccessible areas. The rule does not define the magnitude of the spills and leaks that need to be documented by the licensee. Also, the rule does not define "significant contamination" that needs to be recorded after the cleanup process. Licensees maintain records of information on spills and leaks at their facilities. There is no requirement that this information must be submitted to the NRC. However, the records are available for review by NRC inspectors.

Although 10 CFR 50.75(g) discusses the requirement for records of any remaining residual contamination, there are no regulatory requirements which require remediation while the power plant is operating. A licensee's decision to remediate contamination before the plant is decommissioned is typically based on several factors, including ALARA considerations for potential worker and public dose, cost, feasibility, disposal options, and external stakeholder considerations.

The NRC has clearly defined radiation limits for the decommissioning of a nuclear reactor and release of the facility or site for unrestricted use by members of the public. The requirements are contained in 10 CFR Part 20, Subpart E - "Radiological Criteria for License Termination." The NRC will terminate a Part 50 license and allow the site to be used for any purpose provided that any remaining reactor produced radioactive contamination does not result in an annual dose above 25 mrem. The dose is calculated from all environmental pathways; air, water, food products, residential occupancy and/or industrial use.

10 CFR Part 20, Subpart M — Reports

Section 20.2202 provides criteria for notification of incidents. For incidents involving the release of licensed radioactive material, the reporting criteria is that immediate notification of the NRC is required when the event may have caused or threatens to cause a large dose in excess of regulatory limits to an individual (i.e, 25 rem to the whole body, 75 rem to the lens of the eye, or a shallow-dose equivalent skin or extremity dose of 250 rads). Note that 1 rem is equal to 1000 mrem.

Incidents which require notification within 24 hours involve radiation doses which are lower than described above, but are still doses which are at, near, or slightly above regulatory limits.

In addition to the notification of incidents in 10 CFR 20.2202, there are reporting requirements in 10 CFR 20.2203 which require that a written report be sent to the NRC within 30 days after learning of certain occurrences. These occurrences include: radiation doses in excess of the occupational and public limits in 10 CFR Part 20; or levels of radiation or concentrations of radioactive material in a restricted area in excess of any applicable limit in the facility license; or in an unrestricted area in excess of 10 times any applicable limit in 10 CFR Part 20 or in the facility license.

Specific to power reactors is the requirement to report to the NRC on occurrences in which radiation levels or releases of radioactive material occur in excess of the environmental radiation standards of EPA's 40 CFR Part 190.

10 CFR Part 50.72, Immediate Notification Requirements for Operating Nuclear Power Reactors

This regulation includes requirements for immediate notifications related to the Emergency Classes, and for other non-emergency notifications which require a four-hour report.

The immediate notifications related to the declaration of an emergency at a nuclear power plant are generally for significant events that may have an impact on reactor or public safety. With regard to unplanned liquid releases of radioactive material, licensee emergency plans typically require the declaration of a Notification of Unusual Event (NOUE) if the release exceeds a specified limit. None of the releases discussed in this report met the criteria.

The relevant notification criteria for this reporting requirement is contained in 50.72(b)(2)(xi). This section requires a four-hour report in the event or situation, related to the health and safety of the public or onsite personnel, or the protection of the environment, for which a news release is planned, or notification to other government agencies has been or will be made. Such an event may include an inadvertent release of radioactively contaminated materials.

Guidance and examples for the reporting criteria are contained in NUREG-1022, "Event Reporting Guidelines 10 CFR 50.72 and 50.73." However, there is no specific threshold given on the amount, type, or dose impact of the radioactivity involved in the event. One of the reasons for these four-hour reports is that the NRC requires the same level of information as that communicated by the licensee to other government agencies.

10 CFR 50.73, Licensee Event Report System

This section requires an operating nuclear power plant to submit a Licensee Event Report (LER) for any of the criteria listed in the regulation, within 60 days after the discovery of the event.

The relevant notification criteria for this report is contained in 50.73(a)(2)(viii)(B), which requires a written report for any liquid effluent release that, when averaged over a time period of 1 hour, exceeds 20 times the applicable concentrations specified in Appendix B to 10 CFR Part 20, table 2, column 2, at the point of entry into receiving waters (i.e., unrestricted area) for all radionuclides except tritium and dissolved noble gases. This criteria is well above the abnormal release events that are included in this report.

3.2.1.3 Conclusions

The review of health physics regulatory requirements pertaining to liquid radioactive effluent releases, as described above, leads to the following conclusions:

(1) There is an extensive list of NRC regulations which provide a framework to ensure that

the public health is protected from the release to the environment of licensed radioactive material. This regulatory framework has generally been successful in limiting public radiation doses to below the ALARA guidelines (less than 3 mrem per year due to liquid releases).

(2) The radiological effluent and environmental monitoring program requirements and guidance largely reflect radioactive waste streams that were typically from nuclear plant operation in the 1970's. The issues that were important then, i.e. principal gamma emitters giving the significant dose, while still important today, have been joined by new issues. Today, as a result of better fuel performance, and improved radioactive source term reduction programs, a new radioactive waste source term has evolved. The new liquid radioactive effluent source term is made up of a lower fraction of gamma emitting radionuclides and a higher fraction of weak beta emitters. The NRC program has not evolved with the changes in technology and industry programs.

(3) The REMP has allowed licensees significant flexibility to make changes to their programs without NRC prior approval. The historical trend has been to reduce the scope of the program. There is no guidance on when the program needs to be expanded.

(4) 10 CFR 50.75(g) does not define the magnitude of the spills and leaks that need to be documented by the licensee. Also, the rule does not define "significant contamination" that needs to be recorded after any cleanup process in the licensee's decommissioning files. The records of information on spills and leaks are kept at the licensee's facility and are available for NRC inspection.

(5) 10 CFR 50.75(g) discusses the requirement for records of any remaining residual contamination, however there are no regulatory requirements which require remediation at an operating power plant. A licensee's decision to remediate contamination prior to decommissioning is based on several factors including ALARA considerations for potential worker and public dose, cost, feasibility, disposal options and public stakeholder considerations.

(6) The primary focus of the NRC's radiological effluent and environmental monitoring program requirements and guidance is on routine discharges to the unrestricted area beyond the licensee's site boundary. There are minimal NRC requirements and guidance in place to address actions expected following onsite spills and leakage events.

(7) The existing reporting requirements for abnormal spills and leaks are at a level that is risk informed and appropriate in relation to the other emergency and non-emergency reporting criteria.

3.2.1.4 Recommendations

To address the conclusions on the adequacy of health physics requirements for liquid effluent releases, the following recommendations are provided. These recommendations apply to future licensing of new reactors, and to the extent allowed by legal considerations, should be applied to presently operating reactors.

(1) The NRC should revise the radiological effluent and environmental monitoring program requirements and guidance to be consistent with current industry standards and commercially available radiation detection technology.

(2) Guidance for the REMP should be revised to limit the amount of flexibility in its conduct. Guidance is needed on when the program, based on data or environmental conditions, should be expanded.

(3) Develop guidance to define the magnitude of the spills and leaks that need to be documented by the licensee under 10 CFR 50.75(g). Also, clearly define “significant contamination.” Summaries of spills and leaks documented under 10 CFR 50.75(g) should be included in the annual radioactive effluent release report.

(4) The staff should provide guidance to the industry which expands the use of historical information and data in their 50.75(g) files to the operational phase of the plant. The data provides good information on current and future potential radiological hazards that are important during routine operation, and can aid in planning survey and monitoring programs.

(5) The NRC should evaluate the need to enact regulations and/or provide guidance to address remediation.

(6) The NRC should require adequate assurance that leaks and spills will be detected before radionuclides migrate offsite via an unmonitored pathway.

(7) To support one possible option for recommendation (6), regulatory guidance should be developed to define acceptable methods to survey and monitor on-site ground water and sub-surface soil for radionuclides.

3.2.2 Regulatory Requirements for Systems, Structures and Components Related to Radioactive Leaks

3.2.2.1 Scope and Criteria

Several provisions of the NRC regulations and plant operating licenses (technical specifications) may pertain to structures, systems and components (SSCs) that have experienced radioactive leaks or spills. These include: the general design criteria (GDC) for nuclear power plants (Appendix A to 10 CFR Part 50), or, as appropriate, similar requirements in the licensing basis for a reactor facility; the requirements of 10 CFR 50.55a related to codes and standards; the quality assurance criteria of Appendix B to 10 CFR Part 50; the requirements for monitoring the effectiveness of maintenance at nuclear power plants in 10 CFR 50.65; and 10 CFR Part 54 which covers the requirements for renewal of operating licenses for nuclear power plants.

Based on the industry history of radioactive leaks discussed in Section 2.1.1.2, the leaks can generally be attributed to the following SSCs: fuel transfer systems and spent fuel pools, buried piping, and storage tanks. The purpose of this section of the report is to assess which NRC requirements applied to SSCs that have leaked, and what contribution those requirements make to preventing or detecting leakage.

3.2.2.2 Detailed Discussion of Review

The following regulatory requirements may apply to SSCs that have leaked radioactive liquids. Determining which requirements apply to a specific facility requires a review of the plant’s licensing basis.

General Design Criteria and Quality Assurance Requirements

The primary GDC that apply to the reviewed SSCs with regard to leakage include GDC 60, “Control of releases of radioactive material to the environment;” GDC 61, “Fuel storage and handling and radioactivity control;” and GDC 64, “Monitoring radioactivity releases.”

Operating nuclear power plants are required to implement a quality assurance (QA) program, as described in each facility’s Final Safety Analysis Report (FSAR). This program must meet the criteria of Appendix B to 10 CFR Part 50, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants.” Aspects of a licensee’s QA program may apply to SSCs containing radioactive liquids.

Codes and Standards - 10 CFR 50.55a

10 CFR 50.55a states that ASME Code Class components must meet the requirements of the ASME Boiler and Pressure Vessel Code. Section III of the ASME Code provides the design requirements for ASME Code Class components. Section XI of the ASME Code provides the inservice inspection requirements for ASME Code Class components and the criteria for evaluating, repairing, and replacing items found unacceptable. The ASME Code for Operation and Maintenance of Nuclear Power Plants provides the inservice testing requirements of components.

Maintenance Rule - 10 CFR 50.65

10 CFR 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," (the Maintenance Rule), which went into effect on July 10, 1996, requires licensees to ensure they effectively maintain safety-significant plant equipment in order to minimize the likelihood of failures and abnormal events. Monitoring of such work needs to be established commensurate with safety and, where practical, take into account industry operating experience. Regulatory guidance on the implementation of the Maintenance Rule is primarily provided in Regulatory Guide 1.160, Rev. 2, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants.”

License Renewal Rule - 10 CFR Part 54

The requirements for renewing a nuclear power plant operating license for up to an additional 20 years are presented in 10 CFR Part 54 - License Renewal Rule. Under this rule, applicants are required to identify all SSCs that are within the scope of the rule. A screening review is then required to identify those SSCs that are "passive and long lived" structures and components. For these items, the applicant must demonstrate that the effects of aging will be managed so that the intended function(s) will be maintained consistent with the current licensing basis through the period of extended operation. NRC staff guidance related to license renewal is contained in the "Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants" (SRP-LR) (NUREG-1800), and the "Generic Aging Lessons Learned" (GALL) report NUREG-1801. The GALL report presents an evaluation of existing generic programs to document the conditions under which these programs are considered adequate to manage identified aging effects without making any changes and the conditions under which existing programs should be augmented.

Review of Specific Plant Requirements

The task force reviewed the applicability of the above regulatory requirements against selected radioactive leakage events as described in Section 2.0. SSCs are typically categorized in terms of seismic category, safety, and/or quality classifications.

Braidwood Vacuum Breakers in the Blowdown Line

The licensee identified elevated levels of tritium in ground water at the Braidwood site and in adjacent property, and determined the tritium originated from historical spills from underground piping (circulating blowdown system) that periodically transported liquid radioactive effluent discharges. Since 1996, the licensee documented 17 leaks from piping vacuum breakers. The large volume leaks in 1998 and 2000 were determined to be caused by inadequate preventive maintenance and inadequate design configuration. The licensee's initial corrective actions were to correct individual instances of leakage. Following the significant leak in 2000, the licensee performed a root cause evaluation, which recommended that the licensee institute a preventative maintenance program and modify certain system components.

The primary function of the circulating water blowdown system at the Braidwood site is to provide dilution and a pathway for liquid radioactive waste releases. The secondary function of the circulating water blowdown system is to provide dilution for liquid radioactive waste releases. The blowdown piping is constructed of reinforced concrete pipe.

The circulating water blowdown piping at Braidwood is designated by the licensee as a Safety Category II SSC, which has no public health or safety implication. As stated in the Updated Final Safety Analysis Report (UFSAR), "Safety Category II systems or portions of systems and components do not follow the requirements of Appendix B to 10 CFR 50. The quality assurance standards for these systems and components follow normal industrial standards and any other requirements deemed necessary by the Licensee." Additionally, the blowdown piping does not meet the scoping requirements for the maintenance rule. SSCs that do not meet the scoping criteria of the maintenance rule may continue to have appropriate maintenance activities performed on them as determined by the licensee, based upon factors such as the consequence of SSC failure on power production or economic importance, but it is neither required nor inspected by the NRC.

A further review of the Braidwood UFSAR determined that most radiological waste system components are similarly classified as Safety Category II or Quality Group D. These components are not subject to mandatory in-service inspection or in-service testing requirements that typically apply to SSCs essential to the performance of a safety function.

Based on experience, the task force considered the applicability of NRC requirements to similar SSCs at other plants to be typical of those applied at Braidwood.

Palo Verde, Salem, and Indian Point Spent Fuel Pool Leakage

Palo Verde Unit 1, Salem Unit 1, and Indian Point Units 1 and 2, have experienced spent fuel pool (SFP) leakage that has resulted in the release of radioactive water to the environment. Fuel handling and storage facilities are designed to store spent fuel and remove decay heat from the fuel; protect the fuel from mechanical damage; prevent the loss of water from the pool that could uncover the fuel; and provide the capability for limiting the potential offsite radiation exposures in the event of a significant release of radioactivity from the pool. License technical specifications typically require monitoring to maintain an adequate level of water in the SFP, however, due to evaporation rates and the relative large volumes of water in SFPs, licensees are generally unable to distinguish small leaks from normal evaporation changes in the pool level.

In July, 2005 at Palo Verde Unit 1, the licensee observed water seepage from the SFP south wall. A second leak was found outside the fuel building on the SFP east wall. Chemistry samples of the leakage indicated that the water was from the SFP. Previously, the licensee had identified that the SFP tell-tale drain lines were plugged. The blocked lines caused SFP water to back-up and leak through two adjacent concrete walls. Typically, SFPs are constructed with tell-tale drain lines (leak collection system), which collect any SFP leakage behind the seams of the SFP liner. A review of the requirements applicable to the SFP determined that the SFP structure is constructed and classified as Seismic Category I, the pool liner and the leak detection system are typically listed as not applicable to seismic category or quality group classification. The task force could not identify any generic regulatory requirements that apply to maintenance, surveillance, or routine testing of the SFP liner or the leak detection system. For this specific licensee, however, a self-revealing noncited violation was identified as a result of the licensee's failure to monitor leakage properly using the spent fuel pool leak detection surveillance as required by a site-specific procedure. The NRC staff noted in the inspection report (Inspection Report numbers 05000528/2005004, 05000529/2005004; and 05000530/2005004) that the significance determination process does not specifically address SFP issues.

A similar issue was documented in NRC Information Notice 2004-05, "Spent Fuel Pool Leakage to Onsite Ground Water," related to evidence of radioactive leakage through an interior wall at Salem Unit 1. On September 18, 2002, the licensee for Salem Unit 1 identified evidence of radioactive water leakage through an interior wall. The licensee established a comprehensive task action plan to identify and stop the source of the leakage and evaluate possible undetected leakage outside building structures. The NRC conducted a special inspection regarding the leakage from the Unit 1 fuel handling building (FHB). The staff's inspection report (Inspection Report numbers 05000272/2003006; 05000311/2003006) identified a self-revealing non-cited violation of 10 CFR 50, Appendix B, Criterion XVI, involving failure to promptly detect and correct a condition adverse to quality involving undetected accumulation of borated, contaminated water behind the Unit 1 FHB walls. The licensee's evaluation found that the SFP telltale drains were blocked. The licensee cleaned the telltale drains, which allowed the drainage of the accumulated water between the liner and the SFP concrete structure.

On August 22, 2005, Indian Point Unit 2, identified leakage during the excavation adjacent to the spent fuel pool south wall. The SFP wall consists of four-foot-thick concrete, and is heavily reinforced with steel rebar. The inside of the SFP is lined with 1/4-inch stainless steel plate anchored to the concrete such that the plate and concrete are in contact, with only a small interstitial area between. The SFP is a Class 1 structure as specified in the Indian Point Unit 2 Updated Final Safety Analysis Report. Indian Point Unit 2 was designed and licensed without a spent fuel pool liner leak collection system. The design provisions for the Indian Point Unit 2 SFP include pool level instrumentation with alarms in the control room and 150 gallons per minute water makeup capacity in the event of a design basis accident.

In addition to the identified leakage from the SFP wall, the licensee detected groundwater contamination in onsite monitoring wells. This led the NRC staff to conduct a special inspection to better understand the source of the radiological contamination, the cause, the extent of condition, any potential impact on the spent fuel pool integrity, and to confirm that public health and safety was being maintained as required by the regulatory requirements. The staff's inspection is documented in NRC Special Inspection Report No. 05000247/2005011. Currently, the licensee is investigating if there is a leak in the spent fuel pool stainless steel liner. Approximately 40% of the liner has been inspected with no leaks identified. The licensee is investigating methods and techniques to inspect additional areas of the liner. The licensee is also installing additional monitoring wells to assess and characterize groundwater movement and behavior relative to groundwater contamination in the vicinity of Unit 2. The NRC special inspection staff also reviewed the licensee's structural analysis and confirmed that the assumptions and analytical methods used by the licensee were reasonable, appropriate, and correctly applied. Based on staff's review, it was concluded that the leakage condition affecting the Indian Point Unit 2 SFP structure would not adversely affect the integrity of the structure or its safety function. The NRC staff is continuing to monitor and will issue a followup report related to the licensee's actions to identify, control, mitigate, and remediate (as necessary) the groundwater contamination.

Dresden Storage Tank Piping Leak

In 2004, leakage was discovered in the supply line piping between the condensate storage tank and the high pressure coolant injection (HPCI) system. The piping is approximately 175 feet long and is located in a dirt trench. The licensee replaced approximately 75 feet of piping where leaks had been identified in 2004. The replaced section of piping is buried in a low-strength grout material. In February, 2006, the licensee identified elevated levels of tritium in a monitoring well located near the underground piping. The licensee suspects that the current leak is from the 100 feet of piping that was not replaced in 2004. The licensee had planned to replace the piping in June, 2006 prior to the identification of elevated tritium. The condensate storage tank and associated piping is made of aluminum and is not categorized as Class I. In addition, the licensee has not categorized the condensate storage tank and the associated piping to the HPCI system as safety related. The licensee's UFSAR lists the safety related water source as the torus for the HPCI system. The piping is classified as non-safety related, although the licensee lists it as Augmented Quality under the Exelon quality assurance program. The piping is designed to meet ANSI B31.1 standards. The piping is wrapped with polypropylene pipe wrap material to provide protection from corrosion and electrolysis. The piping consists of 12-inch, 16-inch, 18-inch and 24-inch diameter sections having a nominal wall thickness of 0.375-inch. The required installation testing includes hydrotesting and visual inspection. The licensee's technical specifications require quarterly HPCI surveillance using the subject section of piping as part of the flow path. In addition, the Exelon excavation procedures have the licensee visually inspect the buried piping if the area is excavated in the future. The task force could not identify any generic regulatory requirements that applied to maintenance, surveillance, or routine testing of non-safety related condensate storage tanks and associated piping.

3.2.2.3 Conclusions

Review of regulatory requirements for SSCs that have experienced unmonitored or unplanned liquid radioactive effluent releases as described above, leads to the following conclusions:

(1) Systems containing radioactive liquid that are designated as safety-related, or that are addressed under some aspect of a licensee's quality assurance program, are generally subject to maintenance, inspections, tests, and/or other quality assurance requirements that provide added assurance that the system will not leak, or if it does leak, that the leakage will be detected. Systems that are not safety-related and that are not covered under the quality assurance program generally are subject to less of these measures.

(2) Systems or structures can experience undetected radioactive leaks over a prolonged period of time. Systems or structures that are buried or that are in contact with soil, such as SFPs, tanks in contact with the ground, and buried pipes, are particularly susceptible to undetected leakage.

(3) SFP leakage may be reduced by improved maintenance and trending of the telltale leak detection/monitoring system.

(4) SFP performance deficiencies are not specifically addressed in the NRC inspection program significance determination process.

(5) Leakage from components containing radioactive liquids may be reduced by the use of improved materials, the use of higher level consensus code repair/replacement requirements, improved quality assurance, improved design standards, improved and expanded inspection requirements, improved protection of buried components (galvanic protection, coatings) and/or improved design considerations.

(6) Available information does not suggest a propensity for SFP liner leakage to damage structures. However, long term effects are continuing to be reviewed.

3.2.2.4 Recommendations

The following recommendations address the above conclusions.

(1) SSC's may have a radioactive leak without prompt detection, therefore the NRC should require adequate assurance that leaks and spills will be detected before radionuclides migrate offsite via an unmonitored pathway.

(2) Determine whether there is a need for improved design, materials, and/or quality assurance requirements for SSC's that contain radioactive liquids for new reactors.

(3) The staff should consider whether further action is warranted to enhance the performance of SFP telltale drains at nuclear power plants.

(4) The staff should verify that there has been an evaluation of the effects of long term SFP leakage (boric acid) on safety significant structures (concrete, rebar), or the staff should perform such an evaluation.

(5) The staff should assess whether the maintenance rule adequately covers SSCs that contain radioactive liquids.

(6) The staff should verify that the license renewal process reviews degradation of systems containing radioactive material such as those discussed in this report.

3.2.3 Other Regulatory Limits on Ground-Water Contamination

3.2.3.1 Scope and Criteria

As indicated earlier, inadvertent releases of radioactive material to the environment can result in a heightened level of public concern, as well as concerns expressed by State and local officials. These concerns can be traced, in part, to violations of State environmental protection or natural resource protection regulations. This section provides an overview of relevant state regulations that may result in violations. It takes no position on whether any of these regulations might be pre-empted by federal law.

3.2.3.2 Detailed Discussion of Review

States can use three general types of regulations for nuclear utility compliance determinations: National Pollutant Discharge Elimination System (NPDES) Permit Regulations, Numerical Standards for Ground Water Quality and Non-numerical Rules for Ground Water Quality.

NPDES Permits

The NPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Most States have been delegated authority by the EPA to issue NPDES permits. It is important to note that NPDES permits are not for discharges to ground water but for discharges to surface water. Nevertheless, it is recognized that discharges to surface water bodies or discharges directly to the surface may result in recharge to a shallow aquifer. Therefore, States have considered it appropriate to cite utilities for unpermitted discharges when they lead to degradation of a ground-water resource.

The NPDES permit application requires the applicant to list all pollutants in the discharge. As defined in the Clean Water Act, the term "pollutant" includes "radioactive materials." However, the U.S. Supreme Court, in Train v. Colorado, 426 U.S. 1 (1976), ruled that this definition does not include radioactive materials regulated under the Atomic Energy Act (AEA). In keeping with this ruling, the EPA's NPDES rules exclude AEA materials from the definition of pollutant. See 40 CFR 122.2. Nonetheless, that exclusion has not been adopted by all States. Some NPDES permits impose numerical limits. These can be in terms of a concentration, but can also be in terms of a total quantity. A good example is the State of Vermont's five curie per year limit for tritium. Other permits simply list tritium without a numerical limit and insert a reporting requirement as a condition. Discharge permits are written with a specific discharge compliance point in mind (such as the Connecticut River for Vermont Yankee). The vacuum breaker pit associated with a blowdown line is not such a compliance point, but a release to this pit may result in a violation of permit conditions as well. Additional violations can be cited for failure to maintain equipment associated with the permitted discharge pathway.

Another illustration of a surface discharge requirement imposed on a utility is the 30,000 pCi/L reporting limit for tritium at the Turkey Point nuclear power plant. This technical specification requirement in Florida Power and Light's (FP&Ls) license, refers to effluent discharges into a closed-loop saltwater cooling canal system. The State of Florida takes samples of this canal and reports the results to the utility and to the NRC. There is no ground-water pathway for this discharge.

Numerical Standards for Ground Water Quality

Most States have set numerical standards for ground water quality. For tritium, the standard is taken from the State's own drinking water standard for tritium, which is usually drawn from the EPA standard of 20,000 pCi/L. States that use this standard include New York, California, Illinois, and New Jersey.

Nuclear facility releases that result in ground-water concentrations in excess of this standard can form the basis for violations of State ground-water protection regulations. This violation is not based on effluent concentrations, but based on actions (or failures) that resulted in an aquifer that yields samples with concentrations in excess of the standard.

There are two other "limits" of note. The California EPA has set a Public Health Goal (PHG) of 400 pCi/L for tritium in drinking water. This goal is equivalent to a cancer risk of 10E-6. The original purpose of this goal was for the California Water Resources Control Board to regulate community water systems. This number has been referenced with regard to releases from Indian Point and Braidwood, but is not actually used by California regulators as a compliance standard for nuclear facilities. In fact, the California EPA document states "PHGs are derived for drinking water only and are not intended to be utilized as target levels for the contamination of other environmental media."

News reports have also cited a "Colorado ground-water standard of 500 pCi/L." This number is in fact a Site Specific Surface Water Action Level for the cleanup of the Rocky Flats Environmental Technology Site. This is not a State of Colorado regulation that applies to ground water.

Non-Numerical Rules for Ground Water Quality

States have adopted ground-water protection strategies that frequently include the concept of non-degradation. Although these rules have been adopted under the general authority delegated to the States by the EPA, there are no specific analogous Federal regulations, as is the case for the drinking water rules. In some States, such as Texas, the non-degradation concept is implemented as a policy goal. The underlying objective is to avoid impairment of current and future uses of ground water. Consideration of potential water uses leads to different courses of action depending on whether the aquifer is potable. Some States, such as New Jersey, have complicated non-degradation schemes for chemical pollutants, but still use the EPA drinking water standards for tritium.

Non-degradation rules have no absolute quantity or concentration limit. Depending on the classification of the water, the water quality criteria can be based on site-specific existing conditions, regional background or even detection limits. However, as a practical matter, at least for tritium, the common interpretation is that they are based on anything above the Lower Limit of Detection (LLD). In 2006, ambient tritium concentrations in the United States are below 50 pCi/L, whereas most common methods of detection yield LLDs in the range of 100 to 500 pCi/L. Variations in the LLD from one laboratory to another can lead to compliance disagreements if no guidance documents or prior agreements are negotiated. In Illinois, an LLD of 200 pCi/L was used by Exelon in evaluating ground water near the Braidwood nuclear plant. In New Jersey, the agreed upon LLD for Salem was 300 pCi/L.

These non-numerical rules are usually designed to prevent the degradation of ground water as a natural resource. In fact, some make no overt attempt to limit general public radiation exposure or human health risk. Instead, they focus on the current uses of the water and whether the current use practices can continue. Under Illinois regulations, no person shall cause, threaten or allow the release of any contaminant to a resource ground water such that an existing or potential use of such ground water is precluded. Therefore, it is Illinois' view that if upon hearing about nearby tritium contamination a farmer declines to use his well for watering of livestock or for vegetable irrigation, a violation may result.

Differing Approaches

As discussed above, it appears that without a set of delegated Federal regulations, the States have developed a variety of regulations that, from the point of view of the nuclear utility industry, has no common theme or objective. However, the case can be made that the States have simply developed local regulations that match the local environment and circumstances. The State of Florida has a need to protect a saltwater canal system. The State of Arizona does not, but Palo Verde has ground water at 14 feet below ground surface. The State of Pennsylvania's approach stems from the fact that the Three Mile Island Nuclear Power Plant is built on an island.

3.2.3.3 Conclusions

(1) State regulations are frequently developed and enforced by State environmental and natural resource agencies, not Agreement State programs.

(2) While the NRC is now employing a risk-informed approach to some rulemakings, State environmental and natural resource regulators are not necessarily adopting this approach. Utilities and industry groups should take the State perspective into account when reviewing possible ground-water contamination.

(3) The concept of a "point of compliance" is frequently misunderstood. This is because some State regulations focus on surface discharges in an effort to protect surface water while others focus on the protection of ground water as a resource and are not specific with respect to the source of contamination.

(4) The States have developed a wide variety of regulatory schemes based on site-specific features and issues.

3.2.3.4 Recommendations

(1) The NRC staff should open a dialogue with the States regarding the application of the NPDES system to discharges of radioactive materials to promote a common understanding of how the associated legal requirements in this area are addressed.

3.3 NRC Inspection and Enforcement Program

3.3.1 Scope and Criteria

The Task Force reviewed the NRC inspection program in the area of licensee radiological effluents monitoring and control, and environmental monitoring. The Task Force reviewed the current inspection program requirements, and those that existed prior to NRC's adoption, in April 2000, of the Reactor Oversight Process (ROP). The Task Force also evaluated the current Significance Determination Process (SDP) within the ROP's Public Radiation Safety Cornerstone of the ROP. As part of this review, the Task Force evaluated NRC enforcement actions taken for radioactive liquid releases both prior to the ROP, and under the ROP. The reporting of inspection results under these two programs was also evaluated.

3.3.2 Detailed Discussion of Review

The NRC implements a defined inspection program for nuclear power plants. The program includes inspection oversight of the monitoring and control, and public dose impact, of both routine and non-routine radioactive gaseous, liquid, and particulate effluent releases. The NRC has also established a defined training and qualification program for its inspectors in this area.

The NRC Inspection Manual Chapters (IMC) define and provide specific inspection procedures for evaluating licensee performance. Recent NRC inspection efforts, and program improvement efforts, have mostly focused on the areas of operations and decommissioning.

The NRC inspection program in the plant effluent and environmental areas has undergone various changes since its inception to provide for more effective use of inspection resources and focus on risk significant activities. The changes to the inspection program have also taken into consideration the maturation of the nuclear power industry.

3.3.2.1 Inspection Program Prior to the ROP

Prior to the ROP, the NRC inspection program for radiological effluent monitoring and control, and environmental monitoring, initially provided for specific inspection of program areas via defined individual inspection procedures (IPs). Of particular note, these procedures provided specific guidance to check for unmonitored releases and to ensure radioactive releases were within applicable public dose limits. Inspection Procedure 84725 provided for confirmation of licensee sample analysis programs via NRC analysis of split samples. In addition to these procedures, the IMC 2515 operational inspection program provided for the performance of supplemental inspections in these areas, on an as needed basis. Of particular note, as the industry and inspection process matured, the NRC found it necessary to provide additional guidance on specific topics. This guidance was in the form of “positions” that were published and made available to the public. NUREG/CR-5569, Rev.1, “Health Physics Positions Data Base”, provides the latest guidance in these areas, including guidance on effluents and environmental monitoring.

As part of the inspection program improvement initiative, a new procedure, IP 84750, was established in 1994 to provide for inspection of both radiological effluents and environmental monitoring, as well as radioactive waste treatment. It also included guidance on inspection of ventilation systems. The procedure consolidated various elements of several individual inspection procedures and was conducted on an annual basis with certain aspects (confirmatory measurements and water chemistry) conducted every third year. This procedure also provided for reviews of potential unmonitored effluent release pathways as well as potential public dose consequences. This inspection procedure was the procedure for inspection through April 2000 when the NRC issued the new ROP inspection procedures.

The objective of IP 84750 included ensuring that the licensee effectively controlled, monitored, and quantified releases of radioactive materials in liquid, gaseous, and particulate forms to the environment and ensured that the radiological environmental monitoring programs were effective and implemented. Of particular note, IP 84750 required a check for potential unmonitored releases and a determination that the licensee had evaluated the potential significance of any identified potential unmonitored pathways.

3.3.2.2 Inspections Under the ROP

The NRC's objective in developing the ROP was to inspect and assess licensee performance in a manner that was more risk-informed, objective, predictable, and understandable, than the previous oversight processes. Developing the new ROP involved revising, integrating and streamlining many aspects of the old oversight process, such as the inspection program, assessment process, and enforcement policy. The NRC also developed several new oversight processes such as performance indicators (PIs), and the SDP for evaluating inspection findings.

The ROP's baseline inspection program for radiological effluents and environmental monitoring consists of three elements: a radiological effluent monitoring and controls element; a radiological environmental monitoring element; and a performance indicator verification element. The effluent monitoring and controls program element, performed per IP 71122.01, directly inspects the measurement, processing, and control of radioactive effluent releases and direct radiation shine from nuclear power stations. The environmental monitoring element, performed by IP 71122.03, directly inspects a nuclear power station's program to detect and measure radioactivity in Unrestricted Areas that are attributable to station operations. The environmental program supplements the effluent monitoring program by verifying that the measurable concentrations of radioactive materials and levels of radiation in the environment are in agreement with values predicted by the radioactive effluent monitoring program. The environmental inspection program procedure specifically directs verification that environmental sampling is representative of the release pathways as specified in the licensee's Offsite Dose Calculation Manual (ODCM) and that sampling techniques are in accordance with procedures for the program. The two program aspects are complementary and focus on ensuring dose to members of the public remains well within applicable limits and are ALARA.

The performance indicator (PI) program provides for licensee notification to the NRC when certain quarterly ALARA public dose thresholds are reached as specified in 10 CFR 50, Appendix I. The PI monitors licensee performance in the area of radiological effluent release occurrences per reactor in the previous four calendar quarters. The procedure that verifies a licensee's PI data, IP 71151, specifically directs that known plant incidents be screened involving pipes leaking radioactive liquids or gasses that are not bounded by plant collection systems and that could be a potential unmonitored release path.

In addition, the ROP baseline inspection program also includes a routine oversight component conducted by the NRC Resident Inspector, which indicates that any known unmonitored release paths that may impact the radiological effluent PI should be pursued. In addition, NRC Resident Inspectors routinely review plant corrective action system entries for follow-up, which may identify issues with radioactive liquid releases.

When a licensee for a nuclear power station elects to decommission the plant, the existing effluent and environmental monitoring programs continue. However, licensees may submit requests for modifications of those programs due to the significant reduction in source term and release potential, and associated dose to members of the public, once the reactor is permanently shutdown. The NRC evaluates these change requests and approves changes, consistent with protection of public health and safety. Effluent and environmental program inspections are also conducted during the decommissioning phase of plant life. Decommissioning aspects are further discussed in Section 3.4

3.3.2.3 Effluent Monitoring Program Under the ROP

The NRC inspection program reviews the adequacy and effectiveness of a licensee’s evaluation and control of radioactive material released to the environment that could result in potential doses to the public. The inspectors review implementation of regulatory requirements contained within the station’s Technical Specifications and its ODCM, as well as associated guidance documents (e.g., Branch Technical Positions and Regulatory Guides).

The inspector conducts walk-downs of gaseous and liquid release systems to observe material conditions and confirm the system configuration is as specified in the safety analysis report. The inspector observes routine processing and release of radioactive liquid and gaseous effluents and reviews projected radiation doses to members of the public. Also included is a review of dose calculations to ensure monthly, quarterly, and annual dose calculations for members of the public were properly done. The inspector reviews abnormal releases or releases made with inoperable radiation monitors to verify appropriate compensatory sampling and radiological analyses were conducted, consistent with requirements, and to verify appropriate public dose projections were made. The inspection program provides for review and verifications of changes in systems or the ODCM. Special emphasis is placed on understanding changes in projected doses. The inspection includes reviews of instrument calibrations for both laboratory counting instrumentation and effluent radiation monitoring instrumentation and reviews of the adequacy of the quality assurance of the effluent sampling and analysis program, including inter-laboratory comparisons. The inspection also includes a comprehensive review of a licensee’s problem identification and resolution program to ensure associated problems are identified, characterized, prioritized, entered into the program, and resolved. The routine confirmatory sampling aspect of this procedure was removed from the inspection program in 1996.

3.3.2.4 Environmental Monitoring Program Under the ROP

The NRC’s environmental monitoring requirements on nuclear power stations serve as a check on the effluent monitoring program discussed above. The environmental monitoring program requirements are outlined in the licensee’s Technical Specifications and ODCM. The monitoring requirements are based on an NRC Branch Technical Position and associated NUREGs. The program includes requirements to sample various material that may serve as a pathway of radiation exposure to humans. Of particular note, the program includes specific criteria for minimum detectable activity of radioactivity in the environment and reporting of identified radioactivity.

The principal regulatory requirements in the environmental area focus on evaluating a nuclear power station’s environmental monitoring program, pathways, and detection of radioactivity in the environment that may be attributable to station operations. The NRC inspection program in this area reviews the adequacy and effectiveness of a licensee’s evaluation of environmental radioactivity; validating that the program is adequately monitoring existing effluent release pathways; validating that the program meets regulatory design objectives; and ensuring surveys and controls are in place to prevent inadvertent releases of licensed materials into the public domain.

During the onsite inspection, the inspector conducts walkdowns of selected air sampling stations and Thermoluminescent Dosimeter (TLD) monitoring stations. The inspector observes collection and preparation of a variety of environmental samples and verifies that environmental sampling is representative of the release pathways as specified in the ODCM and that sampling techniques are in accordance with procedures. The inspection includes a review of the calibration and maintenance records of air samplers and composite water samplers. The onsite review covers meteorological monitoring capability to verify operation and calibration of equipment. The inspection program provides for evaluation of missed or lost samples and review of positive sample results to evaluate associated effluent releases that were the likely source of the released material. The inspection also reviews changes to the ODCM as a result of land census and technical justifications for changed sample/monitoring locations. The inspection also reviews calibration of environmental radiation counting systems, quality controls for these systems, and audits and technical evaluations of the vendor's program if a vendor is used to analyze environmental samples. The quality assurance program is also reviewed relative to Technical Specification and ODCM requirements. In addition, the inspection evaluates the licensee's program for unrestricted releases from the radiologically controlled area.

3.3.2.5 NRC Enforcement for Inadvertent Liquid Releases

Background

As discussed in the regulatory programs section, the NRC does not impose defined requirements on operating nuclear power stations to conduct routine, onsite (Restricted Area) ground water monitoring to detect inadvertent releases to the ground water or soils as part of its routine effluent monitoring program or environmental monitoring program unless there is an onsite drinking water well.

When a spill or unmonitored release occurred at a nuclear power station, this matter was historically treated as an out-of-normal condition potentially requiring remediation, conduct of public and occupational dose assessments, and corrective actions, as applicable. The NRC would review these events and consider enforcement actions when there was an NRC determination that the licensee had culpability in the occurrence (i.e., the licensee could have reasonably prevented the event or should have detected it earlier and acted on it earlier).

NRC inspection procedures provide inspection guidance to review these events, including conformance with specific regulatory requirements for conduct of radiological evaluations. The inspection effort includes evaluations to ensure radiological dose projections were made and that any significant spill or leak was included in reports to the NRC as abnormal releases.

In 1988, to provide for improved documentation of these events to support decommissioning, new regulatory requirements were added as 10 CFR 50.75(g) to provide for establishment and maintenance of a decommissioning file for spills and leakage. Consequently, spills or leaks with little or no potential for causing offsite doses to members of the public were treated as unplanned occurrences and were dispositioned via the 10 CFR 50.75(g) process.

Prior to the inception of 10 CFR 50.75(g), leaks or spills with resulting contamination of soil, were typically handled under 10 CFR 20.302 (now 10 CFR 20.2002), or the licensee remediated the contaminated area.

Pre-ROP Enforcement

When considering enforcement for spills or leaks, the NRC used the established Enforcement Policy to evaluate and assign Severity Levels to the incident. The NRC categorized these violations by four levels of severity to show the relative importance or significance. NRC assigned Severity Level I to violations that were the most significant and Severity Level IV violations to the least significant. Severity Level I and II violations were of very significant regulatory concern. In general, Severity Level I and II violations involved potential or actual high consequences to public health and safety. Severity Level III violations also were a cause for significant regulatory concern but did not involve high consequences to public health and safety.

Severity Level IV violations were less serious but were not a minor concern. The NRC typically imposed Civil Monetary penalties for higher severity level violations.

The Task Force charter was to review ground-water events from 1996 to present. With the exception of a Seabrook event, the Task Force did not identify any specific enforcement actions associated with direct spillage or leakage to ground water or soil due to liquid releases for the period 1996 thru April 2000 for purposes of evaluation of pre-ROP enforcement.

To illustrate how spills were treated for enforcement prior to the ROP, the Task Force selected several releases, prior to 1996, that resulted in soil or water contamination. The releases included selected airborne radioactivity releases. The events were reviewed relative to public risk significance and consistency of enforcement. The events reviewed are summarized below. Additional information for some of these occurrences is provided in Section 2.0.

- Unplanned release of contaminated water from Edwin I. Hatch Plant, Unit 1 in December 1986. Licensee personnel did not follow valving procedures for operating spent fuel pool canal seals which resulted in an unmonitored, unplanned release of spent fuel pool water to the onsite environment including a swamp area. The licensee experienced a spill of water (141,000 gallons) containing an estimated 0.20 curies of tritium and 0.373 curies of mixed fission product activity. A special inspection (Augmented Inspection Team) of this event was conducted. The NRC acknowledged that licensee personnel took actions to contain the extent of the contamination and minimize the area of contamination. Notwithstanding, the NRC acknowledged that while the corrective actions to reduce the radiological consequences were excellent, the event demonstrated a lack of insistence on procedural adherence and attention to detail. The circumstances surrounding the event resulted in a Severity Level III violation and a Civil Monetary Penalty. The licensee implemented extensive corrective and remediation actions. The event did not result in any significant public dose impact. (Reference NRC Inspection Reports 50-321/86-41, 50-366/86-41and 50-321/86-43, 50-366/86-43. The NRC issued Information Notice No. 87-13, dated February 24, 1987, following this event).

- Unplanned release of contaminated steam in March 1991 from the James A. FitzPatrick Plant. Licensee personnel did not follow valving procedures for a radioactive waste concentrator which cross-contaminated the auxiliary boiler and caused an airborne radioactivity release (steam plume) from the boiler. This resulted in deposition of onsite contamination and release of contaminated water from a storm drain. An estimated 0.4 to 1.5 curies of mixed fission and activation product activity was released from the boiler, of which an estimated 0.03 to 0.05 curies was released from the site via a storm drain. A special inspection (Augmented Inspection Team) of this event was conducted. Once identified, licensee actions in response to the event were prompt and effective in mitigating the consequences of the release. Notwithstanding, the NRC considered the event serious and was concerned due to inadequate control of activities. The circumstances surrounding the event resulted in the issuance of a Severity Level III violation and a Civil Monetary Penalty. The licensee implemented extensive corrective and remediation actions. The event did not result in any significant public dose impact. (Reference NRC Inspection Report No. 50-333/91-80. The NRC issued Information Notice 91-40, dated June 19, 1991, following this event).

- Airborne radioactivity release from the Hope Creek Station in April 1995. Licensee personnel did not correctly operate a radioactive waste concentrator which caused an airborne radioactivity release resulting in onsite contamination. An estimated 25 gallons of contaminated water, containing approximately 0.085 curies of mixed activation products, was released. A special team inspection of this event was conducted. The NRC acknowledged that, once identified, licensee actions in response to the event were prompt and effective in mitigating the consequences of the release and assessing its impact. Notwithstanding, the NRC considered the event of significant regulatory concern. The circumstances surrounding the event resulted in a Severity Level III violation and proposed Civil Monetary Penalty. The release did not have any significant impact on dose to workers or members of the public. Extensive corrective and remediation actions were implemented. (Reference NRC Inspection Report 50-354/95-05. The NRC issued Information Notice 95-46, dated October 6, 1995, following this event).

- Inadvertent release of contaminated water from the Oyster Creek Nuclear Generating Station in September 1996. Licensee personnel did not follow valving procedures which resulted in an unmonitored, unplanned release of slightly contaminated water (133,000 gallons) to the discharge canal containing approximately 8 curies (principally tritium) of mixed fission and activation radionuclides. The release occurred when the condensate system was cross-tied to the fire protection system, which was being used as an alternate cooling source for air compressors. A special inspection was conducted. The NRC acknowledged that the event was of minimal safety significance due to the very low levels of radioactive contamination involved. Notwithstanding, the event represented a loss of control of plant configuration. The release resulted in NRC issuance of a Severity Level IV violation. The event did not result in any significant public dose impact. (Reference NRC Inspection Report 50-219/96-09).

- Unplanned release of contaminated water to onsite ground water from the Seabrook Station in 1999 due to spent fuel pool water leakage (canal and cask loading area) during refueling activities. The leakage was detected by the licensee during conduct of onsite water sampling. The NRC conducted reviews of this event and did not identify any specific performance deficiency or public dose impact. The NRC concluded that an appropriate evaluation was performed, corrective actions were prioritized and taken, and additional tritium monitoring wells were installed. There was no identified offsite release of contamination. The licensee repaired the leak and remediated the contamination via its ground-water management program. No NRC enforcement action was taken. Current tritium levels are at or near background levels. (Reference NRC Inspection Report Nos. 50-443/2004-04 and 50-443/2005-011).

Post-ROP Enforcement

With the adoption of the ROP, the NRC implemented a Significance Determination Process (SDP) for findings, including violations in the Public Radiation Safety Cornerstone. The screening of findings, for purposes of evaluation via an SDP, is described in IMC 0612, Appendix B. The NRC uses the SDP to evaluate the actual and potential significance of inspection findings and to provide a risk-informed framework for discussing and communicating the significance of inspection findings. The significance of a finding in the SDP is assigned a color: red (high safety significance); yellow (substantial safety significance); white (low to moderate safety significance); and green (very low safety significance). The color scheme can be somewhat compared to the routine assignment of Severity Levels under the previous Enforcement Policy. However, the SDP process is generally focused on the risk significance of a performance deficiency rather than simple compliance. If the finding involves a performance deficiency associated with conformance to regulatory requirements, a violation would be cited, as applicable. However, although a violation may be identified, the violation may be considered minor and not documented consistent with ROP documentation guidance.

The NRC's Enforcement Policy (post-ROP implementation) provides a detailed description of its application under the ROP. The ROP uses an Agency Action Matrix, described in NRC IMC 0305, to determine appropriate agency response to the findings. If violations are identified that are more than minor, they are evaluated via the Public Radiation Safety SDP and documented in an inspection report. These violations are not normally assigned severity levels, nor are they subject to civil penalties. However, violations that are not suitable for evaluation via the SDP could be assigned Severity Levels in accordance with the Enforcement Policy. The

Enforcement Policy states that violations that involve actual consequences such as overexposures to the public or substantial releases of radioactive materials will be assigned Severity Levels and will be subject to civil penalties.

The NRC has issued violations using the ROP and associated SDPs since implementation in April 2000, for radioactive spills and leaks to the soil or ground water. The Task Force selected several releases that resulted in soil or water contamination to illustrate NRC practices in this regard. The releases included airborne radioactivity releases. The events were reviewed relative to consistency of enforcement. The events reviewed are summarized below. Additional information on these occurrences is provided in Section 2.2.

- Unplanned release of contaminated water at Salem Unit 1 to the onsite ground water identified in February 2003. The spent fuel pool tell-tale drain system at Salem Unit 1 became clogged resulting in the leakage into, and collection of water, in a seismic gap between the Fuel Handling Building and the Auxiliary Building. The gap provided an avenue of communication with ground water. Once identified, the licensee took prompt actions to identify the source of the leakage, stop the leakage, evaluate the extent of the condition, characterize the extent and magnitude of the leakage and contamination, and initiate remediation actions. In October 2003, the NRC issued a Green (very low safety significance) finding associated with failure to fully evaluate Unit 1 spent fuel pool leakage which led to the onsite contamination of ground water. A minor violation was also cited associated with failure to maintain up-to-date records of onsite contamination, due to spills or leaks, in accordance with 10 CFR 50.75 (g). The reviews of this event did not identify any offsite release of radioactivity or potential dose to members of the public. Extensive corrective and remediation actions were implemented. (Reference NRC Special Inspection Report No. 05000272/2003006; 05000311/2003006. The NRC issued Information Notice 2004-05, dated March 3, 2004, following this event).

- Spent fuel pool leakage at Indian Point. During Unit 2 fuel handling building (FHB) modification activities, the licensee identified trace leakage of contaminated water from localized cracks in the Unit 2 spent fuel pool (SFP). Subsequent ground-water measurements identified tritium in ground water of up to 600,000 pCi/L in the vicinity of the Unit 2 SFP. The NRC conducted a special inspection of this event, which did not identify significant licensee performance deficiencies. The licensee initiated extensive efforts to characterize the nature and source of the ground-water contamination including the installation of instrumented monitoring wells, comprehensive hydrological and geophysical assessment of the site, engineering efforts to determine the source of contamination, and enhancements to onsite and offsite radiological environmental monitoring. Strontium-90 contamination has also been identified in ground water in the vicinity of Unit 1 which has been in SAFSTOR since 1974. A conservative radiological assessment did not identify any significant public dose impact (maximum dose projection of about 0.1 percent of ALARA criteria for nuclear plant design objectives and limiting conditions for operation). No performance deficiencies have been identified to date, however, NRC inspection activities were continuing to review the licensee efforts and progress to support a final regulatory conclusion. (Reference NRC Special Inspection Report 50-247/2005-11. The NRC issued Information Notice 2006-13, dated July 10, 2006, following this event).

- Unplanned release of contaminated water to the ground water at Braidwood. In November 2005, the licensee identified tritium in shallow, ground-water monitoring wells at the edge of the owner controlled area. The licensee identified that both onsite and offsite ground water had become contaminated by tritium, at various concentrations, as a result of historical leakage from vacuum breakers along the circulating water system blow-down line, which is used for radioactive liquid releases. Low level tritium contamination was identified in one private drinking water well. The licensee's radiological assessment for the event did not identify any significant dose impact to members of the public (maximum projected dose of about 5 percent of the ALARA criteria for nuclear plant design objectives and limiting conditions for operation). The NRC issued a White (low to moderate significance) finding for this event because initially the licensee did not (1) adequately evaluate the radiological hazards associated with the leakage; (2) did not calculate dose to member(s) of the public; (3) did not revise its environmental monitoring program to adequately measure the impact to the environment; (4) did not report aspects of the leakage in its annual effluent report; and (5) did not record the residual contamination in files for decommissioning purposes. (Reference NRC Inspection Reports Nos. 50-456; 457/2006-02, and 50-456; 457/2006-008. This event was included as an example in NRC Information Notice 2006-13, issued July 10, 2006).

The inspections conducted by NRC have not revealed an instance where doses to members of the public approached or exceeded applicable limits due to the unplanned release of radioactive effluents to ground water.

3.3.2.6 Public Radiation Safety SDP

The Public Radiation Safety SDP evaluates the safety significance of inspection findings resulting from the inspection of the licensee effluent controls and environmental monitoring programs. A "finding" is defined as an NRC-identified or self-revealing issue of concern that is associated with a licensee performance deficiency. A performance deficiency is the result of a licensee not meeting a requirement or commitment where the cause was reasonably within the licensee's ability to foresee and correct and which should have been prevented. Findings may or may not be associated with regulatory requirements and, therefore may or may not result in a violation.

The Public Radiation Safety SDP is designed to assess risk for routine plant operation and operational events. It does not assess accident conditions. The Public Cornerstone contains a "public confidence" factor which provides for a higher level of significance than would be warranted solely based on risk from exposure to the radioactive materials. This was because it was recognized by both the NRC and stakeholders that a licensee's control of its radioactive material is a significant issue for members of the public, even when very low levels of radioactive material are involved. The Commission has directed the NRC staff to engage stakeholders to update this SDP to ensure it is consistent with the ROP goals.

3.2.2.7 Reporting of Inspection Results

The Task Force evaluated the documentation of inspection information in NRC inspection reports prior to the ROP and after adoption of the ROP in April 2000. This review also included reviewing the documented bases for arriving at an enforcement decision, as discussed in the inspection report or enforcement documentation. The Task Force reviewed example inspection reports issued under the various report preparation guidance and reviewed various pre- and post ROP enforcement actions.

The Task Force determined that prior to the ROP, NRC inspection reports generally contained a higher level of detail and information about an inspection topic or issue and what aspects of the topic or issue had been reviewed as well as what was identified. In some cases, pre-ROP inspection report documentation provided additional detail about an issue even though there was no associated enforcement actions or apparent risk significance. The Task Force noted that the additional level of information served to provide a record of NRC inspector analysis and thought regarding inspection of a particular topic. The additional information also served to provide information to the public about NRC inspection activities in a particular area as well as the status of a particular program element.

One of the principles of the ROP is that it will focus on significant issues. Lesser issues will be left to the licensee to address via the corrective action program. Therefore after inception of the ROP, absent inspection findings of some significance, inspection reports were prepared in a pre-defined manner with limited discussion of observations and findings. This documentation process is fully described in IMC 0612 and serves to provide a uniform method of determining what should be documented and in what manner. When a performance deficiency is identified under the ROP, IMC 0612 provides extensive detailed guidance as to analysis of findings and which findings are suitable for documenting in a report from a risk significance perspective. This guidance includes how to properly document findings to provide information on risk assessment. This shift in focus regarding risk significance was also apparent in documentation of enforcement issues.

3.3.3 Conclusions

(1) The NRC has an extensive inspection and enforcement program in this area. Enforcement actions have been taken consistent with agency guidance.

(2) The NRC inspection program, in the area of effluent monitoring and control does not provide explicit inspection guidance to evaluate potential onsite contamination events including contamination of the ground water as a result of leakage from systems, components or structures. There are no routine NRC inspection requirements for evaluation of licensee monitoring of onsite ground water. Further, the program does not discuss methods or techniques available to inspectors to question the integrity of the licensee’s systems, components, or structures. For example, guidance is not provided to evaluate a licensee’s methods or techniques for monitoring potential loss of spent fuel pool water and subsequent contamination of ground water.

(3) The current NRC inspection program for inspection in the effluents area does not provide for periodic evaluation of effluent flow paths to ensure additional flow paths (e.g., contaminated storm drains, contaminated ground water, leaking heat exchangers), not currently placed in the ODCM are evaluated and reviewed by the NRC for possible inclusion in the ODCM. These possible release paths could be associated with new construction or cross-contamination of clean systems.

(4) The current NRC inspection documentation guidance requires no documentation of findings that are considered minor in nature and requires limited documentation of licensee identified issues of low significance. This practice does not provide for communication of issues of likely public/stakeholder interest, such as the release of radioactive materials to the environment.

(5) The current SDP process can be enhanced to better address unplanned leaks/spills.

3.3.4 Recommendations

(1) Inspection guidance should be developed to review onsite contamination events including events involving contamination of ground water.

(2) The inspection program should be revised to provide guidance to evaluate effluent pathways such that new pathways are identified and placed in the ODCM as applicable. In addition, guidance should be included as to when a new release path becomes “permanent” for purposes of inclusion in the ODCM and routine annual reporting.

(3) Limited, defined documentation of significant radioactive releases to the environment should be allowed in inspection reports for those cases where such events would not normally be documented under the present guidance.

(4) The staff should revise the Public Radiation SDP to better address the range of events that can occur, including unplanned, unmonitored releases or spills.

3.4 Facility Decommissioning

3.4.1 Scope and Criteria Used for Review

As part of the NRC oversight of decommissioning, the NRC staff reviews records of shut down nuclear plants to identify known or reported events that contaminated ground or surface water. Most decommissioning plants began commercial operation in the 1960's and 1970's, and ceased operation in the 1980's - 1990's, and would therefore fall outside the time range of this study. However, information on subsurface contamination becomes available during site remediation as part of license termination. Most of the sites are demolishing on-site structures, providing unique insights into sources and extent of contamination that occurred during operation. Therefore the task force concluded that information from decommissioning sites may be valuable in reaching conclusions about subsurface contamination, and reviewed selected decommissioning site experience in this regard.3.4.2 Detailed Discussion of Review

A description of identified liquid releases at selected facilities and the known extent of resultant contamination is presented below. The level of detail varies based on the available information from the individual facilities, with more information generally available from plants currently conducting active decommissioning that includes demolition and excavation of on-site buildings and other structures.

Big Rock Point

Big Rock Point was a 75 megawatt electric (MWe) boiling water reactor (BWR) that operated from 1968 until 1997. It is currently in the final phase of decommissioning, and the licensee plans to reduce the size of the site to that needed to support the independent spent fuel storage installation (ISFSI) by the first quarter of CY 2007. In 1984, water leaked from a two-inch aluminum piping connection from the Condensate Storage Tank below the Turbine Building floor. Approximately 20,000 gallons of condensate system water leaked into the soil. Radionuclides present in 1984 included tritium, Mn-54, Cs-137, Co-60 and Ag-110m. A section of the floor in the southwestern corner of the turbine building was cut out and eight barrels of contaminated soil were removed and shipped as low-level radioactive waste. On August 16, 1985, Consumers Power requested NRC approval to retain the remaining contaminated soil. The NRC granted approval on May 8, 1986.

Ground water is monitored by a series of on-site wells. There are two aquifers beneath the site; no contamination was detected in the deep, potable aquifer. Tritium concentrations in the shallow, non-potable ground water were initially far above EPA drinking water guidelines for potable water, but decreased over time from dilution and decay. Current values are less than one half EPA standards and continue to decrease. The monitoring program will cease when the decommissioning activities are complete.

Haddam Neck (Connecticut Yankee)

The Haddam Neck plant was a 590 MWe pressurized water reactor (PWR) that operated from 1968 until 1996. It is currently being dismantled. In October 2005, the licensee identified soil contamination near an exterior SFP wall. Trace indications on the wall indicated potential previous SFP leakage. The soil may have been contaminated by a past SFP leak or by ground water contaminated by leakage from radioactive water storage tanks (RWST) previously identified and corrected by the licensee. The licensee is continuing to evaluate and characterize the onsite contamination as well as the source of the leakage. Other known releases of tritium from the facility are from the discharge canal (routine liquid releases), from a liquid water discharge pipe break (1970s), and from the RWST leak (1990s).

As part of the license termination plan (LTP) activities, the licensee is monitoring the on-site ground water. There are two aquifers beneath the site; both are contaminated with tritium, strontium-90, and low levels of cesium-137. Some relevant information on radionuclide concentrations identified during decommissioning activities follow:

- Tritium concentrations were generally decreasing and all well concentrations are below the EPA drinking water maximum contaminant level (15,000 pCi/L was the highest in June 2002). Some wells indicated increases in the tritium concentration. The tritium concentration in the wells may have been impacted by cessation of pumping the mat sump.

- Sr-90 was detected in 10 monitoring wells in the Radiologically Controlled Area (RCA) and Industrial Area during the last three quarters. Only three are above the EPA drinking water MCL of 8 pCi/L and range from 143 to 116 pCi/L. The three monitoring wells are located in the chemistry lab area, RWST area, and north of the maintenance building; all are adjacent to the containment building.

- Cesium-137 was detected at 58.5 pC/L in June 2002 (RWST area), and south of the Spent Fuel Building ranging from 1.59 to 3.18 pCi/L, in June 2002 and March 2002, respectively. All of these concentrations are well below the EPA drinking water MCL value of 200 pCi/L.

Monitoring will continue for 18 months after remediation to demonstrate compliance with release limits.

Humbolt Bay

Humbolt Bay Unit 3 was a 65 MWe BWR that operated from 1963 to 1976. It is currently in SAFSTOR. The site experienced a number of onsite spills that included tritium. The licensee routinely monitors the ground water with a series of on-site wells. Tritium has been historically detected in quarterly samples from a monitoring well northeast of the reactor building. The highest level detected was 7,600 pCi/L in January 1985. The 1974 spill of contaminated water from the condensate demineralizer room, which overflowed into the Unit 3 yard, was the most probable explanation of the tritium detected in the well. Because of the low concentrations and proximity to the Pacific Ocean, no further action is planned until active decommissioning.

Trojan

Trojan was a 1,100 MWe PWR that operated from 1976 to 1992. In 1999, NRC issued a Part 72 license for an on-site ISFSI. All spent fuel was transferred to the ISFSI by 2004. The licensee completed remediation of remaining buildings and requested termination of the Part 50 license, which the NRC granted in May 2005. The Trojan plant ventilation exhaust contained tritium from multiple sources including spent fuel pool evaporation, minor leaks of reactor coolant fluids in auxiliary systems and Containment Building discharges (purging during shutdown activities and pressure reductions at power). Other sources of tritium released to the environment were the discharge of secondary plant water during periods of steam generator tube leakage and outside liquid storage tanks that were vented to the atmosphere (Refueling and Primary Water Storage tanks). Steam generator water was discharged as liquid to the Turbine Building sump and as a vapor to the atmosphere through the Condenser Off-gas

System and the Main Steam Safety Valves. All of these releases resulted in deposition of tritium on building and ground surfaces that could run off and be collected by the storm drains during rainy periods.

Water contained in the space beneath the Pipe Penetration Area was sampled and analyzed for tritium. Tritium concentrations as high as 304,000 pCi/L have been measured in water samples from this area. Decommissioning activities identified other potential sources of tritium in surface waters within the industrial area. The removal of concrete blocks from the containment structure identified tritium that has been incorporated into the concrete. The concentration of tritium in the containment concrete decreases as a function of the distance from the inner liner. There was a small leak in the SFP's transfer canal liner for a number of years. Water from this leak was captured in leak collection system telltale drains.

The licensee conducted ground-water monitoring as part of decommissioning activities. There are low concentrations of tritium in the ground water associated with excavated areas around plant structures and site utility trenches. Tritium was detected in one shallow monitoring well located just east of the fuel building and appears to be connected to the site excavated areas. No other radionuclides associated with plant operations were detected in any monitoring well. During 1998-2000, the concentration of tritium varied from less than 380 pCi/L to approximately 2,500 pCi/L. A ground-water sample taken in March 2004 from the excavated area beneath the plant structures had a tritium concentration of approximately 4,000 pCi/L. Because of the low concentrations, no further action was necessary to terminate the Part 50 license. The Part 72 license will remain in effect until fuel is shipped off site and any residual contamination is reduced to release limits.

Yankee Rowe

Yankee Rowe was a 185 MWe PWR that operated from 1960 through 1991. The licensee's decommissioning plan was approved in February 1995 and the plant is undergoing dismantlement. The work is about 80 percent complete. The containment and other major structures remain. The owner transferred all of the fuel from the spent fuel pool to the on-site ISFSI. Ground-water monitoring in 2005 showed that tritium increased in shallow locations following uncovering of soil and concrete removal areas; deeper wells were generally unchanged.

A total of 29 ground-water monitoring wells were sampled in the first quarter, and a total of 17 wells were sampled in the fourth quarter of 2005. The number of wells available for sampling was limited by significant demolition activities at the site, including two of the wells with the highest historical tritium concentrations. Ground water entered the Spent Fuel Pit excavation, and the maximum concentration of tritium detected was approximately 46,800 pCi/L. Previous investigations of ground water, soil and concrete in these areas have shown that there were measurable concentrations of tritium. In addition to tritium, cesium-137, cobalt-60 and silver-108m were detected at peak concentrations of 76, 24 and 1.1 pCi/L, respectively.

Increases in the tritium concentrations were observed during 2005 fourth quarter sampling in three of the shallow-aquifer wells and the surface water seep that previously had low or non-detectable tritium results. Two of the wells and the surface water seep are down-gradient and consistent with the migration of tritium known to be in that area. No tritium increases were observed in wells screened below the shallow aquifer. The maximum tritium concentration detected in these samples was 14,730 pCi/L.

Quarterly sampling and analysis of the wells on site since July 2003 has confirmed that although other radionuclides have been found in soil and concrete, tritium is the only plant-related radionuclide present in the ground water. Investigation of the ground-water flow system beneath the site is continuing with installation and testing of additional monitoring wells in 2006. Continued quarterly sampling of the existing and new wells will continue throughout decommissioning and allow further characterization of the occurrence of plant-related radionuclides in ground water at the site.

Zion

In June, 2006, the licensee identified low levels of tritium (~5,000 pCi/L) in one well that was installed as part of the Exelon-wide review of sites for potential radioactive releases. Testing is ongoing and will continue until the unit is decommissioned. Zion was a 2 unit facility that operated from 1973 through 1998.

3.4.3 Conclusions

(1) The available data from decommissioning plants indicates that they all had some level of release to the subsurface during the plant operating life. These releases were generally of a limited leak rate, but likely occurred over an extended time. The predominant radionuclide is tritium, however other radionuclides such as strontium-90 and cesium-137 were also present in some releases.

(2) Many of the leaks occurred in areas not amenable to regular inspection, likely contributing to the leaks not being identified at the time of occurrence. Monitoring of the systems for level or other parameters was not sensitive enough to identify the small leakage rates.

(3) In some cases, the relatively large volumes of contamination above the decommissioning release limits resulted in notable increases in remediation time and costs. The NRC staff estimates the increased cost to be in the tens of millions of dollars, although specific actual cost data is not available to the staff. Nonetheless, thus far every Part 50 licensee has completed remediation despite the added cost.

3.4.4 Recommendations

Based on the above conclusions, the Task Force has the following recommendations:

(1) The NRC should require adequate assurance that leaks and spills will be detected before radionuclides migrate offsite via an unmonitored pathway.

(2) The NRC should develop guidance to the industry for evaluating and monitoring releases from operating facilities via unmonitored pathways.

(3) Guidance should be developed to define the magnitude of the spills and leaks that need to be documented by the licensee under 10 CFR 50.75(g). Also, clearly define "significant contamination." Summaries of spills and leaks documented under 10 CFR 50.75(g) should be included in the annual radioactive effluent release report.

(4) 10 CFR 20.1406 requires in part that applicants for licenses shall describe in their application how facility design and procedures for operation will minimize contamination of the environment. The NRC should develop regulatory guidance to describe acceptable options to meet this requirement.

(5) NRC should evaluate whether the present decommissioning funding requirements adequately address the potential need to remediate soil and ground-water contamination, particularly if the licensee has no monitoring program during plant operation to identify such contamination.

3.5 Industry Actions in Response to Abnormal Liquid Radioactive Releases and DOE/International Perspectives

3.5.1 Scope and Criteria

The task force reviewed the industry actions taken in response to unplanned, unmonitored radioactive liquid releases at several sites. The purpose of this review was to illustrate the range of actions taken, how NRC regulations influenced licensee actions, and how licensee actions were also influenced by other considerations outside of NRC regulatory requirements.

3.5.2 Detailed Discussion of Review

As outlined in Section 3.2 of the report, NRC requirements related to the release of radioactive materials to the environment are based on limiting the radiation dose to members of the public. The licensee is responsible for ensuring that the quantities and types of radioactive material released do not exceed the public radiation dose limits. When unplanned, unmonitored releases occur, licensees are required to survey the contaminated area to assess the impact of the release on public health. Assuming that the resultant calculated radiation dose to the public does not exceed NRC regulatory limits, there are no NRC requirements to remediate the contamination until the plant is decommissioned. This includes contamination that has migrated offsite.

Subsurface migration of radionuclides can be very complex. Some radionuclides such as tritium move at the same rate and direction as ground water, while others such as strontium-90 are subject to retardation, due to chemical interaction with soil, and move much slower than ground water. Migration of radionuclides is controlled initially by the release event which includes the liquid and radionuclide fluxes, and the site-specific ground-water flow behavior. Common release modes include spills and leaks which occur at or near the ground surface where the subsurface is usually partially-saturated since it lies above the local water table (i.e., upper surface of the saturated zone where the water pressure is atmospheric).The initial migration of radionuclides from a leaking pipe, vacuum breaker valve, spent fuel pool, condensate tank or other structure is through the surrounding soil, backfill, or other near-surface, disturbed materials. The direction and rate of migration is influenced by the ambient water content and pressure gradient of the surrounding material, and the associated volume of the liquid released which may cause local saturation (or perching of the effluent). This wetting event can cause the migration of the radionuclides to continue through to the underlying hydrogeologic units which may include potable water sources known as water-table aquifers. When the radionuclides reach the underlying water table, the soil or rock is fully saturated. Although there is mixing and dilution of the radionuclides in the capillary fringe above the water table, the radionuclide migration often develops as a distinct contaminant plume. The contaminant plumes maintain an elongated plume shape in the saturated zone, and may move both horizontally and vertically depending upon local ground-water recharge and flow conditions. As the plume evolves, the radionuclide concentrations may continue to decrease due to mixing and dilution, but may still have elevated concentrations exceeding background levels.

Tritium moves in ground water as tritiated water in both the liquid and vapor phases. Gaseous migration of tritium can be linked to atmospheric deposition of condensated tritiated water or condensation of subsurface water vapor containing tritium, as noted in IAEA and U.S. Geological Survey research studies. One conceptual model at the Palo Verde nuclear power plant site involves gaseous sources due to atmospheric deposition of condensed, tritiated water vapor, and subsurface migration of tritiated water in the unsaturated zone as both liquid and vapor. Confirmation of this conceptual model requires meteorological and soil science monitoring and analyses to determine the subsurface moisture contents, tritiated water sources and flux rates.

Ground-water monitoring programs are designed to both detect the presence and concentration of the contaminants, and to collect data on ground-water behavior indicators (e.g., gradients, flow rates, temperature, and water quality) to determine its direction and rate of movement. This information and its analysis is critical to understanding the potential location, timing and concentrations of radionuclide migration to offsite locations. Information from these monitoring programs are essential in providing the technical bases to determine if and what remediation activities may be needed to reduce the concentrations to levels below EPA drinking water standards. Monitoring data and its analysis are useful in deciding what remediation option can be effective. It also helps decide which wells should be selected and/or installed to remediate the contamination, and to monitor the effectiveness of remediation efforts.

The task force found that licensee responses to releases varied widely across the industry. In some cases, licensees have chosen to only monitor the contaminated area. In other cases, licensees have taken immediate actions to address contamination, generally due to concerns from external stakeholders, as opposed to the potential to exceed any public radiation dose limits. To illustrate the differences in industry actions, the task force considered the actions taken at Hatch, Indian Point, Braidwood, and Salem.

Hatch

Hatch has had several relatively significant unplanned, unmonitored releases over the life of the plant, including releases in 1978 and 1986. Following the release in 1978, the licensee began monitoring site ground water for tritium through wells and surface drains. The majority of the ground-water wells were established during the construction of the plant as part of the site characterization and to map the site hydrology for plant licensing. Seventeen additional wells were installed after tritium was identified in ground water. The licensee also commissioned an independent outside consultant to perform a hydrology study in 1979-1980. This study concluded that small amounts of tritium were seeping into the ground water around the release areas and could be migrating into subsurface drain systems which discharge through surface drains that lead to the Altamaha River.

An event of note occurred on December 3, 1986 when an estimated 141,500 gallons of water escaped from the spent fuel pool (SFP) to a gap between the two reactor buildings and subsequently to other onsite buildings and the surrounding environment. The root cause was operational-configurational control errors resulting in the deflation of SFP seals and the subsequent release. Based on estimates of recovery activities, approximately 124,000 gallons of liquid containing 0.20 Ci of tritium and 0.373 Ci of mixed fission products were released to a swamp located within the licensee-controlled area but which ultimately drains to the Altamaha River. Results of initial environmental surveys conducted by the licensee staff and independently by the State of Georgia, Department of Natural Resources verified that both the tritium and fission products released to the swamp and subsequently to the river posed no immediate danger to downstream water users (if any), or to nearby residents. The long-term onsite and offsite radiological impacts are assessed entirely through continued monitoring of the contaminated area and adjacent off-site pathways. Specifically, the licensee maintains an augmented environmental monitoring program. Periodic reports submitted to the NRC indicate a general reduction in activity in the swamp area resulting from radioactive decay and weathering and the potential erosion and migration of the radionuclides within the originally contaminated area.

The licensee subsequently discovered that a small volume of water containing tritium is being released into the Altamaha River. The licensee assessed the impact of these releases and determined that they are safe and below regulatory limits. Surface water samples collected in the Altamaha River downstream of the Hatch plant have ranged from less than measurable concentrations to a maximum of 275 pCi/L during 2005, indicating that the small volume of ground water released is not increasing the surface water concentrations by a significant amount. The licensee also determined that the closest offsite drinking water well in the direction of ground water movement is 2.1 miles from the plant. Their hydrology studies conclude it would take more than 200 years for water to move through the deep ground-water aquifer to the site boundary (about 1,200 feet), and that in this amount of time, the tritium would radioactively decay away to background levels.

Remedial actions by the licensee included enhanced surveillance by removing insulation from outside radioactive tanks, valves and pumps to inspect for above ground leaks; the isolation and repair of visible leaks detected; the application of sealants to concrete moat surfaces and the sealing of any moat openings; the hiring of an underground piping engineering firm to perform ultrasonic underground piping integrity evaluations of all underground radioactive piping; the installation of a catch tank, flow totalizer and automatic sampler on the subsurface drain line outfall; and the pumping of water from three wells with the highest tritium levels to reduce the amount of tritium which has reached the ground water.

The licensee provides related environmental data to the Environmental Protection Division (EPD) of the Georgia Department of Natural Resources. The Georgia EPD Environmental Radiation Program conducts independent ground-water sampling and analysis, and routinely compares results with the licensee.

In summary, the licensee assessed the impact of the releases to the environment and concluded that no public health impact resulted. The licensee continues to monitor the contamination. No major efforts are being made to remediate the contamination.

Indian Point

As discussed in Section 2.0 of the report, in 2005 the licensee at Indian Point identified leakage of radioactive water from the Unit 2 SFP. Subsequent activities to assess this leakage led to the identification of other leakage from Unit 1. Elected officials, citizens and media expressed significant interest in the event.

The licensee promptly reacted to the discovery of leakage at Unit 2. To assess the resulting contamination, the licensee generally followed the guidance in the recently released Electric Power Research Institute (EPRI) report on ground-water monitoring. EPRI Technical Report 1011730, "Ground-Water Monitoring Guidance for Nuclear Power Plants," issued in September 2005, specifically discusses tritium detection and guidance for ground-water monitoring programs to investigate and sample for on-site contaminants. The licensee contracted geotechnical and ground-water consultants to assist in mapping the contaminant plumes. This involved the installation of numerous shallow wells to help identify the contaminant release points, map the tritium and strontium-90 contaminant plumes, and assess subsequent contaminant migration. In addition to tritium, strontium-90 and nickel-63 were also detected in the ground water.

In the case of Indian Point, the extent of the licensee's efforts to gather specific hydrogeologic information to detect and evaluate contaminant transport, in part to assess the potential radiation dose to the public, is notable. The licensee took the following actions:

- Conducted in plant and outside radiological surveys of the backfill, fractured rock and ground water;

- Attempted to determine the location, timing, and release mechanism and rate of the contaminant releases (both tritium and strontium-90);

- Examined ambient surface and ground-water conditions in the vicinity of the release;

- Identified construction-induced modifications to the hydrogeologic setting affecting infiltration, ground-water flow and transport;

- Determined the presence of buried conduits and imported backfill affecting infiltration and ground-water flow and transport using "blue-prints" and geophysical surveys;

- Identified hydrogeologic units affected by contaminant migration, and their interface with surface water discharges;

- Measured ground-water levels and gradients in the affected hydrogeologic units;

- Sampled existing wells or selected and installed environmental monitoring wells to detect and sample contaminants;

- Evaluated hydrogeologic information and well data (e.g., water-levels, flow rates and contaminant concentration with time) to determine the ground-water flow rates, direction and mixing;

- Mapped the contaminant plume(s) geometries (i.e., lateral, horizontal and depth extent) using monitoring well data, and determined if and where additional wells were needed to understand the plume behavior (e.g., movement and temporal changes of concentrations);

- Determined potential location, and concentrations of radionuclide transport to offsite exposure points of compliance;

- Determined what corrective maintenance action could preclude further releases from the nuclear power plants structures, systems and components;

Indian Point has concluded that the releases do not pose a risk to public health, and at the most may result in a radiation dose to the public of well below 1 mrem for tritium. For strontium-90, however, the dose may be higher but still below the NRC's 10 CFR 50, Appendix I ALARA values. The licensee has notified the NRC by letter stating their intent to continue their efforts to monitor the ground water and to characterize the leakage, however the licensee does not presently intend to carry out any remediation activities.

Braidwood

As discussed in Section 2.0, Braidwood had a number of unplanned releases of radioactive water from the circulating water blowdown piping which discharges to the Kankakee River. In four separate instances occurring in December 1996, December 1998, November 2000 and August 2003, significant releases (some exceeding an estimated 3 million gallons) occurred. The contamination entered the ground water and partially migrated offsite. Tritium below EPA drinking water standards was detected in one offsite drinking water well. Elected officials, citizens and media expressed significant interest in the event.

The licensee commenced actions to assess the contamination in 2005. Similar to the activities at Indian Point, the Braidwood licensee expended considerable effort to sample the surrounding environment in order to characterize the extent of contamination. Exelon has hired a consultant to install several wells to monitor tritium along the blowdown line. Offsite residential wells are included in the REMP monitoring program and are sampled quarterly. The vacuum breaker valves and blowdown lines have been inspected and repaired where necessary. The licensee concluded that the radiation dose to a member of the public due to these releases would be a very small fraction of 1 mrem, and therefore not a public health issue.

Legal action was initiated against the licensee by Will County and the State of Illinois. In April 2006, Exelon and litigating parties reached an agreement to implement an Interim Remedial Action Plan. Specifically, the remedial action involves pumping water from a large pond Exelon recently purchased that is centrally located off-site in the area of the tritium contamination. This pumping will continue until the pond is lowered 7 feet resulting in tens of millions of gallons of water being pumped out over several months. The lowered pond level should reverse the hydraulic gradient and draw contaminated ground water into the pond. The remediation plan includes pumping the additional tritiated water from the pond and surrounding ground water to the Kankakee River via the normal effluent discharge path, the monitored blowdown pipe. The pumped water will be monitored and discharged at a tritium concentration of 200 pCi/L or less. In addition to these remediation efforts, the agreement contains additional requirements for further monitoring, mitigation, remediation, and migration controls; for reporting; and for investigative reports.

Also in response to the event and through interactions with their external stakeholders, the licensee stopped making normal radioactive effluent discharges, and instead collected the radioactive waste in temporary onsite storage tanks. Faced with an increasing number of these onsite tanks, the licensee elected to process the water in the tanks to reactor primary water standards and transfer the water to the primary water storage tanks for reuse in the power plant.

Salem

In early 2003, tritium was detected in shallow ground water on-site near Salem Unit 1. Water samples indicated that the tritium concentrations exceeded the EPA drinking water standard and the New Jersey Ground-Water Quality Criteria. A Remedial Investigation Report identified the source of the abnormal release to be clogged drains in the Salem Unit 1 Spent Fuel Pool. In February 2003, the clogged drains were repaired which stopped the leak. Thirty-six wells were installed to characterize the tritium plume and later used to pump contaminated water as part of a remediation plan approved by the New Jersey Department of Environmental Protection (NJDEP). Wells are monitored monthly to semi-annually based upon sampling results, and are used to determine remediation actions. Eight additional wells were installed during the summer of 2006 to monitor for plant-related concentrations (e.g., tritium, strontium-90, manganese-54, iron-59, cobalt-60, cesium-137 and others) in the shallow ground water. Spent fuel pool telltale drains, seismic gap inventory, and monitoring of onsite and recovery wells are routinely monitored under the approved remedial action plan. Monitoring to confirm no further leakage from the SPF includes sample points and drains which were installed in Units 1 and 2. The licensee reported that there is no evidence of tritium concentrations exceeding EPA or NJDEP ground-water standards at the station boundary or below the first layer of the confining clay unit at approximately 35 foot depth thus precluding any contamination to lower drinking water aquifers.

As discussed above, remediation programs have been implemented at the Salem and Braidwood sites. These efforts illustrate that for remediation to be effective, there must be an understanding of the surface and ground-water interface relationships and how contaminants move through hydrogeologic units to surface water bodies and vice-versa. Monitoring wells and surface water sampling are critical in understanding this relationship and in confirming remediation efforts. The ground-water sampling performed at the Indian Point site demonstrates the potential complexity of water migration in the ground.

As previously noted, the industry guidance on ground-water monitoring is contained in the Electric Power Research Institute (EPRI) Technical Report 1011730, “Ground-Water Monitoring Guidance for Nuclear Power Plants,” issued in September 2005. The EPRI guidance involves state-of-the-art methods for installing, testing, and sampling monitoring wells, and analyzing ground-water flow and contaminant concentration data to determine temporal and spatial trends. The monitoring programs, advocated by the EPRI guidance, involves development of a conceptual site ground-water model, but does not include guidance on numerical modeling of the ground-water flow and transport of contaminants. The EPRI guidance does include the use of geophysical, hydraulic and tracer studies to investigate and characterize the contaminant behavior. The guidance provides licensees with a framework for planning and implementing a ground-water monitoring program that will enable thorough characterization of the site’s ground-water flow system and ground water quality.

Industry Ground Water Protection Initiative

The nuclear industry, under the auspices of the Nuclear Energy Institute (NEI), has responded to the recent events, in part by developing the Industry Ground Water Protection Initiative (initiative). Task Force members participated in several public meetings where NEI and licensee representatives described the initiative. The industry's stated view in these meetings has been that the initiative is not intended to address a public health issue, but rather to increase the level of public confidence in industry activities. The initiative includes the development and implementation of site specific action plans, the intent of which is to "help assure timely detection and effective response to situations involving inadvertent radiological releases in ground water to prevent migration of licensed radioactive material offsite and quantify impacts on decommissioning." The industry required all sites to complete the development of the action plans by August 1, 2006, with implementation to occur some time after that date.

Complexities faced in the recent tritium events involve placement of numerous wells in a variety of geologic media (e.g., soils, unconsolidated glacial deposits, construction backfill, fractured bedrock) requiring prior knowledge of the site geology, building and foundation designs and construction methods. Location and extent of well casing, screens and sampling portals along with the hydrologic behavior of surface water bodies, storm runoff drains and conveyances, and subsurface sumps and drains have contributed to monitoring program difficulties. Although the EPRI guidance addresses many of these issues, the lack of established onsite ground-water monitoring programs coupled with minimal hydrogeologic information encouraged the placement of numerous wells, often simultaneously, such as at Braidwood and Indian Point, to quickly identify the nature and extent of the contaminant migration. Monitoring programs generally evolved in an iterative manner using geologic and hydraulic data and its analysis to determine the need and location for subsequent monitoring wells.

To date, the industry response does not include the use of analytical or numerical models to help guide the monitoring programs and serve as the basis for considering the need and selection of remediation options. Some of the sites have developed conceptual site models which represent an understanding of the hydrogeologic framework. Numerical models are useful in integrating the site information and monitoring data to address uncertainties in the conceptual site models and to predict contaminant transport. Lessons from NRC-funded research, DOE and EPA studies, and consensus industry standards recommend the use of numerical models.

3.5.2.1 NRC Activities Related to Ground Water Analysis

NRC's Office of Nuclear Regulatory Research (RES) is funding research to develop an "Integrated Ground-Water Monitoring Strategy." This project commenced on February 10, 2003. The objective of this project is to develop a strategy that provides an integrated and systematic approach for monitoring and modeling ground-water flow and transport. This strategy addresses monitoring techniques and issues for both the unsaturated and saturated zones. It will be useful in confirming nuclear waste and decommissioning site performance, and quantifying uncertainties. Specific details of this RES project are contained in Appendix C.

3.5.2.2 DOE and EPA Information Sources

The task force also considered whether DOE experience could contribute to the review of release events and remediation. The task force selected the leakage of radioactive water from the spent fuel pool at the High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory (BNL). Although the contamination was confined to the BNL site, the announcement of the discovery of the leakage in 1996, coupled with other public concerns, resulted in intensive public interest. The public reaction to this event is further discussed in Section 3.6. The HFBR was subsequently closed by DOE and the laboratory has embarked on extensive remediation efforts according to EPA regulations.

Earlier in 1989, the BNL site was listed on EPA's National Priorities List (Superfund) because of extensive soil and ground-water contamination due to site operations. In May 1992, DOE, EPA and New York State Department of Environmental Conservation (NYSDEC) entered into a Federal Facilities Agreement to establish and implement a framework for site cleanup activities. In 1999, the Remedial Investigation and Feasibility Study examined several remediation alternatives and established the cleanup remediation actions for the various contaminated areas. The cleanup involves installation of numerous wells to detect radionuclides (principally tritium and strontium-90) and hazardous chemicals [(Volatile Organic Compounds (VOCs)] in ground water, and remediate ground water using "pump and treat" coupled with ion exchange technology to remove the strontium-90, and recirculation of tritiated water into wells upgradient to increase travel time for radioactive decay. Ground-water monitoring and numerical modeling are integrated to both plan the remediation activities and to evaluate their performance.

A detailed discussion of the laboratory's efforts to characterize the ground-water contamination, and the lessons learned from this, are discussed in Appendix C.

3.5.2.3 International Perspectives on Ground-Water Monitoring at Nuclear Power Plant Sites

The IAEA has developed several technical guidance documents related to ground-water monitoring and remediation. Two relevant reports are IAEA-TECDOC 482 on prevention and mitigation of ground-water contamination from radioactive releases, and IAEA safety guide NS-G-3.2 on dispersion of radioactive material in water for site evaluations of nuclear power plants. The first report focuses on information to evaluate contaminant releases and subsequent pathways and transport behavior. It also discusses modeling considerations on how to predict the behavior of radionuclides in ground water. The report outlines existing techniques for preventing offsite releases, and mitigative techniques to address potential offsite releases. The second report is more general and discusses normal and accidental discharges to surface and ground water, and related monitoring programs.

Accidental tritium releases have occurred at nuclear reactor sites in various countries (e.g., Canada and France). International regulatory agencies (e.g., United Kingdom, France and Germany) require periodic monitoring of ground water onsite and offsite at nuclear power plant sites. German and French regulators in particular require reporting of any contamination above detectable limits in ground or drinking water. If radionuclides are found at any level in drinking water, French regulations require that the responsible nuclear power plant take immediate action to remediate the contamination. Such was the case at the Cruas Nuclear Power Plant, where a tritium-contaminated onsite drinking water source forced the plant to take immediate action. For those plants which contaminate onsite ground water, French regulations require that the plume be monitored and reported, but no specific action taken. This approach to regulation reflects that of the European Community in general, which encourages periodic or continuous surveillance of ground water to protect international sources of surface and ground waters under the "Petersburg Agreement."

Tritium migration was detected at the Pickering Nuclear Generating Station located along the north shore of Lake Ontario, in the Province of Ontario, Canada. The station has eight heavy-water reactors that have elevated levels of tritium in the moderating water of each reactor. Leaks containing several billion pCi/L of tritium occurred previously into the ground water at specific locations. The major leak occurred from a sump under the reactor building. Over 300 wells have been installed in the shallow backfill and glacial till deposits surrounding the reactor buildings as well as upgradient and downgradient of the station. The monitoring wells serve as early detectors for offsite migration, and to evaluate the remediation activities following analysis of ground water/surface-water site behavior. Remediation consists of; (1) pumping eight deep foundation drain sumps below the turbine auxiliary building to re-direct tritiated water, and (2) extensive monitoring of the contaminant plume that is naturally attenuating due to very slow ground-water movement in the shallow backfill and glacial till units enabling significant time for radioactive decay. Tritiated water from the foundation drain sumps is mixed with plant cooling water discharge, monitored and released to Lake Ontario at levels far below regulatory limits. The remediation and monitoring program have been ongoing for 5 years (since 2000).

A site specific risk-based generic screening criterion for tritium in groundwater not used as drinking water was developed by Ontario Power Generation and approved by the Canadian Nuclear Safety Commission (CNSC) and Ontario Ministry of the Environment. The generic screening criterion is 3,000,000 Becquerels per liter (81 million pCi/L). Ground-water behavior is routinely monitored and water samples are obtained. This information is part of a site-wide monitoring and modeling program to determine if there are any anomalously high values that need to be investigated. The program results are reported in an annual report which is submitted for review by the CNSC. Based on discussions with Canadian officials, the ground-water modeling for Pickering appears to be advanced.

The ongoing remediation at the Chernobyl plant provides important lessons on ground-water monitoring and dose assessments involving soil contaminant and plant uptake. DOE is funding Lawrence Berkeley National Laboratory to cooperate with the Ukrainian authorities to analyze ground-water monitoring and human exposure data to develop realistic dose models.

3.5.3 Conclusions

(1) When releases of radionuclides occur via unmonitored pathways, it can be difficult to define the source term and identify the specific source of the leak.

(2) The flow of ground water in the unsaturated and saturated zones can be complex and difficult to determine. Human-induced features (e.g., backfills, foundations and structural fills, buried pipelines, disturbed zones in the bedrock) and events (e.g., blasting and dewatering) affect the ground water system and often introduced new pathways for contaminants during the construction and operation of the facility.

(3) Information in the site Final Safety Analysis Report (FSAR) regarding the site hydrogeology is minimal for many sites, and often requires additional site characterization during monitoring well installation and testing following a significant release.

(4) There is no generic regulatory requirement for onsite monitoring of ground water. Many nuclear power plants do not have onsite monitoring wells. Therefore contamination of the soil and ground water onsite can occur without the licensee being aware.

(5) Remediation options rely heavily on ground water system and contaminant behavior data. Remediation options are very site-specific and need a technical basis to judge alternatives including the no-action alternative with monitoring (i.e, monitored natural attenuation).

(6) Remediation of soil and ground-water contamination is not required until decommissioning, as long as the radiation dose limits for the public and for workers are met.

(7) Lessons from NRC-funded research, DOE and EPA studies, and consensus industry standards recommend the use of numerical models.

3.5.4 Recommendations

(1) The NRC should consider the development of guidance on the evaluation of radionuclide transport in ground water. American National Standard (ANSI/ANS) 2.17 addresses this issue and is being extensively updated.

(2) 10 CFR 20.1406 requires in part that applicants for licenses shall describe in their application how facility design and procedures for operation will minimize contamination of the environment. The NRC should develop regulatory guidance to describe acceptable options to meet this requirement.

3.6 Communications with External Stakeholders

3.6.1 Scope and Criteria

The Task Force reviewed NRC communication activities for selected events that are described in Section 2.1.1. The criteria included existing NRC guidance for press releases and public notifications.

3.6.2 Detailed Discussion of Review

The agency's guidelines for public communications revolve around several factors including possible impact on public health and safety; the desire to conduct oversight as transparently as circumstances allow; possible violations of NRC regulations; and significant staff actions regarding specific plants (such as a license amendment) or regarding the nuclear power industry as a whole (such as an Information Notice or other generic communication).

In response primarily to the events at Braidwood and Indian Point, the agency issued the following press releases:

- Press Releases No. I-05-49 and No. I-05-55, describing inspections of the Indian Point spent fuel pool leak;
- Press Release No. 05-136, describing creation of an NRC Web page focused on the Indian Point leak;
- Press Release No. 06-037, discussing the creation of the Liquid Radioactive Release Lessons Learned Task Force;
- Press Release No. 06-072, discussing the agency's continuing efforts regarding inadvertent releases to ground water;
- Press Release No. III-06-026, discussing the agency's White finding and Notice of Violation concerning the release at Braidwood;
- Press Release No. 06-093, discussing the agency's Information Notice regarding ground-water contamination due to leaks.

The agency's preliminary notifications of these events were shared with state officials per the normal practice of the Office of State and Tribal Programs. Other NRC documents related to the events, such as inspection reports, are also publicly available through the ADAMS electronic database. Agency staff also addressed the events during public meetings. These meetings included annual assessments of the Braidwood and Indian Point plants, as well as sessions hosted by licensees to specifically discuss the inadvertent releases. On a number of occasions, staff have provided interviews on this topic area to members of the media. As requested, the agency continues to provide briefings to Congress and to officials in the States of New York and Illinois regarding the Indian Point and Braidwood events.

The NRC also established a web page dedicated to providing the public with information related to inadvertent radioactive liquid releases, and agency actions in response. Most of the material on the web page deals with Braidwood and Indian Point.

None of the events described in Section 2.0 affected public health and safety, which is the most significant factor for the NRC in requiring immediate notification to local residents and government. None of the events thus far have resulted in levels of radioactive material in residential wells that approach EPA or state limits for drinking water.

Despite the lack of public health impacts, the concerns and comments stated at public meetings for the Braidwood and Indian Point events clearly indicated a level of mistrust of both the licensee and NRC. The fact that these releases were accidental in nature; unmonitored; may have occurred or commenced some significant period of time in the past; and may not have been visibly reported to the public when discovered, likely over-shadowed the assurances of the licensee and the NRC that the potential radiation dose to the public was negligible.

As discussed in Section 3.5, the task force also considered the leakage of tritium that occurred from a DOE reactor at the Brookhaven National Laboratory (BNL). In addition to the technical aspects of this event, there are lessons to be learned from the public reaction to the event. Because of the level of public interest, the event was widely covered by the local media. An article in the February 25, 2000 edition of Science describes how weak communications between BNL and their public stakeholders lead to public mistrust of BNL.

In the case of Braidwood, later communication efforts following the initial meetings appeared more successfully in establishing a dialogue with the public. The licensee established a website specifically to address the Braidwood releases (http://www.braidwoodtritium.info/). The licensee also held informational forums where the public could obtain printed information and talk with licensee staff in an informal one-on-one basis. NRC staff who attended these sessions noted a positive public reception to the approach of answering an individual's questions, as opposed to stating facts at a large public meeting. The inclusion of third parties, such as state and local health departments, was also well-received at the meetings.

The task force sampled the state and local reporting requirements for inadvertent releases. In general, the industry's reporting requirements to state and local governments are based primarily on NRC and EPA regulatory limits, and focus primarily on events that present a public health and safety issue. A sampling of approximately a third of the current operating reactor sites showed significant variation in state reporting requirements and very few local reporting requirements. For events that do not rise to NRC or EPA reporting levels, only a third of the states surveyed had a reporting requirement and only one sixth of the sites surveyed had local reporting requirements. The task force noted that Senator Obama of Illinois has introduced legislation (S. 2348) that would require additional reporting of unplanned radioactive releases to the NRC, the State, and the county.

As discussed in Section 3.5, the industry has recognized their shortcomings in communication with the public by the establishment of their "Ground-Water Protection Initiative." The initiative includes specific elements to enhance communications with State and local officials regarding radioactive releases.

3.6.3 Conclusions

(1) None of the events described in Section 2.0 were required by NRC regulations to be promptly reported to the NRC due to exceeding the limits for public radiation doses. Some events may have been promptly reported due to the public interest aspects.

(2) NRC typically only issues press releases for events with the potential to impact public health. Since the events reviewed did not meet this threshold, press releases were issued when significant public interest already existed, such as at Indian Point and Braidwood.

(3) These events can lead to significant interest from elected officials, the media, and the public.

(4) The NRC's communications regarding these events were carried out in accordance with existing guidance.

(5) The most effective public communications efforts focused on public meetings to answer questions and involved third-party representatives to help put the events' risk into perspective.

(6) The primary responsibility for providing information lies with licensees. Nonetheless, the NRC should also strive for openness when public interest may occur.

3.6.4 Recommendations

(1) The NRC's guidelines for "immediate notification" public communications should continue to be based on public health and safety considerations. To support the NRC's openness goals, the NRC staff should consider whether to notify the public of radioactive releases to the environment that are not significant from a radiation dose perspective, but that could be of general public interest nonetheless.

(2) NRC staff should review NUREG/BR-0308, "Effective Risk Communication," and other training tools to ensure an event's risk is provided with appropriate context.

(3) Nuclear power plant licensees should consider entering into agreements with local and state agencies to voluntarily report preliminary information on significant radioactive liquid releases that do not otherwise trigger reporting requirements. The present industry ground water protection initiative may address this.

APPENDIX A

TASK FORCE CHARTER

A.1 Task Force Charter Memorandum

March 10, 2006

MEMORANDUM TO: Stuart Richards, Deputy Director
Division of Inspection and Regional Support
Office of Nuclear Reactor Regulation

FROM: Luis A. Reyes /RA/
Executive Director for Operations

SUBJECT: LIQUID RADIOACTIVE RELEASE LESSONS-LEARNED TASK FORCE AND CHARTER

The purpose of this memorandum is to assign you to lead an inter-office task force to assess the lessons-learned related to the inadvertent release of radioactive liquid to the environment at power reactor sites. Specifically, recently identified incidents at Braidwood, Indian Point, Byron, and Dresden have highlighted tritium contamination of groundwater as a result of unplanned releases due to equipment failure or structural degradation. Although the measured levels of tritium thus far do not appear to present a health hazard to the public, I believe it is necessary to do a broad review to determine whether this is a generic issue for NRC licensees and to recommend possible agency actions to be taken in this area.

The attached charter has been developed to define the objective, scope, expected product, schedule, staffing, and senior management interface. The scope of the task force effort will include the following areas: industry experience; health impacts; the regulatory framework; NRC inspection, enforcement and reporting aspects; industry actions; international perspectives; and communications with external stakeholders.

You will report to the Deputy Executive Director for Reactor and Preparedness Programs. Personnel selected as team members are identified in the attachment. The task force will maintain the Deputy Executive Director and other senior managers informed of the progress of the task force. The task force will provide its observations, conclusions, and recommendations in the form of a written report consistent with the guidance provided in the attached charter.

Attachment: As stated

A.2 Attachment 1 to Task Force Charter

CHARTER FOR THE

LIQUID RADIOACTIVE RELEASE

LESSONS-LEARNED TASK FORCE

Objective

The objective of this Lessons-Learned Task Force is to conduct an evaluation of the NRC's regulatory processes related to the inadvertent unmonitored release of radioactive liquids to the environment (onsite or offsite) in order to identify and recommend areas for improvement applicable to the NRC and/or the industry.

Scope

The task force should address the following areas:

a. An historical review (1996 to present) of known inadvertent releases of significant quantities of radioactive liquid to the environment at power reactor sites, including power reactors in decommissioning.

b. A general assessment of the public health impact of these releases based on existing related guidance and studies.

c. The existing regulatory framework, including both the health physics aspects, the licensee reporting requirements (including making reports to state and local officials), and the regulatory requirements associated with the structures and systems from which the releases have originated.

d. The NRC inspection program requirements, including enforcement. The review should consider these areas both after implementation of the Reactor Oversight Process (ROP), and prior to the ROP.

e. Industry actions in response to these events, including the timing of remediation activities.

f. Implications for decommissioning.

g. International perspectives on this issue.

h. Communications with external stakeholders, including state and local officials, and other federal agencies.

The scope of subjects considered by the task force should not necessarily be limited to those noted above. Should the task force decide to expand or otherwise revise the scope of the charter, the Deputy Executive Director for Reactor and Preparedness Programs should be informed of any significant changes to the charter or the topics of review. The task force may decide to recommend specific issues for consideration by the staff in the longer term.
This charter recognizes that the staff assigned to the Lessons-Learned Task Force will likely also be active participants in the agency's response to the recent events. The task force activities should not interfere with the agency's immediate response to these events.

Expected Product and Schedule

The task force will provide its observations, conclusions, and recommendations in the form of a written report to the Deputy Executive Director for Reactor and Preparedness Programs. The task force review activities should be completed by August 31, 2006.

Staffing

The task force will consist of the following members. All members will serve on a part-time basis (participation on the team can be via teleconference):

Team Leader: Stuart Richards, NRR

Assistant Team Leader: Timothy Frye, NRR

Team Members:
Stephen Klementowicz, NRR
Stacie Sakai, NRR
Chang Li, NRR
James Shepherd, NMSS
Thomas Nicholson, RES
Ronald Nimitz, Region I
George Kuzo, Region II
Steven Orth, Region III
Michael Shannon, Region IV
State Representative (to be identified later)

Other staff members may be consulted on an as needed basis.

Senior Management Interface

The task force will keep senior management informed on the status of the effort and provide early identification of significant findings. In addition, the task force will regularly interface with the cognizant OEDO staff to keep them abreast of progress.

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APPENDIX B

CONSOLIDATED RECOMMENDATIONS LIST

CONSOLIDATED RECOMMENDATIONS LIST

(1) The staff should review and develop a position to address using lake water that contains licensed radioactive material for other site purposes, such as for use in the fire protection system (Section 2.0)

(2) The NRC should develop guidance to the industry for detecting, evaluating, and monitoring releases from operating facilities via unmonitored pathways (Sections 3.1 and 3.4).

(3) The NRC should revise the radiological effluent and environmental monitoring program requirements and guidance to be consistent with current industry standards and commercially available radiation detection technology (Section 3.2.1).

(4) Guidance for the REMP should be revised to limit the amount of flexibility in its conduct. Guidance is needed on when the program, based on data or environmental conditions, should be expanded (Section 3.2.1).

(5) Develop guidance to define the magnitude of the spills and leaks that need to be documented by the licensee under 10 CFR 50.75(g). Also, clearly define "significant contamination." Summaries of spills and leaks documented under 10 CFR 50.75(g) should be included in the annual radioactive effluent release report (Section 3.2.1 and 3.4).

(6) The staff should provide guidance to the industry which expands the use of historical information and data in their 50.75(g) files to the operational phase of the plant. The data provides good information on current and future potential radiological hazards that are important during routine operation, and can aid in planning survey and monitoring programs (Sections 3.2.1 and 3.4).

(7) The NRC should evaluate the need to enact regulations and/or provide guidance to address remediation (Section 3.2.1).

(8) The NRC should require adequate assurance that leaks and spills will be detected before radionuclides migrate offsite via an unmonitored pathway (Sections 3.2.1, 3.2.2, and 3.4).

(9) To support one possible option for recommendation (6) of Section 3.2.1, regulatory guidance should be developed to define acceptable methods to survey and monitor on-site groundwater and sub-surface soil for radionuclides (Section 3.2.1).

(10) The NRC should revise radioactive effluent release program guidance to upgrade the capability and scope of the in-plant radiation monitoring system, to include additional monitoring locations and the capability to detect lower risk radionuclides (i.e., low energy gamma, weak beta emitters, and alpha particles) (Section 3.2.1).

(11) Determine whether there is a need for improved design, materials, and/or quality assurance requirements for SSC's that contain radioactive liquids for new reactors (Section 3.2.2).

(12) The staff should consider whether further action is warranted to enhance the performance of SFP telltale drains at nuclear power plants (Section 3.2.2).

(13) The staff should verify that there has been an evaluation of the effects of long term SFP leakage (boric acid) on safety significant structures (concrete, rebar), or the staff should perform such an evaluation (Section 3.2.2).

(14) The staff should assess whether the maintenance rule adequately covers SSCs that contain radioactive liquids (Section 3.2.2).

(15) The staff should verify that the license renewal process reviews degradation of systems containing radioactive material such as those discussed in this report (Section 3.2.2).

(16) The NRC staff should open a dialogue with the States regarding the application of the NPDES system to discharges of radioactive materials to promote a common understanding of how the associated legal requirements in this area are addressed (Section 3.2.3).

(17) Inspection guidance should be developed to review onsite contamination events including events involving contamination of ground water (Section 3.3).

(18) The inspection program should be revised to provide guidance to evaluate effluent pathways such that new pathways are identified and placed in the ODCM as applicable. In addition, guidance should be included as to when a new release path becomes "permanent" for purposes of inclusion in the ODCM and routine annual reporting (Section 3.3).

(19) Limited, defined documentation of significant radioactive releases to the environment should be allowed in inspection reports for those cases where such events would not normally be documented under the present guidance (Section 3.3).

(20) The staff should revise the Public Radiation SDP to better address the range of events that can occur, including unplanned, unmonitored releases or spills (Section 3.3).

(21) 10 CFR 20.1406 requires in part that applicants for licenses shall describe in their application how facility design and procedures for operation will minimize contamination of the environment. The NRC should develop regulatory guidance to describe acceptable options to meet this requirement (Sections 3.4 and 3.5).

(22) NRC should evaluate whether the present decommissioning funding requirements adequately address the potential need to remediate soil and groundwater contamination, particularly if the licensee has no monitoring program during plant operation to identify such contamination (Section 3.4).

(23) The NRC should consider the development of guidance on the evaluation of radionuclide transport in groundwater. American National Standard (ANSI/ANS) 2.17 addresses this issue and is being extensively updated (Section 3.5).

(24) The NRC's guidelines for "immediate notification" public communications should continue to be based on public health and safety considerations. To support the NRC's openness goals, the NRC staff should consider whether to notify the public of radioactive releases to the environment that are not significant from a radiation dose perspective, but that could be of general public interest nonetheless (Section 3.6).

(25) NRC staff should review NUREG/BR-0308, "Effective Risk Communication," and other training tools to ensure an event's risk is provided with appropriate context (Section 3.6).

(26) Nuclear power plant licensees should consider entering into agreements with local and state agencies to voluntarily report preliminary information on significant radioactive liquid releases that do not otherwise trigger reporting requirements. The present industry groundwater protection initiative may address this (Section 3.6).

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APPENDIX C

OTHER FEDERAL AGENCY EXPERIENCES AND DOCUMENTATION RELATED TO CONTAMINANT MONITORING

DOE EXPERIENCE AT BNL

A relevant example of monitoring and modeling tritium and strontium-90 in ground-water contamination leaking from a reactor is the ongoing cleanup activities at the Brookhaven National Laboratory (BNL). The leakage emanated from the BNL Graphite Research Reactor (BGRR) and the Waste Concentration Facility (WCF) (Brookhaven Associates, 2005). An EPA document (available at the web at http://www.epa.gov/Region2/superfund/npl/0202841c.pdf) states, "In early 1997, monitoring data revealed a plume of tritium contaminated groundwater from the reactor. Tritium, radioactive hydrogen that forms water, was leaking from the spent fuel pool within the High Flux Beam Reactor. The U.S. Department of Energy and U.S. Environmental Protection Agency entered into a Record of Decision (ROD) with the concurrence of the New York State Department of Environmental Conservation (NYSDEC). The ROD established the cleanup decisions for several ground-water contaminant plumes involving both radionuclides and hazardous organic compounds [i.e., VOC's (volatile organic compounds)]. The ROD focus was the protection and remediation of ground-water associated with the EPA-designated sole-source aquifer consisting of three units: the Upper Glacial, the Magothy, and the Lloyd Aquifers.

Numerous wells were installed to map the contaminant plumes, collect hydrogeologic data as input to numerical codes, and to determine the effectiveness of the remediation strategy. The specific cleanup objectives include:

- Meet the drinking water standards in ground water for VOC's, Strontium-90 and tritium:
- Achieve the goal of completing the cleanup of the Upper Glacial Aquifer in 30 years or less; and
- Prevent or minimize further mitigation of VOC's, Strontium-90 and tritium in ground water.

BNL scientists are implementing active treatment of the ground water through various treatment technologies and continued monitoring to achieve the aforementioned objectives. According to the BNL scientists, numerical modeling was instrumental in determining which treatment technology to select, placing of remediation wells, monitoring their performance, and communicating the details and results of their remediation program with local, State and Federal stakeholders.

DOE AND EPA DOCUMENTATION ON CONTAMINANT MONITORING

Another relevant information resource is the joint report from DOE, EPA and DuPont on their 2002 workshop on a barrier system for environmental contaminant containment and treatment (Chien and others, 2005). The workshop proceedings provides information on monitoring in both the unsaturated and saturated zones with real-world examples on practical application of these monitoring methods. The proceedings identify various methods for monitoring including those for the unsaturated zone (e.g, measurement of water content changes, gradients (to determine flow directions and rates), suction samplers for collecting fluids and contaminants in the unsaturated zone) and discuss geophysical techniques useful in characterizing hydrogeologic systems and subsurface contaminants. The proceedings also identify electrochemical sensors and their use in detecting contaminant releases and migration. Major lessons from evaluating the DOE, EPA and industry test cases include: (1) monitoring should allow prediction of failures, if possible, rather than detection of failure through detection of contaminants in downstream wells; (2) measured parameters need to feed into risk assessment models so that the effect of changes in performance can be fully understood in terms of protection of and risk to the public and environment; and (3) systems should require as little onsite presence as possible.

Finally, the U.S. Environmental Protection Agency (EPA) sets the environmental standards for maximum contaminant levels (MCL's) for drinking water. If the drinking water source is ground water, then the MCL's are applied to ground-water wells. Chapter 40 of the Code of Federal Regulations specifies these criteria for compliance monitoring in ground water and soils. Recently EPA has issued guidance on performance monitoring in ground water related to VOC's and monitored natural attenuation for remediation (EPA-600/R-04/027). The guidance describes the integration of monitoring with performance objectives to protect and remediate contaminated hydrogeologic units. Coincident with that guidance, EPA issued a "Handbook of Ground-Water Protection and Cleanup Policies for RCRA Corrective Action" (EPA/530/R-04/030). The guidance discusses cleanup strategies, cleanup goals and levels, point of compliance, practicality and impracticality issues, performance monitoring, and ground-water remedies and demonstrating compliance.

RES PROJECT ON INTEGRATED GROUND-WATER MONITORING STRATEGY

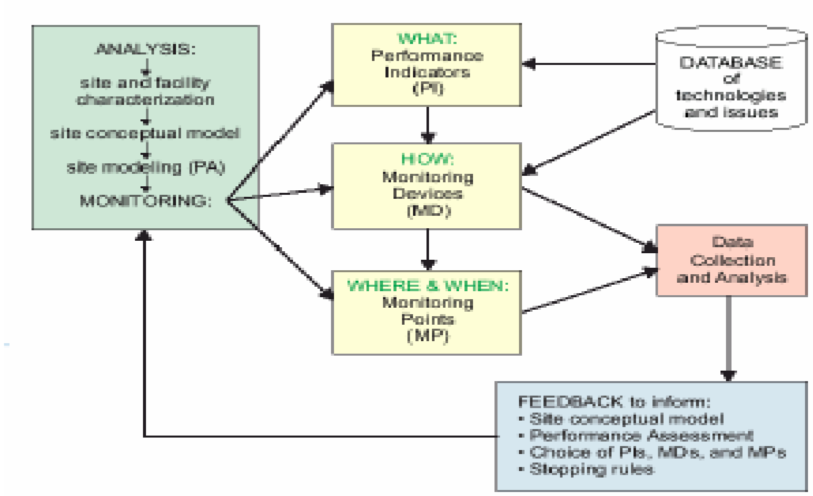
Primarily due to plant decommissioning issues, the NRC Office of Nuclear Regulatory Research (RES) has pursued integrating groundwater modeling with site monitoring activities. Under a contract from the NRC, Advanced Environmental Solutions, LLC (AES) has developed a draft strategy (AES, 2005) which is robust and useful for designing site and facility-specific ground-water monitoring programs to:

- establish background and baseline conditions for ground-water system behavior and quality,
- detect changes to ground-water system behavior and quality,
- assess the effectiveness of contaminant isolation systems and remediation activities,
- communicate the monitored performance indicators through effective data management, analysis, and visualization techniques to decision makers and stakeholders,
- identify the presence of contaminant plumes and preferential ground-water transport pathways,
- test alternative conceptual ground-water flow and transport models,
- aid in the confirmation of the assumptions of the performance assessment (PA) model, and hence the performance of the facility through increased confidence in the PA.

This comprehensive and systematic ground-water monitoring strategy provides the technical bases with citable references and identified guidance and analytical tools for assessing the completeness of an integrated ground-water monitoring program. The strategy focuses on quantifying uncertainties of the hydrologic features, events and processes using real-time, near-continuous monitoring data for confirmation of the PA analysis. The strategy links the ground-water monitoring program to the detection level required for early warning of releases.

The strategy, in part, builds on lessons learned from tritium migration at DOE's Brookhaven National Laboratory reactor, and couples performance modeling to monitoring. For site stewardship, protection of ground water is a key technical issue with a need to focus on monitoring and model confirmation. An important technical objective is the development and testing of integrated ground-water monitoring strategies to understand the selection, placement and calibration of field instruments and methods. The integration involves the coupling of PA model confirmation to ground-water monitoring through the use of performance indicators (e.g., water contents in the unsaturated zone, and ground-water levels and velocities in the saturated zone).

AES developed and presented two technology transfer workshops to NRC staff including NRC Regional Inspectors, and Agreement State regulators on their draft strategy. The workshops included a case study of tritium migration from the Brookhaven National Laboratory reactor.



Integrated Monitoring Strategy **logic showing relationships among various Performance Assessment indicators and monitoring locations, timing, devices and measurements.**

As noted, the AES draft strategy focuses on quantifying uncertainties of the hydrologic features, events and processes using the real-time, near-continuous monitoring data for confirmation of the PA analysis. The strategy will link the ground-water monitoring program to the detection level required for early warning of releases. AES has examined the state-of-the-practice in ground-water monitoring of radionuclides for confirming PA models, and presented their research objectives at a conference on subsurface monitoring and modeling sponsored by the National Ground-Water Association. AES is presently testing their integrated monitoring strategy using field data from DOE remediated sites. "Real-time" monitoring data has been selected and analyzed to evaluate ground-water flow and transport modeling assumptions within the PA models. The tested strategy is being designed for application to both unsaturated and saturated zone systems.

Previous RES-funded studies focused on mitigative techniques to control radionuclide migration following a severe accident. Although these recent contaminant release events do not constitute anything approaching a severe accident (i.e., abnormal releases are above EPA drinking water levels for onsite monitoring wells, but below for offsite potable ground water), the research report (Oberlander and others, 1985) provides information on assessing mitigative strategies to interdict offsite ground-water releases and mentions the value of onsite monitoring programs. The report also addresses different hydrogeologic settings (e.g., fractured rock, unconsolidated deposits, surface-water interfaces with ground water), analysis of radionuclide transport in ground water, sump water releases and nuclear power plant site case studies. One recommendation cited in Research Information Letter 150, “Results of Ground-Water Interdictive Strategy Research for Severe Nuclear Accidents” based on the research, addresses the value of ground-water monitoring programs at reactor sites to determine if there are adequate baseline databases for both hydrogeologic site information, and real-time flow and transport data following a release.