NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

In the Matter of a Renewal and Modification of a State Pollutant Discharge Elimination System ("SPDES") Permit Pursuant to article 17 of the Environmental Conservation Law And Title 6 of the Official Compilation of Codes, Rules and Regulations of the State of New York parts 704 and 750 *et seq.* by Entergy Nuclear Indian Point 2, LLC and Entergy Nuclear Indian Point 3, LLC, Permittee,	**DEC # 3-5522-00011/00004** **SPDES # NY-0004472**
-and-	
In the Matter of the Application by Entergy Nuclear Indian Point 2, LLC and Entergy Nuclear Indian Point 3, LLC, for a Certificate Pursuant to §401 of the Federal Clean Water Act.	**DEC # 3-5522-00011/00030** **DEC # 3-5522-00011/00031**

PREFILED DIRECT TESTIMONY OF

ARNOLD GUNDERSEN

ON BEHALF OF PETITIONERS RIVERKEEPER, INC., SCENIC HUDSON, INC., AND NATURAL RESOURCES DEFENSE COUNCIL, INC.

REGARDING RADIOLOGICAL MATERIALS

PREFILED DIRECT TESTIMONY OF ARNOLD GUNDERSEN ON BEHALF OF PETITIONERS RIVERKEEPER, INC., SCENIC HUDSON, INC., AND NATURAL RESOURCES DEFENSE COUNCIL, INC. REGARDING RADIOLOGICAL MATERIALS

INTRODUCTION

Q. Please state your name.

A. Arnold Gundersen.

Q. Please state your business address.

A. 376 Appletree Point Road, Burlington, VT 05408 and 96 South Union Street, Burlington, VT 05401.

Q. Please state your occupation.

A. I am an independent nuclear engineering and safety expert at Fairewinds Associates. My title is Chief Engineer.

Q. Please describe your educational and professional background and qualifications.

A. I have a Bachelor and Master Degree in Nuclear Engineering from Rensselaer Polytechnic Institute (RPI) cum laude. I was awarded an Atomic Energy Commission Fellowship to pursue my Master Degree in Nuclear Engineering.

After beginning my career as a reactor operator and instructor in 1971, I progressed to the position of Senior Vice President for a nuclear licensee before moving into independent consulting work. I have testified as an expert witness before the Nuclear Regulatory Commission (NRC) Atomic Safety and Licensing Board and Advisory Committee on Reactor Safeguards (ACRS), the State of Vermont Public Service Board, the State of Vermont Environmental Court, the Florida Public Service Commission, and in Federal Court.

I am an author of the first edition of the Department of Energy (DOE) Decommissioning

Handbook. I have more than 39 years of professional nuclear experience *including and not limited to*: Nuclear Power Operations, Nuclear Safety Assessments, Nuclear Power Management, Nuclear Quality Assurance, Radiological Assessment, Archival Storage and Document Control, NRC Regulations and Enforcement, Licensing, Engineering Management, Contract Administration, Reliability Engineering, In-service Inspection, Thermohydraulics, Criticality Analysis, Radioactive Waste Processes, Decommissioning, Waste Disposal, Cooling Tower Operation, Cooling Tower Plumes, Consumptive Water Use, Source Term Reconstruction, Dose Assessment, Technical Patents, Structural Engineering Assessments, Nuclear Fuel Rack Design and Manufacturing, Nuclear Equipment Design and Manufacturing, Public Relations, Prudency Defense, Employee Awareness Programs, and Whistleblower Protection.

My full curriculum vitae is attached to this testimony as **Exhibit AG-Rad-1**.

Q. Please describe your experience with respect to radiological leakage and discharge issues at nuclear power plants.

A. When I began my career, I worked as a radiation-shielding engineer on Newbold Island, which entailed measuring radiation. Early in my career, when Northeast Utilities employed me, I began focusing on radiological release problems at Northeast Utilities' Millstone 1 Nuclear Power Plant. I was the project engineer in the first Monte Carlo calculation of sky shine.[1] I was the project engineer in developing an ammonia sniffer designed to detect Nitrogen 16 (N16) carryover into turbine buildings. I performed numerous gamma and neutron surveys of the Millstone and Connecticut Yankee sites. As the lead engineer for New York State Electric & Gas's proposed nuclear power plant, I was responsible for procuring the Nuclear Steam Supply System, which includes the nuclear reactor and nuclear fuel.

As a senior manager at Nuclear Energy Services in Danbury, Connecticut, I was a

[1] Monte Carlo refers to a certain methodology of performing scientific calculations; Sky shine is the term used for radiation that originates near the surface of the earth with an upward velocity and then is scattered back by the molecules in the atmosphere.

member of the radiation safety committee of this NRC licensee responsible for assuring that all conditions of the NRC license were upheld. Personnel reporting to me conducted contamination assessments of the West Valley New York nuclear reprocessing facility and were assigned to the Shippingport nuclear power plant decommissioning project. I have been employed as a nuclear engineering consultant and engineering expert witness since 1990.

I have provided expertise and testimony in relation to accidental radiological leak issues occurring at nuclear power plants across the U.S., including the following:

- In 2007, I testified before the NRC Atomic Safety and Licensing Board regarding the failure of Entergy Nuclear Operations, Inc.'s Aging Management Program to address the leaking buried and underground pipes at its Pilgrim Nuclear Power Plant outside of Boston, MA.
- I served as a consultant to the Vermont Legislature's Joint Fiscal Office concerning leaking underground pipes at Entergy's Vermont Yankee Nuclear Power Station. I identified the existence of leaking pipes, which Entergy executives had misled investigators about.[2] I also advised the Joint Fiscal Office and Governor elect Shumlin, and provided recommendations to the state legislature, regarding the use of extraction wells at Vermont Yankee to address tritium contamination.
- I briefed the NRC's Regulatory Information Conference in 2009 concerning the identification and remediation of strontium and tritium leaks discovered at Vermont Yankee.
- I briefed investigators of the U.S. Government Accountability Office (GAO) concerning underground contamination from leaky pipes at nuclear reactors. GAO's investigation resulted in a report published in June 2011, entitled *Nuclear*

[2] *See* Vermont Yankee, Office of the Attorney General's Criminal Investigation Report (July 6, 2011), *available at*, http://www.atg.state.vt.us/assets/files/Office%20of%20the%20Attorney%20Generals%20Criminal%20Investigation%20Report%20on%20Vermont%20Yankee.pdf, at 8 ("The AGO investigation, as did that of MLB, readily leads to the conclusion that ENVY and various of its personnel repeatedly misled State officials with direct misstatements and repeatedly failed to clarify misperceptions as to the existence of underground piping carrying radionuclides. These actions and inactions were at best negligent.").

Regulatory Commission: Oversight of Underground Piping Systems Commensurate with Risk, but Proactive Measures Could Help Address Future Leaks, for which I was an expert.

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to demonstrate how Indian Point's persistent, ongoing discharges of radiological materials, including both accidental and purposeful discharges of radioactive liquids, solids, gases, and stormwater to the Hudson River and groundwater in the vicinity of Indian Point, currently and during the plant owner Entergy's proposed 20 year period of extended operation, will continue to impair the Hudson River and the surrounding groundwater for its best usages. Such discharges have occurred, continue to occur, and will continue to occur because the procedures used by Entergy at Indian Point for detecting, preventing, monitoring, and mitigating radioactive leaks into the ground, groundwater, and Hudson River are insufficient. Spent fuel pool, pipe, and other plant component leaks have been significant and will continue to be so, and no commitment has been made to mitigate the spread of radioactive effluents into the groundwater and the Hudson River, despite evidence that such mitigation could be significantly effective.

Q. What did you review in preparing your testimony?

A. I reviewed hundreds of documents provided by Entergy to Riverkeeper in discovery, which were designated by Entergy as relevant to radiological leakage issues at Indian Point. These documents included, but were not limited to: quarterly groundwater monitoring reports generated by Entergy's consultant, GZA GeoEnvironmental, Inc., groundwater monitoring data, engineering reports, documents concerning the investigation of leakage issues at Indian Point, procedure documents, Aging Management Program materials, condition reports, corrective action reports, e-mails, presentations, plans, manuals, notes, checklists, status reports, and other reports.

I also reviewed documents generated by NRC, which were available through NRC's public document database (Agencywide Documents Access and Management System,

ADAMS), related to radiological discharge and leakage issues at Indian Point, including inspection reports, other reports, e-mails, and correspondence.

Additionally, I reviewed documents generated by other government agencies (including the aforementioned GAO report concerning radiological leak issues) and scientific organizations (including information and reports produced by the Union of Concerned Scientists).

Q. What particular issues does your testimony address?

A. My testimony addresses:

- The nuclear power industry's systemic problem with radiological leaks at aging nuclear reactors across the U.S.;
- What radiological leaks and discharges have occurred and currently occur at Indian Point;
- The impact of radiological leaks and discharges at Indian Point, including the existence of extensive plumes of groundwater contamination and releases to the Hudson River;
- Why and how such leaks and discharges will continue to plague the plant during Entergy's proposed 20-year license extension; and
- Entergy's refusal to remediate the contamination, which would prevent accumulation ongoing discharges to the Hudson River.

NUCLEAR INDUSTRY RADIOLOGICAL LEAKAGE ISSUES

Q. Please describe the nuclear power industry's history of radioactive leaks.

A. According to an NRC document entitled *List of Historical Leaks and Spills At U.S. Commercial Nuclear Power Plants*, 38 of the 65[3] nuclear power plant sites have reported tritium leaks in excess of U.S. Environmental Protection Agency (EPA) limits.[4] A copy

[3] The United States has 104 nuclear power plants located at 65 sites. *See* **Exhibit AG-Rad-2** at 2.
[4] EPA maximum contaminant levels for drinking water, measured in picocuries per liter, which is a measure of radioactivity based on the observed decay rate of radium, are as follows: Tritium, 20,000 pCi/l; Strontium-90, 8

of this document is attached to this testimony as **Exhibit AG-Rad-2**. Thus, approximately 59% of nuclear power plant sites have had or currently have nuclear plants that are leaking tritium or tritium that is with other longer-lived radioactive isotopes.

A document generated by the Union of Concerned Scientists further memorializes hundreds of specific incidents of radiological leaks at nuclear power plants around the country. A copy of this document is attached to this testimony as **Exhibit AG-Rad-3**.

Q. Please discuss whether the Federal government has recognized nuclear power plant radioactive leaks as problematic.

A. The NRC has admitted that the magnitude of radiological leaks at nuclear plants were previously unanticipated and are an ever-growing problem. Furthermore, the U.S. Government Accountability Office (GAO) recently finished an investigation of leaking buried pipes at nuclear power plants, and published a report entitled *Nuclear Regulatory Commission: Oversight of Underground Piping Systems Commensurate with Risk, but Proactive Measures Could Help Address Future Leaks* (GAO-11-563, June 2011). I have reviewed this report, and a copy is attached to this testimony as **Exhibit AG-Rad-4**. In this report, GAO concludes that the elimination or reduction in the frequency of radioactive leaks into the soil has not been solved by industry initiatives and is likely to continue or worsen as nuclear plants continue to age. Specifically, GAO explains that:

> [a]s nuclear power plants age, their underground piping systems tend to corrode, but since these systems are largely inaccessible and difficult to inspect, the condition of many underground piping systems at plants across the country is unknown. Further, as pipes continue to age and further corrosion occurs, the likelihood and severity of leaks could increase without mitigating actions.

See **Exhibit AG-Rad-4** at page 1. GAO concludes that "[t]he occurrence of leaks at nuclear power plants from underground piping systems is expected to continue as nuclear power plants age and their piping systems corrode." *See* **Exhibit AG-Rad-4** at page 22.

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pCi/l; Cesium-137, 200 pCi/1. *See* U.S. EPA, Radionuclides in Drinking Water: A Small Entity Compliance Guide (February 2002), *available at*, http://www.epa.gov/ogwdw/radionuclides/pdfs/guide_radionuclides_smallsystems_compliance.pdf, at 13.

Q. Please discuss whether nuclear power plants owned by Entergy Nuclear Operations, Inc. have had issues related to radiological leaks.

A. Eight (8) of the eleven (11) nuclear power plants owned by Entergy have reported tritium leaks and some of these nuclear plants are also leaking other radioactive isotopes like strontium, cesium, and cobalt. *See* **Exhibit AG-Rad-3**. Thus, 73% of the Entergy nuclear power plant sites have experienced leakage issues and radioactive contamination. More than half (59%) of U.S. nuclear power plants are leaking tritium and other longer-lived radioactive isotopes while almost three-quarters (73%) of Entergy's nuclear plant sites are leaking tritium and other longer-lived radioactive isotopes.

Entergy has acquired a number of older nuclear plants and sites. For example, the five nuclear power sites Entergy owns in the northern portion of the U.S. are quite old and all have leaked radioactive fluids. Compared to the national average, because Entergy's fleet of nuclear power plants are simply older than the nation's average, they are much more prone to experience piping failures that leak radioactive fluids. Entergy owns a group of five old reactors located in the northern U.S., all of which have leaked tritium. These five merchant plants have a 100% tritium leak rate compared with a 59% national industry average. *See* **Exhibit AG-Rad-2**; **Exhibit AG-Rad-3**.

Despite the fact that Entergy's northern merchant reactors are older than the industry average, Entergy appears to have failed to adequately fund their maintenance. Two independent studies, one commissioned by Entergy itself on Indian Point and the other commissioned by the Vermont Legislature to evaluate the reliability of Vermont Yankee, have identified resource weakness within Entergy's corporate structure. The latter report, which references the relevant portion of the former report, is attached to this testimony as **Exhibit AG-Rad-5**. These reports indicate that Entergy is simply not committing adequate resources to maintaining its aging nuclear reactors. *See* **Exhibit AG-Rad-5** at pages 9-10. An inadequately funded maintenance program has been determined to be a key contributor to leaks at Entergy's Vermont Yankee plant. Deferred maintenance is also a significant contributing factor to radiological leaks at the Indian Point site.

Notwithstanding this systemic hindrance to effective management of radiological leakage issues, as a result of serious underground piping failures at Entergy's Vermont Yankee nuclear plant, Entergy ostensibly committed to embark on a fleet-wide initiative to become an industry leader in tritium mitigation. A copy of Entergy's news release memorializing this commitment is attached to this testimony as **Exhibit AG-Rad-6**. This "initiative" was ostensibly implemented through Entergy's fleet-wide Aging Management Program (AMP) for buried components and structures, which appears to be contained in two documents: Buried Piping and Tanks Inspection and Monitoring Program, EN-DC-343, Rev. 3, and Buried Piping and Tanks Inspection and Monitoring, CEP-BPT-0100. Copies of these aging management documents are attached to this testimony as **Exhibit AG-Rad-7**.

However, Entergy's fleet-wide effort to address radiological leakage continues to be inadequate. Even with Entergy's AMP and campaign commitment to mitigate tritium leaks, Entergy plants continue to leak tritium and other radioactive isotopes. Two new radioactive leaks were discovered at Vermont Yankee after Entergy announced its new tritium initiative, a tritium leak has persisted at the Pilgrim plant near Boston, and a new tritium leak recently occurred at the Grand Gulf plant in Mississippi. All of these new leaks discovered after Entergy committed itself to be the nationwide leader in tritium leak prevention. In addition to tritium leaks in each of its five oldest reactors, at least two Entergy plants are also leaking radioactive strontium (Sr90) and other radioactive fluids.

INDIAN POINT SITE-SPECIFIC RADIOLOGICAL LEAKS AND DISCHARGES

Q. Please explain the history of accidental radioactive spent fuel pool leaks at the Indian Point site.

A. I have reviewed various Entergy documents explaining the long history of spent fuel pool leaks at the Indian Point plant. One such document entitled "Problem Development Sheet – Groundwater" is attached to this testimony as **Exhibit AG-Rad-8**. Another such document entitled "Groundwater Investigation Executive Summary" is attached to this testimony as **Exhibit AG-Rad-9**. And a third document entitled "Containment Sources

and Release Mechanisms" is attached to this testimony as **Exhibit AG-Rad-10.**

My review of Entergy's documents reveals the following:

Both the Indian Point Unit 1 West Fuel Pool and the Unit 2 spent fuel pool experienced leakage beginning in the 1990's. *See* **Exhibit AG-Rad-8**; **Exhibit AG-Rad-9; Exhibit AG-Rad-10**. While Entergy's documents maintain that the leaks identified in the 1990s were the first to occur, there is no methodology to determine when the leaks actually began. The leaks may have begun as early as 1973 sometime after the first Indian Point plant began operation.

In September 2005, Entergy discovered a crack in the Unit 2 pool and observed seepage of water out of the pool. Monitoring of liquid radioactive waste leaks did not begin at the Indian Point site until this time. This monitoring detected elevated levels of cesium, strontium, tritium, and other radionuclides well in excess of EPA Maximum Contaminant Levels,[5] and revealed that the Unit 1 and 2 pools had been leaking for a long time. Well data from early groundwater monitoring, attached to this testimony as **Exhibit AG-Rad-11**, shows the contamination at extremely high levels, hundreds and thousands times EPA limits.

Entergy's subsequent investigation demonstrated active sources of leakage from the pools. For example, in 2006, the Unit 1 pool "leak collection system" was found to be completely failing, allowing uncollected contaminants to be released; and in 2007, Entergy found a pinhole defect in the stainless steel Transfer Canal liner of the Unit 2 pool causing leaks. *See* **Exhibit AG-Rad-8**; **Exhibit AG-Rad-9; Exhibit AG-Rad-10**.

Also, leaks from the Unit 2 refueling pool have also been a substantial problem.

[5] EPA maximum contaminant levels for drinking water, measured in picocuries per liter, which is a measure of radioactivity based on the observed decay rate of radium, are as follows: Tritium, 20,000 pCi/l; Strontium-90, 8 pCi/l; Cesium-137, 200 pCi/1. *See* U.S. EPA, Radionuclides in Drinking Water: A Small Entity Compliance Guide (February 2002), *available at*, http://www.epa.gov/ogwdw/radionuclides/pdfs/guide_radionuclides_smallsystems_compliance.pdf, at 13.

According to e-mail correspondence among Entergy employees in 2006,

> [t]he Unit 2 Refueling Pool leaks so badly that many CR's [Corrective Action Reports] have been written over the years and we had to literally wear rain coats in the CTMT[6] basement (46' elevation) when we did the loop RTD[7] modification . . . we had to build a tent and put in rain gutters to divert the water.

A copy of this e-mail correspondence is attached to this testimony as **Exhibit AG-Rad-12**.

Q. Please describe any other sources of accidental radiological leakage at the Indian Point site in addition to the spent fuel pool leaks.

A. Aging components and underground piping at Indian Point have experienced leakage issues. For example, in 2009 due to unmonitored, undetected corrosion, a pipe buried eight feet underground at Indian Point leaked, and was discovered only when a plant worker observed water on the floor. This particular leak resulted in more than 100,000 gallons of tritiated water being released directly to the Hudson River. An Entergy Groundwater Monitoring Review Checklist and article discussing this occurrence are attached to this testimony as **Exhibit AG-Rad-13** and **Exhibit AG-Rad-14**, respectively.

By way of another example, in April 1988, it was reported that 8,400 gallons of radioactively contaminated water leaked into the Hudson River through a crack in the condenser blowdown line from the refueling water storage tank heating coil of Unit 2. *See* **Exhibit AG-Rad-3** at page 15.

Accidental spills have also been documented. For example, two Energy Groundwater Monitoring Checklists reveal that in November 2009, a "RWST[8] processing skid" spilled "RWST water to the MOB yard area adjacent to the Unit 2 PAB[9]," which resulted in the

[6] CTMT stands for "containment." The containment basement referred to in this document is located below the leaking plant component.
[7] RTD stands for "resistance temperature device."
[8] RWST stands for "Reactor Waste Storage Tank."
[9] PAB stands for "Primary Auxiliary Building."

detection of "greatly elevated" levels of tritium in the groundwater. Copies of these checklists are attached to this testimony as **Exhibit AG-Rad-15**.

The persistent presence of elevated levels of radioactivity in the storm drains at Indian Point is further evidence of radiological leaks and discharges from plant components, such as pipes and other undetermined/unspecified onsite sources. Entergy's report entitled *Troubleshooting Plan for H-3[10] investigation: Storm Drains System A, March/April 2009 (EN-MA-125)* explains that tritium was found in Storm Drain System A in March of 2009. A copy of this document is attached to this testimony as **Exhibit AG-Rad-16**. Concentrations of tritium in Storm Drain System A were at 90,000 pCi/L, which is at least three times higher than the EPA Maximum Contaminant Level for tritium, that is, 20,000 pCi/L. In following the leak path delineated in the report, one will note that Storm Drain System A ". . . empties into A-6 drain, which does NOT retain water long, passing quickly to the E system where it drains down the old roadway to the old command post area and into the discharge canal" which exits into the Hudson River. The plant staff speculated that these high levels of contamination might be due to failures in "underground piping or an unknown source," but determined that "[t]he most likely cause of the elevated H-3 [tritium] in the effected storm drains was determined to be an accumulation of liquid H-3 condensation from the various airborne vents (washout)…". Thus, this report reveals that "washout" is also a problem at Indian Point.

Q. Please explain what "washout" is.

A. "Washout," also known as "rainout," is a nuclear industry term for airborne tritium releases that are regularly released from nuclear power plants. Such airborne tritium releases are caused by hot radioactive water or radioactive steam leaking from components in the nuclear facility.

[10] H-3 stands for tritium.

Q. How is washout problematic at Indian Point?

A. Aged plants like Indian Point are more susceptible to leakage, as their components have deteriorated and are approaching the end of their design life. These leaks contaminate the air inside the plant with radioactivity. The contaminated air is then released through vents in the roof or out the exhaust stack of the plant. Entergy's Indian Point plants contain numerous airborne vents. Once this humid, radioactive air is released from the building, it condenses and rains down or *washes out* of the air.

Radioactive rain falls on the landscape surrounding Indian Point and also directly into the Hudson River. Leakage that Entergy views as normal on the Indian Point site is creating clouds of tritiated water that migrate offsite and deposit tritium in the Hudson River and adjacent offsite lands. Where the rainout/washout migrates and deposits its radioactive isotopes depends upon weather patterns along the Hudson River and adjacent to the Indian Point site.

Q. What, if any, intentional radiological releases to the environment occur at Indian Point?

A. Entergy discharges radioactive liquid effluent into the river on a regular basis as part of routine operations. Entergy's annual Radioactive Effluent Release Reports (RERR) memorialize these releases. A relevant excerpt of Entergy's 2010 RERR is attached to this testimony as **Exhibit AG-Rad-17**. This report indicates that in 2010, totals of 732 and 658 curies of tritium were released from Units 1/2 and Unit 3, respectively, to the Hudson River through liquid effluent. *See* **Exhibit AG-Rad-17** at pages 17 and 20.

THE IMPACT OF RADIOLOGICAL LEAKS AND DISCHARGES AT INDIAN POINT

Q. Please discuss whether radiological leaks and discharges from Indian Point have contaminated the subsurface and groundwater beneath the facility.

A. Leaks from the spent fuel pools at Indian Point and other onsite sources have resulted in at least two extensive comingled plumes of contamination that underlie the Indian Point site. As explained in Entergy's Groundwater Investigation Executive Summary (**Exhibit**

AG-Rad-9), one plume consists largely of tritium, while the other consists largely of other highly toxic radionuclides including Strontium-90, Cesium-137, Nickel-63, and Cobalt.

Q. What is the level and current status of this contamination in the groundwater?

A. I have reviewed Entergy's quarterly monitoring reports covering up to the second quarter of 2010, as well as data generated through the third quarter of 2010 (these are most recent reports and data that Entergy has provided to Riverkeeper). Relevant excerpts from Entergy's most recent monitoring report, and a copy of the most recent data I reviewed are attached to this testimony as **Exhibit AG-18** and **Exhibit AG-19**, respectively. Entergy's quarterly monitoring report contains radionuclide plume maps, which show the breadth and extensive nature of the contamination. *See* **Exhibit AG-18.** The most recent monitoring data I reviewed reveals that the level of contamination in the groundwater remains high, and that samples from certain monitoring wells continue to exceed EPA Maximum Contaminant Levels. *See* **Exhibit AG-18**; **Exhibit AG-19**. This trend is likely to continue in the foreseeable future. Entergy's most recent monitoring report explains that while some monitoring wells have shown decreased tritium concentrations, "[p]eaks of tritium have been observed in multiple sampling points. . . This long term variability appears to be with the episodic releases of Tritium historically stored in the subsurface. . ." *See* **Exhibit AG-18**. Furthermore, the report states "approximately 70% of the sampling intervals exhibited an increase in Tritium levels . . .". *See* **Exhibit AG-18**. Additionally, this report states that if there are no additional leaks, radionuclides will gradually spread out and have their concentration diluted, and that additional peaks will also be found even if there are no additional leaks: "This additional unsaturated zone source will likely be manifested in the future as additional non-specific peaks in radionuclide levels due to episodic releases to the groundwater . . .". *See* **Exhibit AG-18**. Also, as I will discuss later in my testimony, ongoing and future leaks will continue to add to the existing plumes of contamination, and all indications are that Entergy is going to simply allow such persistent contamination to sit in the groundwater for decades to come without any removal or remediation. So, the level of contamination will likely remain high for the foreseeable future.

Q. Please explain whether radiological leaks and discharges from Indian Point have contaminated the Hudson River.

A. Entergy documents, including Entergy's groundwater monitoring report covering the second quarter of 2010 (**Exhibit AG-Rad-19**) and Entergy's Groundwater Investigation Executive Summary (**Exhibit AG-Rad-9**), explicitly acknowledge that the underground radioactive plumes of contamination migrate and eventually discharge to the Hudson River. Another Entergy document I reviewed explains how the tritium plume from the Unit 2 spent fuel pool "tracks with downgradient groundwater flow through the Unit 2 transformer yard, under the discharge canal and discharges to the river between IP2 and IP1 intake structures." ***See*** **Exhibit AG-Rad-10.** The plumes of contamination will persist in the groundwater for decades and, thus, continually result in radiological discharges to the Hudson River.

Also, as I discussed earlier in my testimony, radioactive materials are otherwise regularly discharged directly into the Hudson River: accidental pipe leaks have resulted in the direct discharges to the river via the discharge canal; contaminated stormwater discharges to the river; washout results in radioactive rain which contaminates the Hudson River; and Entergy intentionally releases radioactive liquid to the river on a regular basis.

Q. Please describe the effect of all of Indian Point's ongoing accidental and planned radiological releases to the Hudson River on recreation in the river, including swimming and fishing, or for the health of the river ecosystem.

A. On June 29, 2005, the National Academy of Sciences issued the BEIR (Biological Effects of Ionizing Radiation) VII Report. A copy of a Report in Brief summarizing this report is attached to this testimony as **Exhibit AG-Rad-20**. According to BEIR VII, all radioactive releases, no matter how low the concentration, have potentially deleterious health effects. As I will discuss in more detail later in my testimony, Entergy is simply allowing the plumes to sit in the groundwater and migrate to the Hudson River for decades to come, without removing and/or remediating the radioactive contamination.

As I discussed earlier, Entergy has acknowledged that the plumes of contamination at the site contain not only tritium but also deleterious substances including Nickel-63, Cesium-137, and Strontium-90. With a 30-year half-life, meaning it contaminates the environment for 300 years,[11] the toxicity of strontium is much greater than that of almost every radioactive isotope released by a nuclear reactor. Entergy has recognized the unique deleterious nature of Strontium-90 as it spreads across the site and into the Hudson River and groundwater. Strontium-90 is called a bone seeker because if it is ingested, it mimics calcium and is absorbed by bone where it can create leukemia and other forms of cancer. Cesium-137 mimics potassium and is absorbed by muscle where it too can cause cancers and deformities. Tritium is basically radioactive water. Wherever there is water in an organic substance, radioactive tritium, also known as tritiated water, can replace water at a cellular level. Tritium can be ingested, inhaled, or absorbed through the skin.

ONGOING AND FUTURE RADIOLOGICAL LEAKS AND DISCHARGES AT INDIAN POINT

Q. Please discuss whether the spent fuel pools at Indian Point are currently leaking and whether they will leak in the future.

A. The Unit 1 Spent Fuel Pool has been completely drained so the pool cannot leak further. However, considerable radiation remains in the concrete and surrounding soil, and groundwater. As discussed already, this contamination actively leaches into the Hudson River.

There is no evidence that leaks in Unit 2's spent fuel pool have been completely repaired or that the pool is now leak proof. In fact, it is impossible to adequately inspect the spent fuel pool for leaks: Entergy has never inspected a significant portion of the stainless steel spent fuel pool liner due to the complete inaccessibility of portions of the pool. Entergy

[11] "Half-life" is defined as "[t]he time required for half the nuclei of a specific radionuclide or radioactive substance to undergo radioactive decay." *See* The American Heritage® Medical Dictionary, Houghton Mifflin Company (2007). A radionuclide will essentially fully decay after approximately 10 half-lives.

cannot adequately access this liner for inspection due to the high density of fuel in the pool and the minimal amount of space between the fuel racks and the bottom and lower sides of the liner. For example, an Entergy e-mail correspondence explains the significant challenges to inspecting the Unit 2 spent duel pool for leaks (and the resulting lack of ability to repair any leaks) because without moving fuel, key areas are totally inaccessible to inspection. A copy of this e-mail is attached to this testimony as **Exhibit AG-Rad-21**. In particular, in this document, Entergy explains that

> the examination of the spent pool floor will be challenging. . . . but to obtain meaningful results is an entirely different story. . . .[A] challenge would be the 30 years of debris accumulated on the bottom of the fuel pool. . . . The alternative to not cleaning would be the equivalent of trying to located [sic] cracks in a sidewalk, with 2" of snow covering the sidewalk. . . . [T]he examination of the spent fuel pool wall behind the fuel racks is especially challenging. . . . While it is important to identify any area of potential leakage, it is also important to consider the ability to repair areas of potential leaks. . . . there are hundreds of indications that would be considered unacceptable and potential leak paths by any welding standard, in the areas we have examined so far. I would not expect the quality of the floor plates or exposed wall sections to be any different.

Another Entergy document states that Entergy's remote operated vehicle encountered "numerous interferences [and] substantial debris on the floor" (with no debris removal plan), when attempting to inspect the area beneath the spent fuel racks. A copy of this document is attached to this testimony as **Exhibit AG-Rad-22**. Another Entergy report also notes how "only a portion of the pool has been able to be inspected due to interference limitations. . . .". *See* **Exhibit AG-Rad-8**. Entergy's Groundwater Investigation Executive Summary explains that "active leaks cannot be completely ruled out." *See* **Exhibit AG-Rad-9**. An Entergy e-mail correspondence further confirms that numerous areas of the Unit 2 spent fuel pool cannot be observed or inspected, and acknowledges the existence of additional leaks that have not yet been identified: "we believe there could be other leaks in the unit 2 fuel pool that we cannot observe. . .". A copy of this e-mail is attached to this testimony as **Exhibit AG-Rad-23**.

Another Entergy report also indicates that the Unit 2 spent fuel pool "does not have a tell tail drain collection system which poses a vulnerability for additional activity leakage." *See* **Exhibit AG-Rad-8.** In contrast, Unit 3 and other nuclear power plants have a collection system underneath the stainless steel cladding of the fuel pool that works to detect leaks.

Furthermore, Entergy has no preventative measures in place to be able to detect and avert future leaks from the Unit 2 pool during the proposed relicensing term. Instead, Entergy relies upon a one-time inspection of a fraction of the pool liner as well as groundwater monitoring, which will admittedly only be able to detect leaks after they occur, for its assurance that the Unit 2 pool will remain sound during the proposed 20-year license renewal period.

Also, the Unit 2 pool is 35-years old and facing the typical bathtub curve issues that aging plants face with concrete and systems degradation. A "bathtub curve" is defined as "the phenomenon that the fraction of products failing in a given timespan is usually high early in the lifecycle, low in the middle, and rising strongly towards the end. When plotted as a curve, this looks like the profile of a bathtub."[12] The bathtub curve phenomenon shows that Entergy's Indian Point spent fuel pools will face more aging and leakage issues as the plant continues to operate, not less. In fact, an Entergy document listing areas/components at the Indian Point site that are susceptible to inadvertent leaks indicates that the potential for leakage relating to the Unit 2 spent fuel pool is "High." A copy of this document is attached to this testimony as **Exhibit AG-Rad-24**.

Given Entergy's own assessment, it is highly likely that the Unit 2 pool will continue to experience radiological leaks.

Additionally, leaks from the Unit 2 refueling pool remain ongoing. It is likely that this problem will continue in the future: when a nuclear fuel pool leaks so extensively that

[12] WordIQ.com, Bathtub curve – Definition, http://www.wordiq.com/definition/Bathtub_curve (last visited July 21, 2011).

raincoats and rain gutters are required prior to employees being able to perform work beneath the fuel pool, it is an indication of abysmal radiation control practices at Indian Point as well as inadequate application of financial resources to repair the problem. *See* **Exhibit AG-Rad-12**. Furthermore, as Entergy correspondence indicates, the "refueling stainless steel liner leaks . . . and never has been effectively repaired." **Exhibit AG-Rad-12**. This correspondence report further explains the degree of difficulty in inspecting the refueling pool: "the Refueling Water Cavity Pool (RWCP) liner never had a video inspection performed . . .". *See* **Exhibit AG-Rad-12**.

Q. Please explain whether pipe and structural leaks at the Indian Point site are currently ongoing and whether they may occur in the future?

A. Based on my review of Entergy's documents concerning radiological leakage issues, ongoing pipe and structural leaks at Indian Point may be occurring now and others will most definitely occur in the future. One chart provided by Entergy (**Exhibit AG-Rad-24**) lists numerous varied locations at the Indian Point site that may currently be leaking tritium and other radioactive isotopes or have a high potential for leakage of tritium and other radioactivity in the future. According to Entergy, there are at least nineteen (19) sources at the Indian Point site that have a "High" potential for leakage of tritium and other radioactive isotopes. ***See*** **Exhibit AG-Rad-24**. Many of the sources of radiological leaks identified by Entergy have already introduced radioactive contamination into the soil and site groundwater at Indian Point. Entergy's (undated) chart evidences a site overrun by significant aging management issues, and once again, Indian Point's aging, degrading components face a bathtub curve, whereby leakage issues will most likely increase over time, and not lessen or cease.

Furthermore, Entergy does not have adequate aging management methods in place in order to be able to detect and prevent future leaks.

Q. Please elaborate upon your position that Entergy does not have adequate aging management methods and programs for detecting and preventing future leaks.

A. I have reviewed various documents related to Entergy's program for managing

problematic leaking components, including documentation concerning Entergy's commitment to become an industry leader in tritium leakage detection and prevention (**Exhibit AG-Rad-6**), Entergy's fleet-wide Aging Management Program (AMP) for leaking buried components and structures (which apparently attempts to fulfill their commitment) (**Exhibit AG-Rad-7**), as well as an Entergy document concerning inspection methods employed for potential sources of tritium at Indian Point. Entergy's document regarding inspection methods, entitled *Potential Sources of Tritium at IPEC & Inspection Method*, is attached to this testimony as **Exhibit AG-Rad-25**. My review of these documents leads me to conclude that Entergy's programs and methods are inadequate to prevent radiological leaks in the future.

Entergy's AMP for buried structures is not designed to identify or stop all potential radiological leaks. A considerable number of components at Indian Point are inaccessible to examination because they are buried, or otherwise obstructed. However, Entergy's AMP does not require inspections of 100% of such components. Many of Indian Point's underground pipes and structures have been buried since the plant began operating and have never been inspected during the plants nearly 40 years of operation. Rather, Entergy's AMP largely provides only for opportunistic inspections, which only uncover a few piping components periodically. Entergy itself readily acknowledges its inability to identify and stop leaks, as an spokesperson stated in response to the February 2009 accidental underground pipe leak: "[i]t's eight feet underground, so there's no way of knowing when you have to replace it." *See* **Exhibit AG-Rad-14**.

These problems are confirmed by GAO's recent investigation report regarding tritium leak issues. In particular, GAO concludes that because "underground piping systems tend to corrode" and are "largely inaccessible and difficult to inspect, . . . pipes will continue to age and further corro[de]" and that the "severity of leaks could increase without mitigating actions." *See* **Exhibit AG-Rad-4**. GAO further states that "[t]he occurrence of leaks at nuclear power plants from underground piping systems is expected to continue." *See* **Exhibit AG-Rad-4**.

Another major concern with Entergy's methods for preventing future radiological leaks is that a vast majority of Indian Point's inspection methods rely only upon physical inspections. Industry experience with physical inspections indicates that they are completely inadequate to detect a leak before it occurs. One Entergy document identifies physical inspection methods for dozens of locations that may currently, or in the future, leak tritium and/or other radioactive isotopes. *See* **Exhibit AG-Rad-25**.

An additional problem is that Entergy's approach to identifying and repairing degraded and/or leaking components is completely reactive, and not proactive or preventative in nature. For example, several Entergy documents I reviewed demonstrate Entergy's reactive approach in addressing the initial discovery of the spent fuel pool leaks in 2005. These documents are collectively attached to this testimony as **Exhibit AG-Rad-26**. One document, entitled *Top Ten Lessons Learned* indicates that Entergy could have attained earlier indications of a problem if staff had performed evaluations earlier, and that Entergy did not effectively review information concerning elevated levels of contamination in sampling results. *See* **Exhibit AG-Rad-26**. Various other documents indicate that outside pressure (including from non-profit organizations like Union of Concerned Scientists, the public, the NRC, the media, and public officials such as the former President Bill Clinton and then-Senator Hilary Clinton) was the primary reason Entergy developed a tritium mitigation program at Indian Point. *See* **Exhibit AG-Rad-26**. Entergy continues to employ a reactive approach to the management of radiological leaks at the Indian Point site, as evidenced by numerous instances whereby Entergy only identifies new leaks when they literally spring, or when they have already manifested in well samples, as opposed to proactively engaging in necessary inspections of problematic or potentially problematic components and structures.

Yet another issue with Entergy's approach to managing radiological leaks at Indian Point is that Entergy is failing to sufficiently fund its maintenance programs. Two independent reports explicitly demonstrate this reality. *See* **Exhibit AG-Rad-5**. As one of the reports explains, "[l]imited resource allocation for non-safety systems" can be characterized as "systemic within Entergy." *See* **Exhibit AG-Rad-5** at page 10. This report further

explains that at Indian Point, "[t]he physical condition of the plant in non-safety areas is visibly deficient" and that "the care and maintenance of some . . . plant systems and structures do not meet the standards of high-performing plants." **Exhibit AG-Rad-5** at pages 9-10. This failure to adequately fund maintenance contributes significantly to the likelihood of radiological leaks at Indian Point.

Based upon Entergy's failure to adequately manage the aging of increasingly degraded plant components, it is expected that many tanks, pipes, and other components on the Indian Point site will leak in the future prior to detection by Entergy.

ENTERGY'S APPROACH TO LONG-TERM CONTAMINATION PLUME MANAGEMENT

Q. Please describe Entergy's approach to addressing the plumes of contamination that underlie the Indian Point site.

A. Entergy has chosen to use Monitored Natural Attenuation as the remedial approach in relation to the contamination from radiological leaks at Indian Point. *See* **Exhibit AG-Rad-18** at page 3-13. This means that the contamination remains in the ground until it migrates to Hudson River and/or decays.

Therefore, Entergy relies solely on groundwater monitoring to "manage" the contamination, as well as the fact that the toxic radionuclides released from the plant will be diluted once they enter the Hudson River.

Q. Please evaluate the effectiveness of Entergy's Monitored Natural Attenuation as a strategy for handling the contamination at Indian Point.

A. Monitored Natural Attenuation is not a remedial approach, because it does nothing to mitigate the progress of the radioactive plumes to the groundwater adjacent to the Indian Point site or into the Hudson River. In light of Entergy's approach, radioactive contamination (from past leaks, current leaks, and likely future leaks) will persist in the groundwater, likely at high levels, and be released to the Hudson River for decades into

the foreseeable future. As I stated previously in this testimony, all radioactive releases, no matter how low the concentration have potentially deleterious health effects. *See* **Exhibit AG-Rad-20**. Therefore, Monitored Natural Attenuation is not a valid remediation approach to the extensive tritium and strontium leakage at Indian Point.

Q. Please explain whether there is preferable approach to handling radiological leaks at Indian Point?

A. Remediation of the radiological contamination via extraction wells is a far superior approach for handling the contamination and leak issues at Indian Point.

Q. What are extraction wells and why do they matter?

A. Extraction wells mitigate the volume and spread of radiation and draw contaminants out of the ground in order to prevent their movement to nearby bodies of water, the existing water table, or to prevent aquifer contamination. At Indian Point, for example, which has tritium and other radioactive isotopes like Strontium (Sr90), an extraction well would reduce the level of contamination in the groundwater and prevent radioactive contamination from spreading across the site and into the Hudson River. Removing a radioactive isotope like Sr90 would prevent its ongoing contamination for 300 years. Sr90 has a half-life of 30 years which means that it will be in the environment for 300 years.

Q. Please explain whether Entergy has considered implementing an extraction system to remediate the contamination at Indian Point.

A. I have reviewed various Entergy documents which indicate that Entergy did pursue an extraction well project at the Indian Point site. According to an Entergy e-mail from May, 2006, Entergy's consultant, GZA, recommended that a remedial extraction well be installed in the Unit 2 spent fuel pool building. A copy of this e-mail is attached to this testimony as **Exhibit AG-Rad-27**. This e-mail explains:

> The remedial option letter is . . . basically complete . . . I showed the team the results of the model and the locations of the proposed pumping wells and rates. Basically, we are recommending a pumping well in the IP2-FSB to address the source of the Tritium.

> A second pumping well would be located in the Superheater building, west of the CS Sump. This well should capture the majority of the Sr contamination on the Unit 1 side.

A later Entergy document indicates that by November 15, 2006, ABS Consulting issued a formal proposal to Entergy "to provide engineering consulting support in a task associated with the development of an ER Response Nuclear Change for the long term installation of a remediation well for groundwater contamination." A copy of this document is attached to this testimony as **Exhibit AG-Rad-28**.

Another Entergy document explains that a Recovery Well (RW-1) was drilled and that pilot tests were performed. A copy of this document is attached to this testimony as **Exhibit AG-Rad-29**.

Q. What were the results of Entergy's pilot tests?

A. The pilot pump tests indicated that remediation of the contamination at Indian Point is feasible. An Entergy document entitled *Groundwater Investigation '06 Quarter 4 Activities and Results* details pilot tests conducted on behalf of Entergy to determine if an extraction well would help to remove tritiated and other radioactively contaminated water from the ground on the Indian Point site. A copy of this document is attached to this testimony as **Exhibit AG-Rad-30**. This document explains the success of the pilot testing as follows:

> Remediation Pilot Test: The groundwater investigation team conducted a pump test to determine if a recovery well, could be used to hydraulically prevent the migration of tritiated groundwater around the Unit 2 Fuel Building. The test is also designed to test the feasibility of pumping groundwater from the area near IP2. **The test did indicate that water could be drawn from around Unit 2 without drawing Sr-90 contaminated water from Unit 1.** The RW-I well pumping did influence water in the Unit 2 Transformer Yard (MW[13]-34) as expected. Sampling from the monitoring wells has resumed. [*Emphasis Added*]

And, an Indian Point Energy Center Status Report from December of 2006 also

[13] "MW" stands for monitoring well.

memorializes the success of the pilot pumping from RW-1:

> Tritium concentrations were reduced during the recent recovery well pump test. The tritium concentration in RW-1 at the beginning of the test was about 100,000 pCi/L and dropped to 19,000 pCi/L at the end of the test. Levels remained lower (30,000 pCi/L) three weeks later. A similar drop was observed in MW-30 . . . The tritium concentration was reduced by about half. This is a limited data set but does provide some evidence that groundwater tritium levels can be reduced in this fashion.

A copy of this Status Report is attached to this testimony at **Exhibit AG-Rad-31**.

Another Entergy document also explained that the pilot test decreased tritium levels significantly, and stated that a "permanent system installation [was] planned for completion in May 2007." *See* **Exhibit AG-Rad-29**.

Q. What is the current status of remediating radioactive underground water through extraction at Indian Point?

A. Although there are numerous reports recommending remediation through extraction of radioactive water, Entergy is not implementing any of these recommendations, and instead has chosen to only rely on Monitored Natural Attenuation. Entergy has chosen not to remediate radioactivity through extraction of radioactive groundwater.

Q. Please discuss whether extraction is possible at Indian Point.

A. The record suggests that there is no reason why extraction is not possible at Indian Point. Furthermore, the documents I have reviewed demonstrate that extraction of tritium and other radioactive isotopes would successfully mitigate the contamination. Moreover, Entergy is using extraction wells at Vermont Yankee and is fully aware of the positive effectiveness of extraction wells upon remediating radioactive isotopic contamination.

Q. Please explain whether there are any limitations to your testimony concerning the efficacy and viability of extraction wells at Indian Point.

A. My review of Entergy's document production reveals a dearth of any information justifying Entergy ultimate decision to not continue with remediation via extraction wells at Indian Point. I have been unable to find any current recommendations regarding extraction wells, and am unable to ascertain what happened to this critical extraction well recommendation. It is, thus, impossible for me to discern any cohesive engineering analysis, and provide an informed opinion regarding Entergy's reasoning for not pursuing extraction. Upon Riverkeeper's specific request for any relevant documentation, Entergy stated that any relevant documents had already been disclosed. Entergy further explained that

> the pump test resulted in pumping-induced detection of IP 1 Sr-90 near the IP2 spent fuel pool. . . Thus, as noted in the Site Investigation Report, more aggressive remediation technologies such as hydraulic containment would alter groundwater flow patterns (e.g., draw groundwater containing Sr-90 from IPI to IP2) and therefore, offered no clear advantages to the recommended monitored natural attenuation remediation strategy. . ."

A copy of Entergy's letter explaining this position is attached to this testimony as **Exhibit AG-Rad-32**.

However, this position is not justified: Entergy documentation, as previously discussed, demonstrates that pilot pumping did not alter Sr-90 contamination flow, and that the extraction had the clear advantage of being successful. *See* **Exhibit AG-Rad-28**; **Exhibit AG-Rad-29**. Moreover, even if the extraction altered the groundwater flow and the contamination plumes, the benefit of extraction outweighs any negative aspect of an altered groundwater flow.

Q. Please discuss the effect of Entergy's failure to implement extraction wells at Indian Point on the existing contamination plumes.

A. Because of Indian Point's age and inadequate preventive maintenance by Entergy, new leaks will likely occur at any time. Airborne "washouts" will also continue. Entergy has

chosen not to remediate the extensive contamination through the use of extraction wells and instead has chosen to allow liquid radioactivity to spread throughout the site and into the Hudson River. Therefore, it is likely that radioactively contaminated water will remain in high concentrations at Indian Point for its continued operational life.

CONCLUSIONS

Q. Please summarize your conclusions regarding radiological leakage and discharge issues at Indian Point.

A. My conclusions are as follows:

1. Entergy's Indian Point Nuclear Power Plant has a long history of accidental and intentional radiological leaks and discharges from various components and structures onsite.
2. These leaks and discharges have resulted in high levels of radioactive contamination in the groundwater beneath Indian Point, as well as ongoing releases to the Hudson River, via the groundwater as well as direct releases and washouts.
3. These leaks and discharges are deleterious for the Hudson River and for the public's use and enjoyment of the river.
4. Given the age of the Indian Point nuclear power plants and their ongoing record of poor maintenance, as well as inadequate resource allocation, inadequate preventative inspection and maintenance procedures, additional leaks will occur in the future.
5. Entergy has chosen to not remediate the contamination that persists at the site and instead, elected to let the plumes naturally attenuate. Mitigation of the plumes was recommended and yet there is no record of implementation of site radioactive remediation technology.
6. Extraction of radioactive contamination from the soil and groundwater is possible, and preferable to allowing the contamination to leak into the Hudson River. Mitigation of radiation plumes at Indian Point would use a proven technology already in use at other nuclear plants, including Entergy's Vermont Yankee plant. Radioactive contamination mitigation should be an immediate priority at Indian Point if it is to continue operation. Failure to do so will result in persistent high levels of contamination in the groundwater,

and discharges to the Hudson River for decades, if not centuries, into the future.

Q. Does this conclude your direct testimony?

A. Yes.

Exhibit List/Bibliography

Exhibit AG-Rad-1: Curriculum Vitae of Arnold Gundersen

Exhibit AG-Rad-2: U.S. NRC, List of Historical Leaks and Spills At U.S. Commercial Nuclear Power Plants, Rev. 7, June 14, 2011 (ADAMS Accession No. ML101270439)

Exhibit AG-Rad-3: Union of Concerned Scientists, Groundwater Events Sorted by Date (September 27, 2010)

Exhibit AG-Rad-4: GAO Report to Congressional Requesters, Nuclear Regulatory Commission, *Oversight of Underground Piping Systems Commensurate with Risk, but Proactive Measures Could Help Address Future Leaks*, GAO-11-563 (June 2011)

Exhibit AG-Rad-5: *Supplemental Report of the Public Oversight Panel Regarding the Comprehensive Reliability Assessment of the Vermont Yankee Nuclear Power Plant* (July 20, 2010)

Exhibit AG-Rad-6: Entergy News Release, *VY Tritium Investigation Determines Source of Tritium in Groundwater; Initial Soil and Groundwater Remediation Now Underway* (March 25, 2010).

Exhibit AG-Rad-7: Entergy Nuclear Management Manual, Buried Piping and Tanks Inspection and Monitoring Program, EN-DC-343 (September 16, 2010)

Exhibit AG-Rad-8: Entergy, Problem Development Sheet - Groundwater

Exhibit AG-Rad-9: Entergy Groundwater Investigation Executive Summary, Indian Point Energy Center, Buchanan, N.Y. (January 2008)

Exhibit AG-Rad-10: Entergy, 9.00 Contaminant Sources And Release Mechanisms

Exhibit AG-Rad-11: NRC Data from Indian Pt. Split Monitoring Well Samples

Exhibit AG-Rad-12 Entergy E-mail Correspondence Between R. Sachatello and F. Madero, Re: *Similarities of the Pool Liners?*, September 25, 2006

Exhibit AG-Rad-13: IPEC Site Management Manual, IP-SMM, CY-110, Rev. 1, 8.6 RGWMP Quarterly Integrated Review Checklist (Quarter 1, 2009)

Exhibit AG-Rad-14: Annie Correal, *Indian Pt. Broken Pipe Spurs Safety Worries*, THE NEW YORK TIMES (March 1, 2009)

Exhibit AG-Rad-15: IPEC Site Management Manual, IP-SMM, CY-110, Rev. 3, 8.6 RGWMP Quarterly Integrated Review Checklist (Quarter 1, 2010); IPEC Site Management Manual, IP-SMM, CY-110, Rev. 1, 8.6 RGWMP Quarterly Integrated Review Checklist (Quarter 2, 2010)

Exhibit AG-Rad-16: Entergy, Nuclear Management Manual, EN-MA-125, Rev. 4, Attachment 9.1, Initial Investigation, *Troubleshooting Plan for H-3 Investigation, Storm Drain System A*, March/April 2009

Exhibit AG-Rad-17: Excerpt of Entergy Nuclear Operations, Inc., Indian Point Unit 1, 2 and 3 Nuclear Power Plants, Docket Nos. 50-03, 50-247, and 50-286, Radioactive Effluent Release Report: 2010 (Full report available via NRC's Agencywide Document Access and Management System (ADAMS), Accession No. ML11172A042)

Exhibit AG-Rad-18: GZA GeoEnvironmental, Inc., Final IPEC Quarterly Long-Term Groundwater Monitoring Report, Quarter Two 2010 (Report No. 10), Indian Point Energy Center, Buchanan, New York, February 15, 2011

Exhibit AG-Rad-19: Entergy Groundwater Monitoring Well Data, Quarter 3, 2010

Exhibit AG-Rad-20: The National Academies, Report in Brief, Beir VII: Health Risks from Exposure to Low Levels of Ionizing Radiation

Exhibit AG-Rad-21: Entergy E-mail Correspondence between P. Deeds and M. Rutkoske, Re: *Spent Fuel Pool Exams - What's Next?*, November 18, 2005

Exhibit AG-Rad-22: Entergy, Unit 2 Spent Fuel Pool Leak, Monitoring Wells and Underground Piping, March 31, 2006

Exhibit AG-Rad-23: Entergy E-mail Correspondence Between R. Sachatello (Entergy) and M. Barvenik (GZA), Re: *Is The Pool Leak Off Collection Box Effective?*, April 26, 2006.

Exhibit AG-Rad-24: Entergy chart of locations onsite at Indian Point with history of and potential for leakage

Exhibit AG-Rad-25: Entergy, Potential Sources of Tritium at IPEC & Inspection Method

Exhibit AG-Rad-26: Entergy, Top Ten Lessons Learned; Entergy E-mail Correspondence Between D. Mayer and G. Hinrichs, Re: *Public Meeting Readiness*, March 24, 2006; Entergy E-mail Correspondence Between M. Barvenik (GZA) and C. Snee (GZA), Re: *Indian Point Nuke*, September 24, 2005; Entergy E-mail Correspondence Between various, Re: *2.206 petition on contaminated water leakage*, Thursday, January 26, 2006

Exhibit AG-Rad-27: Entergy E-mail Correspondence Between D. Winslow and D. Mayer, Re: *Remedial Report*, May 19, 2006.

Exhibit AG-Rad-28: Letter from ABS Consulting to Entergy Nuclear Northeast, Re: Proposal for Development of ER Response Nuclear Change Necessary for Mechanical Portion of Remediation Well RW-1; Indian Point Energy Center Unit 2, ABS Consulting Proposal No. 1650168. November 15, 2006

Exhibit AG-Rad-29: Entergy, Groundwater Status

Exhibit AG-Rad-30: Entergy, Groundwater Investigation '06 Quarter 4 Activities and Results

Exhibit AG-Rad-31: Entergy E-mail Correspondence from K. McMullin to various, Re: *IPEC status report for Dec. 21*, December 21, 2006

Exhibit AG-Rad-32: Letter From P. Bessette (Morgan, Lewis & Bockius LLP, counsel for Entergy) to D. Brancato (Riverkeeper Staff Attorney), Re: Entergy Nuclear Operations, Inc. (Indian Point Nuclear Generating Units 2 and 3), Docket Nos. 50-247-LR and 50-286-LR (June 24, 2011)