行政院原子能委員會委託研究計畫

期末報告

109 年度核電廠除役期間廠址地下水防護管制特性研析

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目錄 頁數

圖目錄 頁數

表目錄 頁數

摘要

核電廠在運轉或除役期間,可能因為放射性污染物質藉由傾洩或洩漏過程意外釋出至地下水，為了保護公共健康與安全，應建立特定廠址地下水防護計畫，以確保及時且有效應變與管理。本計畫目的：(1)蒐集美國核電廠運轉與除役期間廠址地下水防護管制法規架構與業界導則文件，並據以研析運轉與除役核電廠管制方向之差異性。(2)蒐集及彙整美國核電廠廠址地下水防護管制案例與經驗，並研析除役廠址相關規定與特定技術要項、重要參數。(3)藉由研析美國核電廠廠址地下水防護管制法規與美國除役核電廠相關實務經驗,研提我國核電廠地下水防護管制架構之精進及管制技術要項之建議。計畫之整體管制建議如下

1. 參考美國業界作法包括 NEI07-07 指引，建立除役核電廠定期自我評估機制，針對地下水防護計畫與地下水監測計畫，採文件審查、定期/不定期專案視察等管制措施，確認核電廠除役期間地下水防護方案的符合性。
2. 為精進核電廠除役的相關管制，建議持續蒐集國際間地下水防護方案相關資訊，以持續強化核電廠在除役期間地下水防護方案的管制效能。

Abstract

Inadvertent radiological releases can get into groundwater owing to spills or leaks for operating or decommissioning nuclear power plants. To protect public health and safe, a site-specific groundwater protection program shall be established to assure timely responses and effective management. The project purposes are to 1) collect groundwater protection regulations and industry guideline documents of the operating or decommissioning U.S. nuclear power plants and analyze the regulation difference between operating and decommissioning nuclear power plants; 2) collect the cases and experiences of the U.S. nuclear power plants and analyze the regulations, specific techniques, and important parameters of the decommissioning nuclear power plants; and 3) suggest the advanced framework of the groundwater protection regulations for the Taiwan nuclear power plants based on the U.S. cases and experiences. The overall regulatory recommendations of this project are listed as follows.

1. Reference to U.S. industry practices including NEI07-07 guidelines, the establishment of a regular self-assessment mechanism for decommissioning nuclear power plants, for groundwater protection programs and groundwater monitoring programs, documentation review, periodic /irregular inspection and other control measures to confirm the compliance of groundwater protection programs during decommissioning of nuclear power plants.
2. In order to refine the relevant control of decommissioning nuclear power plants, it is recommended to continuously collect information on the international groundwater protection scheme, and to continuously strengthen the control effectiveness of the groundwater protection scheme of decommissioning nuclear power plant.

一、計畫緣起與目的

自 1954 年世界上第一座核能發電廠在蘇聯建立後，目前全世界擁有約 400 多座核能電廠機組並分佈於各先進國家，在天然能源缺乏的台灣，核能的使用曾為我國工商蓬勃發展與人民生活的便利帶來強大且穩定的能源。然而，如同許多使用核能發電的國家，我國也須面臨核電廠除役與放射性廢棄物處理議題。我國核能發電廠(以下簡稱核一廠)1、2 號機運轉執照已分別於 107 年 12 月 5 日及 108 年 7 月 15 日屆滿，依「核子反應器設施管制法」規定，台電公司應向主管機關(原能會)提出除役計畫，該除役計畫須依照原能會「核子反應器設施除役計畫導則」之內容架構撰寫。其中核一廠除役工作時程，台電公司規劃主要分成四個階段，包括除役(decommissioning)過渡階段 8 年、除役拆廠階段 12 年、廠址最終狀態偵測階段 3 年，以及廠址復原階段 2 年，共計 25 年。

過去在核一廠運轉期間，台電公司已建立相關地下水防護方案，以監測地下水相關特性之參數，掌握廠址若發生放射性核種之外釋情境，進入土壤、甚至地下水系統之狀況，可藉由核電廠地下水監測系統加以確認，並建立防範地下水污染或污染擴大情形之應變處理機制。

除役拆除過程會產生大量放射性氣體、液體和固體廢棄物，這些產生的廢棄物可能因為地表與表層土壤的直接連通而進入土壤，或更進一步進入地下水系統而造成土壤或地下水特性的改變，而地下水特性的改變也可能因為地下水與廠區附近河川間的連通性而改變河川系統的特性，因此，土壤、地下水與鄰近廠址河川系統特性的改變，將可能影響除役計畫的時程與投入的資金成本。許多國外之除役經驗顯示，除役期間的活動可能改變核電廠所在的地表下環境土壤與地下水的特性，因此了解核電廠除役期間可能改變廠區地下水系統，預防地下水特性改變、發現地下水特性改變時能對造成地下水特性改變的來源採取應變措施，做好地下水防護的工作，對於除役資金成本控制與避免除役過程複雜化是重要的議題。

本服務案「109 年度核電廠除役期間廠址地下水防護管制特性研析」，鑑於核一廠已進入除役期間，在此期間核電廠仍需持續掌握監測區域及廠址周圍環境地下水之放射性核種變化狀況，確認除役作業並無放射性物質污染地下水之外釋情境。因此，為防範國內核電廠除役期間地下水之污染，必需了解及掌握核電廠廠址地下水防護之特性與評估。此外除在既有監測管制作業外，亦蒐集及彙整美國相關核電廠地下水防護計畫之管制資訊，提出相關廠址地下水防護管制要件與重要參數之管制建議，俾供作為審查管制之參考依據，並精進我國核電廠在除役期間地下水防護管制監督之技術能力。

本計畫目的為：

(1) 蒐集美國核電廠運轉與除役期間廠址地下水防護管制法規架構與業界導則文件，並據以研析運轉與除役核電廠在管制方向之差異性。

(2) 蒐集及彙整美國核電廠廠址地下水防護管制案例與經驗，並據以研析除役廠址相關規定與特定技術要項、重要參數。

(3) 藉由研析美國核電廠廠址地下水防護管制法規與美國除役核電廠相關實務經驗，研提我國核電廠地下水防護管制架構之精進及管制技術要項之建議。

二、研究方法

依照計畫目標，本計畫包括三項主要工作項目。為確實掌握地下水之防護工作與影響地下水之重要特性參數，所規劃地下水防護的相關工作，首先係針對核種在地下水系統遷移行為的物理、化學與生物等機制或過程，以及核種在地下水系統的遷移所造成的地下水系統的核種濃度變化進行簡述。

地下水為一個水溶液系統，因此其特性會受來自地下水系統以外的化學、生物、輻射物質介入其中而改變其地下水質狀態，因此包括「天然過程」或「人為活動」都有可能影響與改變地下水的特性。在無「人為活動」下，地下水的特性主要反應天然過程的水岩交互作用，水岩交互作用將使地下水與其周遭固體礦物顆粒進行化學、生物或輻射物質的交換。而「人為活動」對於地下水特性的影響絕大多數來自地表面的相關人為活動所產生的化學、生物或輻射物質的故意排放或非故意的洩漏，因此地下水防護工作，首要的工作就是控制地面之可能化學、生物或輻射物質來源，避免故意排放或非故意的洩漏，則就無改變地下水特性之虞。

當發生地下水污染時，了解相關地下水化學、生物或輻射物質的遷移機制，掌握地下水中化學、生物或輻射物質分布範圍，對於地下水系統的防護非常重要。由於地下水系統是由固體的礦物顆粒疊組為骨架，在礦物顆粒疊組的骨架間就會形成許多相互連通或相互不連通的孔隙空間(pore space)，地下水則在相互連通的孔隙空間穿梭移動。目前對於地下水的遷移機制並未採微觀描述個別孔隙空間的穿梭移動行為，而係以巨觀的 Darcy 定律來描述地下水的流動行為，在 Darcy (1956)定律的基礎下，地下水的遷移行為主要以包括「移流(advection)」、「水力延散(hydrodynamic dispersion)」、「吸附(sorption」與「衰變(decay)」等 4 個主要機制來描述。其中，移流為溶質以平均滲流的遷移，延散則為地質異質性所造成的溶質遷移的分散行為，吸附則為溶質與固體礦物顆粒的結合、而衰變則為溶質因衰變或造成量的減少。

經由上述地下水特性遷移理論的基礎下，主要工作項目研究方法如下：

(1) 蒐集美國核電廠運轉與除役期間廠址地下水防護管制法規架構與業界導則文件，並據以研析運轉與除役核電廠在管制方向之差異性。

(2) 蒐集及彙整美國核電廠廠址地下水防護管制案例與經驗，並據以研析除役廠址相關規定與特定技術要項、重要參數。

本計畫已完成美國除役核電廠案例蒐集與彙整工作，包括(A)美國紐澤西州Oyster Creek核能發電廠1號機，(B)美國伊利諾州Dresden核能電廠與(C)美國伊利諾州錫安(Zion)核電廠。

(3) 研析美國核電廠廠址地下水防護管制法規與美國除役核電廠相關實務經驗，研提我國核電廠地下水防護管制架構之精進及管制技術要項之建議。

三、結果與討論

3-1 美國核電廠除役相關地下水防護管制法規

3-1-1 NRC 執照設施的地下水品質規範

(Regulation of Groundwater Quality at NRC Licensed Facilities, 網頁擷取時間 2020.11.01 https://www.nrc.gov/reactors/operating/ops-experience/grndwtr-quality-reg.html)

NRC 執照設施的地下水品質管制(Regulation of Groundwater Quality at NRC Licensed Facilities)

NRC 規範地下水品質，以保護公眾和環境規範的方案及活動提出具體內容。NRC 方案在地下水品質規範的差異來自於過去不同的監管規範歷史和立法方向。在某些地點與活動中，地下水品質是由美國環境保護署(U.S. EPA)或州政府所監管。除少數例外情況外，NRC 法規著重於放射性污染(radiological contamination)，而 EPA 或州政府對地下水品質的監管包括放射性和非放射性物質。所有 NRC 執照設施都經過審查和檢查，以確定設施設計和操作控制是否足以防止或減少污染物排放到地下水。

核反應器(Nuclear Reactors)

針對運轉中與新建核子反應器中，NRC 對廠址邊界內外核子反應器的放射性污染進行管制，在廠址邊界外和廠址邊界內的活動，EPA 或州政府對地下水品質進行規範。NRC 法規要求反應器持照人進行描述放射性廢水和輻射暴露，需維持在 NRC 法規規定的限值內，對於新建反應器要求儘量減少污染。要求對設施周圍環境進行地下水監測，以管控可能從正常運轉或事故中釋放的放射性。

除役核設施(Decommissioning Nuclear Facilities)

當持照人永久停止運轉並規劃進行執照終止時,必須提交"除役計畫"或"執照終止計畫"。這些計畫包括針對廠址狀況的完整描述,包括執照活動對地下水的任何放射性污染。計畫中必須描述如何清理地下水、土壤、人造結構和其他廠址特徵,使殘留污染的放射性劑量(radiological dose)符合 NRC 標準。此外,為了達到劑量要求,當一個採樣點的地下水濃度超過 EPA 的最高污染濃度時,NRC 與 EPA 將就廠址的整治情況相互協商。在廠址執照終止並以非限制性使用或限制性使用之前,NRC 會獨立驗證 NRC 所發執照廠址的殘餘放射性(residual radioactivity)是否符合執照終止的標準(approved release criteria)。

3-1-2 NRC 法規-美國聯邦法規 (Code of Federal Regulations,CFR)

美國核電廠除役工作的法律規範,主要由美國核能管制委員會(United States Nuclear Regulatory Commission,簡稱 U.S. NRC)訂定,美國核電廠在地下水防護亦需遵循美國環境保護署(United States Environmental Protection Agency,簡稱 U.S. EPA)與個別的州政府之規定。美國核管會監管電廠廠址及其周遭的地下水品質以保護公眾與環境,美國環境保護署或州政府則針對特定場址地點與活動監管其地下水品質。

NRC 與 EPA 在電廠運轉與除役活動之主要相關法規與導則中,與地下水防護之相關法規內容與規定,整理包括如下:

NRC 的法規在美國聯邦法規(Code of Federal Regulations,簡稱 CFR)中之主題 10"能源"之第一章(NRC regulations, Title 10, Chapter I, of the Code of Federal),第一章分為第 1 部分至 199 部分。第 20 部分(10 CFR Part 20)之次部分 E 提供除役作業的主要輻防要求,其他除役作業相關法規也包括 10 CFR part 20, 50, 70 與 72,地下水防護之相關內容重點摘錄與整理如表 3-1。

(1) 10 CFR Part 20 Standards for Protection Against Radiation

§ 20.1003 Definitions

定義殘餘放射性,包括地下水的放射性。

§ 20.1402 Radiological criteria for unrestricted use

除役後廠址非限制性使用之放射性準則:若殘餘放射性(不含背景輻射)包含來自地下水源的飲用水,對關鍵群體之平均成員所造成的總有效等效劑量,不超過每年 0.25 毫西弗,且殘餘放射性已降至合理抑低的程度時,除役後廠址可被考慮接受為非限制性使用。決定合理抑低程度時,必須把任何可能因除污及廢棄物處置所導致之潛在損傷列入考量。

(2) 10 CFR Part 50 Domestic Licensing of Production and Utilization Facilities

§ 50.55 Conditions of construction permits, early site permits, combined licenses, and manufacturing licenses.

§ 50.55a Codes and standards

針對建造執照之規範標準中對接觸地下土壤、回填或地下水的難以接近的地下混凝土表面進行技術評估，其間隔不得超過 5 年。

§ 50.83 Release of part of a power reactor facility or site for unrestricted use

修訂了環境監測計畫和廠址外的劑量計算手冊，以符合廠址作為非限制性使用。

(3) 10 CFR Part 70 Domestic Licensing of Special Nuclear Material

§ 70.38 Expiration and termination of licenses and decommissioning of sites and separate buildings or outdoor areas

廠址除役執照的相關要求之一，委員會可視情況而定之其他具體地點因素，其中包括如地下水處理活動、自然地下水恢復的監測、可能比推遲清理造成更大環境損害的行動，以及持照人無法控制的其他因素。

(4) 10 CFR Part 72 Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, And Reactor-Related Greater Than Class C Waste

§ 72.30 Financial assurance and recordkeeping for decommissioning

如果在 10 CFR 20.1501(a)下進行的調查中，土壤或地下水中的殘餘放射性檢測程度，要求將這種放射性減少到允許根據本章第 20 部分的除役要求釋放非限制性使用的程度，持照者必須在調查完成後一年內提交新的或修訂的資金計畫。

§ 72.44 License conditions

建立環境監測方案，確保符合廢水的技術規範。根據第 72.4 條向委員會提交年度報告，具體說明在過去 12 個月作業期間，以液體和氣態廢水釋放至環境的每一種主要放射性核種的濃度，以及委員會可能要求的其他資料，以估計排放污水對公眾的最大潛在輻射劑量承諾。根據提交的年度報告和委員會可能從持照人或其他方面獲得的任何補充資料，委員會可適時要求持照者採取委員會認為適當的行動。年度報告必須在 12 個月監測期結束后 60 天內提交。

§ 72.54 Expiration and termination of licenses and decommissioning of sites and separate buildings or outdoor areas.

委員會可核准除役的時程表的申請，並批准終止執照，其中之一委員會可根據具體情況認為適當的其他具體地點因素，如其他政府機構的管制要求、訴訟、地下水處理活動、自然地下水恢復的監測、可能導致比延遲拆除更多的環境損害的行動，以及持照者無法控制的其他因素。

表 3-1 NRC 聯邦法規彙編 10 CFR 相關地下水防護

Regulations	
Chapter I of Title 10, "Energy," of the *Code of Federal Regulations* (CFR)	
Part 20 - STANDARDS FOR PROTECTION AGAINST RADIATION	
§ 20.1003 Definitions.	*Rem* (See § 20.1004). *Residual radioactivity* means radioactivity in structures, materials, soils, groundwater, and other media at a site resulting from activities under the licensee's control. This includes radioactivity from all licensed and unlicensed sources used by the licensee, but excludes background radiation. It also includes radioactive materials remaining at the site as a result of routine or accidental releases of radioactive material at the site and previous burials at the site, even if those burials were made in accordance with the provisions of 10 CFR part 20.
Subpart E—Radiological Criteria for License Termination § 20.1402 Radiological criteria for unrestricted use	A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem (0.25 mSv) per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA). Determination of the levels which are ALARA must take into account consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal.
Part 50 - DOMESTIC LICENSING OF PRODUCTION AND UTILIZATION FACILITIES	
§ 50.55 Conditions of construction permits, early site permits, combined licenses, and manufacturing li-censes. § 50.55a Codes and standards	(I) *Concrete containment examinations: Ninth provision*. During the period of extended operation of a renewed license under part 54 of this chapter, the licensee must perform the technical evaluation under IWL–2512(b) of inaccessible below-grade concrete surfaces exposed to foundation soil, backfill, or groundwater at periodic intervals not to exceed 5 years. In addition, the licensee must examine representative samples of the exposed portions of the below-grade concrete, when such below-grade concrete is excavated for any reason.
§ 50.83 Release of part of a power reactor facility or site for unrestricted use	(a) Prior written NRC approval is required to release part of a facility or site for unrestricted use at any time before receiving approval of a license termination plan. Section 50.75 specifies recordkeeping requirements associated with partial release. Nuclear power reactor licensees seeking NRC approval shall— (1) Evaluate the effect of releasing the property to ensure that-- (i) The dose to individual members of the public does not exceed the limits and standards of 10 CFR Part 20, Subpart D; (ii) There is no reduction in the effectiveness of emergency planning or physical security; (iii) Effluent releases remain within license conditions; (iv) The environmental monitoring program and offsite dose calculation manual are revised to account for the changes; (v) The siting criteria of 10 CFR Part 100 continue to be met; and (vi) All other applicable statutory and regulatory requirements continue to be met.
Appendix A to Part 50—General Design Criteria for Nuclear Power Plants	*VI. Fuel and Radioactivity Control* *Criterion 60—Control of releases of radioactive materials to the environment*. The nuclear power unit design shall include means to control suitably the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences. Sufficient holdup capacity shall be provided for retention of gaseous and liquid effluents containing radioactive materials, particularly where unfavorable site environmental conditions can be expected to impose unusual operational limitations upon the release of such effluents to the environment.
Part 70 - DOMESTIC LICENSING OF SPECIAL NUCLEAR MATERIAL	

§ 70.38 Expiration and termination of licenses and decommissioning of sites and separate buildings or outdoor areas	(i) The Commission may approve a request for an alternate schedule for completion of decommissioning of the site or separate building or outdoor area, and license termination if appropriate, if the Commission determines that the alternative is warranted by consideration of the following: (1) Whether it is technically feasible to complete decommissioning within the allotted 24-month period; (2) Whether sufficient waste disposal capacity is available to allow completion of decommissioning within the allotted 24-month period; (3) Whether a significant volume reduction in wastes requiring disposal will be achieved by allowing short-lived radionuclides to decay; (4) Whether a significant reduction in radiation exposure to workers can be achieved by allowing short-lived radionuclides to decay; and (5) Other site-specific factors which the Commission may consider appropriate on a case-by-case basis, such as regulatory requirements of other government agencies, lawsuits, groundwater treatment activities, monitored natural groundwater restoration, actions that could result in more environmental harm than deferred cleanup, and other factors beyond the control of the licensee.
Part 72 - LICENSING REQUIREMENTS FOR THE INDEPENDENT STORAGE OF SPENT NUCLEAR FUEL, HIGH-LEVEL RADIOACTIVE WASTE, AND REACTOR-RELATED GREATER THAN CLASS C WASTE	
§ 72.30 Financial assurance and recordkeeping for decommissioning	(d) If, in surveys made under 10 CFR 20.1501(a), residual radioactivity in soils or groundwater is detected at levels that would require such radioactivity to be reduced to a level permitting release of the property for unrestricted use under the decommissioning requirements in part 20 of this chapter, the licensee must submit a new or revised decommissioning funding plan within one year of when the survey is completed.
§ 72.44 License conditions	(d) Each license authorizing the receipt, handling, and storage of spent fuel, high-level radioactive waste, and/or reactor-related GTCC waste under this part must include technical specifications that, in addition to stating the limits on the release of radioactive materials for compliance with limits of part 20 of this chapter and the "as low as is reasonably achievable" objectives for effluents, require that: (1) Operating procedures for control of effluents be established and followed, and equipment in the radioactive waste treatment systems be maintained and used, to meet the requirements of § 72.104; (2) An environmental monitoring program be established to ensure compliance with the technical specifications for effluents; and (3) An annual report be submitted to the Commission in accordance with Sec. 72.4, specifying the quantity of each of the principal radionuclides released to the environment in liquid and in gaseous effluents during the previous 12 months of operation and such other information as may be required by the Commission to estimate maximum potential radiation dose commitment to the public resulting from effluent releases. On the basis of this report and any additional information that the Commission may obtain from the licensee or others, the Commission may from time to time require the licensee to take such action as the Commission deems appropriate. The report must be submitted within 60 days after the end of the 12-month monitoring period.
§ 72.54 Expiration and termination of licenses and decommissioning of sites and separate buildings or outdoor areas.	(k) The Commission may approve a request for an alternate schedule for completion of decommissioning of the site or separate building or outdoor area, and license termination if appropriate, if the Commission determines that the alternate schedule is warranted by consideration of the following: (1) Whether it is technically feasible to complete decommissioning within the allotted 24-month period; (2) Whether sufficient waste disposal capacity is available to allow completion of decommissioning within the allotted 24-month

	period; (3) Whether a significant volume reduction in wastes requiring disposal will be achieved by allowing short-lived radionuclides to decay; (4) Whether a significant reduction in radiation exposure to workers can be achieved by allowing short-lived radionuclides to decay; and (5) Other site-specific factors that the Commission may consider appropriate on a case-by-case basis, such as regulatory requirements of other government agencies, lawsuits, groundwater treatment activities, monitored natural groundwater restoration, actions that could result in more environmental harm than deferred cleanup, and other factors beyond the control of the licensee.

針對美國 10 CFR 法規對除役核電廠之相關管制規定與管制方向，重點項目評析如下：

(1) 未來地下水可能作為飲用水水源時，殘餘放射性對一般人造成之年有效劑量值(TEDE)不超過 25 mrem (0.25 mSv)之標準，經查國內核子反應器設施管制法施行細則已有相同規定。

(2) 有關核電廠在進行初步相關環境監測與地下水監測之調查，提交監測方案，並且每一年向主管機關提交年度報告，說明液體及氣態廢水釋放至環境每一種主要放射性核種濃度，以估計排放污水對公眾最大潛在輻射劑量。此部分經查國內各核能電廠已建立地下水防護(監測)方案，每季陳報廠區之地下水監測結果，並依輻防法規，將環境及地下水之監測結果分別納入環境監測報告與輻射安全報告，每年提報原能會。

(3) 有關主管機關可視廠址因素情況，決定除役許可條件，如地下水處理與監測、延後拆除造成環境影響評估等，以及核准除役時程表、批准終止執照等。經查，國內相關法規，如核子反應器設施管制法與施行細則、核子反應器設施除役許可申請審核及管理辦法及除役計畫導則等，已有對應規定。

3-1-3 NRC 針對運轉中電廠地下水防護的相關資訊

U.S. NRC 針對運轉中之電廠為防範地下水污染，列出 U.S. NRC 和 U.S. EPA 對地下水和環境監測的安全要求之相關法規要求清單如表 3-2。

（網頁擷取時間 2020.11.01 https://www.nrc.gov/reactors/operating/ops-experience/tritium/safety-requirements.html）

表 3-2 NRC 和 EPA 對地下水和環境監測的安全要求之相關法規要求清單

NRC Regulatory Requirements	
• 10 CFR Part 20 • 10 CFR Part 50 Appendix A; • 10 CFR Part 50, Appendix A;	Standards for Protection Against Radiation Design Criteria 60, Control of Releases of Radioactive Materials to the Environment. Design Criteria 64, Monitoring Radioactivity Releases.
Regulatory Guide 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 (Rev. 1, 10/75)
Regulatory Guide 1.21	Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants. (Rev. 1, 6/74)
Regulatory Guide 1.143	Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants. (Rev. 2, 11/01)
Regulatory Guide 4.1	Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants. (1/73)
Regulatory Guide 4.2	Preparation of Environmental Reports for Nuclear Power Stations. (Rev. 2, 7/76)
Regulatory Guide 4.8	Environmental Technical Specifications for Nuclear Power Plants (12/75) and Branch Technical Position (Rev. 1, 11/79; specific to environmental monitoring program).
Regulatory Guide 4.15	Quality Assurance for Radiological Monitoring Program (Normal Operation) - Effluent Streams and the Environment.
• NUREG-0472 • NUREG-0473	• Radiological Effluent Technical Specifications for PWRs. (2/80) Radiological Effluent Technical Specifications for BWRs. (7/79)
EPA Regulations	

• 40 CFR Part 190,	• Environmental Radiation Protection Standards for Nuclear Power Operations. (1/77)

NRC 針對運轉中電廠地下水的相關主題，包括地下水中之放射性核種(包括 Tritium, Strontium-90)、放射性廢水與環境報告與地下水中含有放射性物質的電廠廠址，NRC 針對運轉中的電廠透過管制、導則等規範管理電廠，其中針對地下水中含有放射性物質的電廠廠址，美國 NRC 法規要求核電廠必須檢查廠址和環境中是否存在放射性物質、持照者定期檢查其廠址與環境中是否存在放射性物質。

2018 年 9 月更新之核電廠洩漏與傾洩之名單(List of Leaks and Spills at Nuclear Power Plants)，美國目前有 57 個運轉中核電廠，其中記錄顯示 40 個廠址曾發生一次洩漏或傾洩，其洩漏或傾洩氚(tritium)濃度大於或等於 20,000 pCi/L。目前有 9 個採樣點的報告紀錄地下水洩漏的氚超過 20,000 pCi/L。目前在環境或飲用水中未檢測到超過 20,000 pCi/L 的地下水中的氚。氚在環境中會迅速散開和消散，因此，在廠址邊界外通常未檢測到洩漏產生的氚，由於洩漏或傾洩停止後，氚濃度通常會快速降低，因此 NRC 工作人員定期更新此名單，以反應廠址的現況。

地下水的樣本是自現場地點採集並分析包括飲用水井和非飲用水取樣點(例如：地下水監測井、雨水渠、人孔、孔洞、壓電計管、地表水、水坑和雨水)，雖然清單中的某些氚濃度測值超過 20,000 pCi/L，但不曾從飲用水井或都市飲用水系統收集到這些樣本。從飲用水井和市政飲用水系統收集的樣本，均未超過 EPA 的 20,000 pCi/L 飲用水標準，目前所有地下水污染情況，都沒有超過 NRC 的劑量限值(dose limits)或持照者的技術規範限值(licensee's Technical Specification Limits)。

NRC 規定要求對核電廠的所有放射性物質排放進行適當監測，持照者向 NRC 報告放射性物質之排放和所有地下水監測工作的結果。欲掌握了解美國核電廠與地下水分和地下水中的放射性物質的更多資訊，可參閱核電廠的年度報告(Radioactive Effluent and Environmental Reports , REEP)。

針對放射性排放水與環境報告(REEP)，核電廠必須提交兩份年度報告，包括：

(1) 排放水報告(Effluent Report)，

(2) 環境報告(Environmental Report)。

年度報告中排放水報告列出年度從該廠址釋放的液體和氣體排放的放射性物質的濃度，此份報告實際上是根據美國聯邦法規(10 CFR 50.36a)的要求提交的年度放射性排放報告(Annual Radioactive Effluent Release Report, ARERR)。環境報告則列出在發電廠周圍環境中發現的放射

性物質的測量值，此報告係根據美國聯邦法規的要求提交的年度輻射環境運轉報告(Annual Radiological Environmental Operating Report, AREOR)。

3-2 NEI07-07「業界地下水防護倡議-指引文件」2007 年版與 2019 年版比較

NEI 在 2019 年更新 2007 年公布之 NEI07-07「業界地下水防護倡議-指引文件」，修訂目的是根據十多年來運轉經驗、進行評估及審查，以及美國電力研究所((Electric Power Research Institute, EPRI)制訂技術指引來進行更新。兩版本主要差異比較如表 3-3，摘要重點如下:

(1) 「目的 1.1: 場址水文與地質」中，除 2007 年版核電廠目前廠址條件之水文以及地質特性調查(包含主要地下水梯度特性資訊)外，2019 年版增加以此特性建立概念場址模式(Conceptual Site Model, CSM)，因此當核電廠水文或地質特性改變時，除原先須進行廠址最終安全分析報告外，2019 年版增加須更新 CSM。

(2) 「目的 1.2：廠址風險評估」中，2019 年版增加個人工作作業中避免放射性物質污染地下水的可信機制，建議進行預防性保養，以減少因裝置失效導致放射性物質意外釋放至地下水的可能性，另刪除 2007 年版有關長期計畫建立，以執行預防性維護或監督活動內容。

(3) 「目的 1.3：地下水監測」中，2019 年版增加水樣及土樣之品保概念，以及水或空氣中放射性物質可偵測水準之可能性，強調地下水井建置的位置要儘可能在最可能發生洩漏之系統、結構、組件(Systems, Structures, and Components, SSC)附近，並須確認監測地下水中之放射性物質之遷移狀況，另將 2007 年版與利益關係人溝通內容移至第二個單元「溝通」。

(4) 「目的 1.4：整治作業」中，2019 年版增加，以 EPRI 已發展之“核電廠土壤及地下水整治方案(Soil and Groundwater Remediation Guidelines for Nuclear Power Plants)”技術指引文件，協助進行評估和記錄整治作業對核電廠除役之影響。

(5) 「目的 1.5：記錄保存」之內容，2019 年版並無修改。

(6) 「目的 1.6 除役/安全貯存影響」，此部分係在 2019 年版內容中新增，考量近十多年來美國許多核電廠陸續進行除役，重點包括(A)對於目前正在進行或參與除役工作或延遲拆除的廠址，評估這些工作對於地下水防護之影響，(B)當核電廠停止運轉後除役活動報告及執照終止計畫，須以書面程序概述建立或改變地下水相關管制文件內容，(C)當廠址條件或程序規劃變更時(如 SSC、操作風險評估及其他任何 CSM 改變)，評估地下水監測計畫修正之必要性，(D)美國 EPRI 已發展「除役計畫的地下水監測指引(Groundwater Monitoring Guidance for Decommissioning Planning)」提供核電廠從運轉至除役過程中地下水監測規劃。

(7) 「目的 2.2 :自願性溝通」中，2019 年版新增:(A)新增且重大的廠內洩漏、傾洩至地下水，若為同一來源/機制/事件時，不須進行自願性溝通，但該文件記錄應可供利益關係人審查。(B)若 24 小時內可回收及整治的洩漏、傾洩，無須進行溝通。(C)若在 24 小時內收集或整

治傾洩或洩漏且不會進入地下水，不須進行自願性溝通協議。(D)電廠與當地政府協議或溝通，必須以書面方式提供利益關係人查閱。

(8) 「目的 2.4:年度報告」中，2019 年版新增 2008 年後興建的核電廠，在初次燃料裝填之前，建議參考 NEI08-08 進行重要廠內洩漏及傾洩進入地下水與發展及實施所有地下水結果適當程序。另對於洩漏或傾洩的溝通描述，除 2007 版須記錄於 ARERR(Annual Radioactive Effluent Release Report, ARERR)外，2019 年版增加可記錄於 AREOR(Annual Radiological Environmental Operating Report, AREOR)報告中。

(9) 「目的 3.1：方案自我評估與審查」中，2019 年版修改為“維持地下水防護方案有效的監督”。

(10)「目的 3.2：在 NEI 的協助下審查此方案」部分，在 2019 年版本中刪除。

參考來源如下：

- NEI 07-07, Industry Ground Water Protection Initiative - Final Guidance Document, August 2007.
- NEI 07-07, Industry Groundwater Protection Initiative - Final Guidance Document, Revision 1 March 2019.

我國核電廠陸續開始除役，除役過程建議將 2019 年更新之 NEI07-07「業界地下水防護倡議-指引文件」納入考量，依據該文件之重要內容，檢視核電廠除役期間相關作業可進一步精進之作法，特別針對地下水防護方案中之重點項目評析如下：

(1) 依據目的 1.1 場址水文與地質

- 核電廠除調查目前場址之主要地下水梯度資訊等水文及地質特性外，另依據廠址特性建立完整之概念場址模式(CSM)，作為未來規劃地下水防護之重要基礎。
- 除了釐清地下水設施廠區及/或廠外地下水潛在流動途徑，進一步確認了解核種遷移可能。

(2) 依據目的 1.2 廠址風險評估

對於運轉中核電廠或進行除役工作，應評估電廠設計及工作作業可能對於地下水防護之影響，以及任何核電廠所有 SSC 及個人工作作業可能造成放射性污染物質到達地下水之可信機制。各運轉中核電廠應建立定期檢驗 SSC 及工作作業之週期，進行防護性保養或監視行動，以減少因裝置失效導致放射性物質意外釋放至地下水可能。

(3) 依據目的 1.3 場址內地下水監測

考量視需要增加地下水井監測井數，加強監測井建置位置須確保可監測地下水中放射性物

質之遷移。在核電廠內最可能發生洩漏 SSC 或 SSC 洩漏偵測能力有限之地下水流下游處，建置長期地下水監測井及監測計畫，提高監測放射性物質洩漏到地下水之可能性。

(4) 依據目的 1.4 整治作業與目的 1.5 記錄保存

參考 EPRI“核電廠土壤及地下水整治指引”技術指引，協助評估及記錄整治作業對核電廠除役工作之影響。

建立書面整治規範，詳細記錄保留整治洩漏、傾洩或其他污染意外釋出實例之應變決策過程，以防止放射性物質污染物廠外遷移及減少核電廠除役之影響。

(5) 依據目的 1.6 除役/安全貯存影響

參考 EPRI 已發展之「除役計畫之地下水監測指引(Groundwater Monitoring Guidance for Decommissioning Planning)」，提供核電廠從運轉至除役過程中之地下水監測規劃。

(6) 依據目的 1.6 除役的影響

對於目前正在進行或參與除役工作之廠址，評估除役工作對於地下水防護之影響。包括：(A)建立停止運轉後除役活動報告書面文件，以建立或改變地下水相關程序，(B)當廠址條件或程序規劃或改變時，評估何種措施會影響地下水防護、SSC、工作實務風險評估及 CSM 可反映目前條件，若有改變，評估修正地下水監測計畫。當廠址完成地下水放射性物質整治或滿足地下水防護狀態時，確認地下水防護適當性。

(7) 依據第二單元「溝通」

為增加社區居民、公眾及國家對於達成輻射安全與環境保護高標準核電安全之承諾及信心，核電廠應依據 NEI07-07 進行下列項目，(A)對於政府主管機關進行廠址地下水防護倡議定期簡報，(B)對於廠內重大洩漏、傾洩至地下水事件，造成地下水水樣監測結果超過水質標準，應與政府主管機關官員及其他利益關係人進行非正式溝通，並以洩漏、傾洩量或事件嚴重性建立各電廠自願性溝通規範，(C)對於場址地下水水質檢測結果任何一項超過水質標準，核電廠須在 30 日內向政府主管機關提交報告，(D)當核電廠初次裝填核燃料起，每年應報告記錄廠內地下水放射性物質採樣結果，以及廠內重大洩漏及傾洩進入地下水事件之描述，另外與政府官員及其他利益關係人進行溝通內容亦須包含於年度報告。

(8) 依據第三單元方案「監督」

建立自我評估與審查機制，以確保地下水防護方案有效的施行：(A)核電廠在初次臨界後的一年內，應進行初次自我評估，(B)進行定期之地下水防護倡議方案程序性評估，(3)程序性評估應該包括 NEI07-07 所有目的評估，且程序及方案文件記錄應保持一致，可使用「附錄 B:

自我評估清單」逐項檢視核電廠除役程序是否符合地下水防護倡議之規範，定期進行與審視地下水監測計畫，以減少核電廠放射性物質意外排放至地下水層之機會。

表 3-3 NEI07-07「業界地下水防護倡議-指引文件」2007 年版與 2019 年(修正版)比較

NEI07-07「業界地下水防護倡議-指引文件」 March 2019	NEI07-07「業界地下水防護倡議-指引文件」 August 2007	說明
執行摘要 NEI 在 2007 年公布 NEI07-07"業界地下水防護倡議-指引文件"， NEI 07-07 已實施超過 10 年，在這段時間裡，業界地下水防護方案已經成熟，並且在NEI的主持下進行了多次自我評估及兩次審核。此外，NRC 根據檢查程序 71124.07"放射性環境監測程序"，在其一般日常檢查過程中增加了對地下水防護方案審查。本次修訂的目的是根據這些年來操作經驗、進行評估及審查，以及電力研究所(EPRI)製訂技術指引來更新 NEI07-07。 註：在 2009 年 3 月 26 日美國地質學會（USGS）的備忘錄中，改變使用單個單詞"groundwater"取代兩個單詞"ground water"， NEI 07-07 的 2019 修訂版將使用一個單詞 Groundwater 表達，除非原始參考文檔中使用了兩個單詞的版本。	**執行摘要**	2019 年版增加 NEI07-07 提出 10 多年後更新修訂之目的
NEI 07-07 是為了描述業界地下水防護倡議而發展，地下水防護倡議以行動改善公共事業管理及對於放射性物質意外釋出導致地下土壤及地下水水中具有核電廠相關物質，其含量雖低，但可被檢測出。該倡議解決意外釋放發生，超出美國核能監管委員會（NRC）當前要求，且遠低於 NRC 確保公眾健康保護及安全的限	NEI 07-07 是為了描述業界地下水防護倡議而發展，地下水防護倡議以行動改善公共事業管理及對於放射性物質意外釋出導致地下土壤及地下水水中具有核電廠相關物質，其含量雖低，但可被檢測出。該倡議解決意外釋放發生，超出核能監管委員會（NRC）當前要求，且遠低於 NRC 確保公眾健康保護及安全的限制。根	

制。根據 NRC 的規定，進行計畫內液體和空氣釋放措施，不屬於該倡議或本文檔的範圍。該倡議還包括有關公用事業應如何與利益關係人進行溝通的指引。 地下水防護倡議確定實施及時與有效地下水防護計畫所需行動，此外，明確說明目的，且完成每項操作接受標準，以證明已達到目的。如果持照人與利益關係人達成的溝通協議與本文檔中指引有所不同，則應記錄該差異並將其保留為電廠記錄的一部分。 預計該倡議將在 2006 年之後由目前正在運轉或除役的每個核電廠公司，以及每個新建核電站公司實施。如果頒布了新的或經修訂的 NRC 法規以解決地下水防護問題或意外釋放放射性液體，應由核能策略問題諮詢委員會重新審議該倡議。	據 NRC 的規定，進行計畫內液體和空氣釋放措施，不屬於該倡議或本文檔的範圍。該倡議還包括有關公用事業應如何與利益關係人進行溝通的指南。 地下水防護倡議確定實施及時與有效地下水防護計畫所需行動，此外，明確說明目的，且完成每項操作接受標準，以證明已達到目的。如果持照人與權益相關者達成的溝通協議與本文檔中指南有所不同，則應記錄該差異並將其保留為電廠記錄的一部分。 預計該倡議將在 2006 年之後由目前正在運轉或除役的每個核電廠公司，以及每個新建核電站公司實施。如果頒布了新的或經修訂的 NRC 法規以解決地下水防護問題或意外釋放放射性液體，應由核能策略問題諮詢委員會重新審議該倡議。	
目錄 執行摘要 簡介 目的 背景 一、地下水防護方案 目的 1.1：場址水文與地質 目的 1.2：廠址風險評估 目的 1.3：場址內地下水監測 目的 1.4：整治作業 目的 1.5：記錄保存 目的 1.6：除役/安全貯存影響 二、溝通 目的 2.1 利益關係人簡報 目的 2.2 自願性溝通 目的 2.3 三十日報告 目的 2.4 年度報告	**目錄** 執行摘要 簡介 目的 背景 一、地下水防護方案 目的 1.1：場址水文與地質 目的 1.2：廠址風險評估 目的 1.3：場址內地下水監測 目的 1.4：整治作業 目的 1.5：記錄保存 二、溝通 目的 2.1 利益關係人簡報 目的 2.2 自願性溝通 目的 2.3 三十日報告 目的 2.4 年度報告	2019 年版增加目的 1.6，更改目的 3.1，刪減目標 3.2

三、方案監督 目的 3.1 方案自我評估與審查 詞彙表 附件 1. 附件 2. 附錄 A 附錄 B	三、方案監督 目的 3.1 **執行**自我評估 **目標 3.2：在 NEI 的協助下審查這項方案** 詞彙表 附件 1. 附件 2. 附錄 A 附錄 B	
簡介 已經發生了核電廠及持照人檢測到因意外對土壤和/或地下水釋出放射性物質，而造成污染的事件。雖然未發現任何實例威脅到公共健康及安全或環境保護，但當地利益關係人對此事非常關注。根據業界地下水防護倡議(GPI)，要求運轉中或除役核電廠的每個公司成員都要製訂並實施針對特定廠址/公司的地下水防護計畫，以確保即時有效地管理涉及放射性物質*意外釋放到地下水*的情況，並在 2006 年 7 月 31 日之前實施自願性溝通*計畫。在 2006 年之後新建造每個電廠公司成員都將制定適當的廠址程序及/或程序，以符合 GPI，並在初次燃料裝填之前，實施這些程序。一個有效的、技術上正確的地下水防護計畫需要進行持續審查和評估。	**簡介** 過去十年中，已經發生了核電廠及持照人檢測到因意外對土壤和/或地下水釋出放射性物質，而造成污染的事件。雖然未發現任何實例威脅到公共健康及安全或環境保護，但當地利益關係人對此事非常關注。根據業界地下水防護倡議(GPI)，要求運轉中或除役核電廠的每個公司成員都要製訂並實施針對特定廠址/公司的地下水防護計畫，以**保證**即時有效地管理涉及放射性物質*意外釋放到地下水*的情況，並在 2006 年 7 月 31 日之前實施自願性溝通*計畫。在 2006 年之後新建造每個電廠公司成員都**應**制定適當的廠址程序及/或程序，以符合 GPI，並在初次**接收核燃料**之前，實施這些程序。一個有效的、技術上正確的地下水防護計畫**至少進行一年以上實施及**持續審查和評估。	兩版本大致上一致，僅文字上修正，刪除地下水防護計畫**至少進行一年以上實施**
目的 業界地下水防護倡議將幫助持照人： 1.改善涉及放射性洩漏進入地下水情況之管理。 2.改善與外部利益關係人溝通，以增強當地社區、國家、NRC 及大眾對核電業界高標準輻射安全和環境保護的承諾、信任和信心。	**目的** 業界地下水防護倡議將幫助持照人： 1.改善涉及放射性洩漏進入地下水情況之管理。 2.改善與外部利益關係人溝通，以增強當地社區、國家、NRC 及大眾對核電業界高標準輻射安全和環境保護的承諾、信任和信心。	兩版本完全一致

本業界倡議僅適用於電廠運轉產生的放射性物質。	本業界倡議僅適用於電廠運轉產生的放射性物質。	
背景 要求核電廠持照人控制及監視放射性液體及空氣物質釋放，以確保它們保持在管制標準之下，並且不會對公共健康及安全構成威脅。隨著時間流逝，持照人逐漸減少對環境排放，因此，由於這些排放受到一定的控制，居住在這些設施附近的人每年不會受到超過 1 毫侖目劑量。持照人建立此方案及程序仔細控制放射性物質，但是放射性物質有時會發生洩漏及傾洩事件，並且設備可能會發生故障。隨著電廠在 1990 年代末至 2000 年代初開始除役，發現了地下及/或地下水污染的實例。此外，一些運轉設備由於傾洩、洩漏或設備故障而導致地下水污染。在某一案例中，位於核電廠附近建物內一口私人井中發現低劑量放射性物質。 業界意識到儘管這些意外釋出本身並不是重大公共衛生問題，但這些意外污染的情況仍構成了公眾信心挑戰。 2006 年 5 月，美國商業核電廠通過核能研究所(NEI)地下水防護倡議(GPI)(附件 1)。 NEI 的核能策略議題諮詢委員會(NSIAC)一致投票通過實施這些自願性措施，以最大程度減少放射性液體意外釋放到環境中的可能性，並增強公眾對核電業信任和信心。 NRC 另一項工作為成立液體放射性釋放經驗教訓特別工作組，以評估動力反應爐廠址放射性液體向環境意外釋出， NRC 於 2006 年 7 月 10 日發布了訊息通告 2006-13“由於未發現放射性水體洩漏造成的地下	**背景** 要求核電廠持照人控制及監視放射性液體及空氣物質釋放，以確保它們保持在管制標準之下，並且不會對公共健康及安全構成威脅。隨著時間流逝，持照人逐漸減少對環境排放，因此，由於這些排放受到一定的控制，居住在這些設施附近的人每年不會受到超過 1 毫侖目劑量。持照人建立此方案及程序仔細控制放射性物質，但是放射性物質有時會發生洩漏及傾洩事件，並且設備可能會發生故障。隨著電廠在 1990 年代末至 2000 年代初開始除役，發現了地下及/或地下水污染的實例。此外，一些運轉設備由於傾洩、洩漏或設備故障而導致地下水污染。在某一案例中，位於核電廠附近建物內一口私人井中發現低劑量放射性物質。 業界意識到儘管這些意外釋出本身並不是重大公共衛生問題，但這些意外污染的情況仍構成了公眾信心挑戰。 2006 年 5 月，美國商業核電廠通過核能研究所(NEI)地下水防護倡議(GPI)(附件 1)。 NEI 的核能策略議題諮詢委員會一致投票通過實施這些自願性措施，以最大程度減少放射性液體意外釋放到環境中的可能性，並增強公眾對核電業信任和信心。 NRC 另一項工作為成立液體放射性釋放經驗教訓特別工作組，以評估動力反應爐廠址放射性液體向環境意外釋出， NRC 於 2006 年 7 月 10 日發布了訊息通告 2006-13“由於未發現放射性水體洩漏造成的地下	兩版本幾乎完全一致

水污染”，總結對未發現設施結構洩漏而多處設施地下水放射性污染的調查，儲存或運輸放射性流體的系統或組件，指示持照人檢查該訊息是否適用於其設施，並審慎考慮採取措施，以避免類似的問題。 NRC 工作組的最終報告於 2006 年 9 月 1 日公布，其中包括 26 項建議，供 NRC 進一步審議。 該報告指出: 專案小組最重要結論是對公共衛生的影響，儘管在許多核電業事件中，放射性液體未經計畫及不受監控地釋放到環境中，但根據現有數據，並未發現任何影響公眾健康的情況。 核能提供了當今社會所需大部分電力，並且必須成為未來多樣化發電組合的一部分，有助於減少國家對化石燃料的依賴，以及減少溫室氣體的排放。每個核電廠持照人都自願實施 “地下水防護倡議”，並將在將來持續做，因為他們意識到公眾信賴及信任對於其設施持續成功運轉至關重要。	水污染”，總結對未發現設施結構洩漏而多處設施地下水放射性污染的調查，儲存或運輸放射性流體的系統或組件，指示持照人檢查該訊息是否適用於其設施，並審慎考慮採取措施，以避免類似的問題。 NRC 工作組的最終報告於 2006 年 9 月 1 日公布，其中包括 26 項建議，供 NRC 進一步審議。 該報告指出: 專案小組最重要結論是對公共衛生的影響，儘管在許多核電業事件中，放射性液體未經計畫及不受監控地釋放到環境中，但根據現有數據，並未發現任何影響公眾健康的情況。 核能提供了當今社會所需大部分電力，並且必須成為未來多樣化發電組合的一部分，有助於減少國家對化石燃料的依賴，以及減少溫室氣體的排放。每個核電廠持照人都自願實施 “地下水防護倡議”，並將在將來持續做，因為他們意識到公眾信賴及信任對於其設施持續成功運轉至關重要。	
一、地下水防護方案 **行動 1: 對於意外釋放的放射性物質至地下水進行情況改善之管理** 為了避免放射性物質在核電廠區外遷移及量化除役之影響，地下水防護倡議方案內容主要目的是對於放射性物質意外釋放至地下水確保即時預測及有效反應，該程序須明確敘述每一項程序條件與頻率，以確保了解放射性物質洩漏及傾洩發生之可能，以及設備老化狀況。美國電力研究所 (Electric Power Research Institute，EPRI)已發展關於核電廠地下水防護計畫實施指引以符合行動 1，EPRI 針對核電廠地下水防護指引	**一、地下水防護方案** **行動 1: 對於意外釋放的放射性物質至地下水進行情況改善之管理** 為了避免放射性物質在核電廠區外遷移及量化除役之影響，地下水防護倡議方案內容主要目的是對於放射性物質意外釋放至地下水**保證**即時預測及有效反應，該程序須明確敘述每一項程序條件與頻率，以確保了解放射性物質洩漏及傾洩發生之可能，以及設備老化狀況。美國電力研究所 (Electric Power Research Institute，EPRI)**正在財務支持**發展關於核電廠地下水防護計畫實施指引以符合行動 1，EPRI 針對核電廠**實施**	2019 年版 ERPI 發展核電廠地下水防護計畫敘述略為修改

文件目的是說明如何控制放射性物質、最小化意外之放射性物質釋放至環境及最小化地下水污染長期花費。	地下水防護**方案**指引目的是說明如何控制放射性物質、最小化意外之放射性物質釋放至環境及最小化地下水污染長期花費。	
目的 1.1：場址水文與地質 此目的主要是進行核電廠目前場址條件之水文以及地質特性調查，包含主要地下水梯度特性資訊，此特性為場址概念模式(CSM)建立基礎。 接受標準： 註：第 a-c 項接受標準頃向於確保建立一個適當 CSM，因此如果該廠區已有 CSM，則進行第 d 項接受標準 a. 進行水文地質及地質調查研究，以確定主要的地下水流動特性和梯度。 b. 視情況必要性，審查現有水文地質、地質、歷史環境研究、核電廠允許或執照之相關報告。 c. 釐清地下水設施廠區及/或廠外地下水潛在流動途徑，以確認了解核種遷移可能。 d. 建立定期審查廠址水文地質研究的週期，至少只要發生以下任何一種情況，都應執行廠址審視： 1. 廠區內大量施工。 2. 廠址特性受到嚴重干擾。 3. 廠址內或廠外附近地區地下水使用行為重大改變。 4. 廠址內或廠外附近地區地下水抽水率明顯改變。 e. 視情況必要性，隨水文或地質特性的改變，更新場址概念模式及場址最終安全分析報告。	**目的 1.1：場址水文與地質** 此目的主要是進行核電廠目前場址條件之水文以及地質特性調查，包含主要地下水梯度特性資訊。 接受標準： a. 進行水文地質及地質調查研究，以確定主要的地下水流動特性和梯度。 b. 視情況必要性，審查現有水文地質、地質、歷史環境研究、核電廠允許或執照之相關報告。 c. 釐清地下水**從廠址位置至廠外位置**潛在**遷移**流動途徑。 d. 建立定期審查廠址水文地質研究的週期，至少只要發生以下任何一種情況，都應執行廠址審視： 1. 廠區內大量施工。 2. 廠址特性受到嚴重干擾。 3. 廠址內或廠外附近地區地下水使用行為重大改變。**或** 4. 廠址內或廠外附近地區地下水抽水率明顯改變。 e. 視情況必要性，隨水文或地質特性的改變，更新場址最終安全分析報告。	2019 年版增加場址概念模式(CSM)
目的 1.2：廠址風險評估 依據電廠設計及操作確認廠址風險: 1.2.1 評估核電廠所有系統(systems)、結構 (structures)、或組件	**目的 1.2：廠址風險評估** 依據電廠設計及操作確認廠址風險: 1.2.1 評估核電廠所有系統(systems)、結構 (structures)、或組件	1.增加確認個人工作作業中採取維護、操作及支援等活動

(components)(以上簡稱為 SSC)中任何可能有放射性污染物質，以及這些物質到達地下水可信機制。 1.2.2 評估核電廠所有操作中任何所有可能放射性污染物質，以及這些物質到達地下水可信機制。 接受標準： a. 確認可能會發生洩漏的 SSC 設備(例如：SSC 例如包括:加注儲水罐(refueling water storage tanks)、消耗燃料池(spent fuel pools)、消耗燃料池洩漏檢測系統(spent fuel pool leak detection systems)、室外儲油罐(outdoor tanks)、室外存放受污染設備(outdoor storage of contaminated equipment)、埋設管道(buried piping)、保留池或盆或水庫(retention ponds or basins or reservoirs)、攜帶蒸汽的管道(lines carrying steam))中任何所有可能放射性污染物質，以及這些物質到達地下水可信機制。 b. 確認現有洩漏檢測方法能檢驗所有 SSC 設備，例如：地下水監測、操作員巡視檢查、工程現場巡查、履勘、洩漏檢測系統檢查或定期完整性測試。 c. 確認個人工作作業中採取維護、操作及支援等活動行為造成或避免放射性污染物質藉由傾洩或洩漏過程至地下水可信機制。 d. 評估潛在強化洩漏防止系統及方案，包括額外或增加測試頻率、履勘、檢查或完整性測試等。 e. 評估潛在強化避免放射性污染物質藉由傾洩或洩漏過程至地下水之措施，包括重新密封或鋪設表面、設置傾洩收集容器設備、進行防護性	(components)(以上簡稱為 SSC)中任何可能有放射性污染物質，以及這些物質到達地下水可信機制。 1.2.2 評估核電廠所有操作中任何所有可能放射性污染物質，以及這些物質到達地下水可信機制。 接受標準： a. 確認可能會發生洩漏的 SSC 設備**與工作作業**(例如：SSC 例如包括:**如在室外，**加注儲水罐(refueling water storage tanks)、消耗燃料池(spent fuel pools)、消耗燃料池洩漏檢測系統(spent fuel pool leak detection systems)、室外儲油罐(outdoor tanks)、室外存放受污染設備(outdoor storage of contaminated equipment)、埋設管道(buried piping)、保留池或盆或水庫(retention ponds or basins or reservoirs)、攜帶蒸汽的管道(lines carrying steam)。)中任何所有可能放射性污染物質，以及這些物質到達地下水可信機制。 b. 確認現有洩漏檢測方法能檢驗所有 SSC 設備**與工作作業**，例如：地下水監測、操作員巡視檢查、工程現場巡查、洩漏履勘、檢測系統檢查或定期完整性測試。 c. **確認**潛在強化洩漏偵測系統及方案，包括額外或增加測試頻率、履勘、檢查或完整性測試等。 d. **確認**潛在強化避免放射性污染物質藉由傾洩或洩漏過程至地下水之措施，包括重新密封或鋪設表面、設置傾洩收集容器設備。	行為造成或避免放射性污染物質藉由傾洩或洩漏過程至地下水可信機制 2. 刪除長期計畫建立，以執行預防性維護或監督活動內容

保養或監視行動，以減少因裝置失效導致意外放射性物質釋放至地下水可能。 f. 確認追蹤修正措施之機制及場址過程。 g. 建立定期檢驗 SSC 及工作作業之週期。 註: 放射性污染物質到達地下水可信機制是指 SSC 與環境間一個屏障失效後可能會導致無意或意外對地下水或土壤的污染	 e. 確認追蹤修正措施之機制及場址過程。 f. 建立長期計畫以執行預防性維護或監督活動，以最大程度地減少由於設備故障而無意中釋放放射性物質可能性。 g. 建立定期檢驗 SSC 及工作作業之週期。	
目的 1.3：場址內地下水監測 建立場址地下水監測計畫，確保能夠及時發現放射性物質意外釋放到地下水中。 接受標準： a. 利用目的 1.1 調查的場址水文和地質研究資料，設立廠區地下水監測井的位置位於由電廠至地下水流下游處場區邊界內，井建置位置確保可監測地下水中放射性物質遷移。 b. 地下水監測井設置位置實際上盡可能在最可能發生洩漏之 SSC 附近，以增加放射性物質洩漏到地下水之監測可能性或 SSC 洩漏偵測能力其他方法有限之處。 c. 建立採樣與分析協定，包括地下水和土壤之分析靈敏度評估、品質保證及品質控制程序，考慮來自於水或空氣中計畫性釋出放射性物質可被偵測水準之可能性。	**目的 1.3：場址內地下水監測** 建立場址地下水監測計畫，確保能夠及時發現放射性物質意外釋放到地下水中。 接受標準： a. 利用目的 1.1 調查的場址水文和地質研究資料，設立廠區地下水監測井的位置位於由電廠至地下水流下游處場區邊界內。 b. **視情況必要性，考慮前哨井放置於**最可能發生洩漏之 SSC 附近，以增加放射性物質洩漏到地下水之監測可能性或 SSC 洩漏偵測能力有限之處。 c. 建立採樣與分析協定，包括地下水和土壤之分析靈敏度評估。**在根系或未飽和地下水區進行氚採樣較不可行，可能需要進行其他評估。對於分開或重複樣品與分析靈敏度，應與外部利益關係人討論或取得同意，以防止將來發**	1.文字小幅修訂 2. 增加井建置位置與品保及偵測水準概念 3.增加地下水監測井設置位置 4.刪除與利益關係人溝通內容

d. 建立長期地下水監測計畫，並且具有正式文件可以查詢，放射環境監測計畫（Radiological Environmental Monitoring Program，REMP*）中也包含地下水監測位置，並修正場址的ODCM/ODAM*及確保清楚區別兩方案不同點。 *凡註明，見詞彙表 e. 定期檢查現有的檢測站或分析化驗室的檢測設備能力。另外，檢驗分析規範及獲得結果所需的時間須納入重要的考慮因素。 f. 建立地下水井預防性維護的長期計畫。 g. 確定地下水監測計畫定期審查之週期。	**生爭議。** d. 建立長期地下水監測計畫，並且具有正式文件可以查詢，放射環境監測計畫（Radiological Environmental Monitoring Program，REMP*）中包含地下水監測位置，並修正場址的ODCM/ODAM*。 *凡註明，見詞彙表 e. 定期檢查現有的檢測站或分析化驗室的檢測設備能力。另外，獲得結果所需的時間須納入重要的考慮因素。 f. 建立地下水井預防性維護的長期計畫。 g. 確定地下水監測計畫定期審查之週期。	
目的 1.4：整治作業 建立整治規範，以防止放射性物質污染物廠外遷移及減少核電廠除役之影響。 接受標準： a. 建立書面程序，概述整治洩漏、傾洩或其他污染意外釋出實例之應變決策過程。此過程隨各場址特性不同而有所差異性，並應考慮放射性物質遷移途徑。 b. 視情況必要性，評估及記錄整治作業對核電廠除役工作有或沒有影響，EPRI 已發展"核電廠土壤及地下水整治指引"技術指引協助此領域。	**目的 1.4：整治作業** 建立整治規範，以防止放射性物質污染物廠外遷移及減少核電廠除役之影響。 接受標準： a. 建立書面程序，概述整治洩漏、傾洩或其他污染意外釋出實例之應變決策過程。此過程隨各場址特性不同而有所差異性，並應考慮放射性物質遷移途徑。 **b. 評估由於計畫性液體或空氣物質釋放出放射性物質檢測水準被檢出之可能性。** c. 視情況必要性，評估及記錄整治作業對核電廠除役工作有或沒有影響。	1. 新增參考一份 EPRI 技術文件 2.將 2007 版 1.4 (b)移至 2019 版 1.3(c)
目的 1.5：記錄保存	**目的 1.5：記錄保存**	兩版本完全

根據 10 CFR 50.75 (g) 的要求，任何電廠洩漏、傾洩及整治工作等應詳細記錄保留，並且可供檢索查詢。 接受標準： 建立記錄保存計畫，以滿足 10 CFR 50.75 (g) 的要求。請注意，這些記錄用於確定執行調查區域類別（請參閱 NRC 法規摘要 2002-02 與最近提交除役計畫及執照終止計畫有關的學習課程）。	根據 10 CFR 50.75 (g) 的要求，任何電廠洩漏、傾洩、整治工作等應詳細記錄保留，並且可供檢索查詢。 接受標準： 建立記錄保存計畫，以滿足 10 CFR 50.75 (g) 的要求。請注意，這些記錄用於確定執行調查區域類別（請參閱 NRC 法規摘要 2002-02 與最近提交除役計畫及執照終止計畫有關的學習課程）。	一致
目的 1.6：除役/安全貯存影響 對於場址目前正在進行或參與除役工作或安全貯存，評估這些工作對於地下水防護之影響。EPRI 已發展「除役規劃地下水監測指引」協助核電廠從運轉至除役過程中，進行地下水監測規劃。 接受標準： a. 建立書面程序概述管制文件內容，如停止運轉後除役活動報告及執照終止計畫，以建立或改變地下水相關程序。 b. 當場址條件或程序規劃及/或改變時: 1.評估何種措施會影響地下水防護。 2.評估 SSC 及工作實務風險評估可反映目前條件。 3.評估場址概念模式可反映目前條件。 4.當 SSC、工作實務風險評估改變及其他任何場址特性概念模式改變時，評估修正地下水監測計畫可反映上述改變，如採樣頻率及監測井數量。 c.當場址地下水防護放射性物質整治完成或當達到執照終止計畫任何地下水及狀態需求滿足時，確認評		2019 版新增目的 1.6：

估及維護地下水防護適當元素。		
二、溝通 **行動 2: 改善與外在利益關係人溝通，以增加對於社區居民、國家、NRC、公眾，達成高標準公眾輻射安全與環境保護核電安全承諾及信心。**	**二、溝通** **行動 2: 改善與外在利益關係人溝通，以增加對於社區居民、國家、NRC、公眾，達成高標準公眾輻射安全與環境保護核電安全承諾及信心。**	
目的 2.1 利益關係人簡報 在地下水防護倡議發展初期，每一位持照人對於政府進行該廠址地下水防護倡議定期簡報，電廠在 2020/1/1 後開始運轉者，應進行期初簡報。 接受標準： a.持照人應該討論: 1.背景或業界事件造成地下水防護倡議。 2.如果有額外的資訊，政府需要良好了解這議題，或需從民眾角度看待這議題。 3.如何政府使用或分配這資訊。 b. 持照人需要考慮包括額外的資訊，或如有必要，與政府定期討論更新地下水防護。 c. 持照人在多州有多個核電廠與多個電力公司，強烈建議持照人與政府進行自願性溝通與努力協調使其一致。	**目的 2.1 利益關係人簡報** 每一位持照人對於政府**應**進行該廠址地下水防護倡議**期初與**定期簡報。 接受標準： a.持照人應該討論: 1.背景或業界事件造成地下水防護倡議。 2.如果有額外的資訊，政府需要良好了解這議題，或需從民眾角度看待這議題。 3.如何政府使用或分配這資訊。 b. 持照人需要考慮包括額外的資訊，或與政府定期討論更新地下水防護。 c. 持照人在多州內有多個核電廠與多個電力公司，強烈建議持照人**努力協調與彼此互相溝通，與政府的初期簡報及自願性溝通內容應保持一致**。	1.文字小幅修訂 2.2019 年版明定電廠在 2020/1/1 後開始運轉者，應進行期初簡報
目的 2.2 自願性溝通 盡快與適當官員及其他利益關係人進行非正式*溝通，並視情況必要性，根據廠址特定程序的要求向 NRC 進行後續通知，對於新/或重大廠內洩漏、傾洩至地下水，視情況必要性，廠內外採集水樣監測結果超過 ODCM / ODAM 中所述 REMP 中標準水質標準等情況。	**目的 2.2 自願性溝通** 盡快與適當官員進行非正式*溝通，並視情況必要性，向 NRC 進行後續通知，對於重大*廠內洩漏、傾洩至地下水，廠內外採集水樣監測結果超過 ODCM / ODAM 中所述 REMP 中標準水質標準等情況。	1. 2019 版本增加與利益關係人溝通 2. 增加可以不進行自願性溝通

*凡註明，見詞彙表 註: 當後來樣本證明是來自同一來源/機制/事件時，預期不會產生自願性溝通，該文件記錄應可供利益關係人審查。	*凡註明，見詞彙表	之條件
接受標準： 本指引提供了自願性溝通門檻，某些州可能要求不同溝通門檻，持照人應記錄與官員達成的任何與業界指引不同協議。	接受標準： 本指引提供了自願性溝通門檻，某些州可能要求不同溝通門檻，持照人應記錄與官員達成的任何與業界指引不同協議。	
a. 根據廠址特定程序的要求，如果意外洩漏或傾洩至環境，已經或可能進入地下水及符合下列任一條件，與當地官員及其他利益關係人進行溝通，應該下一個工作天完成。	a.如果意外洩漏或傾洩至環境，已經或可能進入地下水及符合下列任一條件，與當地官員進行溝通，應該下一個工作天完成。	
1. 如果含有放射性物質來源的洩漏或傾洩超過 100 加侖。	1. 如果含有放射性物質來源的洩漏或傾洩超過 100 加侖。	
2. 如果含有放射性物質來源的洩漏或傾洩無法定量，但可能超過 100 加侖。	2. 如果含有放射性物質來源的洩漏或傾洩無法定量，但可能超過 100 加侖。**或**	
3. 無論量或活動，任何洩漏或傾洩，持照人必定保證進行自願性溝通。	3. 無論體積或活度，任何洩漏或傾洩，持照人必定保證進行自願性溝通。	
及		
4. 無論體積或活度，洩漏或傾洩量事件無法根據目的 1.4 在 24 小時內完全回收及整治(即在 24 小時內洩漏或傾洩可回收及整治，無溝通必要) 。		
決定洩漏或傾洩是否啟動自願性溝通，附錄 A 提供洩漏、傾洩及地下水監測結果啟動自願性溝通規範流程圖。	決定洩漏、傾洩是否啟動自願性溝通，**除上述 2.2.a i 至 iii 之外，請考慮以下三個說明**:	
(A) 洩漏或傾洩：表示意外事件或干擾系統或組件性能，此事件門檻是確保讓政府官員意識到此感興趣的事件，並讓他們了解持照人	(A) 洩漏或傾洩：表示意外事件或干擾系統或組件性能，此事件門檻是確保讓政府官員意識到此感興趣的事件，並讓他們了解持照人	

為制止及補救此事件所採取的措施。無論當地地下水是否是或做為飲用水水源，"洩漏"事件造成地下水水質都應符合標準。由固體廢棄物或蒸汽產生洩漏或傾洩出液體量應根據 2.2.a 1 至 4 進行評估。	為制止及補救此事件所採取的措施。無論當地地下水是否是或做為飲用水水源，"洩漏"事件造成地下水水質都應符合標準。由固體廢棄物或蒸汽產生洩漏或傾洩出液體量應根據 2.2.a 1 至 **3** 進行評估。	
(B) 含有放射性物料來源: 當將樣本分析高於檢測下限（分析靈敏度）時，液體(包括蒸汽)可獲得統計上有效的陽性結果，偵測到含有放射性物料的來源分析靈敏度，至少達到持照人對於所有放射性液體放流物如同 ODCM/ODAM 註明之同位素所偵測出最低檢測限。	(B) 含有放射性物料來源: 當將樣本分析高於檢測下限（分析靈敏度）時，液體(包括蒸汽)可獲得統計上有效的陽性結果，偵測到含有放射性物料的來源分析靈敏度，至少達到持照人對於所有放射性液體放流物之**全部**同位素所偵測出最低檢測限。	
(C) 到達地下水可能性: 傾洩或洩漏到達地下水可能性： 1. 直接傾洩或洩漏到原生土壤或覆蓋物上; 2. 如果表面破裂或為多孔或未密封材料，傾洩或洩漏到人造表面(即混凝土或瀝青)上; 3. 傾洩或洩漏直接進入未加襯砌或不可滲透的池塘或蓄水池(即與地下水保持水文上連通的水）。 一般建築物或密閉單元內部傾洩或洩漏不可能進入地下水，尤其是如果建築物或密閉單元具有排水和集水系統。 但是集排水系統應作為 SSC 風險評估的一部分進行評估。 註: 根據目標 1.4 收集或整治傾洩或洩漏，若在 24 小時內恢復不會進入地下水，將不須進行自願性溝通協議。	(C) 到達地下水可能性: 傾洩或洩漏到達地下水可能性： 1. 直接傾洩或洩漏到原生土壤或覆蓋物上; 2. 如果表面破裂或為多孔或未密封材料，傾洩或洩漏到人造表面(即混凝土或瀝青)上; 3. 傾洩或洩漏直接進入未加襯砌或不可滲透的池塘或蓄水池(即與地下水保持水文上連通的水）。 一般建築物或密閉單元內部傾洩或洩漏不可能進入地下水，尤其是如果建築物或密閉單元具有排水和集水系統。 但是集排水系統應作為 SSC 風險評估的一部分進行評估。 根據目標 1.4 傾洩或洩漏**至不透水或半不透水表面，可在下個工作日結束前**收集或整治，將不須進行自願性溝通協議。	
持照人應記錄與政府官員及其他利益關係人達成協議，特定廠	持照人應記錄與政府官員達成協議，**此**記錄部分與業界指引不	

址程序所要求作為記錄部分與業界指引不同，這些由當地政府提供協議或指引成為溝通指引，但必須以書面方式提供利益關係人查閱。	同。**例如，一些州或地方政府表示他們不希望洩漏、傾洩被包含在自願性溝通協定中，或者自願性溝通應在較短的時間內完成。** **附錄 A 提供洩漏、傾洩及地下水監測結果啟動自願性溝通規範流程圖。**	
b. 對於確認水樣分析結果，根據特定廠址程序的要求與政府官員及利益關係人溝通，必須在下一個工作日結束前完成。 1. 當廠外地下水與地面水超過 ODCM / ODAM 中所述 REMP 任何水質標準規定。 2. 當廠內地面水在水文上連接地下水，或地下水被當作飲用水使用，廠內或廠區下游處水樣超過 ODCM / ODAM 中所述 REMP 水質標準規定。 所根據實例是來自地下水使用有管轄權監管機構的文件，持照人應該撰寫廠區內地下水目前或未來將不被當作飲用水使用之結論。附錄 A 提地下水監測結果啟動自願性溝通規範流程圖。	b. 對於水樣分析結果，與政府官員溝通，必須在下一個工作日結束前完成。 1. 當廠外地下水與地面水超過 ODCM / ODAM 中所述 REMP 任何水質標準規定。**或** 2. 當廠內地面水在水文上連接地下水，或地下水被當作飲用水使用，水樣超過 ODCM / ODAM 中所述 REMP 水質標準規定。 所根據實例是來自地下水使用有管轄權監管機構的文件，持照人應該撰寫廠區內地下水目前或未來將不被當作飲用水使用之結論。附錄 A 提地下水監測結果啟動自願性溝通規範流程圖。	
c. 當廠址特定程序要求與政府官員及利益關係人進行溝通，若使用適當的管制標準，必須清楚明確量化實際釋放資訊(即使其透明化)，下列訊息應被當作非正式溝通一部分: 1. 溝通被當作 NEI 地下水防護倡議文件一部分。 2. 洩漏、傾洩或地下水採樣的日期與時間。 3. 無論傾洩是否被裝起來或洩漏停止。	c. 當與政府官員進行溝通，若使用適當的管制標準，必須清楚明確量化實際釋放資訊(即使其透明化)，下列訊息應被當作非正式溝通一部分: 1. 溝通被當作 NEI 地下水防護倡議文件一部分。 2. 洩漏、傾洩或地下水採樣的日期與時間。 3. 無論傾洩是否被裝起來或洩漏停止。	

4. 如果知道洩漏、傾洩或地下水採樣的位置。 5. 如果知道洩漏或傾洩來源。 6. 污染物及已確定濃度之清單。 7. 已經採取動作描述及未來動作一般性描述。 8. 若此時可以獲得，對於一般大眾每年可能或邊界劑量估計。 9. 提供額外或後續訊息估計時間。 d. 當廠址特定程序要求與政府官員及利益關係人進行溝通，依據 10 CFR 50.72(b)(2)(xi)也需要通知 NRC，持照人應進行這項通知與目前已有方案保持一致。 e. 如同目的 2.2 所述，使用 email(GRPGroundwater Issuese@nei.org)與 NEI 聯繫，可視為溝通事件一部分。	4. 如果知道洩漏、傾洩或地下水採樣的位置。 5. 如果知道洩漏或傾洩來源。 6. 污染物及已確定濃度之清單。 7. 已經採取動作描述及未來動作一般性描述。 8. 若此時可以獲得，對於一般大眾每年可能或邊界劑量估計。**及** 9. 提供額外或後續訊息估計時間。 d. 當與政府官員進行溝通，依據 10 CFR 50.72(b)(2)(xi)也需要通知 NRC，持照人應進行這項通知與目前已有方案保持一致。 e. 如同目的 2.2 所述，使用 email(**GW_Notice@nei.org**)與 NEI 聯繫，可視為溝通事件一部分。	
目的 2.3 三十日報告 對於廠內地下水水質檢測結果是或可能當作飲用水水源任何一項超過如 ODCM / ODAM 中所述，持照人既有的 REMP 30 日廠外水樣檢測結果規定之水質標準，持照人須在 30 日內向 NRC 提交一份報告，這廠內外地下水 30 日報告副本也須提供政府官員。 註:某些廠址的 ODCM 可能寫成 31 天，對於這些廠址 31 天報告可以被接受。 接受標準： a. 對於業界倡議所有地下水水樣必須對於 ODCM / ODAM 中所述電廠 REMP 水質標準與限制進行分析與比較，2006 年前 ODCM / ODAM 要求敘明 REMP 地下水水質檢測結果超過任何 REMP 報告	**目的 2.3 三十日報告** 對於廠內地下水水質檢測結果是或可能當作飲用水水源任何一項超過如 ODCM / ODAM 中所述，持照人既有的 REMP 30 日廠外水樣檢測結果規定之水質標準，持照人須在 30 日內向 NRC 提交一份報告，這廠內外地下水 30 日報告副本也須提供政府官員。 接受標準： a. 對於業界倡議所有地下水水樣必須對於 ODCM / ODAM 中所述電廠 REMP 水質標準與限制進行分析與比較，2006 年前 ODCM / ODAM 要求敘明 REMP 地下水水質檢測結果超過任何 REMP 報告	1.增加註解

的水質標準，必須在 30 日內向 NRC 提交報告。在倡議下，向 NRC 提交 30 日報告也須包括廠內水井水樣結果超過任何 REMP 報告的水質標準，廠內或廠址下游處地下水未來當作飲用水使用，以及到達地下水可能性。若地下水目前未被當作飲用水使用，但是瓶裝水，電廠仍將其地下水視為飲用水潛在來源，參見目的 2.2 接受標準 b，以書面建立具正當理由基礎之地下水有利的使用。 在 30 日報告文件初步發現地下水污染超過 REMP 報告的水質標準，若每次被懷疑來自同一污染團持續水樣超過 ODCM / ODAM 中所述 REMP 水質標準規定，將不被預期寫入 30 天的書面報告內。持照人應該根據不預期條件改變評估額外報告或通溝之需要。 b. 30 天特別報告應該包括: 1. 根據地下水防護倡議報告提出之敘述。 2. 污染物與檢驗濃度清單。 3. 採取行動之描述。 4. 對於一般大眾每年可能或邊界劑量估計。 5. 若必要，將採取修正的動作，以減少大眾每年預計劑量低於 10 CFR 50 附錄 I 的限制。 c. 所有 2.3.a 項目中所寫 30 天 NRC 報告將同時交給政府官員。	的水質標準，必須在 30 日內向 NRC 提交報告。在倡議下，向 NRC 提交 30 日報告也須包括廠內水樣結果超過任何 REMP 報告的水質標準，地下水未來當作飲用水使用，以及到達地下水可能性。若地下水目前未被當作飲用水使用，但是瓶裝水，電廠仍將其地下水視為飲用水潛在來源，參見目的 2.2 接受標準 b，以書面建立具正當理由基礎之地下水有利的使用。 在 30 日報告文件初步發現地下水污染超過 REMP 報告的水質標準，若每次被懷疑來自同一污染團持續水樣超過 ODCM / ODAM 中所述 REMP 水質標準規定，將不被預期寫入 30 天的書面報告內。持照人應該根據不預期條件改變評估額外報告或通溝之需要。 b. 30 天特別報告應該包括: 1. 根據地下水防護倡議報告提出之敘述。 2. 污染物與檢驗濃度清單。 3. 採取行動之描述。 4. 對於一般大眾每年可能或邊界劑量估計。 5. 若必要，將採取修正的動作，以減少大眾每年預計劑量低於 10 CFR 50 附錄 I 的限制。 c. 所有 2.3.a 項目中所寫 30 天 NRC 報告將同時交給政府官員。	
目的 2.4 年度報告 根據放射性環境監測方案 (REMP)，從 2006 起年度放射性環境運作報告 (Annual Radiological Environmental Operating Report，	**目的 2.4 年度報告** 根據放射性環境監測方案 (REMP)，從 2006 起年度放射性環境運作報告 (Annual Radiological Environmental Operating Report，	1.文字小幅修訂 2.2019 年版增加 2008 年後興建的

AREOR)記錄全部廠內地下水放射性物質採樣結果及新且重大廠內洩漏及傾洩進入地下水描述，及/或 RETS 的年度放射性廢水排放報告(Annual Radioactive Effluent Release Report，ARERR)亦為適當報告程序。 接受標準： a. 若為 2008 年後興建的核電廠，在初次收到核燃料之前，需要包括重要廠內洩漏及傾洩進入地下水與發展及實施所有地下水結果適當程序，建議參考 2008 年 12 月 NEI08-08" 污染物生命週期最小化一般 FSAR 範例指引"。 b. 廠內地下水採樣結果報告應該根據下列: 1. 地下水採樣結果採用為地下水防護倡議為基礎，但不為 REMP 方案之一部分，例如根據 10 CFR 50.36a(a)(2) 要求 ARERR 報告在 2006 年調查階段行動計畫所獲得水樣。 2. 當依據目的 1.3 接受標準 d 點 ODCM / ODAM 中所述 REMP 所建立長期監測採樣點，監測結果將於 AREOR 中報告，若長期監測採樣點未列於 REMP 內，則於 ARERR 中報告。 c. 除目的 2.4 b 點外，若有任何進行自願性溝通年度報告內容應包括: 1.依據目的 2.2 接受標準 a 點，所有洩漏或傾洩的溝通描述必須包含於 ARERR 或 AREOR 報告中。 2. 依據目的 2.2 接受標準 b 點，所有廠內外地下水採樣結果超過	AREOR)記錄全部廠內地下水採樣結果及新且重大廠內洩漏及傾洩進入地下水描述，或 RETS 的年度放射性廢水排放報告(Annual Radioactive Effluent Release Report， ARERR)亦為適當報告程序。 接受標準： ***a.*** **對 ODCM / ODAM 或適當程序的適當改變，預計將在某個時限內完成，以支持 2007 年報告 2006 年正在運轉或除役的核電廠採用地下水防護倡議表現。對於新電廠，在初次收到核燃料之前，需要包括重要廠內洩漏及傾洩進入地下水與發展及實施所有地下水結果適當程序。** b. 廠內地下水採樣結果報告應該根據下列: 1. 地下水採樣結果採用為地下水防護倡議為基礎，但不為 REMP 方案之一部分，例如根據 10 CFR 50.36a(a)(2) 要求 ARERR 報告在 2006 年調查階段行動計畫所獲得水樣。 2. 當依據目的 1.3 接受標準 d 點 ODCM / ODAM 中所述 REMP 所建立長期監測採樣點，監測結果將於 AREOR 中報告，若長期監測採樣點未列於 REMP 內，則於 ARERR 中報告。 c. 除目的 2.4 b 點外，進行自願性溝通內容應包括: **ARERR 及 / 或 AREOR 包括下列:** 1.依據目的 2.2 接受標準 a 點，所有洩漏或傾洩的溝通描述必須包含於 ARERR。 2. 依據目的 2.2 接受標準 b 點，所有廠內外地下水採樣結果超過	核電廠建議參考 NEI08-08

ODCM / ODAM 中所述 REMP 報告門檻的溝通，必須包含於 AREOR 或 ARERR 報告中。	ODCM / ODAM 中所述 REMP 報告門檻的溝通，必須包含於 AREOR 或 ARERR 報告中。	
三、方案監督 **行動 3:方案監督以確保地下水防護方案有效的施行** **目的 3.1 方案自我評估與審查** 維持地下水防護倡議方案有效的監督。(見附錄 B) 接受標準： a. 獨立且具有專業知識的個體應在初次臨界後的一年內進行初次自我評估，此步驟僅適用於符合在 2020/01/01 以後開始運轉的電廠。 b. 地下水防護倡議方案程序性評估應該在初次自我評估後每五年至少一次定期進行，這程序性評估應該根據記錄管理方案進行維護。 c. 這程序性評估應該至少包括本文件所有目的評估，與電廠適用程序及方案保持一致之文件記錄。	**三、方案監督** **行動 3:方案監督以確保地下水防護方案有效的施行** **目的 3.1 執行自我評估** **執行**地下水防護倡議方案**自我評估**。(見附錄 B) 接受標準： a. 獨立且具有專業知識的個體應在實施後一年內進行初次期自我評估。**對於已存在之電廠，此評估不超過 2008/12/31，對於新建電廠則應於初次臨界後的一年內進行**。 b. 地下水防護倡議方案**定期自我**評估應該在初次自我評估後每五年至少一次進行。 c. 這**自我**評估應該至少包括本文件所有目的評估。 d. **這自我評估應該**與電廠適用程序及方案保持一致之文件記錄。	1. 2019 年版增加審查並修正初期自我評估時間
	目標 3.2：在 NEI 的協助下審查這項方案 **在 NEI 協助下，對於地下水防護倡議方案進行審查，至少包括持照人的自我評估。** **接受標準：** **a. 獨立且具有專業知識的個體應該根據目標 3.1.a，在初次自我評估的一年內進行審查。** b. **根據目標 3.1.b 執行執照的定期自我評估之後，應每 5 年對地下水防護倡議方案進行一次定期審查。**	1. 2019 年版全部刪除

• 詞彙表 • *AREOR:*是指年度放射環境操作報告，向 NRC 摘要 REMP 的結果。 • *ARERR:*表示根據 10 CFR 50.36a (a)(2)所要求的年度放射性廢水排放報告，摘要核電廠設施中液體、空氣及固體廢物釋放，並提供由於這些釋放的計算劑量。 • *可靠機制:*放射性物質到達地下水的*可靠機制*是 SSC 與環境之間的屏障失效，可能會導致地下水或原生土壤意外或無意污染。 • 地下水:GPI 中*地下水*是指地下任何的水，無論是在地球的未飽和、根系或在飽和層內。 • *非正式(溝通):*是指持照人與州/地方政府官員之間，通常使用電話進行溝通方式。 根據 10 CFR 50.72，隨後向 NRC 通知應與電廠執行政策一致。 • *具執照物料:*(來自 10 CFR 20.1003)是指由委員會頒發一般或特定執照，針對接獲、擁有、使用、轉讓或處置來源物料、特殊核物料或副產品。 • *ODCM / ODAM:*是指廠外劑量計算手冊或廠外劑量評估手冊或相同文件，技術規範要求持照人手冊包含劑量評估方法和放射廢水技術規範。 • *REMP:*是指 ODCM / ODAM 所述之放射性環境監測計畫，該計畫可提供暴露途徑內輻射及放射性物質測量，以及從電廠運轉中，這些放射性元素導致電廠內人員可能最高輻射暴露。	• 詞彙表 • *AREOR:*是指年度放射環境操作報告，向 NRC 摘要 REMP 的結果。 • *ARERR:*表示根據 10 CFR 50.36a (a)(2)所要求的年度放射性廢水排放報告，摘要核電廠設施中液體、空氣及固體廢物釋放，並提供由於這些釋放的計算劑量。 • 地下水:GPI 中*地下水*是指地下任何的水，無論是在地球的未飽和、根系或在飽和層內。 • *非正式(溝通):*是指持照人與州/地方政府官員之間，通常使用電話進行溝通方式。 根據 10 CFR 50.72，隨後向 NRC 通知應與電廠執行政策一致。 • *具執照物料:*(來自 10 CFR 20.1003)是指由委員會頒發一般或特定執照，針對接獲、擁有、使用、轉讓或處置來源物料、特殊核物料或副產品。 • *ODCM / ODAM:*是指廠外劑量計算手冊或廠外劑量評估手冊或相同文件，技術規範要求持照人手冊包含劑量評估方法和放射廢水技術規範。 • *REMP:*是指 ODCM / ODAM 所述之放射性環境監測計畫，該計畫可提供暴露途徑內輻射及放射性物質測量，以及從電廠運轉中，這些放射性元素導致電廠內人員可能最高輻射暴露。	2019 年版增加"可靠機制" 詞彙

• *RETS:*是指控制廠中放射性液體和空氣物質釋放所需放射性廢水排放技術規範。 在 NUREG CR-1301 中可以找到標準放射性廢水排放技術規範。 • *重大(洩漏及傾洩):*是指公眾或利益關係人有興趣關心的項目或意外事件，這既不是意指或參考管制性術語，也不表示洩漏及傾洩有公共健康及安全或環境保護的結果。 • *自願性*:GPI 中的*自願性*，是指法令或法規未要求的內容 • *動詞「可以(may)」、「應(shall」、「應該(should)」、「將要(will)」和「將要(would)」:*具有核電業界常用的含義(請參閱 ANSI N42.14-1999)，「應(shall)」表示要求、「應該(should)」表示建議、「可以(may)」表示允許	• *RETS:*是指控制廠中放射性液體和空氣物質釋放所需放射性廢水排放技術規範。 在 NUREG CR-1301 中可以找到標準放射性廢水排放技術規範。 • *重大(洩漏及傾洩):*是指公眾或利益關係人有興趣關心的項目或意外事件，這既不是意指或參考管制性術語，也不表示洩漏及傾洩有公共健康及安全或環境保護的結果。 • *自願性*:GPI 中的*自願性*，是指法令或法規未要求的內容 • *動詞「可以(may)」、「應(shall」、「應該(should)」、「將要(will)」和「將要(would)」:*具有核電業界常用的含義(請參閱 ANSI N42.14-1999)，「應(shall)」表示要求、「應該(should)」表示建議、「可以(may)」表示允許	

NEI 07-07, Rev 1 August 2019 **ATTACHMENT 1** 附件 1 Nuclear Energy Institute Industry Initiative on Ground Water Protection	NEI 07-07 (Final) August 2007 **ATTACHMENT 1** 附件 1 Nuclear Energy Institute Industry Initiative on Groundwater Protection
2006年5月NEI地下水防護業界倡議	2006年5月NEI地下水防護業界倡議
目標： 1. 針對涉及放射性的地下水洩漏進行改善管理。 2. 增強當地社區、國家、NRC及大眾對核電業界高標準輻射安全和環境保護承諾之信任和信心。 行動： 到2006年7月31日，每個運轉或停止運轉的核電廠將： 1. 制定公司/特定廠址的行動計畫，幫助確保及時偵測並有效回應涉及放射性物質意外洩漏至地下水情況，以防止放射性物	目標： 1. 針對涉及放射性的地下水洩漏進行改善管理。 2. 增強當地社區、國家、NRC及大眾對核電業界高標準輻射安全和環境保護承諾之信任和信心。 行動： 到2006年7月31日，每個運轉或停止運轉的核電廠將： 1. 制定公司/特定廠址的行動計畫，幫助確保及時偵測並有效回應涉及放射性物質意外洩漏至地下水情況，以防止放射性物

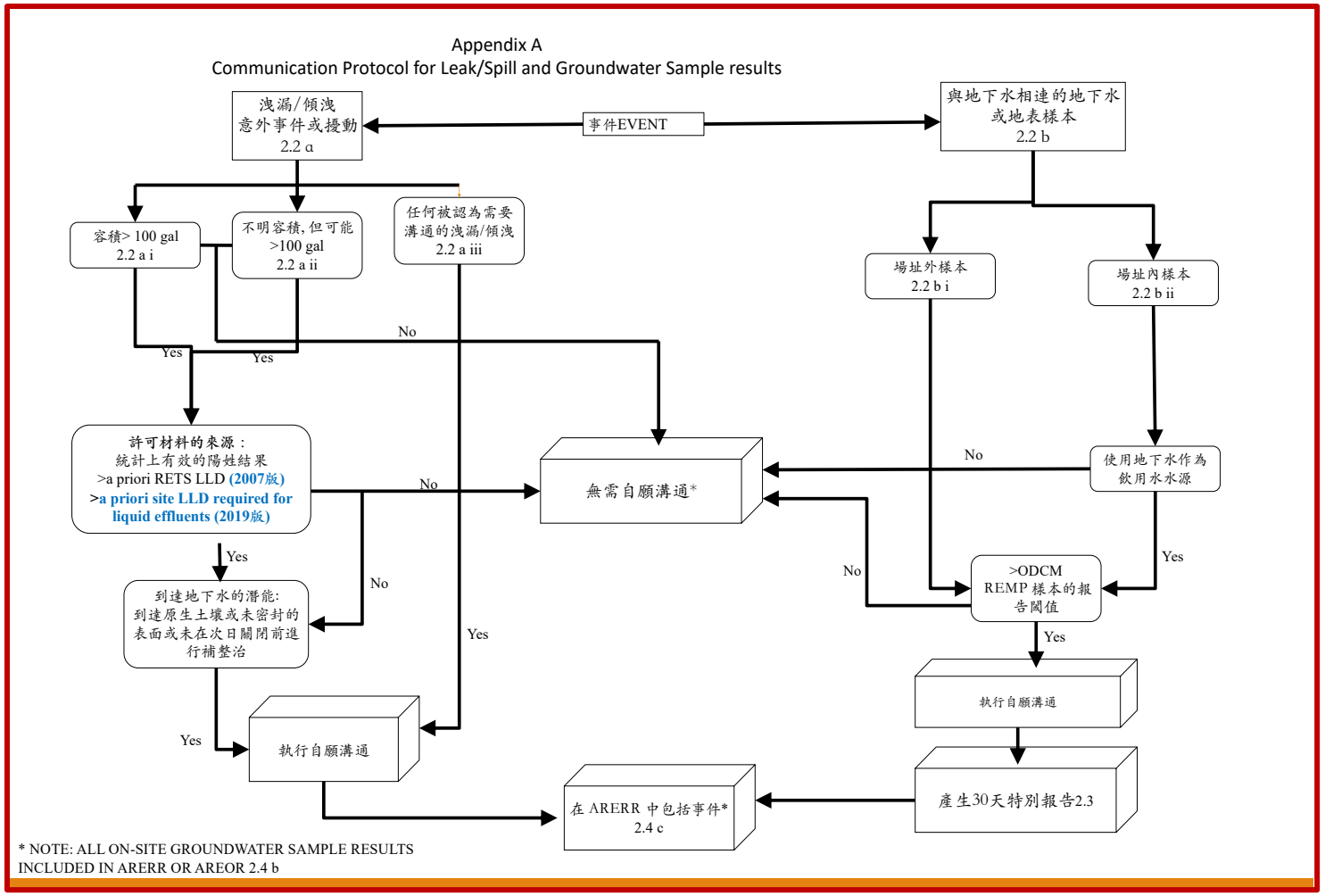
質遷移至廠外，並量化對除役的影響。 2. 擴大持照人現有放射環境監測計畫（Radiological Environmental Monitoring Program， REMP）報告要求的範圍，包括以下額外自願性正式和非正式報告： 2.1 從2006年開始每年REMP報告中記錄所有場址內地下水水樣監測結果及描述任何重大廠內洩漏及傾洩進入地下水事件； 2.2對於廠內地下水水質檢測結果是或可能當作飲用水水源任何一項超過持照人既有的REMP 30日廠外水樣檢測結果規定之水質標準，持照人須在30日內向NRC提交一份報告，這廠內外地下水30日報告副本也須提供適當的國家機構；及 2.3對於重大廠內洩漏、傾洩至地下水（見條款2.1），廠內外採集水樣監測結果超過REMP標準水質標準（請參閱第2.2條），盡快與適當官員進行非正式溝通及若適當向NRC進行後續通知。	質遷移至廠外，並量化對除役的影響。 2. 擴大持照人現有放射環境監測計畫（Radiological Environmental Monitoring Program， REMP）報告要求的範圍，包括以下額外自願性正式和非正式報告： 2.1 從2006年開始每年REMP報告中記錄所有場址內地下水水樣監測結果及描述任何重大廠內洩漏及傾洩進入地下水事件； 2.2對於廠內地下水水質檢測結果是或可能當作飲用水水源任何一項超過持照人既有的REMP 30日廠外水樣檢測結果規定之水質標準，持照人須在30日內向NRC提交一份報告，這廠內外地下水30日報告副本也須提供適當的國家機構；及 2.3對於重大廠內洩漏、傾洩至地下水（見條款2.1），廠內外採集水樣監測結果超過REMP標準水質標準（請參閱第2.2條），盡快與適當官員進行非正式溝通及若適當向NRC進行後續通知。

NEI 07-07, Rev 1 August 2019 **ATTACHMENT 2** 附件2	NEI 07-07 (Final) August 2007 **ATTACHMENT 2** 附件2
常見問題	**常見問題**
1) Q: “發展和實施針對特定場址/電力公司地下水防護計畫”的承諾是否包括對於更多監控井進行鑽探、修改工廠系統、結構或組件等的承諾？ A: 不能。電力公司應完成對於每個特定場址狀況具體評估，並安排所需改善以符合“幫助確保及時偵測並有效回應對放射性物質意外洩漏至地下水的情況，以防止放射性物質遷移至廠外及最小化除役衝擊的目標”，所需改進的範圍將在很大程度上取決於特定場址的條件，例如，洩漏或傾洩的歷史及目前用於檢測洩漏和監測現場地下水程序的範圍和品質，廠址內地下水監測計畫（包括地下水監測井目的和位置）應基於概念性場址模型(CSM)，評估應定期重新評估。	1) Q: “發展和實施針對特定場址/電力公司地下水防護計畫”的承諾是否包括對於更多監控井進行鑽探、修改工廠系統、結構或組件等的承諾？ A: 不能。電力公司應完成對於每個特定場址狀況具體評估，並安排所需改善以符合“幫助確保及時偵測並有效回應對放射性物質意外洩漏至地下水的情況，以防止放射性物質遷移至廠外及最小化除役衝擊的目標”，所需改進的範圍將在很大程度上取決於特定場址的條件，例如，洩漏或傾洩的歷史及目前用於檢測洩漏和監測現場地下水程序的範圍和品質，**評估應定期重新評估。**

2) Q: 行動2下自願性溝通協定與2006年之前生效的報告要求有何關係？ A: 每位持照人已經在某些執照（即RETS，REMP或ODCM / ODAM）中指定報告的要求，而這些標準可能因不同廠址而有所不同。10 CFR第20和50部分還包含適用於所有持照人的相關報告要求。此外，某些持照人可能具有涉及州或地方機構和官員報告要求或承諾。自願性溝通協定目的在於補充每個場址現有報告要求，若適當，要與核電廠有關聯的州和地方官員及NRC保持聯繫，以告知放射性地下水意外洩漏有關的情況和事件發生。 3) Q: 目標1.1的接受標準d中的"廠內重大建設"或"廠址性質重大干擾"是什麼意思？ A: "重大"是指建設或干擾影響地下水流動的可能性，例如大型鋪路計畫，獨立的廢燃料儲存安裝(ISFSI)建築或新建築物等。例如新建核電廠持照人審查預先許可因建築物和結構的建造或土壤壓密而引起水文和地質特徵變化。 **4) Q: 目標1.1至1.3中的"定期審查(Periodic review)"是什麼意思？** **A: "定期(Periodic)"旨在使每個持照人能力根據場址概念性模式(CSM)所支持的特定場址因素、運轉狀態（即新核電廠，運轉設施或除役與SSC風險排名）來進行審核之頻率。兩次檢查之間的時間間隔應根據特定場址情況而定，且不得超過5年。** **5) Q: "定期審查"如何適用於正在進行或已經完成除役的核電廠？** **A: 建議與常見問題4一致，每個持照人都應評估及更新CSM、SSC優先指標及長期地下水監測計畫，以結合場址條件的變化，並最佳化GWPP，確保以有效率且經濟有效方式達到行動1的目標。** **6) Q: 可以互換的概念性場址模式或場址概**	2) Q: 行動2下自願性溝通協定與2006年之前生效的報告要求有何關係？ A: 每位持照人已經在某些執照（即RETS，REMP或ODCM / ODAM）中指定報告的要求，而這些標準可能因不同廠址而有所不同。10 CFR第20和50部分還包含適用於所有持照人的相關報告要求。此外，某些持照人可能具有涉及州或地方機構和官員報告要求或承諾。自願性溝通協定目的在於補充每個場址現有報告要求，若適當，要與核電廠有關聯的州和地方官員及NRC保持聯繫，以告知放射性地下水意外洩漏有關的情況和事件發生。 3) Q: 目標1.1的接受標準d中的"廠內重大建設"或"廠址性質重大干擾"是什麼意思？ A: "重大"是指建設或干擾影響地下水流動的可能性，例如新建核電廠持照人審查預先許可因建築物和結構的建造或土壤壓密而引起水文和地質特徵變化。

念性模式是什麼意思？ **A:** 根據電力研究所（**EPRI**）：“場址概念性模式整合關注污染物、電廠**SSC**、歷史及可能持續意外釋放，以及場址水文地質等可用訊息，以形成一致性的假設，解釋觀察到地面污染物分佈、來源、運輸途徑、環境中污染物宿命與傳輸，以及對受體的風險。 或 美國測試與材料學會將場址概念模式或概念場址模式定義為“書面或圖形表示之環境系統以及確定污染物從源頭通過環境介質到環境之接受者的生物、物理和化學過程。” **7) Q:** 目標**1.6.a**指出：“建立書面程序概述法規文件中的承諾，例如停止運轉後除役活動報告（**PSDAR**）和執照終止計畫（**LTP**），對應建立/更改與地下水相關的程序。”這些程序應何時制定？ **A:** 根據操作經驗，建議在停止運轉後不久對地下水程序、監測井網和程序進行修訂。這可能導致程序在停止運轉之前就開始，例如：可以在知道或推測停止運轉日期時開始。	

附錄 A


Appendix A
Communication Protocol for Leak/Spill and Groundwater Sample results
洩漏/傾洩
意外事件或擾動
2.2 a
事件EVENT
與地下水相連的地下水
或地表樣本
2.2 b
容積> 100 gal
2.2 a i
不明容積,但可能
>100 gal
2.2 a ii
任何被認為需要
溝通的洩漏/傾洩
2.2 a iii
場址外樣本
2.2 b i
場址內樣本
2.2 b ii
No
Yes
Yes
許可材料的來源：
統計上有效的陽姓結果
>a priori RETS LLD (2007版)
>a priori site LLD required for
liquid effluents (2019版)
No
無需自願溝通*
No
使用地下水作為
飲用水水源
Yes
Yes
No
到達地下水的潛能:
到達原生土壤或未密封的
表面或未在次日關閉前進
行補整治
No
>ODCM
REMP 樣本的報
告閾值
Yes
Yes
Yes
執行自願溝通
執行自願溝通
在 ARERR 中包括事件*
2.4 c
產生30天特別報告2.3
* NOTE: ALL ON-SITE GROUNDWATER SAMPLE RESULTS
INCLUDED IN ARERR OR AREOR 2.4 b

附錄 B

自我評估清單 目的 3.1

Plant or Utility Being Reviewed: Date of Review

Reviewers:

	NEI 07-07, Rev 1 August 2019		NEI 07-07 (Final) August 2007
指引	目的/接受標準		目的/接受標準
1.1 確保目前地質及水文場址特性可以提供根據此場址條件瞭解主要地下水梯度。 此特性是 CSM 的基礎。		1.1 確保目前地質及水文場址特性可以提供根據此場址條件瞭解主要地下水梯度。	
1.1.a	進行水文地質及地質研究，以確定主要的地下水流特性及梯度。	1.1.a	進行水文地質及地質研究，以確定主要的地下水流特性及梯度。
1.1.b	若適當，審查現有水文地質及地質研究、歷史環境研究及執照或執照相關報告。	1.1.b	若適當，審查現有水文地質及地質研究、歷史環境研究及執照或執照相關報告。
1.1.c	確定地下水遷移從廠內至廠外地點，透過地下水可能途徑。	1.1.c	確定地下水遷移從廠內至廠外地點，透過地下水可能途徑。
1.1.d	建立場址水文地質研究定期審查的頻率。至少，只要發生以下任何情況，都應執行審查: 1. 廠區內大量施工。 2. 廠址特性受到嚴重干擾。 3. 廠址內或廠外附近地區地下水使用行為重大改變。 4. 廠址內或廠外附近地區地下水抽水率明顯改變。	1.1.d	建立場址水文地質研究定期審查的頻率。*
1.1.e	若適當，更新 CSM 和場址的最終安全分析報告，並更改水文及/或地質情況。	1.1.e	若適當，更新場址的最終安全分析報告，並更改水文及/或地質情況。

1.2 根據電廠設計和工作作業確定廠址風險。		1.2 根據電廠設計和工作作業確定廠址風險*	
1.2.1	評估所有包含或可能包含放射性物質的系統、結構或元件 (systems， structures， or components， SSCs) ，並據此評估放射性物質到達地下水的可信機制(Credible Mechanism)。		
1.2.2	評估工作作業涉及放射性物質，並據此評估放射性物質到達地下水的可信機制。		
1.2.2.a	確定涉及或可能合理預期涉及放射性物質的每個 SSC，並據此確定放射性物質到達地下水的可信機制。SSC 例如包括:填換燃料儲水槽(refueling water storage tanks)、用過燃料池(spent fuel pools)、用過燃料池洩漏檢測系統(spent fuel pool leak detection systems)、室外儲槽(outdoor tanks)、室外存放受污染設備(outdoor storage of contaminated equipment)、埋設管道(buried piping)、保留池或盆或水庫(retention ponds or basins or reservoirs)、蒸汽管線(lines carrying steam)。	1.2.a	確定涉及或可能合理預期涉放射性物質的每個 SSC 及**工作作業**，並據此確定放射性物質到達地下水的可信機制。*
1.2.2.b	確定涉及或可能涉及放射性物質的每個 SSC 的現有洩漏檢測方法，並且意外釋放到地下水的可信潛勢。地下水監測、操作員巡視檢查、工程現場巡查、履勘、洩漏檢測系統檢查或定期完整性測試。	1.2.b	確定涉及或可能涉及放射性物質的每個 SSC **及工作作業**的現有洩漏檢測方法，並且意外釋放到地下水的可信潛勢。*
1.2.2.c	確定工作作業，包括下列行動: 個人維護、操作或支援活動期間可能導致或防止來源放射性物質洩漏或傾洩釋		

	放至地下水的機制。		
1.2.2.d	評估潛在增強洩漏檢測系統或方案，包括額外或增加檢查、巡查、履勘或完整性測試的頻率。	1.2.c	評估潛在增強洩漏檢測系統或方案。*
1.2.2.e	評估潛在增強防止洩漏或傾洩到達地下水措施，包括重新密封或鋪裝表面、安裝傾洩控制措施、執行預防性維護或監控活動，以盡量減少因設備故障而意外釋放放射性物質的可能性。	1.2.d 1.2.f	評估潛在增強防止洩漏或傾洩到達地下水措施。* 制定**長期計畫**，執行預防性維護或監控活動，以盡量減少因設備故障而意外釋放放射性物質的可能性。
1.2.2.f	確認追蹤修正措施的機制或廠址過程。	1.2.e	確認追蹤修正措施的機制或廠址過程。
1.2.2.g	確定定期審查 SSC 和工作作業的頻率。	1.2.g	確定定期審查 SSC 和工作作業的頻率。
1.3 建立場址內地下水監測方案，確保及時偵測意外釋放到地下水的放射性物質。			1.3 建立場址內地下水監測方案，確保及時偵測意外釋放到地下水的放射性物質。
1.3.a	利用根據目標 1.1 開發的水文和地質研究，考慮設置地下水監測井在廠區下游處至場址執照所界定邊界內。水井之放置，應以確保監測到地下水遷移途徑。	1.3.a	利用根據目標 1.1 開發的水文和地質研究，考慮設置地下水監測井在廠區下游處至場址執照所界定邊界內。
1.3.b	地下水監測井設置位置實際上盡可能在最可能發生意外釋出或 SSC 洩漏偵測能力其他方法有限之處。	1.3.b	**若適當，考慮前哨井放置於**最可能發生洩漏之 SSC 附近，以增加意外釋出到地下水之監測可能性或 SSC 洩漏偵測能力有限之處。
1.3.c	建立地下水和土壤採樣與分析協定，包括分析靈敏度要求、品質保證及品質控制程序，考慮來自於水或空氣中計畫性釋出放射性物質，其可被偵測到之可能性。	1.3.c	建立地下水和土壤採樣與分析協定，包括分析靈敏度要求。*
1.3.d	建立長期地下水監測計畫，並且具有正式文件，REMP 中包含地下水監測位置，並修正場址的 ODCM/ODAM 及確保清楚區別兩方案不同點。	1.3.d	建立長期地下水監測計畫，並且具有正式文件*

1.3.e	定期檢查現有的檢測站或合約實驗室的分析能力。另外，檢驗分析協定及獲得結果所需的時間須納入重要的考慮因素。	1.3.e	定期審查現有的工作站或合約實驗室的分析能力。*
1.3.f	建立地下水井預防性維護之長期方案 。	1.3.f	建立地下水井預防性維護之長期方案
1.3.g	建立地下水監測方案定期審查的頻率。	1.3.g	建立地下水監測方案定期審查的頻率。
1.4 建立整治之策略，防止放射性物質在場外遷移，並減少除役影響。		1.4 建立整治之策略，防止放射性物質在場外遷移，並減少除役影響。	
1.4.a	建立書面程序，概述整治洩漏、傾洩或其他污染意外釋出實例之應變決策過程。此過程隨各場址特性不同而有所差異性，並應考慮放射性物質遷移途徑。	1.4.a	建立書面程序，概述整治洩漏、傾洩或其他污染意外釋出實例之應變決策過程。此過程隨各場址特性不同而有所差異性，並應考慮放射性物質遷移途徑。
		1.4.b	**評估由於計畫性液體或空氣物質釋放出放射性物質檢測水準被檢出之可能性**。
1.4.b	若適當，評估及記錄整治作業對核電廠除役工作有或沒有影響。	1.4.c	若適當，評估及記錄整治作業對核電廠除役工作有或沒有影響。
1.5 確保電廠洩漏、傾洩、整治工作記錄保留，並且可供檢索查詢，以滿足 10 CFR 50.75(g)的要求。		1.5 確保電廠洩漏、傾洩、整治工作記錄保留，並且可供檢索查詢，以滿足 10 CFR 50.75(g)的要求。	
1.5.a	建立記錄保存計畫，滿足 10 CFR 50.75(g) 的要求。 請注意，這些記錄用於確定執行調查區域類別（請參閱 NRC 法規摘要 2002-02 與最近提交除役計畫及執照終止計畫有關的學習課程）。	1.5.a	建立記錄保存計畫，滿足 10 CFR 50.75(g) 的要求。
1.6 除役/安全貯存影響。			

1.6.a	建立書面程序概述管制文件內容，如停止運轉後除役活動報告及執照終止計畫，以建立或改變地下水相關程序。		
1.6.b	當場址條件或程序規劃及/或改變時: 1.評估何種措施會影響地下水防護。 2.評估 SSC 及工作實務風險評估可反映目前條件。 3.評估場址概念模式可反映目前條件。 4.當 SSC、工作實務風險評估改變及其他任何場址特性概念模式改變時，評估修正地下水監測計畫可反映上述改變，如採樣頻率及監測井數量。		
1.6.c	確認場址放射性物質整治完成之前，對地下水防護適當元素進行評估和維護，包括監測和整治任何已確認超過飲用水標準之地下水污染。		
2.1 在地下水防護倡議發展初期，每一位持照人對於政府應進行其特定廠址地下水防護倡議定期簡報，電廠在 2020/1/1 後開始運轉者，應進行初期簡報。		2.1 每一位持照人對於政府應進行其特定廠址地下水防護倡議定期簡報。	
2.1.a	持照人應該討論: 1.背景或業界事件造成地下水防護倡議。 2. 如果有額外的資訊，政府需要良好了解這議題，或需從民眾角度看待這議題。 3.政府如何使用或分配這資訊。	2.1.a	持照人應該討論: 1.背景或工業事件造成地下水防護倡議。 2. 如果有額外的資訊，政府需要良好了解這議題，或需從民眾角度看待這議題。 3.政府如何使用或分配這資訊。
2.1.b	持照人需要考慮包括額外的資訊，或與政府定期討論更新地下水防護。	2.1.b	持照人需要考慮包括額外的資訊，或與政府定期討論更新地下水防護。

2.1.c	持照人在多州有多個核電廠與多個電力公司，強烈建議持照人與政府進行自願性溝通與努力協調使其一致。與政府的初期簡報及自願性溝通內容應保持一致。	2.1.c	持照人在多州有多個核電廠與多個電力公司，強烈建議持照人與政府進行自願性溝通與努力協調使其一致。與政府的初期簡報及自願性溝通內容應保持一致。
2.2 盡快與適當官員進行非正式溝通，若適當，再向 NRC 進行後續通知，關於重大廠內洩漏、傾洩至地下水，廠內外採集水樣監測結果超過 ODCM / ODAM 中所述 REMP 中標準水質標準等情況。		2.2 盡快與適當官員進行非正式溝通，若適當，再向 NRC 進行後續通知，關於重大廠內洩漏、傾洩至地下水，廠內外採集水樣監測結果超過 ODCM / ODAM 中所述 REMP 中標準水質標準等情況。*	
2.2.a	如果意外洩漏或傾洩至環境，已經或可能進入地下水及超過以下任何標準符合下列任一條件，與政府官員進行溝通，應該下一個工作天完成。1. 如果含有放射性物質來源的洩漏或傾洩超過 100 加侖。2. 如果含有放射性物質來源的洩漏或傾洩無法定量，但可能超過 100 加侖。3. 無論量或活動，任何洩漏或傾洩，持照人必定保證進行自願性溝通。及無論量或活動，洩漏或傾洩量事件無法根據目的 1.4 在 24 小時內完全回收及整治。	2.2.a	如果意外洩漏或傾洩至環境，已經或可能進入地下水及超過以下任何標準符合下列任一條件，與政府官員進行溝通，應該下一個工作天完成。1. 如果含有放射性物質來源的洩漏或傾洩超過 100 加侖。2. 如果含有放射性物質來源的洩漏或傾洩無法定量，但可能超過 100 加侖。3. 無論量或活動，任何洩漏或傾洩，持照人必定保證進行自願性溝通。*
2.2.b	對於水樣結果，必須在下一個工作日結束前完成與政府官員:1. 當廠外地下水與地面水超過 ODCM / ODAM 中所述 REMP 任何水質標準規定。2. 當廠內地面水在水文上連接地下水，或地下水被當作飲用水使用，廠內或廠區下游處水樣超過 ODCM / ODAM 中所述 REMP 任一水質標準規定。	2.2.b	對於水樣結果，必須在下一個工作日結束前完成與政府官員:1. 當廠外地下水與地面水超過 ODCM / ODAM 中所述 REMP 任何水質標準規定。2. 當廠內地面水在水文上連接地下水，或地下水被當作飲用水使用，水樣超過 ODCM / ODAM 中所述 REMP 任一水質標準規定。
2.2.c	與政府官員進行溝通，當使用適當的管制標準，必須清楚明確量化實際釋放資訊。	2.2.c	與政府官員進行溝通，當使用適當的管制標準，必須清楚明確量化實際釋放資訊。*
2.2.d	與政府官員進行溝通，依據 10 CFR 50.72(b)(2)(xi)也需	2.2.d	與州和/或地方官員**的自願溝通可能還需要依 NRC 要求之通**

	要通知 NRC，持照人應進行這項通知與目前已有方案保持一致。		**知根據 10 CFR 50. 72(b)(2)(xi)。持照人應執行符合其現有計畫的通知。**
2.2.e	使用 email(GRPGroundwaterIssues@nei.org)與 NEI 聯繫，可視為溝通事件一部分。	2.2.e	使用 email(**GW_Notice@nei.org**)與 NEI 聯繫，可視為溝通事件一部分。
2.3. 對於廠內地下水水質檢測結果是或可能當作飲用水水源任何一項超過持照人既有 REMP/ODCM 的 30 日廠外水樣結果之水質標準，持照人須在 30 日內向 NRC 提交一份報告，這廠內外地下水 30 日報告副本也須提供政府官員。		2.3 對於廠內地下水水質檢測結果是或可能當作飲用水水源任何一項超過持照人既有 REMP/ODCM 的 30 日廠外水樣結果之水質標準，持照人須在 30 日內向 NRC 提交一份報告，這廠內外地下水 30 日報告副本也須提供政府官員。	
2.3.a	對於業界倡議所有地下水水樣必須對於 ODCM / ODAM 中所述電廠 REMP 水質標準與限制進行分析與比較。	2.3.a	對於業界倡議所有地下水水樣必須對於 ODCM / ODAM 中所述電廠 REMP 水質標準與限制進行分析與比較。*
2.3.b	30 天特別報告應包括接受標準 2.3.b.中所列項目	2.3.b	30 天特別報告應包括所列項目*
2.3.c	所有 2.3.a 項目中所寫 30 天 NRC 報告將同時交給政府官員。	2.3.c	所有 2.3.a 項目中所寫 30 天 NRC 報告將同時交給政府官員。
2.4 由 2006 年開始每年在適當報告程序中，對於 REMP 每年放射性環境運作報告(AREOR)或對於 RETS 每年放射性廢水排放報告(ARERR)記錄廠內地下水放射性物質採樣結果及任何重大廠內洩漏及傾洩進入地下水。		2.4 由 2006 年開始每年在適當報告程序中，對於 REMP 每年放射性環境運作報告(AREOR)或對於 RETS 每年放射性廢水排放報告(ARERR)記錄**全部**採樣結果及任何重大廠內洩漏及傾洩進入地下水。	
2.4.a	若為 2008 年後興建的核電廠，在初次燃料裝填之前，需要包括重要廠內洩漏及傾洩進入地下水與發展及實施所有地下水結果適當程序，建議參考 2008 年 12 月 NEI08-08”污染物生命週期最小化一般 FSAR 範例指引”	2.4.a	**在 2007 年報告完成對 ODCM/ODAM 或適當程序的適當改變。對於新廠址，應在初次燃料裝填之前，需要包括重要廠內洩漏及傾洩進入地下水與發展及實施所有地下水結果適當程序。***
2.4.b	廠內地下水採樣結果報告應該根據下列:1. 地下水採樣結果採用為地下水防護倡議為基礎，但不為 REMP 方案	2.4.b	廠內地下水採樣結果報告根據下列:1. 地下水採樣結果採用為地下水防護倡議為基礎，但不為 **ARERR 的** REMP 方案之一

	之一部分，例如根據 10 CFR 50.36a(a)(2) 要求 ARERR 報告在 2006 年調查階段行動計畫所獲得水樣。2. 當依據目的 1.3 接受標準 d，ODCM / ODAM 中所述 REMP 所建立長期監測採樣點，監測結果將於 AREOR 中報告，若長期監測採樣點未列於 REMP 內，則於 ARERR 中報告。		部分。2. **對於** ODCM / ODAM 中所述 REMP **的**長期監測採樣點，監測結果將於 AREOR 中報告，若長期監測採樣點未列於 REMP 內，則於 ARERR 中報告。*
2.4.c	除目的 2.4 b 點外，若有任何進行自願性溝通，年度報告內容應包括:1.依據目的 2.2 接受標準 a 點，所有洩漏或傾洩的溝通描述必須包含於 ARERR 或 AREOR 報告中。2. 依據目的 2.2 接受標準 b 點，所有廠內外地下水採樣結果超過 ODCM / ODAM 中所述 REMP 報告門檻的溝通，必須包含於 AREOR 或 ARERR 報告中。	2.4.c	除目的 **2.1 b** 點外，自願性溝通應包括:**下列需在 REOR 或 ARERR 報告包括**:1.依據目的 2.2 接受標準 a 點，所有洩漏或傾洩的溝通描述必須包含於 ARERR 報告中。2. 依據目的 2.2 接受標準 b 點，所有廠內外地下水採樣結果超過 ODCM / ODAM 中所述 REMP 報告門檻的溝通，必須包含於 AREOR 或 ARERR 報告中。
3.1 進行方案監督以確保地下水防護方案有效的施行		3.1	**執行地下水防護倡議自我評估(參考此檢查表)**
3.1.a	獨立且具有專業知識的個體應在初次臨界後的一年內進行初期自我評估，此步驟僅適用於符合在 2020/01/01 以後運轉的電廠。	3.1.a	獨立且具有專業知識的個體應在一年內進行初期自我評估。*
3.1.b	地下水防護倡議方案程序性評估應該在初次自我評估後每五年至少一次定期進行，這程序性評估應該根據記錄管理及隨電廠生命維持。	3.1.b	地下水防護倡議方案**定期自我**評估應該在初次自我評估後每五年至少一次進行。
3.1.c	這自我程序性評估應該至少包括本文件所有目的評估，與電廠適用程序及程序保持一致之文件記錄。	3.1.c	這自我程序性評估應該至少包括本文件所有目的評估。
		3.1.d	**這自我程序性評估應該與電廠適用程序保持一致之文件記錄**。

		3.2 在 NEI 協助下，進行地下水防護倡議方案進行審查，至少包括持照人的自我評估。	
		3.2.a	獨立且具有專業知識的個體應該根據目標 3.1.a，在初次自我評估的一年內進行審查。
		3.2.b	根據目標 3.1.b 執行執照的定期自我評估之後，應每 5 年對地下水防護倡議方案進行一次定期審查。

Detailed requirements are in the Industry Groundwater Protection Initiative Final Guidance document， rev. 1， March 2019.

* Detailed requirements are in the Industry Ground Water Protection Initiative Final Guidance document - August 2007

Additional Comments As Required:

Detailed requirements are in the Industry Groundwater Protection Initiative Final Guidance document， rev. 1， March 2019.

3-3 美國核電廠廠址地下水防護與管制案例

針對美國核電廠 Oyster Creek Nuclear Generating Station (OCNGS)、Dresden Nuclear Power Station (DNPS)與 Zion Nuclear Power Station (ZNPS)進行除役電廠相關地下水監測內容整理。

3-3-1 美國紐澤西州核電廠 Oyster Creek Nuclear Generating Station (OCNGS)運轉與除役之地下水防護工作

■ 紐澤西州執行核電廠輻射環境監測計畫

（資料來源：Department of Environmental Protection Division of Climate, Clean Energy & Radiation Protection, Radiation Protection Element Monthly Report, 2019）

Oyster Creek 核能發電廠 1 號機的運轉執照期限為 2029 年 4 月 9 日，Exelon 電力公司是美國一家公共事業控股公司，也是美國目前最大的核電公司，其擁有 10 座發電廠，每年發電可達到 1.8 萬百萬瓦，佔美國核電力發電量的 20%。Exelon 公司決定 2018 年 10 月 31 日終止 Oyster Creek 核能發電廠運轉，正式於 2018 年 9 月 17 日永久停止運轉，2018 年提出停止運轉後除役活動報告(Post-Shutdown Decommissioning Activities Report, PSDAR)。

紐澤西州有四座核電廠針對廠周圍地區進行全面的輻射環境監測計畫(Radiological Environmental Monitoring Program, REMP)。2019 年 12 月，該計畫收集了 80 個樣本，其中包括地表水 8 個樣本，無地下水樣本。在 2010 年 11 月之前，Oyster Creek 未定期排放液態水至環境中。根據向 Oyster Creek 核電廠發出的 DEP 指令(EA ID #: PEA100001)和《溢漏補償和控制法》(Spill Compensation and Control Act, N.J.S.A. 58:10- 23.11)，Exelon 需要清理和清除 2009 期間發生的地下管道洩漏致現場廠址的氚。2010 年 11 月下旬，開始在 Oyster Creek 抽取地下水，以提供正在進行的氚地下水監測專案。經 DEP 批准，Exelon 從專用泵井(MW-73)取樣地下水，測量抽取地下水中的氚濃度，並將其排放。因除役活動而排出的放射性液體污水將由 HDI (Holtec Decommissioning International)監測。HDI 從專用泵井(MW-73)取樣量測地下水中的氚濃度。除地下水監測外，電廠還必須在除役和最終執照終止期間處理和排放液體污水。相關 Oyster Creek 核電廠氚洩漏的資訊，可在網站查詢 HTTP://www.state.nj.us/dep/rpp/bne/octritium.htm。

■ OCNGS 放射性地下水監測

Exelon 公司為 OCNGS 進行的年度放射性地下水防護計畫(Annual Radiological Groundwater Protection Program, RGPP)，2018 年提出之報告是運轉中之狀態，也就是針對 2017 年(Jan. 1~ Dec. 31, 2017)進行之地下水(groundwater)、地表水(surface water)與雨水(precipitation water)樣本監測，監測區域(如圖 3-1)包括電廠內和電廠外共 65 個採樣點，253 個樣本進行 713 次分析，分析項目與濃度範圍如表 3-4。

圖 3-1 OCNGS 的 RGPP 採樣點

資料來源：Sampling Location-selected Cohansey And Cape May Formation Wells, Oyster Creek Generating Station, 2018)

在 2009 年，OCNGS 有三次受污染水意外排放到地下水中，在汽機廠房(Turbine building)以西發現一溶解相污染團(plume)在多數的監測井均檢測出，監測結果顯示，在 66 個地下水井樣本檢測，其中 3 個樣本之 K-40 (珈瑪放射核種 Potassium-40)濃度為 90～114 pCi/L；在 4 個地表水樣本的其中 3 個檢測到濃度從 249～326 pCi/L；針對氚之檢測，Exelon 規定實驗室的檢測極限值(200 pCi/L)比美國環境保護署(USEPA)規定的飲用水限值(20,000 pCi/L)低 100 倍，Exelon 在地下水樣本中檢測到氚的濃度為 <200～9,800 pCi/L，測得氚的濃度以 MW-561 井最高；在所有之地下水樣本中均未檢測出 Strontium-89 (Sr-89)與 Strontium-90 (Sr-90)；地下水樣本檢測 Gross Alpha 與 Gross Beta 結果顯示，其中 44 個地下水井點採集了 50 個樣本，在任一樣本中均未檢測到 Gross Alpha (可溶性)，其中有 10 個樣本中檢測出 Gross Alpha (懸浮性)範圍從 3.0～16.3 pCi/L，在 41 個樣本中檢測到 Gross Alpha (可溶性)範圍從 1.0～48.0 pCi/L，在 12 個樣本中檢測到 Gross Alpha (懸浮性)範圍從 2.4～38.7 pCi/L。

Exelon 公司也選定一組特定點的地下水樣本做難測核種分析(Hard-To-Detect analyses)，地下水分析項目包括 Americium-241 (Am-241), Cerium-242 (Cm-242), Cerium-243/244 (Cm-243/244), Plutonium-238 (Pu-238), Plutonium-239/240 (Pu-239/240), Uranium-234 (U-234), Uranium-235 (U-235), Uranium-238 (U-238), lron-55 (Fe-55)與 Nickel-63 (Ni-63)，分析結果其中在 9 個樣品中，有 1 個樣本檢測出 U-234 與 U-238，U-234 濃度為 1.16 pCi/L，U-238 濃度為 1.23 pCi/L。

表 3-4 2018 與 2019 年 OCNGS 的 RGPP 報告監測結果

	2018	2019
監測期間	Jan. 1~ Dec. 31, 2017	Jan. 1~ Dec. 31, 2018
環境介質	地下水、地表水	地下水、地表水
樣本數	253	271
採樣點	65	63
分析樣本數	713	761
	濃度(檢出樣本數/總樣本數)	
Gamma-emitting radionuclide Potassium-40 (K-40)	地下水 90 至 114 pCi/L (3/66) 地表水 249 至 326 pCi/L (3/4)	地下水 65 至 73 pCi/L (2/63) 地表水 186 至 237 pCi/L (3/4)
tritium	<200-9,800 pCi/L MW-561 井濃度最高	<174-3,030 pCi/L MW-571 井濃度最高
Strontium-89 (Sr-89) Strontium-90 (Sr-90)	未檢出	未檢出
	濃度(樣本數/地下水井)	
Gross Alpha (Dissolved)	未檢出	0.4-3.9 pCi/L (7/56)
Gross Alpha (Suspended)	3.0 到 16.3 pCi/L	2.0-8.4 pCi/L (8/56)
Gross Beta(Dissolved)	1.0 到 48.0 pCi/L	0.9-31.5 pCi/L (47/56)
Gross Beta(Suspended)	2.4 到 38.7 pCi/L (50/44)	1.8-13.5 pCi/L (12/56) (56/50)
Hard-To-Detect analyses	濃度 pCi/L (樣本數/總樣本數)	
Americium-241 (Am-241) Cerium-242 (Cm-242) Cerium-243/244 (Cm-243/244) Plutonium-238 (Pu-238) Plutonium-239/240 (Pu-239/240) Uranium-234 (U-234) Uranium-235 (U-235)	U-234:1.16 pCi/L U-238 :1.23 pCi/L (1/9)	未檢出 U-234 與 U-238 (視為背景值)

Uranium-238 (U-238) Iron-55 (Fe-55) Nickel-63 (Ni-63)

■ OCNGS 之放射性環境監測計畫

資料來源：Annual Radiological Environmental Operating Report-2011, (2012), Exelon

2012 年 Exelon 公司提出 OCNGS 年度放射性物質環境運轉報告(Annual Radiological Environmental Operating Report)，係 Exelon 公司針對 OCNGS 進行 2011 年的放射性環境監測計畫(Radiological Environmental Monitoring Program, REMP)，其中總共收集 1244 樣本，分析檢測 1622 個樣本，與過去的檢測紀錄比較並無對環境產生可逆性的影響。Exelon 公司在 1966 年即針對 OCNGS 進行運轉前的放射性環境監測計畫(preoperational Radiological Environmental Monitoring Program)執行兩年後，在 1969 年執行運轉中之 REMP，分析是由 Teledyne Brown Engineering(TBE), Mirion Technologies 與 Environmental Inc. (Midwest Labs)進行樣本收集後分析。

放射性環境計監測畫(REMP)中，樣本的採集主要考量放射性核種經由環境進入人體的路徑(pathway)，採樣地點的選擇是以樣本的可獲得性(availability)、當地氣象、水文地質特性、當地人口特性與土地使用為考量因素，並嚴格對放流水進行監測，針對放射性物質釋放至環境中之濃度不可超過法規限值。

2010 年 10 月 Exelon 公司開始對 OCNGS 2009 年發生洩漏造成的地下水氚進行積極補救。採取策略(Actions Taken)包括補償行動(Compensatory)、監測井設置(Installation of Monitoring Wells)與回復/反轉污染團的行動(Actions to Recover/Reverse Plumes)。

補償行動

2009 年 10 月開始對因 2009 年發生的洩漏造成的地下水氚進行積極整治。

設置監測井

2010 年設置監測井可以針對氚污染團與場址水文情況更佳掌握。共設 W-581, W-591, W-601, W-611, W-62, W-631, W-64, W-65, W-661, W-67, W-681, W-691, W-701, W-71, W-72, W-73 (pumping well)等 16 口井(如圖 3-1)。

回復/反轉污染團的行動

針對地下水中之氚在 W-73 井進行抽取地下水，將污染團回復以解決地下水氚問題。

REMP 中針對地表水、飲用水與地下水均進行監測，其中地下水檢測氚與珈瑪放射核種並未出現在地下水中。此報告中之主要內容：

- 判斷在主要的途徑中是否有顯著的放射性物質的增加。
- 比較背景放射性在環境中包括建物是否有任何的改變。
- 確認電廠控制放射性物質的釋放是否確實。
- 確實執行電廠外之劑量估算手冊中(Oyster Creek's Offsite Dose Calculation Manual, ODCM)的放射性物質調查之一節。

在水域環境監測主要收集地表水、飲用水、地下水、魚、貝與底泥等。針對 6 個飲用水井(1N, 1S, 37, 38, 39, 114)進行每月監測，2 個地下水井(MW-24-3A, W-3C)每季監測。監測結果顯示，1 號井由於位於 OCNGS 現場，可能受核電廠的放射性物質釋放的影響，38 號站因距離設施(1.6 英里)、深度(約 360 英尺)可能受 OCNGS 的廢水排放的影響。37、39 號井位於區域地下水流方向(東南)的上坡，不太可能受到 OCNGS 的排放水的影響，其深度(> 200 英尺)和距離現場(分別為 2.2 和 3.5 英里)，它們不太可能受到 OCNGS 運轉的影響。分析結果均未檢測到氚，且低於 1E+3 pCi/升的最小可檢測濃度。地表水、飲用水與地下水均需要檢測氚，在地下水樣本中均未檢測到氚，Gamma 分析樣本都低於最低可測濃度(Minimum detectable concentration, MDC)。REMP 地下水監測珈瑪放射核種等 12 個核種，包括 Mn-54, Co-58, Fe-59, Co-60, Zn-65, Zr-95, Nb-95, I-131, Cs-134, Cs-137, Ba-140 與 La-140。

■ OCNGS 之 2012 與 2019 RGPP 監測結果比較

參考資料：

Oyster Creek Generating Station unit 1-Annual Radiological Groundwater Protection Program Report, April 2012, Exelon

Oyster Creek Generating Station unit 1-Annual Radiological Groundwater Protection Program Report, April 2019, Exelon

Teledyne Brown Engineering (TBE) and Environmental Inc. (Midwest)於 2011 與 2018 年期間執行之放射性物質地下水防護計畫(Radiological Groundwater Protection Program, RGPP)，RGPP 長期目標包括如下，除了第 14 項不同外，其他的目標均為一致。

(1) 確保地質和水文的場址特徵，可提供目前的場址現況之主要地下水梯度的了解
(2) 根據電廠設計與工作現況確認場址風險
(3) 評估系統、結構及組件(簡稱 **SSC**)含有放射性物質，以及放射性物質進入地下水的過程與機制
(4) 評估工作操作含有放射性物質，以及放射性物質進入地下水機制
(5) 執行現場監測(on-site monitoring)，確保及時檢測放射性意外釋放到地下水
(6) 瞭解 REMP(Radiological Environmental Monitoring Program)外之放射性物質的背景濃度
(7) 評估過去排放的重複使用/回收之氣體或液體廢水放射性(從環境返回運轉核能設施)

(8) 確保建立監測井的選擇、安裝和汰除的管控機制

(9) 執行整治協定，以防止放射性物質異地廠址外之遷移，並盡量減少除役影響

(10) 確保保留和可取得洩漏、傾洩、補救工作記錄，以符合 10 CFR 50.75(g)規範

(11) 定期就 RGPP 與指定的州/地方官員進行溝通

(12) 若土壤、地下水或地表水意外釋放放射性物質，需確保及時進行口頭和書面報告

(13) 記錄並回報所有適用的 RGPP 資料

(14) 在 PI-AA-120 “Issue Identification And Screening Process”中描述的修正方案流程，確認並解決缺失(2012)；在 PI-DC-125 “Decommissioning Corrective Action Program”中描述的修正方案流程，確認並解決缺失(2019)

(15) 執行計畫監督，確保自願性 RGPP 的有效實施

2018 年的監測結果顯示，多數水井之監測頻率減少，部分水井之監測頻率維持不變，其中有 13 口水井在 2011 年時監測次數共計 12 次，頻率為一個月監測一次，井名分別為 MW-15K-1A、MW-50、MW-52、MW-53、MW-54、MW-55、MW-56I、MW-57I、MW-62、MW-64、MW65、MW-67、W-3，井位置如圖 3-2，這 13 口水井的採樣點分布非常接近，也是 2011 年監測頻率最高的井。

但與 2018 年的監測結果比較發現這 13 口水井的監測次數都呈現明顯降低，監測次數在一年內約三到四次間，監測頻率約三個月一次，其中井 MW-50、MW-52、MW-53、MW-54 等四口水井的監測頻率為 3 次/年；井 MW-15K-1A、MW-55、MW-56I、MW-57I、MW-62、MW-64、MW65、MW-67、W-3 等九口水井的監測頻率為 4 次/年。

針對 2011 年和 2018 年的監測地下水水井資料，其中有四口水井的資料中有明顯差異，其分別為井 MW-51、W-19、W-27 與 SEWER PIT 等，在圖 3-2 中只看到 W-19 與 W-27(標示藍色)。其中，在 2011 年井 MW-51、W-19、W-27 的監測頻率是一年一次，監測的放射性物質氚，2018 年未進行監測，在 2018 新增井 SEWER PIT 測得之氚濃度為<186 pCi/L 監測頻率是一年一次。2018 年的地下水監測項目中增加放射性物質 Sr-89, Be-7 與 K-40。詳細的監測結果如表 3-5。

圖 3-2 OCNGS 的 RGPP 採樣點

註：紅框為監測頻率高之 13 口水井，W-19 與 W-27(標示藍框)

資料來源：Sampling Location-selected Cohansey And Cape May Formation Wells, Oyster Creek Generating Station, 2018

表 3-5 OCNGS 之 2012 與 2019 年 RGPP 監測結果

	2012	2019
監測期間	Jan. 1~ Dec. 31, 2011	Jan. 1~ Dec. 31, 2018
環境介質	地下水	地下水
樣本數	1072	271
採樣點	65	63
分析樣本數	2104	761
	濃度(檢出樣本數/總樣本數)	
Gamma-emitting radionuclide Potassium-40 (K-40)	---	地下水 65 至 73 pCi/L (2/63) 地表水 186 至 237 pCi/L (3/4)
tritium	<200-994000pCi/L MW-67 最高濃度	<174-3,030 pCi/L MW-571 井濃度最高
Strontium-89 (Sr-89)	---	未檢出
Strontium-90 (Sr-90)	未檢出	未檢出
	濃度 pCi/L (樣本數/地下水井)	
Gross Alpha (Dissolved)	0.4-5.7(9/47)	0.4-3.9(7/56)
Gross Alpha (Suspended)	1.2-19.9(19/47)	2.0-8.4 (8/56)
Gross Beta (Dissolved)	1.3-109(45/47)	0.9-31.5 (47/56)
Gross Beta (Suspended)	1.8-77.5(22/47)	1.8-13.5 (12/56)
	(47/42)	(56/50)
Hard-To-Detect analyses	濃度 pCi/L(樣本數/總樣本數)	
Americium-241 (Am-241) Cerium-242 (Cm-242) Cerium-243/244 (Cm-243/244) Plutonium-238 (Pu-238) Plutonium-239/240 (Pu-239/240) Uranium-234 (U-234) Uranium-235 (U-235) Uranium-238 (U-238) Iron-55 (Fe-55) Nickel-63 (Ni-63)	U-234 濃度 0.41-1.74 U-238 濃度 0.44-1.81 (視為背景值)	未檢出

■ Oyster Creek 核電廠停止運轉後除役活動報告(Oyster Creek Nuclear Generating Station, Post-Shutdown Decommissioning Activities Report, 2018)

OCNGS 根據 10 CFR 50.82 “Termination of license” (a)(4)(i)提出除役工作，2018 年提出停止運轉後除役活動報告(Post-Shutdown Decommissioning Activities Report, PSDAR)。在此份報告中相關之除役項目與地下水相關重點如下：

(1)地表土壤、地表下介質與地下水須符合標準 10 CFR 20.1402

(2)為了滿足執照終止標準，需要移除地下管道(或類似物品)和相關土壤

(3)針對地下水防護與放射性除役計畫(Groundwater Protection and Radiological Decommissioning Records Program)-根據核能研究所(NEI)技術報告 07-07, NEI 07-07, “Industry Groundwater Protection Initiative - Final Guidance Document”，提到 OCNGS 目前正在實施地下水防護方案，在除役期間將持續進行。10 CFR 50.75(g)要求現有放射性除役記錄計畫，Exelon 將繼續保存，在地下水防護計畫的監測結果或 10 CFR 50.75(g)中所紀錄的事件之監測結果，均未顯示發現長半衰期核種(long-lived radionuclides)，此為根據 10 CFR 20.1402 之規定中非限制性地外釋，“非限制性使用的放射性標準”。

(4)OCNGS 除役的環境影響，OCNGS 從 Forked 河南岸獲得地表水，用於冷卻用水、冷卻和稀釋水。此外，現有的現場井提供可飲用和不可飲用的地下水作為各項使用。Exelon 預計現有的現場井，將繼續提供飲用水和非飲用水地下水，供 OCNGS 除役期間使用 。

(5)可能影響地表水質的除役活動，包括燃料清除、穩定、大型部件拆卸、除污和拆卸以及結構拆除。雨水徑流和意外排放(溢出)是除役期間最有可能進入地表水的污染物來源。關於地下水，GEIS (Generic Environmental Impact Statement)指出，拆除混凝土結構和儲存現場瓦礫，可能導致當地水化學的變化(更高的鹼度)，但這些變化對水質的非輻射影響在所有核電廠都是無法偵測的。

(6)在 OCNGS 除役期間，Exelon 將繼續遵守相關法規，這些法規要求報告危害性物質之洩漏。整治活動需要符合《Industrial Sites Recovery Act 業界場址回復法》並與 NJDEP 協商及時完成。除役期間地下水使用量的減少，預計不會改變地下水流動路徑或以其他方式影響正在進行的補救活動。

(7)NRC 整體的結論是對於所有設施，除役對地表和地下水品質的影響將很小。因為 OCNGS 的設計、位置、配置、運轉歷史或除役計畫沒有任何改變或結論不一致，Exelon 將遵守保護地表水和地下水資源的法規和執照要求，因此 Exelon 已經確定，除役對水質的影響很小。

(8)執照終止的環境影響評估– NUREG-1496，根據 10 CFR 50.82(a)(9)要求，在預期執照終止日期之前至少兩年，沒有任何特別的特定場址因素、嚴重的地下水污染、異常人口統計數據或實際非限制性外釋顯示來自於 OCNGS 執照終止所產生的影響，將與 NUREG-1496 中評估類似。

3-3-2 美國伊利諾州核電廠 Dresden Nuclear Power Station 地下水防護

資料來源：Dresden Nuclear Power Station Unit 1, 2 and 3-Annual Radiological Groundwater Protection Program Report, May 2018, Exelon

Dresden Nuclear Power Station (DNPS)執行之放射性物質地下水監測計畫(RGPP)，主要是在長期監測並驗證廠區範圍內之水文地質，其中設有地下水井與地表水採樣點，其 RGPP 設立於 2006 年且與 REMP 互為獨立進行。監測地下水井設有篩網，並在地表附近適當密封，以防止地表水侵入，這些井是根據規範、標準與程序而設計。DNPS 地下水監測井分為“淺”(深度為 15 至 35 英尺)、“中度”(深度為 35 至 55 英尺)、“深”(深度為 100 英尺以上)。超過 100 英尺深井大多無水，不被包含在 RGPP 中，地面水採樣點在廠內水道和冷卻池中的採樣位置。

DNPS 之 RGPP 目標:

RGPP 目標是提供長期監測，以驗證整個廠區範圍內的水文地質研究，特別是提供保護區(Protected Area, PA)中地下水氚濃度的短期變化，如果地下水水樣的同位素結果超過了本程序規定的標準值，則可能顯示從上方溢出了新的溢出物或地面系統含有氚水的地下管道中出現新洩漏。

具體目標包括：

(1)對選定位置進行例行性水樣和放射性分析。

(2)及時向利益關係人報告具有潛在放射性物質新洩漏、傾洩或其他發現。

(3)定期評估分析結果以確定不利趨勢。

(4)採取必要的修正措施以保護地下水資源。

RGPP 目標的執行：

(1)DNPS 將繼續對選定地點的水體，進行例行取樣和放射性元素分析。

(2)DNPS 已實施程序作為及時確認和報告新的洩漏、傾洩或其他具有可能放射性物質之發現。

(3)DNPS 工作人員和諮詢水文地質學家不斷評估分析結果，以查明不利趨勢。

(4)如果在地下水監測分析結果中發現不利趨勢，將進行進一步調查。如果調查發現洩漏或不明傾洩，將採取修正措施。

RGPP 監測重點如下：

(1)電廠過去 50 年的歷史中經歷了地下管線的洩漏和含有放射性水的系統中的洩漏

(2)DNPS 廠址中劃定一保護區(Protected Area, PA)，在 PA 保護區造成氚污染

(3)電廠在 2006 年進行全面性的水文地質調查(Fleetwide Hydrogeologic Investigation, HIR)

- ✓ 確認每個地點的地下水流動特徵
- ✓ 在調查中編製了一份歷史傾洩和洩漏清單，以及電廠之地下水水文詳細分析
- ✓ 將當地受污染地區的氚污染濃度與附近地下水流速度與方向，以產生受污染的地下水污染團推測
- ✓ 如果受污染的地下水污染團通過地下水監測井的路徑，可以預期這個井的氚濃度會增加至最大濃度，然後隨著時間而漸減少

• **全面性的水文地質調查**(HIR)

顯示地下水在廠址的移動速度非常緩慢，其中還有一塊受拘限岩層(馬奎塔頁岩層，The Maquoketa Shale Layer)，在地表面以下約 55 英尺，阻礙地下水移動低於此深度。

在 RGPP 共設有 96 個採樣點(圖 3-3)，包括保護區(PA)內建立 47 口地下水監測井，其中一些井在安全圍欄內形成一個環，其餘的井則安裝在工廠地下管線系統附近，該管線中含有放射性物質的水。廠外建立 30 口地下水監測井，其中大部分在礦井周邊形成環形。設有 12 個地表水監測位置，有 4 個降雨監測位置。從 2011 年到 2012 年，有額外 8 個位置進行了研究，但目前只有 4 個位置成為永久 RGPP 計畫的一部分，另設有 1 個前哨井和 2 個 CST 洩漏檢測閥，這 3 個採樣點處於閒置狀態，僅用於定性故障排除。

在 2018 年 RGPP 報告中，對來自 80 個採樣點的 280 個樣本進行了 693 次分析，監測結果如表 3-6。前哨井(也稱為嬰兒井)是為監測當地淺層地下水而設置的井，通常與歷史性地下管線洩漏有關，這些井不編碼或僅臨時性設置，大多數前哨井的深度為 6 到 12 英尺，由 2 英寸的無篩網 PVC 管組成。此外 DNPS 在賓州有兩個基本的雨水徑流下水道系統：一個雨水系統的路線向東，然後向北，然後排入 1 號機組的入流水道，另一個雨水系統的路線向西，然後向北，通過一條油水分離器並排入熱渠道，1 號機組的進水渠道和熱渠道最終都通向冷卻池，RGPP 有 12 個地表水採樣點，以監控這些系統。

總體而言，整個核電廠氚濃度下降，核電廠持續執行氚監測計畫，每月/每季對部分淺層及中層含水層井、污水處理廠水及雨水排放水進行採樣。但冷凝水儲存槽區域內的濃度持續升高（EN-DR-408-4160 中的事件 20）。至 2015 年 12 月，已積極進行整治，2015 年 8 月安裝了兩

個整治井，目的是將氚化水抽出地面，水通過廢液體處理系統處理，於 2015 年 12 月開始主動整治，一直持續到 2017 年。

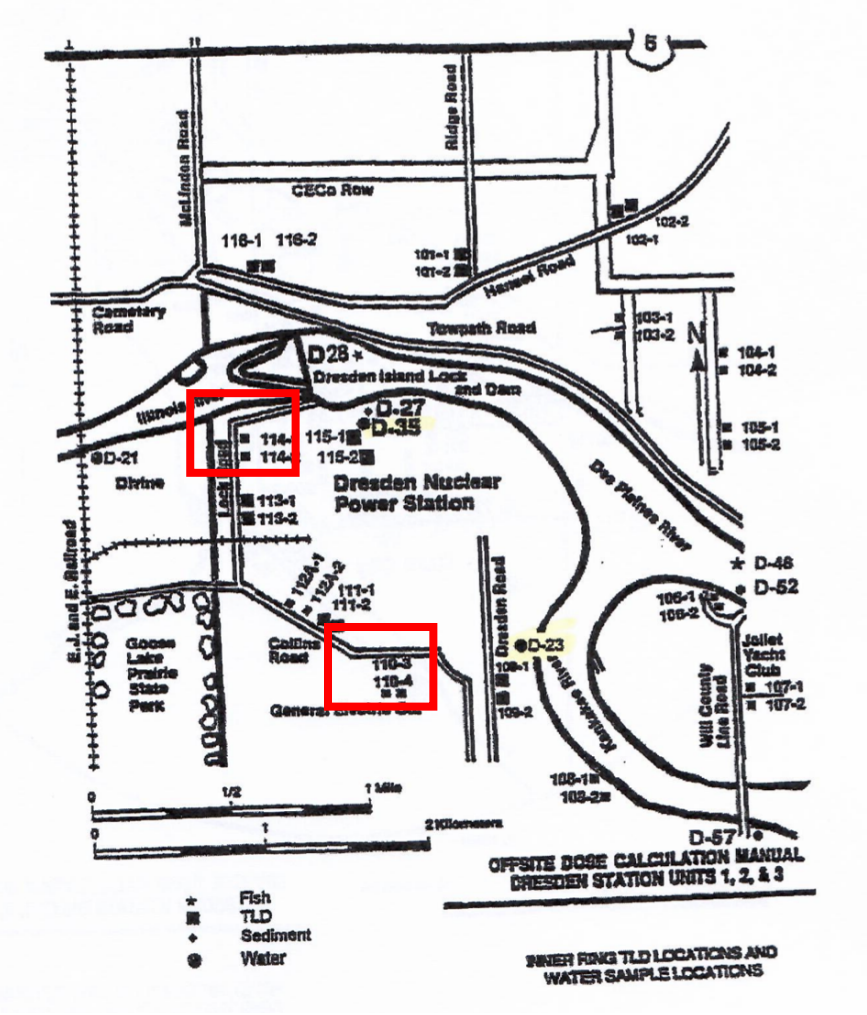


圖 3-3 DNPS 的 RGPP 採樣點

REMP 地下水監測點: D-23、D-35

RPGG(2019 年 1 月 1 日至 12 月 31 日)針對地下水進行監測：

保護區內有 47 口地下水觀測井

保護區外有 30 口地下水觀測井

廠內有 12 個地表水採樣點

4 個雨量採樣點

1 個洩漏前哨井與 2 個偵測閥

共 96 採樣點

前哨井(sentinel well)

表 3-6 DNPS 與 ZNPS 之 RGPP 監測結果

	DNPS	ZNPS
監測期間	Jan. 1~ Dec. 31, 2017	Jan. 1~ Dec. 31, 2015
環境介質	地下水	地下水
樣本數	280	-
採樣點	80	46
分析樣本數	693	-
	濃度	
Gamma-emitting radionuclide	---	地下水
Potassium-40 (K-40)		88-98 pCi/L 地表水--未檢出
tritium	<20,000 pCi / L MD-11 和 MW-DN-124-1 最高濃度>20,000 pCi / L	未檢出
Strontium-89 (Sr-89)	未檢出---	未檢出
Strontium-90 (Sr-90)	MW-DN-105S 濃度為 1.4-2.0 pCi / L	未檢出
	濃度 pCi/L	
Gross Alpha (Dissolved)	2.9-3.0	2.2-20.9
Gross Alpha (Suspended)	1.4-8.6	未檢出
Gross Beta (Dissolved)	1.1-37.8	
Gross Beta (Suspended)	2.2-11.0	
Hard-To-Detect analyses	濃度 pCi/L	
Americium-241 (Am-241) Cerium-242 (Cm-242) Cerium-243/244 (Cm-243/244) Plutonium-238 (Pu-238) Plutonium-239/240 (Pu-239/240) Uranium-234 (U-234) Uranium-235 (U-235) Uranium-238 (U-238) Iron-55 (Fe-55) Nickel-63 (Ni-63)	U-234 濃度: MD-11-0.39 pCi / L MW-DN-101-1:0.26-0.46 pCi / L U-238 濃度: MW-DN-101-1:0.18-0.33 pCi / L Ni-63 濃度: MW-DN-101-1 、 MW-DN-119-1：6.2-48. 7 pCi / L	未檢出

3-3-3 美國伊利諾州核電廠 Zion Nuclear Power Station 地下水防護

資料來源：Zion Nuclear Power Station Units 1 and 2-Annual Radiological Groundwater Protection Program Report, May 2016, Exelon

Zion 核電廠(Zion Nuclear Power Station, ZNPS)位於伊利諾伊州錫安市，毗鄰密西根湖，核電廠有兩個反應爐機組，由 Exelon 公司擁有與運轉，1 號機組在 1973 年 12 月發生事故，2 號機組在 1974 年 9 月發生事故，該廠於 1998 年 1 月永久停止運轉。廠址位於伊利諾伊州東北部的密歇根湖西岸，距伊利諾伊州芝加哥以北約 50 英里。Exelon 在 2006 年進行了完整的計畫評估 ZNPS 電廠運轉對地下水與地表水之影響，在 2016 年 RGPP 報告涵蓋了 Teledyne Brown Engineering (TSE)和 Environmental Inc. (Midwest Labs)在 2015 年收集的樣本進行的分析。

RGPP 的長期目標如下：

(1)在對環境和潛在飲用水源造成重大放射性影響之前，確定合適的位置，以監測及評估電廠運轉潛在影響。

(2)了解廠址附近當地水文地質狀況，並維持對地表及淺層地下水流模型有最新了解。

(3)在選定位置進行例行性水樣及放射性物質分析。

(4)及時向大眾報告新的洩漏、傾洩或其他具有潛在放射性物質的檢測結果。

(5)定期評估分析結果，以確定不利趨勢。

(6)採取必要的修正性措施以保護地下水資源。

(7)RGPP 佐助實施執照終止計畫(LTP)的地下水特徵相關要求，並最終根據 LTP 的要求實現地下水符合一般法令規定。

RGPP 目標的執行：

(1)Exelon 及其顧問確定了第一階段研究中所述的位置。第一階段研究由 Conestoga Rovers and Associates (CRA)進行，其結果和結論已在各州特定的報告中提供給州和聯邦監管機構以及公眾。

(2)ZNPS 報告中描述了當地的水文地質狀況，根據正在進行的量測，定期更新地表和淺層地下水流模型。

(3)ZNPS 將持續對選定地點進行例行水樣及放射性物質分析。

(4)ZNPS 繼續採用既定程序來及時識別及報告新的洩漏、傾洩或其他具有潛在放射性物質的發現。

(5)ZNPS 工作人員及諮詢水文地質學家持續評估分析結果，以確定不利趨勢。

ZNPS 依放射性物質地下水防護計畫，採集廠內監測井之地下水與地表水樣，ZNPS 並無廠外之監測井(圖 3-4)，監測結果如表 3-6，針對 2015 年發生洩漏，在洩漏點採集土壤樣品，並根據最終狀態調查計畫標記該區域以進行清理。此外並對附近下游 RGPP 的井進行採樣，發現洩漏的水沒有滲入地下水，地下水檢測結果顯示低於要求的最低檢測限值。ZNPS 並未需要採取補償行動(compensatory actions)，不需要安裝新的監測井，亦不需要採取措施來復原任何污染團(plumes)。

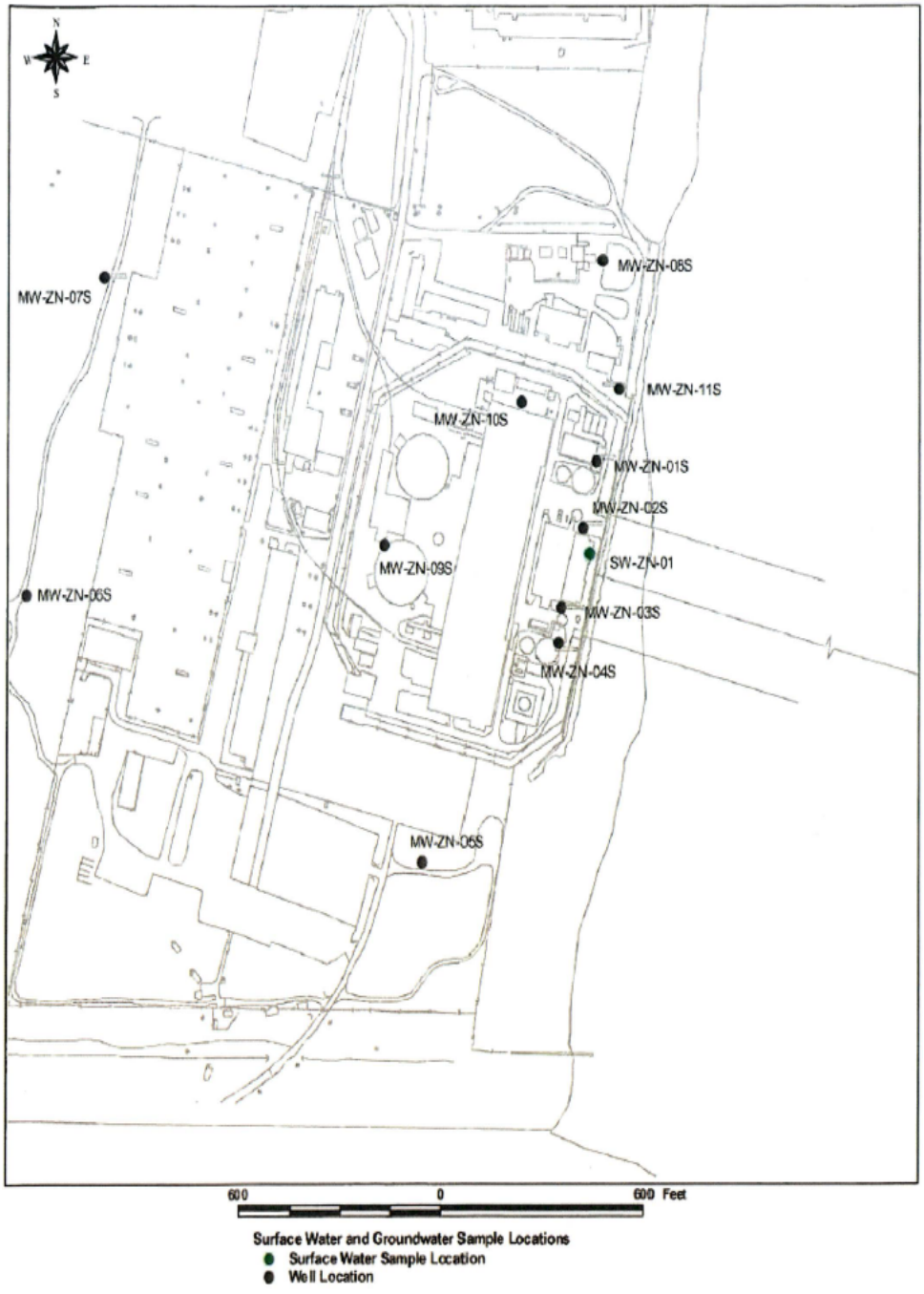


圖 3-4 Zion 的 RGPP 採樣點

本計畫已彙整美國三座除役核電廠，包括 Oyster Creek Nuclear Generating Station (OCNGS)、Dresden Nuclear Power Station (DNPS)與 Zion Nuclear Power Station (ZNPS)地下水監測相關內容，OCNGS 核電廠於 2018 年 9 月 17 日永久停止運轉，ZNPS 核電廠及 DNPS 核電廠 1 號機已除役超過 20 年，重點評析如下：

(1)建立完整之放射性環境監測計畫(REMP)-特別主要考慮放射性核種經由環境進入人體的路徑(pathway)進行樣本的採集，採樣地點的選擇應以樣本的可獲得性(availability)、當地氣象、水文地質特性、當地人口特性與土地使用為考量因素，並嚴格對放流水進行監測，針對放射性物質釋放至環境中之濃度不可超過法規限值。

(2)建立放射性物質地下水防護計畫(RGPP)之長期目標與 RGPP 監測重點。

(3)依據 NEI07-07 目的 2.4，建立並每年提交年度放射性環境運轉報告(AREOR)及/或年度放射性廢水排放報告(ARERR)完整記錄地下水監測結果。

(4)美國除役核電廠建立全面性之水文地質調查(HIR)，並依此建立場址概念模式(CSM)。

(5)若場址條件或程序規劃改變時，評估是否會影響地下水防護方案，若有影響，評估修正地下水監測計畫。

(6)美國除役核電廠，廠址大部分監測井一年應進行 4 次地下水採樣與檢測工作，其中氚每一季每口監測井皆要檢驗，其他放射性元素至少每口監測井每半年檢驗一次，待地下水水質變化穩定後，或發生廠內重大洩漏、傾洩至地下水事件，再檢討地下水採樣與檢測頻率。

(7)持續彙整 OCNGS 核電廠除役後之資訊與地下水監測計畫內容，以作為我國核電廠除役之參考。

3-3-4 美國核電廠洩漏資訊彙整

參考資料

NRC IN 2006-13, “Ground-Water Contamination Due to Undetected Leakage of Radioactive Water,” dated July 10, 2006 (ADAMS Accession No. ML060540038)

NRC IN 2012-05, “Abnormal Releases of Radioactive Material In Liquids Potentially Resulting in Groundwater Contamination” dated April 25, 2012 (ADAMS Accession No. ML120410213)

根據美國核能管理委員會(NRC)發佈 NRC Information Notice 2012-05 及 2006-13 報告中之電廠洩漏原因，彙整核電廠發生洩漏資訊與地下水防護相關工作，此資訊通告(Information Notice, IN)是針對未檢測到含有或傳輸放射性液體的設施結構、系統或組件洩漏而導致多個設

施發生的地下水放射性污染，IN 中彙整異常釋放的電廠，並確認了這些電廠系統和最常與這些異常釋放相關的原因。業者規劃提供更積極的現況管理，以減少意外之釋放。持照者亦維持其運轉和設計與執照基礎一致，以儘量減少意外之釋放。

以下分別敘述電廠之相關基本資料與發生洩漏資訊，包括 2006 與 2012 報告中之除役與運轉中核電廠，並彙整 2012 與 2006 報告中發生洩漏之除役與運轉中之核電廠進行洩漏的處置方式與地下水防護/監測計畫，如表 3-7 與表 3-8。表 3-9 與表 3-10 是彙整 NRC IN 2006 與 NRC IN 2012 之電廠基本資料與反應器類型。

整理結果發現除役與運轉中之核電廠都有發生放射性物質洩漏之事件，除役電廠之原因多是因為除役殘留與冷凝水管線或排氣管線發生洩漏，而運轉中核電廠則多是循環水沖放系統的真空破除器、高壓冷卻水系統地下管線與冷凝水傳送管線發生洩漏，核電廠針對洩漏採取的處置方式與地下水防護/監測計畫，則著重於立即並持續進行地下水質監測、搜集洩漏資料與分析地下水文地質情況與規劃安裝洩漏檢測和監視設備等，針對除役電廠則加強與政府、產業、學術專家及民眾之溝通並詢問意見，討論核電廠地下水污染對策是否需要修改，減少電廠除役對環境造成之影響。

表 3-7 2006 報告中之除役與運轉中核電廠進行洩漏的處置方式與地下水防護/監測計畫

除役電廠	發生洩漏物質 &設備	針對洩漏之 處置方式	地下水防護 /監測計畫
Indian Point 1	strontium-90 (除役殘留)	水文地質評估	-
Haddam Neck (Connecticut Yankee Atomic Power Plant)	tritium cesium-137 strontium-90 (除役殘留)	去除大量土壤,並用乾淨的土壤回填開挖的區域。	定期的地下水質監測報告
電廠(運轉中)			
Braidwood 1 Braidwood 2	tritium (循環水系統沖放管線的真空破除器)	通知 NRC 並立即停止放射性液體的排放	執行補救策略，實施地下水的控制和氚的去除。
Byron 1 Byron 2	tritium (循環水系統沖放管線的真空破除器)	暫停管線釋放放射性液體並修復真空破除器(Vacuum Breaker)及密封閥門室地板	持續進行地下水質監測，計劃安裝洩漏檢測和監視設備
Indian Point 2	tritium 用過燃料池（SFP）裂縫	確認地下水污染源 設置廠址內外之地下水質監測	設置地下水質監測
Dresden 2&3	tritium (冷凝水儲存槽到 2 號機和 3 號機的高壓冷卻水系統地下管線)	隔離管線並修復洩漏處	檢查地下水的移動情形，並將過去的洩漏事件彙整，分析地下水文地質情況

表 3-8 2012 報告中之除役與運轉中核電廠進行洩漏的處置方式與地下水防護/監測計畫

除役電廠	發生洩漏物質 &設備	針對洩漏之 處置方式	地下水防護 /監測計畫
Oyster Creek	tritium (冷凝水傳送鋁管的地下埋管)	更換洩漏管線	採樣地下水及地表水，確保能夠及時發現放射性物質洩漏；執行補救，減少電廠除役造成之影響
Vermont Yankee	tritium (廢氣管管道前的一對洩水管以及混凝土管道的地面洩水)	停止洩漏，清理溝槽中引起堵塞及腐蝕的碎屑。	成立組織，舉辦研討會，聽取政府、產業、學術專家及民眾的意見，討論核電廠地下水污染對策是否需要修改
電廠(運轉中)			
Dresden 2&3	tritium (冷凝水傳送的地下管線)	隔離洩漏之管道並修復洩漏處	採樣檢測地下水和地表水
Edwin I. Hatch 1 Edwin I. Hatch 2	tritium (冷凝水傳送的地下管線)	立即停止使用傳送管線並除去污染源	確定環境的輻射情形和放射性物質濃度，評估發電設備的運行對環境的放射性影響
LaSalle 1 LaSalle 2	tritium (1 號機組之冷凝水儲存槽底部的三個小孔)	修復洩漏孔	評估並比較數據並與運轉前數據

表 3-9 電廠基本資料與反應器類型(NRC IN 2006-13)

除役電廠	反應器類型	除役時間	洩漏事件
Indian Point 1	PWR	1974	strontium-90 (除役殘留)
Dresden 1	BWR	1978	-
Haddam Neck (Connecticut Yankee Atomic Power Plant)	PWR	2004	tritium cesium-137 strontium-90 (除役殘留)
電廠（運轉中）		運轉期限	
Braidwood 1	PWR	1987/07/02- 2046/10/17	tritium (2005/11)
Braidwood 2		1988/05/20- 2047/12/18/	
Byron 1	PWR	1985/02/14- 2044/10/31	tritium (2006/04 修復)
Byron 2		1987/01/30- 2046/11/06	
Dresden 2	BWR	1991/02/20, renewed:2004/10/28- 2029/12/22	tritium (2004/08、2006/02)
Dresden 3		1971/01/12, renewed:2004/10/28- 2031/01/12	
Indian Point 2	PWR	1973/09/28, renewed:2018/09/17- 2024/04/30	tritium (2005/09)
Indian Point 3		1975/12/12, renewed:2018/09/17- 2025/04/30	

PWR: Pressurized Water Reactor

BWR: Boiling Water Reactor

表 3-10 電廠基本資料與反應器類型(NRC IN 2012-05)

除役電廠	反應器類型	除役時間	洩漏事件
Dresden 1	BWR	1978	-
Oyster Creek	BWR	2018	tritium (2009/08/25) (運轉期間)
Vermont Yankee	BWR	2014	tritium (2010/01/07) (運轉期間)
電廠（運轉中）		運轉期限	
Dresden 2	BWR	1991/02/20, renewed:2004/10/28-2029/12/22	tritium (2009/06)
Dresden 3		1971/01/12, renewed:2004/10/28-2031/01/12	
Edwin I. Hatch 1	BWR	1974/10/13, renewed:2002/01/15-2034/08/06	tritium (2011/09/28)
Edwin I. Hatch 2		1978/06/13, renewed:2002/01/15-2038/06/13	
LaSalle 1	BWR	2016/10/19-2042/10/17	tritium (2010/07/01)
LaSalle 2		2016/10/19-2043/12/16	

■ **電廠 Braidwood Nuclear Power Plant**

- 狀態：運轉
- 運轉執照期限：

  Unit1：1987/07/02-2046/10/17

  Unit2：1988/05/20- 2047/12/18/
- 反應器類型：Pressurized Water Reactor (PWR)
- 發生洩漏情況：
- 污染物：氚

1996, 1998 及 2000 年皆有發生沖放管線洩漏，廠內地下水深井之監測數據 282,000 (pCi/L)，廠外居家用井監測濃度為 1,600 (pCi/L)，地下水污染範圍被定義在電廠外圍延伸 2000 英尺乘 2500 英尺。

2005/11/03 在監控範圍的邊界處之地下水淺井檢測到 58,000 pCi/L 的氚，被認為與過去的洩漏事件有關：

- 洩漏之設備：循環水系統沖放管線的真空破除器（vacuum breakers along the circulating water system blowdown)
- 針對洩漏之處置方式：通知 NRC 並立即停止放射性液體的排放

  NRC 檢討電廠後續處理應做到的部分：

  (1) 充分評估與洩漏有關的放射性危害

  (2) 計算放射性物質對居民的劑量

  (3) 修改環境監測計畫，充分衡量放射性物質對環境的影響

  (4) 在其年度廢水報告中報告洩漏的事件

  (5) 除役時將殘留污染記錄在文件中

- 自 2005/11/30 發現地下水污染以來，已暫停放射性液體的排放。
- 液態放射性廢棄物被儲存在臨時儲存槽中，直到沖放管線確認修復後，放射性液體的排放才會恢復。
- 所屬公司 Exelon 於 2005/11-2006/03 實施一項積極而全面的地下水調查計畫，針對私井例行性的採樣和監測。
- 截至 2006/01/06 在廠內和廠外之監測井中測得約 250,000 pCi/L 的氚，並在一個廠外住宅飲用水井中測得 1,524 pCi/L 的氚。

- 2005/12/12 NRC 進行檢查，評估電廠的恢復工作和污染團特徵。
- 2005/12/20 工作人員參加了在伊利諾伊州環境保護局的會議，討論污染物的確切來源、監測程序和初步表徵，以及污染的成因與未來計畫。
- 地下水防護/監測計畫：
  (1) 2005/03 伊利諾州環保署指出在電廠附近的居家水井中檢測出氚，便開始監測社區與電廠之間的地下水質，並在鄰近電廠的排水溝檢測到氚，但由於未發現其他於廠外的污染情形，因而設置額外的監測井找尋污染來源。
  (2) 2006/03 Interim Remedial Action Plan (IRAP)：目的是盡快執行補救策略，以便在真空破除器(VB)的下游區域實施地下水遷移控制和氚的去除。
  (3) 氚的去除以抽出 Exelon Pond 的地表水來實施，這將抑制池塘中的水位並產生洩降錐(drawdown)，使地下水流向 Exelon Pond 的北部，隨時間的增加緩解氚濃度，去除 VB 下游和 Smiley Road 以南主要污染團中的氚，防止氚進一步遷移到 Exelon Pond 之外。
  (4) IRAP 的第二個目標是當從 Exelon Pond 泵送的地下水和沖放管線中的水混合在一起時，確保沖放管線中氚的濃度低於 200 pCi / L。

■ **電廠 Byron Nuclear Power Plant**

- 狀態：運轉
- 運轉執照期限：

  Unit1：1985/02/14-2044/10/31

  Unit2：1987/01/30-2046/11/06
- 反應器類型：Pressurized Water Reactor (PWR)
- 發生洩漏情況：
- 污染物：氚

針對循環水系統沖放管線啟動了採樣和分析，發現六個閥門室(valve vaults)中有五個的積水(standing water)檢測之 tritium 濃度高達 80,000 pCi/L。民井的檢測中並沒有發現沖放污染，在閥門室附近安裝額外的監測井檢測到兩個閥門室附近有氚污染。2006/4，完成對真空破除器和閥門室的修復及密封閥門室的地板，可通過循環水系統沖放管線排放。

- 洩漏之設備：循環水系統沖放管線的真空破除器(vacuum breakers along the circulating water system blowdown)與 Braidwood 造成洩漏的閥門(valve)類似。
- 針對洩漏之處置方式：

暫停沖放管線釋放放射性液體並修復真空破除器及密封閥門室地板。

- 地下水防護/監測計畫：

持續進行地下水質監測，觀察含氚的水在閥門室外的遷移。NRC 繼續收集 Byron 地區居民飲用水井和其他地下水井的獨立樣本並"分割"樣本，以確定 tritium 污染的程度。修復後進行釋放時，工作人員觀察真空破除器以確保沒有洩漏。該公司計劃安裝洩漏檢測和監視設備。

■ **電廠 Dresden Nuclear Power Station**

- 狀態：運轉
- 運轉執照期限：

Unit1：1978/10 停止運轉 (in SAFSTOR)

Unit2：1991/02/20, renewed:2004/10/28-2029/12/22

Unit3：1971/01/12, renewed:2004/10/28-2031/01/12

- 反應器類型：Boiling Water Reactor (BWR)
- 發生洩漏情況：
- 污染物：氚

時間：2004/08、2006/02

2004/08/30 發現污染的濃度高達每升 900 萬 pCi / L，其中深井的採樣(飲用水)亦呈現此高濃度。洩漏來源為從冷凝水儲存槽到 2 號機和 3 號機的高壓冷卻水系統(HPCI system)的地下管線。冷凝水儲存槽是 HPCI 系統的正常水源，抑壓池(torus)亦是相關的安全水源，並且兩個機組的 HPCI 系統都與抑壓池(torus)相同。

- 洩漏之設備：

2004/08：連接到冷凝水儲存槽的地下管線

2006/02：2004 年未更換的地下管線

- 針對洩漏之處置方式：

隔離洩漏之管線並修復洩漏處。

- 地下水防護/監測計畫：

2006 夏季, 全面之水文地質調查(fleet-wide hydrogeologic investigation)調查地下水的移動情形，並將過去的洩漏事件彙整，分析地下水文地質情況。根據 fleet-wide Hydrogeologic Investigation Report (HIR)，電廠監測點的地下水流動非常緩慢，在地表以下約 55 英尺處有一個拘限岩層(confining rock layer)，阻礙了該深度以下的地下水流動。

■ **電廠 Haddam Neck Station (Connecticut Yankee Atomic Power Plant)**

- 狀態：除役
- 運轉執照期限：1968 啟用，1996 停止生產電力，2004 除役
- 反應器類型：Pressurized Water Reactor
- 發生洩漏情況：
- 污染物：tritium, cesium-137 and strontium-90
- 洩漏之設備：除役電廠殘留
- 針對洩漏之處置方式：

  去除大量的土壤和基岩，並用乾淨的土壤回填開挖的區域。
- 地下水防護/監測計畫：

  定期的地下水質監測報告

  季度抽樣：2001/12，2002/03，2002/06

  後續抽樣：2002/01，2002/02

■ **電廠 Indian Point Nuclear Generating Station**

- 狀態：

  Unit1：除役 SAFSTOR

  Unit2：運轉

  Unit3：運轉
- 運轉執照期限：

  Unit1： 1974/10 關廠

  Unit2：1973/09/28 renewed: 2018/09/17-2024/04/30

  Unit3：1975/12/12 renewed: 2018/09/17-2025/04/30
- 反應器類型：Pressurized Water Reactor (PWR)
- 發生洩漏情況：
- 污染物：

  Unit 1: strontium-90

  Unit 2: 氚

  時間：2005/09
- 洩漏之設備：

Unit 1: SAFSTOR 殘留污染

Unit 2: 用過燃料池(spent fuel pool (SPF))之損壞

- 針對洩漏之處置方式：

(1) 設置監測井

(2) 廠址的水文及地球物理評估分析

(3) 確定污染源

(4) 加強廠內和廠外放射環境監測

- 地下水防護/監測計畫：

2006/12/22 Groundwater Investigation

調查影響當地地下水的放射污染源，建立準確的地下水概念模型。電廠之水文地質分析顯示，地下水流向 Hudson River，幾乎沒有地下水污染超出廠址邊界的可能性，也沒有任何廠外環境監測地點檢測到與電廠有關的放射性物質；依放射性物質評估證實，公共衛生和安全沒有受到影響，而根據 NRC 法規，對居民的劑量影響可忽略不計。

■ **電廠 Oyster Creek Nuclear Generating Station**

- 狀態：除役 SAFSTOR

2018/09/17 永久停止運轉

2018/09/25 Fuel Removed

- 運轉執照期限：

1991/07/02 renewed: 2009/06/03-2029/04/09

- 反應器類型： Boiling Water Reactor (BWR)
- 發生洩漏情況：
- 污染物：氚

時間：2009/08/25

- 洩漏之設備：

冷凝水傳送鋁管

- 針對洩漏之處置方式：

更換洩漏管線

- 地下水防護/監測計畫：

Radiological Groundwater Protection Program (RGPP) 2018/01/01-2018/12/31

採樣站內與站外的地下水及地表水，確保廠址之地質和水文的特徵有助於了解地下水情形，目的：

(1) 確認電廠設計和實際作業的風險

(2) 評估所有包含或可能包含放射性物質的 SSCs(systems, structures, or components)及涉及放射性物質的工作，確認可以使放射性物質污染地下水的可信機制

(3) 進行監控，確保能夠及時發現地下水的放射性物質洩漏

(4) 根據需求，了解 REMP 之外的放射性分析物的背景濃度

(5) 評估運轉的核電廠設施的氣態或液態廢水中，已排放的放射性廢水的回收/再利用

(6) 建立控制措施以設置和淘汰監測井

(7) 執行補救協議，防止放射性物質的遷移並盡量減少電廠除役造成之影響

(8) 確保洩漏、外溢、補救措施的記錄得以保留並可以檢索

(9) 確保在 RGPP 上與指定的地方官員進行定期聯繫

(10) 如果放射性物質意外釋放到土壤、地下水或地表水中，確保及時進行口頭和書面報告

(11) 記錄並報告所有適用的 RGPP 數據

(12) 透過"Decommissioning Corrective Action Program"確認及解決缺失

(13) 進行計畫監督以確保 RGPP 的有效實施

■ **電廠 Dresden Nuclear Power Station**

- 狀態：運轉
- 運轉執照期限：

  Unit1：1978/10 停止運轉 (in SAFSTOR)

  Unit2：1991/02/20, renewed:2004/10/28-2029/12/22

  Unit3：1971/01/12, renewed:2004/10/28-2031/01/12
- 反應器類型：Boiling Water Reactor (BWR)
- 發生洩漏情況：

  污染物：氚

  時間：2009/06
- 洩漏之設備：

  2009/06：冷凝水傳送地下管線
- 針對洩漏之處置方式：

隔離洩漏之管線並修復洩漏處

- 地下水防護/監測計畫：

2018 Annual Radiological Groundwater Protection Program Report (RGPP)

長期監測，旨在驗證 fleet-wide Hydrogeologic Investigation Report (HIR)的水文地質研究結論，分別採樣檢測地下水和地表水，地下水監測井分為“shallow”(深度 15-35 英尺)，“Intermediate”(深度 35-55 英尺)和“deep”(深度超過 100 英尺)，而所有深度 100 英尺以上的井(deep)均已乾涸，並已從 RGPP 中移除，地表水的採樣則是在電廠的渠道和冷卻池(station's canals and cooling pond)中。

■ **電廠 Edwin I. Hatch Nuclear Plant**

- 狀態：運轉
- 運轉執照期限：

Unit1：1974/10/13 renewed：2002/01/15-2034/08/06

Unit2：1978/06/13 renewed：2002/01/15-2038/06/13

- 反應器類型：Boiling Water Reactor (BWR)
- 發生洩漏情況：

污染物：氚

時間：2011/09/28

- 洩漏之設備：

冷凝水傳送管線

- 針對洩漏之處置方式：

立即停止使用傳送管線，除去污染源後監測井內氚濃度下降，地下水樣品中未檢測到氚以外的放射性污染。受影響的地下水位於一個隔離的含水層中，該含水層之地下水不用於飲用水，往後也不具備作為飲用水的潛力。

- 地下水防護/監測計畫(Radiological Environmental Monitoring Program, REMP)：

目的：

(1) 確定周圍環境的輻射情形和放射性物質濃度

(2) 評估 Alvin W. Vogtle 核電廠（VEGP）的運轉對環境的影響

針對地下水的部分：

(1) 為確保遵守 NEI 07-07 (Industry Ground Water Protection Initiative - Final Guidance Document)，運轉之公司 Southern Nuclear Company (SNC)制定了 Nuclear Management Procedure, Radiological Groundwater Protection Program。該計畫包含針對特定監測點的監控及技術基礎和通信協議(以確保放射性物質的洩漏得到適當處理和傳達)。為了防止放射性物質洩漏到地下水，SNC 制定了地下管線和儲存槽的檢查計畫。

(2) 2016 年未對地下水防護計畫進行任何更改。

(3) 電廠維護之水井的採樣頻率符合 NEI 07-07 的要求。2016 年的分析結果均在本報告規定的範圍內。

■ **電廠 LaSalle County Station**

- 狀態：運轉
- 運轉執照期限：

  Unit1：2016/10/19-2042/10/17

  Unit2：2016/10/19-2043/12/16
- 反應器類型：Boiling Water Reactor (BWR)
- 發生洩漏情況：

  時間：2010/07/01

  污染物：氚
- 洩漏之設備：

  1 號機組之冷凝水儲存槽底部的三個小孔
- 針對洩漏之處置方式：

  修復冷凝水儲存槽上的洩漏孔，洩漏之污染並未擴展到非管制區域。

  2010/06/15 例行季度測試時，未發現可檢測到的放射性物質。
- 地下水防護/監測計畫(Radiological Environmental Monitoring Program)：

  2017/01/01-2017/12/31

評估為此計畫收集的所有數據並與運轉前數據進行比較發現，電廠的運轉對環境沒有有害的放射性影響。

地下水：

氚：在每個位置的季度採樣中未檢測到氚，符合合約要求。

Gamma Spectrometry：在每個位置的季度採樣中未檢測到 gamma-emitting nuclides，符合合約要求。

■ **電廠 Vermont Yankee**

- 狀態：除役
- 運轉執照期限：

  1972 年開始運轉，於 2014/12/29 永久停止運轉，並於 2015/01/12 從該反應器中移出燃料。
- 反應器類型：boiling water reactor (BWR)
- 發生洩漏情況：

  時間：2010/01/07

  污染物：氚
- 洩漏之設備：

  廢氣管道前的一對洩水管以及從通道內的混凝土裂隙漏出
- 針對洩漏之處置方式：

  停止地下管線洩漏，清理了廢棄管通道前管線中引起堵塞及管線腐蝕的碎屑。

  電力公司建立評估小組追蹤氚的污染源，並製定加強的抽樣計畫，檢測結果只有淺層地下水中含有氚。在電廠或 Connecticut River 的任何飲用水井樣本中均未發現氚污染。

  清除洩漏區域附近的污染土壤，並汲取受污染的地下水回收用於反應器設施。
- 地下水防護/監測計畫：

  成立地下水污染專案小組，檢視 NRC 在洩漏事件上所做的工作，並思考是否可以採取其他措施，舉辦公開研討會，聽取政府、產業、學術專家及民眾的意見，討論 NRC 的核電廠地下水污染對策是否需要修改。

  Entergy Nuclear -Vermont Yankee (ENVY)公司提出“Hydrogeological Investigation of Tritium in Groundwater at Vermont Yankee Nuclear Power Station”報告，繪製地下水氚污染團分布圖，調查其結構、系統和組件(例如地下埋管和儲存槽)，以確定可能的污染源和污染原因。

3-3-5 美國核電廠用過燃料池洩漏資訊彙整

針對美國 NRC 在 2014 年 NUREG-2157 中附錄 E-用過燃料池洩漏分析，截至 2014 年 5 月，有 100 座商用核反應器在美國運轉，另有 5 個額外的核反應器在建設中。這些運轉中的反應器位於美國 30 個州的 62 個地點。這 100 個反應器中，有 65 個是壓水式反應器與 35 個沸水式反應器。由於其中一些反應器共用用過燃料池，因此有 55 個沸水反應器的用過燃料池。除了運轉反應器的用過燃料池外，還有 6 個用過燃料池(5 個壓水式反應器，1 個沸水式反應器)位於 5 個除役反應器場址。

NUREG-2157 中附錄 E-描述了短期貯存範圍內用過燃料池洩漏對環境的影響，針對於在 GEIS (Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel)中提出的分析，美國核能管制委員會(NRC)假設在反應器獲准運轉的 60 年內，從池中移除用過核燃料(用過燃料)，一旦從用過燃料池中移除，用過燃料將轉移到乾貯桶中貯存在獨立的用過燃料貯存裝置中，或運往貯存庫。附錄 E 評估用過燃料池之洩漏對廠址外之潛在環境影響，包括意外、自然事件如地震可能破壞用過燃料池與用過燃料池洩漏對地下水、地表水、土壤和公眾健康的潛在場外環境影響等。

NRC 已確認 7 個廠址因用過燃料池之污染，污染物自用過燃料池遷移至廠外，其中 2 個廠址(Hatch 與 Turkey Point)之用過燃料池洩漏與電廠之運轉相關，這些電廠之洩漏立即確認並採取行動以減少對環境的影響，其中 5 個廠址(Indian Point, Palo Verde, Salem, Seabrook 與 Watts Bar)之用過燃料池洩漏未被檢測出。除此，2 個廠址(San onofre 與 Yankee Rowe)用過燃料池洩漏可能是廠址內污染之可能污染來源，附錄 E 中將以上發生用過燃料池洩漏主要分為三種，分別是運轉中洩漏、確認用過燃料池洩漏與潛在之用過燃料池洩漏，分述如下：

運轉中洩漏(Operational Releases)

- **Hatch 核電廠**

洩漏日期：1986/12

洩漏放射性物質：Tritium and mixed fission products

洩漏情況：

約有 124,000 加侖的液體(含 0.2 Ci 的 tritium 和 0.373 Ci 的混合裂變產物)釋放到控制區域內的沼澤中、而沒有公眾劑量(public dose)產生。在廠址位置外未檢測到水污染，並實施長期的

監測。

◆Turkey Point 核電廠

洩漏日期：1988/08

洩漏放射性物質：Tritium, cesium-137, and cobalt-60

洩漏情況：

大約 6 至 7 加侖的液體(23 至 26 公升)中含有 2.5 * 10-3 μCi/ cm3 的 cesium-137、2.5 * 10-4 μCi/ cm3 的 tritium 和 2.2* 10-2 μCi/ cm3 的 cobalt-60 釋放到雨水渠道。洩漏物質排入冷卻管的入口，該冷卻管為大型封閉迴圈的廠內流動路徑。

<u>確認用過燃料池洩漏(Confirmed Spent Fuel Pool Leaks)</u>

◆Indian Point 核電廠 (Units 1 and 2)

洩漏日期：2005/08

洩漏放射性物質：Tritium, nickel-63, cesium-137, strontium-90, and cobalt-60

洩漏情況：

在廠址邊界內檢測到的最大污染為 tritium (200,000 pCi/L), nickel-63 (100 pCi/L), strontium-90 (50 pCi/L)。假設地下水直接排入哈德遜河，計算得 Total body dose = 0.0021 (mrem/year)(Entergy 2006)，表示為 NRC 對輻射劑量標準的 0.0021％。

◆Palo Verde 核電廠 (Unit 1)

洩漏日期：2005/07

洩漏放射性物質：Tritium, cobalt-60, antimony-125, and cesium-137

洩漏情況：

在例行的監控(routine surveillance)下發現用過燃料池洩漏之放射性液體排放至環境中。

◆Salem 核電廠 (Unit 1)

洩漏日期：2002/9

洩漏放射性物質：Tritium

洩漏情況：

在廠址邊界內檢測到的最大污染，地震帶附近所測得最高濃度 tritium (15,000,000 pCi/L)；廠址位置外未檢測到水污染。

◆Seabrook 核電廠

洩漏日期：1999/06

洩漏放射性物質：Tritium

洩漏情況：

在廠址邊界內檢測到的最大污染： tritium (750,000 pCi/L)，地下水污染團沒有移動到廠址外。

◆**Watts Bar 核電廠 (Unit 1)**

洩漏日期：2002/08

洩漏放射性物質：Tritium

洩漏情況：

在環境監測下發現用過燃料池洩漏之放射性液體排放至環境中。在廠址邊界內檢測到的最大污染： tritium (550,000 pCi/L)，地下水污染團沒有移動到廠址外。

潛在之用過燃料池洩漏(Potential Spent Fuel Pool Leaks)

◆San Onofre **核電廠**(Unit 1)

洩漏日期：1986

洩漏放射性物質：Tritium, cesium-137

洩漏情況：

在除役期間發現受污染地下水，來源尚未確定，其中可能是 1986 至 1989 年從用過燃料池中洩漏，而在環境監測中並未發現源自於 San Onofre 的放射性物質。

◆Yankee Rowe **核電廠**

日洩漏期：1979/1999

洩漏放射性物質：Tritium

洩漏情況：

1979 年安裝襯管前用過燃料池疑似會定期洩漏，但是根據水位的變化和補給水率無法確定洩漏量。1999 年的額外洩漏被確認為來自用過燃料池，估計洩漏率約為每年 10 加侖(38 升)。而地下水污染的最主要來源是離子交換坑(ion-exchange pit)的洩漏，在用過燃料池和離子交換坑(ion-exchange pit)之間的牆上的結構裂隙，洩漏約 200 萬加侖(760 萬公升)的污水。

對地下水的影響

運轉中與除役核電廠之用過燃料池洩漏對地下水的影響取決於：

(1) 從用過燃料池排放的水的量和速度

(2) 用過燃料池水的放射性物質含量與濃度及水的化學特性

(3) 地下水流向及流量

(4) 與場外地下水受體的距離

(5) 放射性物質穿過地下的速度或傳輸速率

(6) 放射性物質衰變速率

根據檢測和監視機制、放射性物質傳輸的物理過程以及用過燃料池廠址內的水文特徵，NRC 結論是在短期內因洩漏而對地下水品質造成的放射性影響很小。用過燃料池洩漏仍留在現場或排放到大型地表水體(稀釋)，或因洩漏量少、期間短、當地水文地質條件影響，對於作為飲用水的非廠址內地下水井都沒有影響，上述列出的用過燃料池洩漏事件均未導致飲用水污染。

發生洩漏因應的方案及監測

在短期內用過燃料池的設計(不銹鋼襯套和洩漏收集系統)和運轉控制(監視和監視用過燃料池水位)使長時間的洩漏不被檢測到的可能性不大。近期及未來都必須在用過燃料池於水力梯度或地下水補注性質易造成污染擴散的區域中，需有定期的環境監測程序，從廠外用於飲用水或灌溉的地下水源中取樣，包括鄰近的每個私井。如果洩漏造成的污染超過公共供水放射性物質污染標準，EPA 可以根據 Safe Drinking Water Act (EPA 1991)採取緊急行動，包括提供替代水及對可能受影響用戶的通知與污染整治。

NRC 地下水工作組

2006 年成立了內部的經驗回饋專案小組，針對核電廠在非計畫內、未經監控的放射性液體排放，進行系統性的審查：

(1) 關於放射性液體排放至環境的公共健康影響

(2) NRC 的法規架構

(3) 相關的檢查及執行計畫

(4) 業界報告的需求

(5) 隨著過去的業界行為的重大疏忽排放

(6) 國際間的看法(主要來自加拿大的 tritium 排放經驗)

(7) NRC 與民眾的交流

經驗回饋專案小組在期末報告(NRC 2006b)中提出了 26 項建議，針對在非計畫內、未經監控的排放，進行法規的加強或管理指南；額外也在除役資金和執照更新方面進行其他審查，並加強與大眾的溝通。

儘管許多業界事件造成非計畫內、未經監控的將放射性液體排放到環境中，但根據現有數據，專案小組並未發現任何放射性液體的排放有影響公共健康的情況(NRC 2006b)。2010 年，更多與核電廠運轉有關的疏忽性放射性物質異常排放，NRC 成立了地下水專案小組，重新評估了經驗回饋專案小組期末報告中的建議，審查了 NRC 員工採取的作法，以解決核電廠地下管線洩漏的問題；並針對更近期從系統中排放氚進行審查，而不是在與核電廠內用過燃料池排放到地下水相關的。其工作範圍包括：

(1) 產業經歷

(2) 對健康的影響

(3) 法規架構

(4) NRC 檢查和分析

(5) 執行和報告方面

(6) 產業作為

(7) 國際間的看法

(8) 與外部利益關係人的溝通

完成審查後，透過 NRC 對地下水洩漏和溢漏的反應，來確認其保護大眾健康、安全和環境的任務。

四、結論與建議

核電廠在運轉或除役期間之地下水特性，可能因為放射性污染物質藉由傾洩或洩漏過程至地下水而改變，因此為了保護公共健康與安全，發展並實施特定廠址的地下水防護計畫，以確保能及時且有效的應變與管理放射性物質的意外排放至地下水事件是除役期間之重要議題，本計畫完成三項重要工作項目，並據以研析核電廠除役期間廠址之地下水防護工作，摘錄重點如下所述。

A. 美國核電廠運轉與除役期廠址地下水防護管制法規–研析運轉與除役核電廠在管制方向之差異性

美國聯邦法規(CFR)相關核電廠與地下水監測重點彙整如下:

1. 10 CFR Part 20： §20.1003 定義殘餘放射性，包括地下水的放射性，§20.1402 規範除役後廠區殘餘放射性對關鍵群體之平均成員所造成的總有效等效劑量，不超過每年 0.25 毫西弗，且殘餘放射性已降至合理抑低的程度時，廠址除役後可被考慮接受為非限制性使用；§20.1501(a)進行調查中，要求土壤或地下水中的殘留放射性水平須降低至除役釋出非限制性使用的程度。
2. 10 CFR Part 50： §50.55 針對建廠執照之規範標準中，對接觸地下土壤、回填或地下水難以接近的地下混凝土表面進行技術評估，§50.83 修訂了環境監測計畫及廠址外的劑量計算手冊，以符合電廠可以非限制性使用。
3. 10 CFR Part 70： §70.38 相關廠址除役及執照效期與中止，NRC 可視地點因素情況而定，其中包括如地下水處理、監測自然地下水、可能比延後拆除清理造成更大環境損害行動，以及持照人無法控制的其他因素。

B. NEI07-07「業界地下水防護倡議-指引文件」–研析運轉與除役核核電廠在管制方向之差異性

美國核電廠已實施 NEI 07-07 超過 10 年，業界地下水防護方案已日漸成熟，我國運轉中核電廠已建立相關方案，除役期間仍須維持並精進地下水防護方案。本計畫今年度完成 NEI07-07「業界地下水防護倡議-指引文件」2007 年版與 2019 年版比較，在 2019 年版與 2007 年版最大的差異性是增加以下項目：

1. 核電廠目前場址條件之水文及地質特性調查，除包括主要地下水梯度特性資訊外，並以此特性建立場址概念模式(CSM)。
2. 確認核電廠個人工作作業中所採取之維護、操作及支援等活動行為，其將造成或可避免放射性污染物質藉由傾洩或洩漏過程至地下水之可信機制。

3. 確認監測井建置位置與品保，以及偵測水準概念。

4. 對除役的影響。

5. 除政府外，須與利益關係人溝通，以及可以不進行自願性溝通之條件。

6. 自我審查評估概念，並修正初次執行自我評估時間。

我國核電廠在運轉期間以及依運轉執照屆期開始之除役期間，針對地下水防護措施之管制，可再檢視以下事項並視需要精進：

1. 評估電廠設計及工作作業可能影響地下水之風險與因應對策–先評估放射性物質可能由結構、系統、組件，或實務作業，而外釋到地下水之可信機制(credible mechanism)，並進一步檢視監測採樣區之地下水監測防範措施與可能之強化措施，以減少因 SSC 失效或作業導致放射性物質意外釋放至地下水之可能性。
2. 若廠址條件或程序規劃改變時，評估是否會影響地下水防護方案，若有影響，則評估修正地下水監測計畫。
3. 建立定期之程序性自我評估與審查機制，程序性評估應該包括 NEI07-07 所有目的評估，建議參考「附錄 B:自我評估清單」逐項檢視核電廠除役程序與地下水防護倡議規範之符合性，並定期進行與審視地下水防護計畫與地下水監測計畫。

C. 美國核電廠廠址地下水防護管制案例與經驗–研析除役廠址相關規定與特定技術要項、重要參數

核電廠除役相關地下水防護措施，建議持續蒐集並彙整美國核電廠(例如，OCNGS)除役期間相關資訊與其地下水監測計畫內容及結果，以作為我國核電廠除役之管制參考。

D. 整體之管制建議

1. 參考美國業界作法包括 NEI07-07 指引，建立除役核電廠定期自我評估機制，針對地下水防護計畫與地下水監測計畫，採文件審查、定期/不定期專案視察等管制措施，確認核電廠除役期間地下水防護方案的符合性。
2. 為精進核電廠除役的相關管制，建議持續蒐集國際間地下水防護方案相關資訊，以持續強化核電廠在除役期間地下水防護方案的管制效能。

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附錄 A

註： 2019 版本差異以底線標示、2007 版本差異以**粗體**標示

NEI 07-07 Rev 1 March 2019	NEI 07-07 (Final) August 2007
EXECUTIVE SUMMARY	**EXECUTIVE SUMMARY**
In 2007 NEI published NEI 07-07, "Industry Groundwater Protection Initiative - Final Guidance Document." NEI 07-07 has been implemented for over 10 years. During this time industry groundwater programs have matured and have undergone multiple self-assessments and two cycles of reviews performed under the auspices of NEI. Additionally, the NRC had added a review of groundwater programs to their routine inspection process under Inspection Procedure 71124.07, "Radiological Environmental Monitoring Program." The purpose of this revision is to update NEI 07-07 based on these years of operating experience, assessments and reviews performed, and technical guidance developed by the Electric Power Research Institute (EPRI). NOTE: In a March 26, 2009, memo the United States Geological Society (USGS) transitioned to the use of the single word "groundwater" vs. "ground water." This revision 1 of NEI 07-07 will use the one-word expression unless the two word version was used in original referenced documents.	
NEI 07-07 was developed to describe the industry's Groundwater Protection Initiative. The Groundwater Protection Initiative identifies actions to improve utilities' management and response to instances where the inadvertent release of radioactive	NEI 07-07 was developed to describe the industry's **Ground Water** Protection Initiative. The **Ground Water** Protection Initiative identifies actions to improve utilities' management and response to instances where the inadvertent release of

substances may result in low but detectible levels of plant-related materials in subsurface soils and water. The inadvertent releases addressed by this initiative fall outside the current requirements of the U.S. Nuclear Regulatory Commission (NRC) and are well below the NRC's limits that ensure protection of public health and safety. Planned liquid and airborne releases performed in accordance with NRC 's regulations are not included in the scope of the initiative or this document. The initiative also includes guidance on how the utilities should communicate with their stakeholders about those instances. The Groundwater Protection Initiative identifies those actions necessary for implementation of a timely and effective groundwater protection program. In addition, objectives are specified to accomplish each action and the acceptance criteria to demonstrate that the objectives have been met. If a licensee reaches an agreement on communication with their stakeholders that differs from the guidance in this document, that difference shall be documented and retained as part of plant records. It is expected that this initiative will be implemented by each member company currently operating or decommissioning a nuclear power plant and by each member company constructing a new plant after year 2006. In the event that new or amended NRC regulations are enacted that address groundwater protection or inadvertent releases of radioactive liquids, this initiative should be revisited by the Nuclear Strategic Issues Advisory Committee.	radioactive substances may result in low but detectible levels of plant-related materials in subsurface soils and water. The inadvertent releases addressed by this Initiative fall outside the current requirements of the Nuclear Regulatory Commission (NRC) and are well below the NRC’s limits that ensure protection of public health and safety. Planned liquid and airborne releases performed in accordance with NRC’s regulations are not included in the scope of the Initiative or this document. The Initiative also includes guidance on how the utilities should communicate with their stakeholders about those instances. The **Ground Water** Protection Initiative identifies those actions necessary for implementation of a timely and effective **ground water** protection program. In addition, objectives are specified to accomplish each action and the acceptance criteria to demonstrate that the objectives have been met. If a licensee reaches an agreement on communication with their stakeholders that differs from the guidance in this document, that difference shall be documented and retained as part of plant records. It is expected that this Initiative will be implemented by each member company currently operating or decommissioning a nuclear power plant and by each member company constructing a new plant after year 2006. In the event that new or amended NRC regulations are enacted that address **ground water** protection or inadvertent releases of radioactive liquids, this **Initiative** should be revisited by the Nuclear Strategic Issues Advisory Committee.

NEI 07-07 Rev 1 March 2019	NEI 07-07 (Final) August 2007
TABLE OF CONTENTS	**TABLE OF CONTENTS**
EXECUTIVE SUMMARY	EXECUTIVE SUMMARY
INTRODUCTION	INTRODUCTION
PURPOSE	PURPOSE
BACKGROUND	BACKGROUND
1.GROUNDWATER PROTECTION PROGRAM.	1.GROUND WATER PROTECTION PROGRAM
OBJECTIVE 1.1 SITE HYDROLOGY AND GEOLOGY	OBJECTIVE 1.1 SITE HYDROLOGY AND GEOLOGY
OBJECTIVE 1.2 SITE RISK ASSESSMENT	OBJECTIVE 1.2 SITE RISK ASSESSMENT
OBJECTIVE 1.3 ON-SITE GROUNDWATER MONITORING	OBJECTIVE 1.3 ON-SITE GROUND WATER MONITORING
OBJECTIVE 1.4 REMEDIATION PROCESS	OBJECTIVE 1.4 REMEDIATION PROCESS
OBJECTIVE 1.5 RECORD KEEPING	OBJECTIVE 1.5 RECORD KEEPING
OBJECTIVE 1.6 DECOMMISSIONING/SAFSTOR IMPACTS	
2.COMMUNICATION	2.COMMUNICATION
OBJECTIVE 2.1 STAKEHOLDERS BRIEFING	OBJECTIVE 2.1 STAKEHOLDER BRIEFING
OBJECTIVE 2.2 VOLUNTARY COMMUNICATION	OBJECTIVE 2.2 VOLUNTARY COMMUNICATION
OBJECTIVE 2.3 THIRTY-DAY REPORTS	OBJECTIVE 2.3 THIRTY-DAY REPORTS
OBJECTIVE 2.4 ANNUAL REPORTING	OBJECTIVE 2.4 ANNUAL REPORTING
PROGRAM OVERSIGHT	PROGRAM OVERSIGHT
OBJECTIVE 3.1 PROGRAM SELF-ASESSMENT AND REVIEW	**OBJECTIVE 3.1 PERFORM A SELF-ASSESSMENT**
	OBJECTIVE 3.2 REVIEW THE PROGRAM UNDER THE AUSPICES OF NEI
3.GLOSSARY	3.GLOSSARY
ATTACHMENT 1	ATTACHMENT 1
ATTACHMENT 2	ATTACHMENT 2
APPENDIX A	APPENDIX A
APPENDIX B	APPENDIX B

NEI 07-07 Rev 1 March 2019	NEI 07-07 (Final) August 2007
INDUSTRY GROUNDWATER PROTECTION INITIATIVE-FINAL GUIDANCE DOCUMENT	**NDUSTRY GROUND WATER PROTECTION INITIATIVE-FINAL GUIDANCE DOCUMENT**
INTRODUCTION	**INTRODUCTION**
There have been instances of nuclear power plants and materials licensees detecting contamination from inadvertent releases of licensed material to soil and/or groundwater. While none of the identified instances has threatened public health and safety or compromised environmental protection, local stakeholders have expressed concern.	**Over the last ten years**, **there** have been instances of nuclear power plants and materials licensees detecting contamination from inadvertent releases of licensed material to soil and/or groundwater. While none of the identified instances has threatened public health and safety or compromised environmental protection, local stakeholders have expressed concern.
Under the Industry Groundwater Protection Initiative (GPI), each member company operating or decommissioning a nuclear power plant was required to develop and implement a site-specific/company groundwater protection program to ensure timely and effective management of situations involving inadvertent releases of licensed material* to groundwater and to implement voluntary* communication programs by July 31, 2006. Each member company constructing a new plant after year 2006 will develop the appropriate site procedures and/or programs to meet the GPI and implement them prior to initial fuel load. An effective, technically sound groundwater protection program requires on-going review and evaluation.	Under the Industry **Ground Water** Protection Initiative (GPI), each member company operating or decommissioning a nuclear power plant was required to develop and implement a site-specific/company **ground water** protection program **to assure** timely and effective management of situations involving inadvertent releases of licensed material∗ to **ground water*** and to implement voluntary* communication programs by July 31, 2006. Each member company constructing a new plant after year 2006 **shall** develop the appropriate site procedures and/or programs to meet the GPI and implement them prior to initial **receipt of nuclear fuel.** An effective, technically sound **ground water** protection program **may take at least a year to implement and** requires on-going review and evaluation.
PURPOSE	**PURPOSE**
The Industry Groundwater Protection Initiative will help licensees to:	The Industry **Ground Water** Protection Initiative will help licensees to:

1. Improve management of situations involving inadvertent radiological releases that get into groundwater. 2. Improve communication with external stakeholders to enhance trust and confidence on the part of local communities, states, the NRC, and the public in the nuclear industry's commitment to a high standard of public radiation safety and protection of the environment. This industry initiative only applies to licensed radioactive materials that are or were generated as a result of plant operations.	1. Improve management of situations involving inadvertent radiological releases that get into **ground water**. 2. Improve communication with external stakeholders to enhance trust and confidence on the part of local communities, **States**, the NRC, and the public in the nuclear industry's commitment to a high standard of public radiation safety and protection of the environment. This **Industry Initiative** only applies to licensed radioactive materials that are or were generated as a result of plant operations
BACKGROUND	**BACKGROUND**
Nuclear power plant licensees are required to control and monitor releases of radioactive liquids and airborne materials to ensure that they remain below regulatory limits and do not pose a threat to public health and safety. Over time, licensees have progressively reduced their releases to the environment such that individuals living near these facilities typically would not receive more than 1 millirem per year due to these controlled discharges. Licensees establish programs and procedures to carefully control radioactive material, however, leaks and spills occasionally occur and equipment can fail. As plants began to undergo decommissioning in the late 1990s to early 2000s, instances of subsurface and/or groundwater contamination were identified. In addition, several operating facilities also identified groundwater contamination resulting from spills and leaks or equipment failure. In one instance, low levels of licensed	Nuclear power plant licensees are required to control and monitor releases of radioactive liquids and airborne materials to ensure that they remain below regulatory limits and do not pose a threat to public health and safety. Over time, licensees have progressively reduced their releases to the environment such that individuals living near these facilities typically would not receive more than 1 millirem per year due to these controlled discharges. Licensees establish programs and procedures to carefully control radioactive material, however, leaks and spills occasionally occur and equipment can fail. As plants began to undergo decommissioning in the late 1990s to early 2000s, instances of subsurface and/or **ground water** contamination were identified. In addition, several operating facilities also identified **ground water** contamination resulting from spills and leaks or equipment failure. In one instance, low levels of licensed material were

material were detected in a private well located on property adjacent to a nuclear power plant.	detected in a private well located on property adjacent to a nuclear power plant.
The industry recognized that these instances of inadvertent contamination posed a public confidence challenge even though the releases themselves were not a significant public health issue. In May 2006, the U.S. commercial nuclear power plants adopted the Nuclear Energy Institute (NEI) Groundwater Protection Initiative (GPI) (Attachment 1). The Nuclear Strategic Issues Advisory Committee (NSIAC) of NEI unanimously voted to implement these voluntary measures to minimize the potential for inadvertent releases of radioactive liquids to the environment and to enhance public trust and confidence in the industry.	The industry recognized that these instances of inadvertent contamination posed a public confidence challenge even though the releases themselves were not a significant public health issue. In May 2006, the U.S. commercial nuclear power plants adopted the Nuclear Energy Institute (NEI) Groundwater Protection Initiative (GPI) (Attachment 1). The Nuclear Strategic Issues Advisory Committee of NEI unanimously voted to implement these voluntary measures to minimize the potential for inadvertent releases of radioactive liquids to the environment and to enhance public trust and confidence in the industry.
Working in parallel, the NRC formed a Liquid Radioactive Release Lessons Learned Task Force to assess the inadvertent release of radioactive liquid to the environment at power reactor sites. On July I 0, 2006, the NRC issued Information Notice 2006-13, "Ground-water Contamination due to Undetected Leakage of Radioactive Water," that summarized its review of radioactive contamination of groundwater at multiple facilities as a result of undetected leakage from facility structures, systems, or components that contain or transport radioactive fluids. Licensees were instructed to review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. The final report of the NRC's task force was issued on September 1, 2006, and included 26 recommendations for additional consideration	Working in parallel, the NRC formed a Liquid Radioactive Release Lessons Learned **Taskforce** to assess the inadvertent release of radioactive liquid to the environment at power reactor sites. On July 10, 2006, the NRC issued Information Notice 2006-13 “Ground-water Contamination due to Undetected Leakage of Radioactive Water” that summarized its review of radioactive contamination of **ground water** at multiple facilities as a result of undetected leakage from facility structures, systems, or components that contain or transport radioactive fluids. Licensees were instructed to review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. The final report of the NRC’s **Taskforce** was issued on September 1, 2006 and included **twenty-six** recommendations for additional

by the NRC. The report stated: '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." Nuclear power provides a significant portion of the electricity needed by society today and must be part of the future diversified generation mix in order to help reduce this nation's reliance on fossil fuels and to reduce the emission of greenhouse gases. Each licensee has voluntarily implemented the Groundwater Protection Initiative and will continue to do so in the future, recognizing that public confidence and trust are critical to the continued successful operation of their facilities.	consideration by the NRC. The report stated: “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.” Nuclear power provides a significant portion of the electricity needed by society today and must be part of the future diversified generation mix, **helping to** reduce this nation’s reliance on fossil fuels and to reduce the emission of greenhouse gases. Each licensee has voluntarily implemented the Groundwater Protection Initiative and will continue to do so in the future, recognizing that public confidence and trust are critical to the continued successful operation of their facilities.

NEI 07-07 Rev 1 March 2019	NEI 07-07 (Final) August 2007
1.GROUNDWATER PROTECTION PROGRAM	1.**GROUND WATER** PROTECTION PROGRAM
ACTION 1 IMPROVE MANAGEMENT OF SITUATIONS INVOLVING INADVERTENT RADIOLOGICAL RELEASES THAT GET INTO GROUNDWATER	ACTION 1 **Improve management of situations involving inadvertent radiological releases that get into ground water**
Each licensee shall develop a written Groundwater Protection Initiative (GPI) program that describes their approach to ensure timely detection and effective response to situations involving inadvertent radiological releases to groundwater in order to prevent migration of licensed radioactive material off-site and to quantify impacts on decommissioning. The GPI program shall specify the frequency at which and/or conditions under which each program element is performed to ensure that the licensee's understanding of the site, the potential for leaks or spills to occur, or for equipment to degrade over time accurately reflect actual conditions.	Each licensee shall develop a written **Ground Water** Protection Initiative (GPI) program that describes their approach to **assure** timely detection and effective response to situations involving inadvertent radiological releases to **ground water** to prevent migration of licensed radioactive material off-site and to quantify impacts on decommissioning. The GPI program shall specify the frequency at which and/or conditions under which each program element is performed to ensure that the licensee’s understanding of the site, the potential for leaks or spills to occur, or for equipment to degrade over time accurately reflect actual conditions.
The Electric Power Research Institute (EPRI) has developed a technical guideline for the implementation of groundwater protection programs at nuclear power plants to meet Action 1. The stated objectives of the EPRI document, "Groundwater Protection Guidelines for Nuclear Power Plants," is to demonstrate a commitment to controlling licensed material, minimize potential unplanned, unmonitored releases to the environment from plant operations, and minimize long-term costs associated with potential groundwater and subsurface	The Electric Power Research Institute (EPRI) **is sponsoring development** of a technical guideline **for** implementation of **ground water** protection programs at nuclear power plants to meet Action 1. The stated objectives of the EPRI “**Guideline for Implementing a Groundwater Protection Program at Nuclear Power Plants**” is to demonstrate a commitment to controlling licensed material, minimize potential unplanned, unmonitored releases to the environment from plant operations, and minimize long-term costs associated with potential **ground water** and

contamination. Other technically sound, documented approaches that meet the baseline requirements and recommendations in the EPRI Guideline may also be used.	subsurface contamination. Other technically sound, documented approaches that meet the baseline requirements and recommendations in the EPRI Guideline may also be used.
OBJECTIVE 1.1 SITE HYDROLOGY AND GEOLOGY	OBJECTIVE 1.1 SITE HYDROLOGY AND GEOLOGY
Ensure that the site characterization of geology and hydrology provides an understanding of predominant groundwater gradients based upon current site conditions. This characterization is the basis for the Conceptual Site Model (CSM).	Ensure that the site characterization of geology and hydrology provides an understanding of predominant **ground water** gradients based upon current site conditions.
Acceptance Criteria NOTE: Acceptance Criteria *a-c* are intended to ensure an adequate Conceptual Site Model has been developed. Therefore, proceed to Acceptance Criteria d if the station has a CSM. a. Perform hydrogeologic and geologic studies to determine predominant groundwater flow characteristics and gradients. b. As appropriate, review existing hydrogeologic and geologic studies, historical environmental studies, and permit or license related reports. c. Identify potential groundwater pathways—on-site and/or off-site—at the facility to ensure migration of source materials is understood. d. Establish the frequency for periodic reviews of site hydrogeologic studies. As a minimum, reviews should be performed whenever any of the following occurs:	Acceptance Criteria a. Perform hydrogeologic and geologic studies to determine predominant ground water flow characteristics and gradients. b. As appropriate, review existing hydrogeologic and geologic studies, historical environmental studies, and permit or license related reports. c. **Identify potential pathways for ground water migration from on-site locations to off-site locations through ground water.** d. Establish the frequency for periodic reviews of site hydrogeologic studies. As a minimum, reviews should be performed whenever any of the following occurs:

➢ Substantial on-site construction ➢ Substantial disturbance of site property ➢ Substantial changes in on-site or nearby off-site use of water ➢ Substantial changes in on-site or nearby off-site pumping rates of groundwater e. As appropriate, update the CSM and the site's Final Safety Analysis Report with changes to the characterization of hydrology and/or geology.	➢ Substantial on-site construction**,** ➢ Substantial disturbance of site property**,** ➢ Substantial changes in on-site or nearby off-site use of water, **or** ➢ Substantial changes in on-site or nearby off-site pumping rates of ground water. e. As appropriate, update the site's Final Safety Analysis Report with changes to the characterization of hydrology and/or geology.
OBJECTIVE 1.2SITE RISK ASSESSMENT	OBJECTIVE 1.2 SITE RISK ASSESSMENT
Identify site risks based on plant design and work practices: 1.2.1Evaluate all systems, structures or components (SSCs) that contain or could contain licensed material and for which there is a credible mechanism for the licensed material to reach groundwater. 1.2.2 Evaluate work practices that involve licensed material and for which there is a credible mechanism for the licensed material to reach groundwater.	Identify site risks based on plant design and work practices: 1.2.1 Evaluate all systems, structures, or components (SSCs) that contain or could contain licensed material and for which there is a credible mechanism for the licensed material to reach **ground water.** 1.2.2 Evaluate work practices that involve licensed material and for which there is a credible mechanism for the licensed material to reach **ground water.**
Acceptance Criteria a. Identify each SSC that involves or could reasonably be expected to involve licensed material and for which there is a credible mechanism for the licensed material to reach groundwater. Examples of SSCs of interest include: refueling water storage tanks, spent fuel pools, spent fuel pool leak detection systems, outdoor tanks, outdoor storage of contaminated equipment, buried piping, retention ponds or basins or reservoirs, lines carrying steam.	Acceptance Criteria a. Identify each SSC **and work practice** that involves or could reasonably be expected to involve licensed material and for which there is a credible mechanism for the licensed material to reach **ground water**. Examples of SSCs of interest include: refueling water storage tanks, **if outdoors**; spent fuel pools**;** spent fuel pool leak detection systems; outdoor tanks; outdoor storage of contaminated equipment; buried piping; retention ponds or basins or reservoirs; lines carrying steam.

b. Identify existing leak detection methods for each SSC that involves or could involve licensed material and for which there is a credible potential for inadvertent releases to groundwater. These may include groundwater monitoring, operator rounds, engineering walk-downs or inspections, leak-detection systems, or periodic integrity testing. c. Identify work practices that include actions taken by individuals during maintenance, operational, or support activities which could result in or prevent a spill or leak of a source material that has a credible mechanism for release to groundwater. d. Evaluate for potential enhancements to leak detection systems or programs. These may include additional or increased frequency of rounds or walk-downs or inspections, or integrity testing. e. Evaluate potential enhancements to prevent spills or leaks from reaching groundwater. These may include resealing or paving surfaces, installing spill containment measures, performing preventative maintenance or surveillance activities to minimize the potential for inadvertent releases of licensed materials due to equipment failure. f. Identify the mechanism or site process for tracking corrective actions.	b. Identify existing leak detection methods for each SSC **and work practice** that involves or could involve licensed material and for which there is a credible potential for inadvertent releases to **ground water.** These may include **ground water** monitoring, operator rounds, engineering **walkdowns** or inspections, leak-detection systems, or periodic integrity testing. **c. Identify potential enhancements to leak detection systems or programs. These may include additional or increased frequency of rounds or walkdowns or inspections, or integrity testing.** **d. Identify potential enhancements to prevent spills or leaks from reaching ground water. These may include resealing or paving surfaces or installing spill containment measures.** **e. Identify the mechanism or site process for tracking corrective actions.**

g. Establish the frequency for periodic reviews of SSCs and work practices.	**f. Establish long term programs to perform preventative maintenance or surveillance activities to minimize the potential for inadvertent releases of licensed materials due to equipment failure.** g. Establish the frequency for periodic reviews of SSCs and work practices.
A "credible mechanism for the licensed material to reach groundwater" is considered one wherein the failure of a single barrier between the SSC and the environment could result in inadvertent or unintentional contamination of groundwater or native soil.	
OBJECTIVE 1.3 ON-SITE GROUNDWATER MONITORING Establish an on-site groundwater monitoring program to ensure timely detection of inadvertent radiological releases to groundwater.	OBJECTIVE 1.3 ON-SITE GROUNDWATER MONITORING Establish an on-site **ground water** monitoring program to ensure timely detection of inadvertent radiological releases to **ground water**.
Acceptance Criteria a.Using the hydrology and geology studies developed under Objective I. I, consider placement of groundwater monitoring wells downgradient from the plant but within the boundary defined by the site license. Wells should be placed to ensure groundwater migration pathways are monitored. b.Groundwater monitoring wells should be placed as close as practical to SSCs that have the highest potential for inadvertent releases that could reach groundwater or SSCs where other means of leak detection capability is limited. c.Establish sampling and analysis protocols, including analytical sensitivity requirements	Acceptance Criteria a.Using the hydrology and geology studies developed under Objective 1.1, consider placement of **ground water** monitoring wells downgradient from the plant but within the boundary defined by the site license. **b.Consider, as appropriate, placing sentinel wells closer to SSCs** that have the highest potential for inadvertent releases that could reach **ground water** or SSCs **where leak** detection capability is limited. c.Establish sampling and analysis protocols, including analytical sensitivity requirements,

and quality assurance/quality control processes for groundwater and soil, where applicable. Consider the potential for detectible levels of licensed material resulting from planned releases of liquids and/or airborne materials.	**for ground water and soil. Sampling for tritium in the vadose or unsaturated zone may not be practicable and may require additional evaluation. For split or duplicate samples, analytical sensitivity levels should be discussed with and agreed to by those external stakeholders responsible for the analyses to preclude future disputes.**
d. Establish a formal, written program for long-term groundwater monitoring. For those groundwater monitoring locations that are also included in the REMP* revise the site's ODCM/ODAM* and ensure the distinction between the prograins is clear. *Wherever indicated, see glossary	d. Establish a formal, written program for **longterm ground water** monitoring. For those **ground water** monitoring locations that are included in the REMP∗, revise the site's ODCM/ODAM*. ***wherever** indicated, see glossary
e.Periodically review existing station or contract lab(s) analytical capabilities. An important consideration is the analytical protocols and times needed to obtain results.	e.Periodically review existing station or contract lab(s) analytical capabilities. An important consideration is **the time** needed to obtain results.
f.Establish a long-term program for preventative maintenance of groundwater wells.	f. Establish a long-term program for preventative maintenance of **ground water** wells.
g. Establish the frequency for periodic review of the groundwater monitoring program.	g. Establish the frequency for periodic review of the **ground water** monitoring program.
OBJECTIVE 1.4 REMEDIATION PROCESS	OBJECTIVE 1.4 REMEDIATION PROCESS
Establish a remediation protocol to prevent migration of licensed material off-site and to minimize decommissioning impacts.	Establish a remediation protocol to prevent migration of licensed material off-site and to minimize decommissioning impacts.
Acceptance Criteria a.Establish written procedures outlining the decision making process for remediation of	Acceptance Criteria a. Establish written procedures outlining the decision making process for remediation of

leaks and spills or other instances of inadvertent releases. This process is site specific and shall consider migration pathways. b.Evaluate and document, as appropriate, decommissioning impacts resulting from remediation activities or the absence thereof. **EPRI has developed a technical guideline, "Soil and Groundwater Remediation Guidelines for Nuclear Power Plants," to assist in this area.**	leaks and spills or other instances of inadvertent releases. This process is site specific and shall consider migration pathways. **b. Evaluate the potential for detectible levels of licensed material resulting from planned releases of liquids and/or airborne materials.** c. Evaluate and document, as appropriate, decommissioning impacts resulting from remediation activities or the absence thereof.
OBJECTIVE 1.5 RECORD KEEPING	OBJECTIVE 1.5 RECORD KEEPING
Ensure that records of leaks, spills and remediation efforts are retained and retrievable to meet the requirements of 10 CFR 50.75(g).	Ensure that records of leaks, spills, remediation efforts are retained and retrievable to meet the requirements of 10 CFR 50.75(g).
Acceptance Criteria Establish a record keeping program to meet the requirements of 10 CFR 50.75(g). Note that these records are used to determine an area's classification for purposes of performing surveys see NRC Regulatory Issue Summary 2002-02, "Lessons Learned Related to Recently Submitted Decommissioning Plans and License Termination Plans."	Acceptance Criteria **a.** Establish a record keeping program to meet the requirements of 10 CFR 50.75(g). Note that these records are used to determine an area's classification for purposes of performing surveys **(**see NRC Regulatory Issue Summary 2002-02 **Lessons** Learned Related to Recently Submitted Decommissioning Plans and License Termination **Plans).**

OBJECTIVE 1.6 DECOMMISSIONING/SAFSTOR IMPACTS	
For sites entering/participating in active decommissioning or SAFSTOR, evaluate the impact that associated activities will have on the groundwater protection program. NOTE: EPRI has developed technical guidance, "Groundwater Monitoring Guidance for Decommissioning Planning," that is designed to assist utilities in planning for changes needed to their groundwater monitoring programs as they transition from operational to decommissioning status. Acceptance Criteria a. Establish written procedures outlining the commitments made in regulatory documents such as the Post-Shutdown Decommissioning Activities Report (PSDAR) and License Termination Plan (LTP). Establish/change groundwater related procedures accordingly. b. As site conditions/processes are planned and/or changed: 1. Evaluate the impact of how actions could impact groundwater protection. 2. Assess the SSCs and Work Practice Risk Assessments to reflect current conditions. 3. Assess the CSM to reflect current conditions. 4. Assess the groundwater monitoring program to reflect changes in the SSC and Work Practice Risk Assessments and any	

changes in the CSM e. g., sampling frequency and number of sample wells. c. Verify that appropriate elements of groundwater protection are evaluated and maintained until radiological remediation of the site is complete and until the license termination plan and any state and local groundwater related requirements have been satisfied.	

COMMUNICATION	COMMUNICATION
ACTION 2 IMPROVE COMMUNICATION WITH EXTERNAL STAKEHOLDERS TO ENHANCE TRUST AND CONFIDENCE ON THE PART OF LOCAL COMMUNITIES, STATES, THE NRC, AND THE PUBLIC IN THE NUCLEAR INDUSTRY'S COMMITMENT TO A HIGH STANDARD OF PUBLIC RADIATION SAFETY AND PROTECTION OF THE ENVIRONMENT.	ACTION 2 **Improve communication with external stakeholders to enhance trust and confidence on the part of local communities, States, the NRC, and the public in the nuclear industry's commitment to a high standard of public radiation safety and protection of the environment.**
OBJECTIVE 2.1STAKEHOLDERS BRIEFING	OBJECTIVE 2.1 STAKEHOLDER BRIEFING
During the initial development of the GPI, each licensee conducted periodic briefings of their site-specific GPI program with the designated state/local officials. This initial briefing will be performed by sites that begin operation after 01/01/2020.	**Each** licensee **should conduct initial and** periodic briefings of their **site specific** GPI program with the designated **State/Local** officials.
Acceptance Criteria a. The licensee should discuss: ➢ The background or industry events that led to the GPI. ➢ If there is additional information that the **state/local** officials need to better understand the issue, or place it in perspective for their constituents. ➢ "How" the state/local officials will use or distribute the information. b. Licensees should consider including additional information or updates on groundwater protection in periodic discussions with state/local officials, as necessary.	Acceptance Criteria a. The licensee should discuss: ➢ The background or industry events that led to the GPI. ➢ If there is additional information that the **State/Local** officials need to better understand the issue or place it in perspective for their constituents. ➢ "How" the **State/Local** officials will use or distribute the information. b. Licensees should consider including additional information or updates on **ground water** protection in periodic discussions with **State/Local** officials.

c.For licensees that are in states where multiple nuclear power plants are located with multiple owner companies, it is highly recommended that the licensees coordinate their efforts such that voluntary communications with state/local officials are consistent.	c. For licensees that are in **States** where multiple nuclear power plants are located **and** multiple owner companies, it is highly recommended that the licensees coordinate their efforts **and communicate with each other. The initial briefing for the State/local officials and the contents of a voluntary communication should be consistent.**
OBJECTIVE 2.2 VOLUNTARY COMMUNICATION	OBJECTIVE 2.2 VOLUNTARY COMMUNICATION
Make informal* communication as soon as practicable to appropriate state/local officials and to other stakeholders as required by site specific procedures with follow-up notification to the NRC, as appropriate, regarding new and/or significant on-site leaks/spills into groundwater and on-site or off-site water sample results exceeding the criteria in the REMP as described in the ODCM/ODAM, as appropriate. * Wherever indicated, see glossary	Make informal∗ communication as soon as practicable to appropriate **State/Local** officials, with follow-up notification to the NRC, as appropriate, **regarding significant*** on-site leaks/spills into **ground water** and on-site or off-site water sample results exceeding the criteria in the REMP as described in the ODCM/ODAM. * **wherever** indicated, see glossary
NOTE: It is not expected that a voluntary communication be generated when a subsequent sample(s) is documented to be from the same source/mechanism/event. Documentation shall be created to show that the subsequent samples were all part of the same source/mechanism/event. The documentation shall be available for stakeholder review.	
Acceptance Criteria This guidance provides a threshold for voluntary communication. Some states may require different communication thresholds; the licensee shall document any agreements	Acceptance **Criteria:** This guidance provides a threshold for voluntary communication. Some **States** may require different communication thresholds; the licensee shall document any agreements

with state/local officials that differ from Industry guidance. a. Communication to the designated state/local officials and other stakeholders as required by site specific procedures shall be made before the end of the next business day if an inadvertent leak or spill to the environment has or can potentially get into the groundwater and exceeds any of the following criteria: i. If a spill or leak exceeding l 00 gallons from a source containing licensed material. ii. If the volume of a spill or leak cannot be quantified but is likely to exceed 100 gallons from a source containing licensed material. iii. Any leak or spill, regardless of volume or activity, deemed by the licensee to warrant voluntary communication. AND iv. The spill or leak, regardless of volume or activity, occurs which cannot be completely recaptured or remediated per Objective 1.4 within 24 hours of discovery of the event-i.e., if the spill or leak is recaptured or remediated within 24 hours no communication is required. To determine whether a leak or spill would trigger voluntary communication, Appendix A provides a flowchart for the voluntary communication protocol as it applies to leaks or groundwater sample results.	with **State/Local** officials that **differs** from Industry guidance. a. Communication to the designated **State/Local officials shall** be made before the end of the next business day if an inadvertent leak or spill to the environment has or can potentially get into the **ground water** and exceeds any of the following criteria: i. If a spill or leak exceeding 100 gallons from a source containing licensed **material,** ii. If the volume of a spill or leak cannot be quantified but is likely to exceed 100 gallons from a source containing licensed material**, or** iii. Any leak or spill, regardless of volume or activity, deemed by the licensee to warrant voluntary communication. To determine whether a leak or spill would trigger voluntary communication, **consider the clarification in the following three text boxes in addition to 2.2.a i to iii above:**

LEAK OR SPILL: The "leak or spill" represents an inadvertent event or perturbation in a system or component's performance. This event threshold is intended to ensure that state/local officials are made aware that there has been an event of interest at the site and to keep them apprised of the licensee's action to contain and, as needed, remediate the event. "Leak or spill" events that meet the criteria shall be communicated regardless of whether or not the on-site groundwater is, or could be used as, a source of drinking water. The quantity of liquid resulting from leaks or spills of solid materials or waste or steam leaks should be evaluated with respect to 2.2.a.i-iv, inclusive.	LEAK OR SPILL: The “leak or spill” represents an inadvertent event or perturbation in a system or component’s performance. This event threshold is intended to ensure that **State/Local** officials are made aware that there has been an event of interest at the site and to keep them apprised of the licensee’s action to contain and, as needed, remediate the event. “Leak or spill” events that meet the criteria shall be communicated regardless of whether or not the on-site **ground water** is, or could be used as, a source of drinking water. The quantity of liquid resulting from leaks or spills of solid materials or waste or steam leaks should be evaluated with respect to **2.2.a.i to iii,** inclusive.
SOURCE CONTAINING LICENSED MATERIAL: A liquid, including steam, for which a statistically valid positive result is obtained when the sample is analyzed to the following a priori lower limits of detection (analytical sensitivity). The analytical sensitivity for identifying a source containing licensed material is, at a minimum, the licensee's lower limits of detection that are required for radioactive liquid effluents for isotopes as specified in the ODCM/ODAM.	SOURCE CONTAINING LICENSED MATERIAL: A liquid, including steam, for which a statistically valid positive result is obtained when the sample is analyzed to the following a priori lower limits of detection (analytical sensitivity). The analytical sensitivity for identifying a source containing licensed material is, at a minimum, the licensee’s lower limits of detection that are required for radioactive liquid effluents **for all isotopes.**
POTENTIAL TO REACH GROUNDWATER Spills or leaks with the potential to reach groundwater:	POTENTIAL TO REACH GROUND WATER Spills or leaks with the potential to reach **ground water:**

➢ Spill or leak directly onto native soil or fill. ➢ Spill or leak onto an artificial surface—i.e., concrete or asphalt—if the surface is cracked or the material is porous or unsealed. ➢ Spill or leak that is directed into unlined or non-impervious ponds or retention basins-i.e., water hydrologically connected to groundwater. A spill or leak inside a building or containment unit is generally unlikely to reach groundwater, particularly if the building or containment unit has a drain and sump system. However, the sump and drain system should be evaluated as part of the SSC risk assessment. **NOTE:** A spill or leak that is recaptured or remediated per Objective 1.4 within 24 hours of discovery and that does not have potential to reach groundwater does not trigger the voluntary communication protocol.	➢ Spill or leak directly onto native soil or fill, ➢ Spill or leak onto an artificial surface (i.e. concrete or asphalt) if the surface is cracked or the material is porous or unsealed, ➢ Spill or leak that is directed into unlined or **non impervious** ponds or retention basins **(**i.e. water hydrologically connected to **ground water).** A spill or leak inside a building or containment unit is generally unlikely to reach **ground water,** particularly if the building or containment unit has a drain and sump system. However, the sump and drain system should be evaluated as part of the SSC risk assessment. A spill or leak **to a semi-impermeable or impermeable surface** that is recaptured or remediated per Objective 1.4 **before the close of the next business day** does not trigger the voluntary communication protocol.
The licensee shall document any agreement with state/local officials and other stakeholders as required by site specific procedures that differ from this industry guidance as part of their record. Such agreements or guidance provided by these officials override the communication guidance in this document but must be documented and kept current for stakeholder review.	The licensee shall document any agreement with **State/Local** officials **that differs from this Industry guidance as part of their record. For example, some states or local authorities have indicated that they do not wish leaks/spills to be included in the voluntary communication protocol or that the voluntary communication should be completed in a shorter timeframe.** **Appendix A provides a flowchart for the**

	communication protocol as it applies to leaks or spills or groundwater sample results.
b.Communication with the designated state/local officials and to other stakeholders as required by site specific procedures shall be made before the end of the next business day for a confirmed water sample result: i. Of off-site groundwater or surface water that exceeds any of the REMP reporting criteria for water as described in the ODCM/ODAM. ii. Of on-site surface water that is hydrologically connected to groundwater, or of groundwater that is or could be used as a source of drinking water-either onsite or downgradient from the site- that exceeds any of the REMP reporting criteria for water as described in the ODCM/ODAM. The licensee shall document the basis for concluding that the on-site groundwater is not or would not be considered a source of drinking water. Examples of a defensible basis are documents from the regulatory agency with jurisdiction over groundwater use. Appendix A provides a flowchart for the communication protocol as it applies to groundwater sample results.	b. Communication with the designated **State/Local** officials **shall** be made before the end of the next business day for **a water sample result** i. Of off-site **ground water** or surface water that exceeds any of the REMP reporting criteria for water as described in the ODCM/ODAM, **or** ii. Of on-site surface **water, that** is hydrologically connected to **ground water**, or **ground water** that is or could be used as a source of drinking **water, that** exceeds any of the REMP reporting criteria for water as described in the ODCM/ODAM The licensee shall document the basis for concluding that the on-site **ground water** is not or would not be considered a source of drinking water. Examples of a defensible basis are documents from the regulatory agency with jurisdiction over **ground water** use. Appendix A provides a flowchart for the communication protocol as it applies to groundwater sample results.
c. When communicating to the state/local officials and to other stakeholders as required by site specific procedures, be clear and precise in quantifying the actual release information as it applies to the appropriate	c. When communicating to the **State/Local** officials, be clear and precise in quantifying the actual release information as it applies to the appropriate regulatory criteria **(i.e.** put it in perspective**)**. The following information

regulatory criteria—i.e., put it in perspective. The following information should be provided as part of the informal communication: i. A statement that the communication is being made as part of the NEI Groundwater Protection Initiative ii. The date and time of the spill, leak, or sample result(s) iii. Whether or not the spill has been contained or the leak has been stopped iv. If known, the location of the leak or spill or water sample(s) v. The source of the leak or spill, if known vi. A list of the contaminant(s) and the verified concentration(s) vii. Description of the action(s) already taken and a general description of future actions viii. An estimate of the potential or bounding annual dose to a member of the public, if available at this time ix. An estimated time/date to provide additional information or follow-up	should be provided as part of the informal communication: i. A statement that the communication is being made as part of the NEI **Ground Water** Protection Initiative**,** ii. The date and time of the spill, leak, or sample result(s)**,** iii. Whether or not the spill has been contained or the leak has been stopped**,** iv. If known, the location of the leak or spill or water sample(s)**,** v. The source of the leak or spill, if known**,** vi. A list of the contaminant(s) and the verified concentration(s)**,** vii. Description of the action(s) already taken and a general description of future actions**,** viii. An estimate of the potential or bounding annual dose to a member of the public if available at this time**, and** ix. An estimated time/date to provide additional information or follow-up**.**
d. Voluntary communication to state and/or local officials and to other stakeholders as required by site specific procedures may also require NRC notification under 10 CFR 50.72 (b)(2)(xi). Licensees should perform these notifications consistent with their existing program. e. Contact NEI by email to GRPGroundwaterIssues@nei.org as part of a voluntary communication event as described in Objective 2.2.	d. Voluntary communication to **State** and/or **Local** officials may also require NRC notification under 10 CFR 50.72(b)(2)(xi). Licensees should perform these notifications consistent with their existing program. e. Contact NEI by email to **GW_Notice@nei.**org as part of a voluntary communication event as described in Objective 2.2.
OBJECTIVE 2.3 THIRTY-DAY REPORTS	OBJECTIVE 2.3 THIRTY-DAY REPORTS
Submit a written 30-day report to the NRC for	Submit a written 30-day report to the NRC for

any water sample result for on-site groundwater that is or may be used as a source of drinking water that exceeds any of the criteria in the licensee's existing REMP as described in the ODCM/ODAM for 30-day reporting of off-site water sample results. Copies of the written 30-day reports for both on-site and off-site water samples shall also be provided to the appropriate state/local officials.	any water sample result for on-site **ground water** that is or may be used as a source of drinking water that exceeds any of the criteria in the licensee's existing REMP as described in the ODCM/ODAM for 30-day reporting of off-site water sample results. Copies of the written 30-day reports for both on-site and off-site water samples shall also be provided to the appropriate **State/Local** officials.
NOTE: Some site ODCM's may state 31 days. The 31-day report is acceptable for those sites.	
Acceptance Criteria a. All groundwater samples taken for the industry initiative shall be analyzed and compared to the standards and limits contained in the station's REMP as described in the ODCM/ODAM. Pre-2006 ODCM/ODAM requirements specify a written 30-day report to the NRC for REMP sample results that exceed any of the REMP reporting criteria. Under the initiative, a written 30-day NRC report is also required for on-site well sample results that exceed any of the REMP reporting criteria and could potentially reach the groundwater that is or could be used in the future as a source of drinking water, either onsite or downgradient from the site. If the groundwater is not currently used for drinking water but is potable, each station should consider the groundwater as a potential source of drinking water—see Objective 2.2, Acceptance Criterion b for documentation needed to establish a defensible basis for determining the beneficial use(s) of groundwater.	Acceptance Criteria a. All **ground water** samples taken for the **Industry Initiative** shall be analyzed and compared to the standards and limits contained in the station's REMP as described in the ODCM/ODAM. Pre-2006 ODCM/ODAM requirements specify a written 30-day report to the NRC for REMP sample results that exceed any of the REMP reporting criteria. Under the **Initiative**, a written 30-day NRC report is also required for all on-site sample results that exceed any of the REMP reporting criteria and could potentially reach the **ground water** that is or could be used in the future as a source of drinking **water. If the ground water** is not currently used for drinking water but is potable, each station should consider the **ground water** as a potential source of drinking water **(**see objective 2.2 **acceptance criterion** b for documentation needed to establish a defensible basis for determining the beneficial use(s) of **ground water**).

The initial discovery of groundwater contamination greater than the REMP reporting criterion is the event documented in a written 30-day report. It is not expected that a written 30-day report will be generated each time a subsequent sample(s) suspected to be from the same "plume" identifies concentrations greater than any of the REMP criteria as described in the ODCM/ODAM. The licensee should evaluate the need for additional reports or communications based on unexpected changes in conditions.	The initial discovery of **ground water** contamination greater than the REMP reporting criterion is the event documented in a written 30-day report. It is not expected that a written 30-day report will be generated each time a subsequent sample(s) suspected to be from the same “plume” identifies concentrations greater than any of the REMP criteria as described in the ODCM/ODAM. The licensee should evaluate the need for additional reports or communications based on unexpected changes in conditions.
b. The 30-day special report should include: i. A statement that the report is being submitted in support of the GPI ii. A list of the contaminant(s) and the verified concentration(s) iii. Description of the action(s) taken iv. An estimate of the potential or bounding annual dose to a 1nember of the public v. Corrective action(s), if necessary, that will be taken to reduce the projected annual dose to a member of the public to less than the limits in 10 CFR 50 Appendix I c. All written 30-day NRC repo11s generated under item 2.3.a are to be concurrently forwarded to the designated state/local officials.	b. The 30-day special report should include: i. A statement that the report is being submitted in support of the GPI**,** ii. A list of the contaminant(s) and the verified concentration(s)**,** iii. Description of the action(s) taken**,** iv. An estimate of the potential or bounding annual dose to a member of the public**, and** v. Corrective action(s), if necessary, that will be taken to reduce the projected annual dose to a member of the public to less than the limits in 10 CFR 50 Appendix I**.** c. All written 30-day NRC reports generated under item 2.3.a are to be concurrently forwarded to the designated **Stat/ Local** officials.
OBJECTIVE 2.4 ANNUAL REPORTING	OBJECTIVE 2.4 ANNUAL REPORTING
Document on-site groundwater sample results of licensed material and a description of any new significant on-site leaks/spills into groundwater for each calendar year in the Annual Radiological Environmental Operating Report (AREOR) for REMP and/or	Document **all on-site ground water** sample results and a description of **any significant** on-site leaks/spills into **ground water** for each calendar year in the Annual Radiological Environmental Operating Report (AREOR) for **REMP or** the Annual Radioactive

the Annual Radioactive Effluent Release Report (ARERR) for the RETS as contained in the appropriate reporting procedure, beginning with the report for calendar year 2006.	Effluent Release Report (ARERR) for the RETS as contained in the appropriate reporting procedure, beginning with the report for calendar year 2006.
Acceptance Criteria a. For plants constructed after 2008, appropriate procedures that require inclusion of significant on-site leaks/spills into groundwater and all on-site groundwater results shall be developed and implemented prior to initial receipt of nuclear fuel see NEI 08-08, "Generic FSAR Template Guidance for Life-Cycle Minimization of Contamination," December 2008.	Acceptance Criteria**:** a. **The appropriate changes to the ODCM/ODAM or to the appropriate procedures were expected to be completed in a timeframe to support the 2007 report of 2006 performance for plants that were operating or decommissioning when the GPI was adopted. For new plants, appropriate procedures that require inclusion of significant on-site leaks/spills into ground water and all on-site ground water results shall be developed and implemented prior to initial receipt of nuclear fuel.**
b. Reporting of on-site groundwater sample results shall be as follows: i. Groundwater sample results that are taken in support of the GPI but are not part of the REMP program e. g., samples obtained during the investigatory phase of the Action Plan circa year 2006-are reported in the ARERR required by 10 CFR 50.36a (a)(2). ii. Once the long-term monitoring sample points have been established per Objective 1.3, Acceptance Criterion d, the results are reported in the AREOR for those sample points that are included in the REMP as described in the ODCM/ODAM. The sample results for those long-term monitoring sample points that are not included in REMP are	b. Reporting of on-site **ground water** sample results shall be as follows: i. **Ground water** sample results that are taken in support of the GPI but are not part of the REMP program **(**e.g. samples obtained during the investigatory phase of the Action Plan circa year 2006**)** are reported in the ARERR required by 10 CFR 50.36a (a)(2). ii. Once the **longterm** monitoring sample points have been established per Objective 1.3, **acceptance** criterion d, the results are reported in the AREOR for those sample points that are included in the REMP as described in the ODCM/ODAM. The sample results for those **longterm** monitoring sample points that are not included in REMP are

reported in the ARERR.	reported in the ARERR.
c. In addition to 2.4.b, voluntary communications, if any are made, shall be included in an annual report as follows: i. A description of all spills or leaks that were communicated per Objective 2.2, Acceptance Criterion a shall be included in the ARERR and/or AREOR. ii. All on-site or off-site groundwater sample results that exceeded the REMP reporting thresholds as described in the ODCM/ODAM that were communicated per Objective 2.2, Acceptance Criterion b shall be included in either the ARERR and/or in the AREOR.	c. In addition to 2.4.b, voluntary **communications shall** be included in an annual report as follows: i. A description of all spills or leaks that were communicated per Objective 2.2 **acceptance criterion a** shall be included in the ARERR 又 ii. All on-site or **off-site ground water** sample results that exceeded the REMP reporting thresholds as described in the ODCM/ODAM that were communicated per Objective 2.2 **acceptance** criterion b shall be included in either the ARERR and/or in the AREOR.

PROGRAM OVERSIGHT	PROGRAM OVERSIGHT
ACTION 3 PERFORM PROGRAM OVERSIGHT TO ENSURE EFFECTIVE IMPLEMENTATION OF THE GPI PROGRAM	ACTION 3 **Perform program oversight to ensure effective implementation of the GPI program**
OBJECTIVE 3.1 PROGRAM SELF-ASESSMENT AND REVIEW Maintain active oversight of the GPI program-see Appendix B.	OBJECTIVE 3.1 PROGRAM SELF-ASESSMENT **Perform a self-assessment of the GPI program (see Appendix B).**
Acceptance Criteria a. An independent, knowledgeable individual(s) shall perform an initial self-assessment within one year after initial criticality-this step only applies to units that begin operation after 01/01/2020. b.A programmatic assessment of the GPI program shall be performed periodically at least once every 5 years after initial self-assessment. Programmatic assessments should be maintained according to the records management program. c.The programmatic assessment, at a minimum, shall include evaluating the implementation of all the objectives identified in this document and be documented consistent with applicable station procedures and programs.	Acceptance Criteria **a.** An independent, knowledgeable individual(s) shall perform the initial self-assessment within one year **of implementation. For existing plants, this means no later than December 31, 2008; for new plants this means within one year after initial criticality.** **b. Perform periodic self-assessment of the GPI program at least** once every 5 years after initial self-assessment. **c. The self-assessment, at a minimum, shall include evaluating implementation of all of the objectives identified in this document.** **d. The self-assessment shall be documented consistent with applicable station procedures and programs.**
	OBJECTIVE 3.2 REVIEW THE PROGRAM UNDER THE AUSPICES OF NEI **Conduct a review of the GPI program,**

	including at a minimum the licensee's self-assessments, under the auspices of NEI.
	Acceptance Criteria: **a. An independent, knowledgeable individual(s) shall perform the initial review within one year of the initial self-assessment performed per Objective 3.1.a above.** **b. Periodic review of the GPI program should be performed every 5 years, subsequent to the license's periodic self-assessment performed per Objective 3.1.b. above.**
GLOSSARY	GLOSSARY
AREOR means the Annual Radiological Environmental Operating Report - summarizes the results of the REMP to the NRC.	AREOR means the Annual Radiological Environmental Operating Report – summarizes the results of the REMP to the NRC.
ARERR means the Annual Radioactive Effluent Release Report as required by IO CFR 50.36a (a)(2) - summarizes the releases of liquid, airborne and solid wastes from the facility and provides the calculated doses attributable to those releases.	ARERR means the Annual Radioactive Effluent Release Report as required by 10 CFR 50.36a (a)(2) – summarizes the releases of liquid, airborne**,** and solid wastes from the facility and provides the calculated doses attributable to those releases.
Credible mechanism for the licensed material to reach groundwater is considered one wherein the failure of a single barrier between the SSC and the environment that could result in inadvertent or unintentional contamination of groundwater or native soil.	
Groundwater as used in the GPI means any subsurface water, whether in the unsaturated or vadose zone, or in the saturated zone of the earth.	**Ground water** as used in the GPI**, means** any subsurface water, whether in the unsaturated or vadose zone, or in the saturated zone of the earth.
Informal (communication) means a communication, typically by telephone,	Informal (communication) means a communication, typically by telephone,

between licensee personnel and the state/local officials. Subsequent notification of the NRC under 10 CFR 50.72 should be performed consistent with station policy.	between licensee personnel and the **State/Local** officials. Subsequent notification of the NRC under 10 CFR 50.72 should be performed consistent with station policy.
Licensed material—from 10 CFR 20.1003— means source material, special nuclear material, or bypr?duct material received, possessed, used, transferred or disposed of under a general or specific license issued by the Commission.	Licensed material **(**from 10 CFR 20.1003**)** means source material, special nuclear material, or byproduct material received, possessed, used, transferred or disposed of under a general or specific license issued by the Commission.
ODCM/ODAM means the Offsite Dose Calculation Manual or Offsite Dose Assessment Manual or equivalent document. The licensee's manual required by Technical Specification that contains the dose assessment methodology and radiological effluent technical specifications.	ODCM/ODAM means the Offsite Dose Calculation Manual or Offsite Dose Assessment Manual or equivalent document. The licensee’s manual required by Technical Specification that contains the dose assessment methodology and radiological effluent technical specifications.
REMP means the Radiological Environmental Monitoring Program specified by the ODCM/ODAM that provides measurements of radiation and of radioactive materials in those exposure pathways and for those radionuclides which lead to the highest potential radiation exposures of individuals resulting from the station operation.	REMP means the Radiological Environmental Monitoring Program specified by the ODCM/ODAM that provides measurements of radiation and of radioactive materials in those exposure pathways and for those radionuclides, which lead to the highest potential radiation exposures of individuals resulting from the station operation.
RETS means the Radiological Effluent Technical Specifications required to control the release of radioactive liquids and airborne materials from the site. Standard radiological effluent technical specifications are found in NUREG CR-1301.	RETS means the Radiological Effluent Technical Specifications required to control the release of radioactive liquids and airborne materials from the site. Standard radiological effluent technical specifications are found in NUREG CR-1301.
Significant (leak or spill) means an item or incident that is of interest to the public or stakeholders. It does not imply or refer to regulatory terminology nor is it intended to indicate that the leak or spill has public health and safety or environmental protection consequences.	Significant (leak or spill) means an item or incident that is of interest to the public or stakeholders. It does not imply or refer to regulatory terminology nor is it intended to indicate that the leak or spill has public health and safety or environmental protection consequences.

Voluntary as used in the GPI means not required by statute or regulation.	Voluntary as used in the GPI**,** means not required by statute or regulation.
Verbs "may," "shall," "should," "will," and "would" have the meanings commonly used in the nuclear power industry—see ANSI N42. l 4- l999. "Shall" denotes a requirement; "should" denotes a recommendation; "may" denotes permission.	Verbs “may”, “shall”, “should”, “will”, and “would” have the meanings commonly used in the nuclear power industry **(**see ANSI N42.14-1999**)**. "Shall" denotes a requirement; "should" denotes a recommendation; "may" denotes permission**.**

NEI 07-07 Rev 1 March 2019	NEI 07-07 (Final) August 2007
ATTACHMENT 1 Nuclear Energy Institute Industry Initiative on Groundwater Protection May 2006	ATTACHMENT 1 Nuclear Energy Institute Industry Initiative on **Ground Water** Protection May 2006
Objectives:	Objectives:
I. Improve management of situations involving inadvertent radiological releases that get into groundwater. 2. Enhance trust and confidence on the part of local communities, states, the NRC, and the public in the nuclear industry's commitment to a high standard of public radiation safety and protection of the environment.	1.Improve management of situations involving inadvertent radiological releases that get into **ground water.** 2.Enhance trust and confidence on the part of local communities, **States**, the NRC, and the public in the nuclear industry's commitment to a high standard of public radiation safety and protection of the environment.
Actions: By July 31, 2006, each member company operating or decommissioning a nuclear power plant will:	Actions: By July 31, 2006, each member company operating or decommissioning a nuclear power plant will:
1. Put in place a company/site-specific action plan(s) to help assure timely detection and effective response to situations involving inadvertent radiological releases in groundwater to prevent migration of licensed radioactive material offsite and quantify impacts on decommissioning. 2. Expand the scope of the licensee's existing Radiological Environmental Monitoring Program (REMP) reporting requirements to include additional voluntary formal and informal reporting as follows: 2.1 Document all onsite groundwater sample results and a description of any significant onsite leaks/spills into groundwater for each calendar year in the Annual REMP Report, beginning with the report covering the calendar	1. Put in place a company/site-specific action plan(s) 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. 2. Expand the scope of the licensee's existing Radiological Environmental Monitoring Program (REMP) reporting requirements to include additional voluntary formal and informal reporting as follows: 2.1 Document all onsite **ground water** sample results and a description of any significant onsite leaks/spills into **ground water** for each calendar year in the Annual REMP Report, beginning with the report covering the calendar year 2006**;**

year 2006. 2.2 Submit a 30-day report to the NRC for any water sample result for on-site groundwater that is or may be used as a source of drinking water that exceeds the criteria in the licensee's existing REMP for 30-day reporting of off-site water sample results. Copies of 30-day reports for both onsite and offsite water samples will also be provided to the appropriate state agency. 2.3 Make informal notification as soon as practicable to appropriate state/local officials with follow-up notification to the NRC, as appropriate, regarding significant on-site leaks/spills into groundwater-see Item 2.1 and on-site or off-site water sample results exceeding the criteria in the REMP-see Item 2.2.	2.2 Submit a 30-day report to the NRC for any water sample result for **onsite ground water** that is or may be used as a source of drinking water that exceeds the criteria in the licensee's existing REMP for 30-day reporting of **offsite** water sample results. Copies of 30-day reports for both onsite and **offsite** water samples will also be provided to the appropriate State agency**; and** 2.3 Make informal notification as soon as practicable to appropriate **State/Local** officials, with follow-up notification to the NRC, as appropriate, regarding significant **onsite** leaks/spills into **ground water (**see Item 2.1**)** and **onsite** or **offsite** water sample results exceeding the criteria in the REMP **(**see Item 2.2**)**.

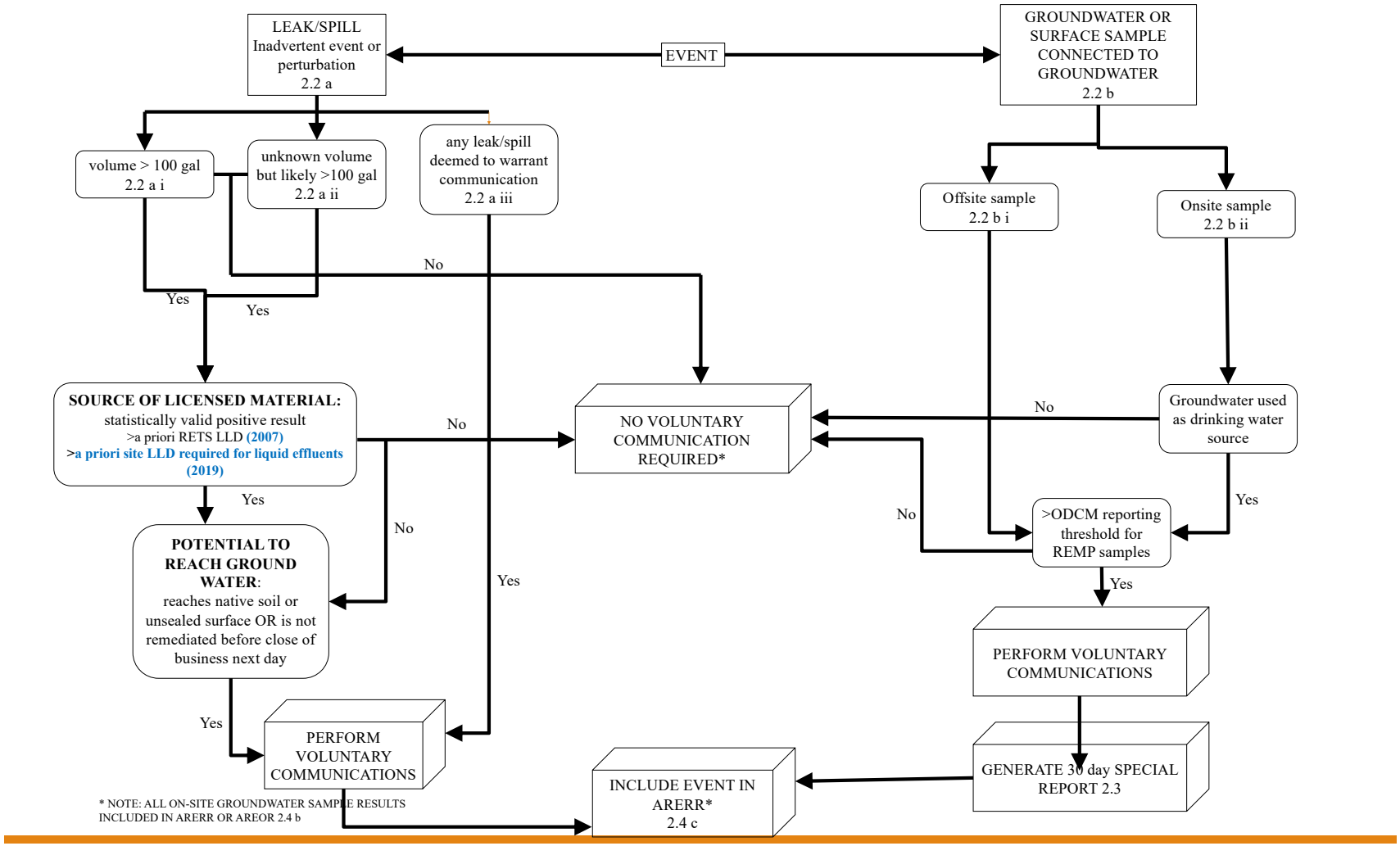
ATTACHMENT 2 FREQUENTLY ASKED QUESTIONS	ATTACHMENT 2 FREQUENTLY ASKED QUESTIONS
1) Q: Does the commitment to "develop and implement a site-specific/company groundwater protection program" specifically include a commitment to drill more monitoring wells, modify plant systems, structures, or components, etc.?	1) Q: Does the commitment to "develop and implement a site-specific/company **ground water** protection program" specifically include a commitment to drill more monitoring wells, modify plant systems, structures, or components, **etc?**
A: No. Companies are expected to complete an evaluation of the specific situation at each site and identify and schedule needed improvements to meet the objective of "help[ing] assure timely detection and effective response to situations involving inadvertent radiological releases to groundwater to prevent migration of licensed	A: No. Companies are expected to complete an evaluation of the specific situation at each site and identify and schedule needed improvements to meet the objective of "help[ing] assure timely detection and effective response to situations involving inadvertent radiological releases to **ground water** to prevent migration of licensed

radioactive material off-site and minimize the impacts on decommissioning." The scope of the needed improvements will largely depend on site-specific conditions, e.g., the history of leaks or spills and the extent and quality of current programs for detecting leaks and monitoring on-site groundwater. The on-site groundwater monitoring program, including groundwater monitoring well purpose and location should be based on the Conceptual Site Model. The evaluation should be periodically reassessed.	radioactive material off-site and minimize the impacts on decommissioning." The scope of the needed improvements will largely depend on site-specific conditions, e.g., the history of leaks or spills and the extent and quality of current programs for detecting leaks and monitoring on-site **ground water. The** evaluation should be periodically reassessed.
2) Q: How does the voluntary communication protocol under Action 2 relate to reporting requirements in effect before 2006?	2) Q: How does the voluntary communication protocol under Action 2 relate to reporting requirements in effect before 2006?
A: Every licensee already has certain reporting requirements specified in their license, i.e., in the RETS, REMP, or ODCM/ODAM, although these criteria may vary somewhat from site to site. 10 CFR Parts 20 and 50 also contain relevant reporting requirements that apply to all licensees. In addition, some licensees may have reporting requirements or commitments that involve state or local agencies and officials. The voluntary communication protocol is intended to supplement the existing body of reporting requirements at each site in order to assure that all sites, at a minimum, consistently inform appropriate state and local officials, and the NRC as appropriate, regarding conditions and occurrences related to inadvertent radiological releases to the groundwater at the site.	A: Every licensee already has certain reporting requirements specified in their license, i.e., in the RETS, REMP, or ODCM/ODAM, although these criteria may vary somewhat from site to site. 10 CFR Parts 20 and 50 also contain relevant reporting requirements that apply to all licensees. In addition, some licensees may have reporting requirements or commitments that involve **State** or local agencies and officials. The voluntary communication protocol is intended to supplement the existing body of reporting requirements at each site in order to assure that all sites, at a minimum, consistently inform appropriate **State** and local officials, and the NRC as appropriate, regarding conditions and occurrences related to inadvertent radiological releases to the **ground water** at the site.
3) Q: What is meant by "substantial on-site construction" or "substantial disturbance of site property" in Acceptance Criterion d to Objective 1.1?	3) What is meant by “substantial on-site construction” or “substantial disturbance of site property” in **acceptance criterion** d to Objective 1.1?
A: "Substantial" refers to the likelihood that the construction or disturbance has affected the	A: “Substantial” refers to the likelihood that the construction or disturbance has affected the

subsurface flow of groundwater e.g., major paving projects, constructions of an ISFSI, or new buildings, etc. Licensees at new plants should, for example, review their pre-licensing characterization of hydrology and geology for changes that result from construction of buildings and structures or compaction of soil.	subsurface flow of **ground water. Licensees** at new plants should, for example, review their pre-licensing characterization of hydrology and geology for changes that result from construction of buildings and structures or compaction of soil.
4) Q: What is meant by "periodic review" in Objectives I.I to 1.3?	
A: "Periodic" is intended to give each licensee the ability to base the frequency of the reviews on site specific factors that are supported by the conceptual site model, operating status i.e., new plant, operating facility or decommissioning- and SSC risk ranking. The time period between reviews should be based on site specific conditions and not exceed 5 years.	
5) Q: How does the "periodic review" apply to plants that are in the process of or have completed decommissioning activities?	
A: It is recommended that consistent with FAQ 4, each of the licensees shall evaluate and update the CSM, SSC priority index, and long term groundwater monitoring program to incorporate changes in site conditions and optimize the GWPP to ensure that Action 1 objectives are met in an efficient and cost effective manner.	
6) Q: What is meant by Conceptual Site Model or Site Conceptual Model, which are interchangeable?	
A: According to the Electric Power Research Institute (EPRI), "A Site Conceptual Model integrates available information regarding contaminants of concern, plant SSCs, historical and potentially on-going inadvertent releases, and site hydrogeology to form a unifying hypothesis explaining the observed ground	

contaminant distribution, source areas, transport pathways, contaminant fate and transport in the environment, and risk to receptors. 1"	
OR	
The America Society for Testing and Materials defines the site conceptual model or conceptual site model as a "written or pictorial representation of an environmental system and the biological, physical, and chemical processes that determine the transport of contaminants from sources through the environmental media to environmental receptors in the system.2,	
7) Q: Objective 1.6.a states, "Establish written procedures outlining the commitments made in regulatory documents such as the Post-Shutdown Decommissioning Activities Report (PSDAR) and License Termination Plan (LTP). Establish/change groundwater related procedures accordingly." When should these procedures be developed?	
A: Based upon operational experience, it is recommended that the revisions to the groundwater program, monitoring well network and procedures be in place shortly after shutdown. This could result in the development of the procedures beginning before shutdown-e.g., could start when the shutdown date is known or suspected.	

APPENDIX A
COMMUNICATION PROTOCOL FOR LEAK/SPILL AND GROUNDWATER SAMPLE RESULTS



APPENDIX B
SELF ASSESSMENT CHECKLIST
OBJECTIVE 3.1

Plant or Utility Being Reviewed: Date of Review

Reviewers:

NEI 0707, Rev 1 March 2019		NEI 0707 (Final) August 2007	
Guideline Section	Objective/Acceptance Criteria	Guideline Section	Objective/Acceptance Criteria
1.1	Ensure that the site characterization of geology and hydrology provides an understanding of predominant groundwater gradients based upon current site conditions. This characterization is the basis for the CSM.	1.1	Ensure that the site characterization of geology and hydrology provides an understanding of predominant **ground water** gradients based upon current site conditions.
1.1.a	Perform hydrogeologic and geologic studies to determine predominant groundwater flow characteristics and gradients.	1.1.a	Perform hydrogeologic and geologic studies to determine predominant **ground water** flow characteristics and gradients.
1.1.b	As appropriate, review existing hydrogeologic and geologic studies, historical environmental studies, and permit or license related reports.	1.1.b	As appropriate, review existing hydrogeologic and geologic studies, historical environmental studies, and permit or license related reports
1.1.c	Identify potential pathways for groundwater migration from on-site locations to off-site locations through groundwater.	1.1.c	Identify potential pathways for **ground water** migration from on-site locations to off-site locations through **ground water**.
1.1.d	Establish the frequency for periodic reviews of site hydrogeologic studies. As a minimum, reviews should be performed whenever any of the following occurs: ● Substantial on-site construction	1.1.d	Establish the frequency for periodic reviews of site hydrogeologic studies.*

	● Substantial disturbance of site property ● Substantial changes in on-site or nearby off-site use of water Substantial changes in on-site or nearby off-site pumping rates of groundwater		
1.1.e	As appropriate, update the CSM and the site's Final Safety Analysis Report with changes to the hydrology and/or geology.	1.1.e	As appropriate, update the Final Safety Analysis Report with changes to the hydrology and/or geology.
1.2	Identify site risk based on plant design and work practices.*	1.2	Identify site risk based on plant design and work practices*
1.2.1	Evaluate all systems, structures, or components (SSCs) that contain or could contain licensed material and for which there is a credible mechanism for the licensed material to reach groundwater.	**1.2.a**	**Identify each SSC and work practice that involves or could reasonably be expected to involve** licensed material and for which there is a credible mechanism for the licensed material to reach **ground water**.* **(類似 2019 1.2.2.b 的內容)**
1.2.2 1.2.2.a	Evaluate work practices that involve licensed material and for which there is a credible mechanism for the licensed material to reach groundwater. Identify each SSC that involves or could reasonably be expected to involve licensed material and for which there is a credible mechanism for the licensed material to reach groundwater. Examples of SSCs of interest include: refueling water storage tanks, spent fuel pools, spent fuel pool leak detection systems, outdoor tanks, outdoor storage of contaminated equipment, buried piping, retention ponds or basins or reservoirs, lines carrying steam.	1.2.b 1.2.c	Identify existing leak detection methods for each SSC **and work practice that** involves or could involve licensed material and for which there is a credible potential for inadvertent releases to **ground water.*** **(類似 2019 1.2.2.b 的內容)** **Identify potential enhancements to leak detection systems or programs.***

1.2.2.b	Identify existing leak detection methods for each SSC that involves or could involve licensed material and for which there is a credible potential for inadvertent releases to groundwater. These may include groundwater monitoring, operator rounds, engineering walk-downs or inspections, leak-detection systems, or periodic integrity testing. **(類似 2007 1.2.b 的內容)**	1.2.d	**Identify potential enhancements to prevent spills or leaks from reaching ground water.***
1.2.2.c	Identify work practices that include actions taken by individuals during maintenance, operational, or support activities, which could result in or prevent a spill or leak of a source material that has a credible mechanism for release to groundwater.		
1.2.2.d	Evaluate for potential enhancements to leak detection systems or programs. These may include additional or increased frequency of rounds or walk-downs or inspections, or integrity testing.	1.2.e	**Identify the mechanism or site process for tracking corrective actions. (2019 1.2.2.f 內容一致)**
1.2.2.e	Evaluate potential enhancements to prevent spills or leaks from reaching groundwater. These may include resealing or paving surfaces, installing spill containment measures, performing preventative maintenance or surveillance activities to minimize the potential for inadvertent releases of licensed materials due to equipment failure.	1.2.f	**Establish long term programs to perform preventative maintenance or surveillance activities to minimize the potential for inadvertent releases of licensed materials due to equipment failure.**
1.2.2.f	Identify the mechanism or site process for tracking corrective actions. **(2007 1.2.e 內容一致)**		
1.2.2.g	Establish the frequency for periodic reviews of SSCs and	1.2.g	**Establish the frequency for periodic reviews of SSCs and**

	work practices.		**work practices.**
1.3	Establish an on-site groundwater monitoring program to ensure timely detection of inadvertent radiological releases to groundwater.	1.3	Establish an on-site **ground water** monitoring program to ensure timely detection of inadvertent radiological releases to **ground water**.
1.3.a	Using the hydrology and geology studies developed under Objective 1.1, consider placement of groundwater monitoring wells downgradient from the plant but within the boundary defined by the site license. Wells should be placed to ensure groundwater migration pathways are monitored.	1.3.a	Using the hydrology and geology studies developed under Objective 1.1, consider placement of **ground water** monitoring wells downgradient from the plant but within the boundary defined by the site license.
1.3.b	Groundwater monitoring wells should be placed as close as practical to SSCs that have the highest potential for inadvertent releases that could reach groundwater or SSCs where other means of leak detection capability is limited.	1.3.b	**Consider, as appropriate, placing sentinel wells** closer to SSCs that have the highest potential for inadvertent releases that could reach **ground water** or SSCs where leak detection capability is limited.
1.3.c	Establish sampling and analysis protocols, including analytical sensitivity requirements and quality assurance/quality control processes for groundwater and soil, where applicable. Consider the potential for detectible levels of licensed material resulting from planned releases of liquids and/or airborne materials.	1.3.c	Establish sampling and analysis protocols, including analytical sensitivity requirements, **for ground water and soil.***
1.3.d	Establish a formal, written program for long-term groundwater monitoring. For those groundwater monitoring locations that are also included in the REMP, revise the site's ODCM/ODAM and ensure the distinction between the programs is clear.	1.3.d	Establish a formal, written program for **longterm ground water** monitoring.*
1.3.e	Periodically review existing station or contract lab(s) analytical capabilities. An important consideration is the	1.3.e	Periodically review existing station or contract lab(s) analytical capabilities.*

	analytical protocols and times needed to obtain results.		
1.3.f	Establish a long-term program for preventative maintenance of groundwater wells.	1.3.f	Establish a **longterm** program for preventative maintenance of **ground water** wells.
1.3.g	Establish the frequency for periodic review of the groundwater monitoring program.	1.3.g	Establish the frequency for periodic review of the **ground water** monitoring program.
1.4	Establish a remediation protocol to prevent migration of licensed material off-site and to minimize decommissioning impacts.	1.4	Establish a remediation protocol to prevent migration of licensed material off-site and to minimize decommissioning impacts
1.4.a	Establish written procedures outlining the decision making process for remediation of leaks and spills or other instances of inadvertent releases. This process is site specific and shall consider migration pathways.	1.4.a	Establish written procedures outlining the decision making process for remediation of leaks and spills or other instances of inadvertent releases. This process is site specific and shall consider migration pathways
		1.4.b	**Evaluate the potential for detectible levels of licensed material resulting from planned releases of liquids and/or airborne materials.**
1.4.b	Evaluate and document, as appropriate, decommissioning impacts resulting from remediation activities or the absence thereof.	1.4.c	Evaluate and document, as appropriate, decommissioning impacts resulting from remediation activities or the absence thereof.
1.5	Ensure that records of leaks, spills, and remediation efforts are retained and retrievable to meet the requirements of 10 CFR 50.75(g).	1.5	Ensure that records of leaks, spills, remediation efforts are retained and retrievable to meet the requirements of 10 CFR 50.75(g).
1.5.a	Establish a record keeping program to meet the requirements of 10 CFR 50.75(9). Note that these records are used to determine an area's classification for purposes of performing surveys-see NRC Regulatory Issue Summary 2002-02, "Lessons Learned Related to Recently Submitted	1.5.a	Establish a record keeping program to meet the requirements of 10 CFR 50.75(**g**)

	Decommissioning Plans and License Termination Plans.»		
1.6	Decommissioning/SAFSTOR Impacts		
1.6.a	Establish written procedures outlining the commitments made in the Post-Shutdown Decommissioning Activities Report (PSDAR). Establish/change groundwater related procedures accordingly		
1.6.b	As site conditions/processes are planned and/or changed: 1. Evaluate the impact of how actions could impact groundwater protection. 2. Assess the system, structure and components (SSC) and Work Practice Risk Assessments to reflect current conditions. 3. Assess the CSM to reflect current conditions. 4. Assess the groundwater monitoring program to reflect changes in the SSC and Work Practice Risk Assessments and any changes in the CSM-e.g., sampling frequency and number of sample wells.		
1.6.c	Verify that appropriate elements of groundwater protection are evaluated and maintained until radiological I remediation of the site is complete, including the monitoring and remediation of any identified groundwater contamination above drinking water standards.		
2.1	During the initial development of the GPI, each licensee conducted periodic briefings of their site-specific GPI	2.1	**Each licensee should conduct initial and** periodic briefings of their **site specific** GPI program with the designated **State/Local**

	program with the designated state/local officials. This initial briefing will be performed by sites that begin operation after 01/01/2020.		officials
2.1.a	The licensee should discuss i) The background or industry events that led to the GPI; ii) If there is additional information that the state/local officials need to better understand the issue or place it in perspective for their constituents; iii) "How" the state/local officials will use or distribute the information.	2.1.a	The licensee should discuss i) The background or industry events that led to the GPI ii) If there is additional information that the **State/Local** officials need to better understand the issue or place it in perspective for their constituents iii) “How” the **State/Local** officials will use or distribute the information
2.1.b	Licensees should consider including additional information or updates on groundwater protection in periodic discussions with state/local officials.	2.1.b	Licensees should consider including additional information or updates on **ground water** protection in periodic discussions with **State/Local** officials
2.1.c	For licensees that are in states where multiple nuclear power plants are located and multiple owner companies, it is highly recommended that the licensees coordinate their efforts and communicate with each other. The initial briefing for the state/local officials and the contents of a voluntary communication should be consistent.	2.1.c	For licensees that are in **States** where multiple nuclear power plants are located and multiple owner companies, it is highly recommended that the licensees coordinate their efforts and communicate with each other. The initial briefing for the **State/local** officials and the contents of a voluntary communication should be consistent.
2.2	Make informal communication as soon as practicable to appropriate state/local officials, with follow-up notifications to the NRC, as appropriate, regarding significant "on-site leaks/spills into groundwater and on-site or off-site water sample results exceeding the criteria in the REMP as described in the OCDM/ODAM. *	2.2	Make informal communication as soon as practicable to appropriate **State/Local** officials, with follow-up notifications to the NRC, as appropriate, regarding significant "on-site leaks/spills into **ground water** and on-site or off-site water sample results exceeding the criteria in the REMP as described in the OCDM/ODAM.*
2.2.a	Communication with the designated state/local officials shall be made before the end of the next business day if an inadvertent leak or spill to the environment has or can	2.2.a	Communication with the designated **State/Local** officials shall be made before the end of the next business day if an inadvertent leak or spill to the environment has or can potentially get into

	potentially get into groundwater and exceeds any of the following criteria: i) If a spill or leak exceeding 100 gallons from a source containing licensed material; ii) If the volume of a spill or leak cannot be quantified, but is likely to exceed 100 gallons from a source containing licensed material; iii) Any leak or spill, regardless of volume or activity, deemed by the licensee to warrant voluntary communication. AND The spill or leak, regardless of volume or activity, occurs which cannot be completely recaptured or remediated per Objective 1.4 within 24 hours of discovery of the event.		groundwater and exceeds any of the following criteria: i) If a spill or leak exceeding 100 gallons from a source containing licensed material; ii) If the volume of a spill or leak cannot be quantified, but is likely to exceed 100 gallons**,** from a source containing licensed material**,** or iii) Any leak of spill, regardless of volume or activity, deemed by the licensee to warrant voluntary communication. *
2.2.b	Communication with the designated state/local officials shall be made before the end of the next business day for a water sample result: (i) Of off-site groundwater or surface water that exceeds any of the REMP reporting criteria for water as described in the ODCM/ODAM; (ii) Of on-site surface water that is hydrologically connected to groundwater or groundwater that is or could be used as a source of drinking water-either onsite or downgradient from the site-that exceeds any of the REMP reporting criteria for water as described in the ODCM/ODAM.	2.2.b	Communication with the designated **State/Local** officials shall be made before the end of the next business day for a water sample result (i) **of** off-site **ground water** or surface water that exceeds any of the REMP reporting criteria for water as described in the ODCM/ODAM**, or** (ii) **of** on-site surface water**,** that is hydrologically connected to **ground water,** or **ground water** that is or could be used as a source of drinking water**, exceed** any of the REMP reporting criteria for water as described in the ODCM/**ODA**
2.2.c	When communicating to the state/local officials, be clear and precise in quantifying the actual release information as it applies to the appropriate regulatory criteria.	2.2.c	When communicating to the **State/Local** officials, be clear and precise in quantifying the actual release information as it applies to the appropriate regulatory criteria. *
2.2.d	Voluntary communication to state and/or local officials may also require NRC notification under 10 CFR 50. 72(b)(2)(xi). Licensees should perform these notifications	2.2.d	Voluntary communication to **State** and/or **Local** officials may also require NRC notification under 10 CFR 50.72(b)(2)(xi). Licensees should perform these notifications consistent with their

	consistent with their existing program.		existing program
2.2.e	Contact NEI by email to GRPGroundwaterIssues(@,nei.orq as part of a voluntary communication event.	2.2.e	Contact NEI by email to **GW_Notice@nei.org** as part of a voluntary communication event
2.3	Submit a written 30-day report to the NRC for any water sample result for on-site groundwater that is or may be used as a source of drinking water that exceeds any of the criteria in the licensee's existing REMP/ODCM for 30-day reporting of off-site water sample results. Copies of the written 30-day reports for both on-site and off-site water samples shall also be provided to the appropriate state/local officials.	2.3	Submit a written 30-day report to the NRC for any water sample result for on-site **ground water** that is or may be used as a source of drinking water that exceeds any of the criteria in the licensee's existing REMP/ODCM for 30-day reporting of off-site water sample results. Copies of the written 30-day reports for both on-site and off-site water samples shall also be provided to the appropriate **State/Local** officials.
2.3.a	All groundwater samples taken for the Industry Initiative shall be analyzed and compared to the standards and limits contained in the station's REMP as described in the ODCM/ODAM.	2.3.a	All **ground water** samples taken for the Industry Initiative shall be analyzed and compared to the standards and limits contained in the station's REMP as described in the ODCM/ODAM*
2.3.b	The 30-day special report should include the items listed in Acceptance Criteria 2.3.b	2.3.b	The 30-day special report should include the items listed*
2.3.c	All written 30-day NRC reports generated under item 2.3.a are to be concurrently forwarded to the designated state/local officials.	2.3.c	All written 30-day NRC reports generated under item 2.3.a are to be concurrently forwarded to the designated **State/Local** officials
2.4	Document on-site groundwater sample results of licensed material and a description of any significant on-site leaks/spills into groundwater for each calendar year in the Annual Radiological Environmental Operating Report (AREOR) for REMP or the Annual Radioactive Effluent Release Report (ARERR) for the RETS as contained in the appropriate Site reporting procedure, beginning with the	2.4	Document **all** on-site **ground water** sample results and a description of any significant on-site leaks/spills into **ground water** for each calendar year in the Annual Radiological Environmental Operating Report (AREOR) for REMP or the Annual Radioactive Effluent Release Report (ARERR) for the RETS as contained in the appropriate Site reporting procedure, beginning with the report for calendar year 2006.

	report for calendar year 2006.		
2.4.a	For plants constructed after 2008 appropriate procedures that require inclusion of significant on-site leaks/spills into groundwater and all on-site groundwater results shall be developed and implemented prior to initial receipt of nuclear fuel-see NEI 08-08, "Generic FSAR Template Guidance for Life-Cycle Minimization of Contamination," December 2008.	2.4.a	**Complete appropriate changes to the ODCM/ODAM or to the appropriate procedures to support the 2007 report. For new plants,** appropriate procedures that require inclusion of significant on-site leaks/spills into ground water and all on-site ground water results shall be developed and implemented prior to initial receipt of nuclear fuel*
2.4.b	Reporting of on-site groundwater sample results shall be as follows: i. Groundwater sample results that are taken in support of the GPI but are not part of the REMP program-e.g., samples obtained during the investigatory phase of the Action Plan circa year 2006-are reported in the ARERR required by 10 CFR 50.36a (a)(2). ii. Once the long-term monitoring sample points have been established per Objective 1.3, Acceptance Criterion d, the results are reported in the AREOR for those sample points that are included in the REMP as described in the ODCM/ODAM. The sample results for those long-term monitoring sample points that are not included in REMP are reported in the ARERR.	2.4.b	Report on-site **ground water** sample results as follows i) **Ground water** sample results that are taken in support of the GPI but not part of REMP in the ARERR ii) **For longterm** sample points that are included in the REMP as described in the ODCM/ODAM, **the results are reported in the AREOR; those longterm sample points that are not included in REMP, the results** are reported in the ARERR *
2.4.c	In addition to 2.4.b, voluntary communications, if any are made, shall be included in an annual report as follows: i. A description of all spills or leaks that were communicated per Objective 2.2, Acceptance Criterion	2.4.c	In addition to **2.1.b**, voluntary communications shall be included as follows: **the following are to be included in either the ARERR and/or the AREOR** i) A description of all spills or leaks that were communicated per Objective 2.2 **acceptance criterion** a shall be included in the

	a shall be included in the ARERR and/or AREOR. ii. All on-site or off-site **groundwater** sample results that exceeded the REMP reporting thresholds as described in the ODCM/ODAM that were communicated per Objective 2.2, Acceptance Criterion b shall be included in either the ARERR and/or in the AREOR.		ARERR **ii)** All on-site or off-site **ground water** sample results that exceeded the REMP reporting thresholds as described in the ODCM/ODAM that were communicated per Objective 2.2 **acceptance criterion** b shall be included in either the ARERR and/or the AREOR
3.1	Perform program oversight to ensure effective implementation of the GPI program.	3.1	Perform **a self-assessment** of the GPI program **(references this check sheet)**
3.1.a	An independent, knowledgeable individual(s) shall perform an initial self-assessment within one year after initial criticality—this step only applies to units that begin operation after 01/01/2020.	3.1.a	An independent, knowledgeable individual(s) shall perform **the** initial **self assessment** within one year **of implementation.***
3.1.b	A programmatic assessment of the GPI program shall be performed periodically but at least once every 5 years after initial self-assessment. Programmatic assessments should be maintained according to the records management program and be available for the life of the plant	3.1.b	**Perform periodic self-assessments of the GPI program** at least once every five years after initial self-assessment.
3.1.c	The self-assessment, at a minimum, shall include evaluating implementation of all of the objectives identified in this document and be documented consistent with applicable station procedures and programs.	3.1.c	The self-assessment, at a minimum, shall **evaluate** implementation of all objectives identified in this document.
		3.1.d	**The self-assessment shall be documented consistent with applicable procedures.**
		3.2	**Conduct a review of the GPI program, including at a**

			minimum the licensee's self assessments, under the auspices of NEI.
		3.2.a	**An independent, knowledgeable individual(s) shall perform the initial review within one year of the initial self-assessment performed per objective 3.1.a above**
		3.2.b	**Periodic review of the GPI program should be performed every five years, subsequent to the license's periodic self-assessment performed per Objective 3.1.b above.**