**UNITED STATES OF AMERICA**
**NUCLEAR REGULATORY COMMISSION**

**BEFORE THE ATOMIC SAFETY AND LICENSING BOARD**

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| In the Matter of: | ) | |
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| FLORIDA POWER & LIGHT COMPANY | ) | Docket No. 50-250-SLR-2 |
| | ) | Docket No. 50-251-SLR-2 |
| (Turkey Point Nuclear Generating Units 3 and 4) | ) | |
| | ) | May 8, 2024 |
| (Subsequent License Renewal Application) | ) | |

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**MIAMI WATERKEEPER'S MOTION TO ADMIT AMENDED AND NEW CONTENTIONS IN RESPONSE TO NRC STAFF'S FINAL SITE-SPECIFIC ENVIRONMENTAL IMPACT STATEMENT**

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## I. INTRODUCTION

Pursuant to 10 C.F.R. § 2.309(c) and the Atomic Safety and Licensing Board's ("Board") Scheduling Order,[1] Miami Waterkeeper ("Petitioner") hereby moves for the admission of amended and new contentions regarding the Final Site-Specific Environmental Impact Statement[2] ("2024 FSEIS") for Florida Power and Light Company's ("FPL") proposed subsequent license renewal issued by the Nuclear Regulatory Commission ("NRC") Staff in March 2019.

Petitioner respectfully submits a revised version of the previously admitted contention (Contention 1), broken into three sub-issues highlighting three distinct but related ways in which

[1] Atomic Safety and Licensing Board Panel Initial Scheduling Order, ADAMS Accession No. ML24086A446 (March 26, 2024) (hereinafter "Scheduling Order.").

[2] Final Site-Specific Environmental Impact Statement for License Renewal of Nuclear Power Plants Regarding Subsequent License Renewal for Turkey Point Nuclear Generating Units Nos. 3 and 4, ADAMS Accession No. ML24087A061 (March 2024) (hereinafter "2024 FSEIS").

the groundwater analysis in the 2024 FSEIS is inadequate. Petitioner also respectfully requests admission of two new contentions (Contentions 2 and 3).

The amended Contention 1 asserts that the 2024 FSEIS fails to adequately address a previously identified omission contained in Draft Site-Specific Environmental Impact Statement ("2023 DSEIS"). New Contention 2 asserts that the 2024 FSEIS fails to adequately analyze impacts to the Miami cave crayfish. Both of these contentions are based upon the 2024 FSEIS, which was not previously available and is materially different to the 2023 DSEIS. Petitioner also moves to admit new Contention 3 regarding the reasonably foreseeable environmental effects that are caused by climate change, based on information published in an April 2, 2024 U.S. Government Accountability Office report that was previously unavailable and remains unaddressed in the 2024 FSEIS.[3] All contentions are timely in accordance with prior rulings of this Board. In addition, Petitioner has previously established standing in this proceeding and need not do so again.[4]

## II. BACKGROUND

### A. Procedural Background

On November 27, 2023 and pursuant to 10 C.F.R. § 2.309 and the NRC's Federal Register notice published at 88 Fed. Reg. 62,110 (Sept. 8, 2023), Petitioner submitted a Request for Hearing and Petition to Intervene in the above-captioned matter.[5] Petitioner articulated five contentions in the Petition addressing various deficiencies in NRC Staff's 2023 DSEIS,[6]

[3] 10 C.F.R. § 2.309(c)(1).

[4] 10 C.F.R. § 2.309(c)(2)(4).

[5] Miami Waterkeeper Request for Hearing and Petition to Intervene, ADAMS Accession Number ML23331A971 (Nov. 27, 2023).

[6] NUREG-1437, Site-Specific Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 5a, Second Renewal Regarding Subsequent License Renewal for Turkey Point Nuclear

published as part of the subsequent renewal license application process for Turkey Point Nuclear Generating Station, Units 3 and 4, in Miami-Dade County, Florida.

Following full briefing and an oral argument on the admissibility of each contention, the Board on March 7, 2024 issued Memorandum and Order LBP-24-3, granting Petitioner's hearing request and admitting a reformulated version of one of the five contentions.[7] In that Order, the Board also found that Petitioner had established standing. Petitioner relies on the same facts for standing, with no material changes, and incorporates by reference the previous standing declarations of Dr. Rachel Silverstein and Dr. Philip Stoddard. On March 22, 2024, Petitioner, FPL, and NRC Staff filed a joint motion regarding the hearing schedule, mandatory disclosures, and hearing file obligations in this proceeding.[8] The Board issued an Initial Scheduling Order that provided Petitioner the opportunity to file new and amended contentions within 40 days of publication of the 2024 FSEIS.[9]

On March 29, 2024, NRC Staff published the 2024 FSEIS.[10] Based on the 2024 FSEIS, on April 4, NRC Staff filed an unopposed motion to dismiss reformulated Contention 1 as moot, which Petitioner joined on the condition that the proceeding remain open and Petitioner would be

Generating Units Nos. 3 And 4, Draft, ADAMS Accession No. ML23242A216 (Aug. 2023) (hereinafter "2023 DSEIS").

[7] Atomic Safety and Licensing Board Panel Memorandum and Order (Granting Request for Hearing), LBP-24-03, ADAMS Accession No. ML24067A280 (Mar. 7, 2024) (hereinafter "March 7, 2024 Board Order").

[8] Joint Motion Regarding Hearing Schedule, Mandatory Disclosures, and Hearing File Obligations, ADAMS Accession No. ML24082A084 (Mar. 22, 2024).

[9] Atomic Safety and Licensing Board Panel Initial Scheduling Order, ADAMS Accession No. ML24086A446 (Mar. 26, 2024).

[10] Final Site-Specific Environmental Impact Statement for License Renewal of Nuclear Power Plants Regarding Subsequent License Renewal for Turkey Point Nuclear Generating Units Nos. 3 and 4, ADAMS Accession No. ML24087A061 (Mar. 2024) (hereinafter "2024 FSEIS").

provided an opportunity to file new or amended contentions by the 40 day post-FSEIS deadline—that is, by May 8, 2024.[11]

Petitioner today timely files amended and new contentions based on the 2024 FSEIS.

**B. Legal Standards**

A license renewal application review typically implicates issues that fall into one of two broad areas: safety/aging management issues, and public health/environmental impacts. Petitioner's contentions are focused on environmental and public health impacts. The scope of this current NRC proceeding with respect to environmental issues is established by 10 C.F.R. Part 51, which requires the NRC Staff to weigh all environmental effects of the proposed action in this proceeding.[12]

A petitioner must file a motion to amend the admitted contention and/or to admit a new contention.[13] For example, a contention challenging an omission in the environmental report may not migrate to challenge the adequacy of new information or analysis provided in the DSEIS; the contention would need to be amended.[14] New and amended contentions are admissible as long as the intervenor demonstrates good cause by showing that the contention is supported by new information that (1) was not previously available; (2) is materially different from information that was previously available, and (3) is timely filed.[15] The Board has

[11] Joint Unopposed Motion to Dismiss Reformulated Contention 1 as Moot and Position of the NRC Staff and Miami Waterkeeper Regarding Opportunity to File New or Amended Contentions, ADAMS Accession No. ML24095A314 (Apr. 4, 2024).

[12] 10 C.F.R. § 51.71 n.3; 10 C.F.R. § 51.94. *See also* 10 C.F.R. §§ 51.21, 51.70-72, 51.92, 51.94, 51.104.

[13] *Progress Energy Fla., Inc*. (Levy County Nuclear Power Plant, Units 1 and 2), LBP-11-01, 73 NRC 19, 26 (2011).

[14] *Private Fuel Storage, LLC*, LBP-01-23, 54 NRC at 172 n.3.

[15] 10 C.F.R. § 2.309(f)(2), 2.309(c)(1).

previously ruled that while "intervenors must respond to new information when it first becomes available, they need not do so until the information is actually used by the NRC Staff to form its conclusions on impacts in the DSEIS."[16]

In addition, an amended or new contention must also satisfy the general contention admissibility requirements of 10 C.F.R. § 2.309(f)(1), including providing: (i) "a specific statement of the issue of law or fact to be raised or controverted," (ii) "a brief explanation of the basis for the contention," (iii) a demonstration "that the issue raised in the contention is within the scope of the proceeding," (iv) a demonstration "that the issue raised in the contention is material to the findings the NRC must make,"[17] (v) "a concise statement of the alleged facts or expert opinions which support the [intervenor's] position on the issue," and (vi) "sufficient information to show that a genuine dispute exists with the applicant/licensee on a material issue of law or fact."

## III. AMENDED CONTENTION

In its March 26, 2024 Initial Scheduling Order, the Board ruled that new or amended contentions based on the 2024 FSEIS will be considered timely if filed within 40 days of the publication of the 2024 FSEIS[18]—that is, on or before May 8, 2024. Here, Petitioner timely amends its reformulated admitted contention (Contention 1) and files two new contentions.

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[16] *Powertech USA, Inc*. (Dewey-Burdock in Situ Uranium Recovery Facility), LBP-13-09, 78 NRC 37, 93 (2013).

[17] A "material" issue is one that would make a difference in the outcome of the proceeding. Rules for Practice for Domestic Licensing Proceedings—Procedural Changes in the Hearing Process, 54 Fed. Reg. 33,168, 33,172 (Aug. 11, 1989). *See also Entergy Nuclear Vermont Yankee, LLC & Entergy Nuclear Operations, Inc.* (Vermont Yankee Nuclear Power Station), LBP-4-28, 60 NRC 548, 557 (Nov. 22, 2004).

[18] Scheduling Order at 2-3.

In its March 7, 2024 Order, the Board admitted a reformulated version of Petitioner's Contention 1:

> The 2023 Draft SEIS fails to take a hard look at impacts to groundwater quality because it does not include an adequate explanation for the Staff's conclusion that the uncertainty in retracting the hypersaline groundwater plume could result in moderate impacts.[19]

Petitioner moves to amend this Contention based on new and materially different information in the 2024 FSEIS. As shown below, this contention challenges the adequacy of the new information provided regarding the assessment of the impact of operation during the renewal period on groundwater resources.

**1. Petitioner satisfies the "good cause" standard for its amended contentions.**

The Board should amend and admit Contention 1 because good cause exists to amend the contention and Contention 1 meets the admissibility requirements in 10 C.F.R. § 2.309(f).

First, good cause—defined as timely and based on previously unavailable and materially different information[20]—exists to amend Contention 1. Per the Board's Scheduling Order, this motion to amend is timely.[21] The 2024 FSEIS also includes new information that was previously unavailable in the 2023 DSEIS: whereas the 2023 DSEIS omitted adequate explanation of the predictions regarding the hypersaline plume, the 2024 FSEIS now includes a shallow, inadequate evaluation of this issue.[22] It is this inadequate evaluation that the amended Contention 1 now challenges. Because the basic form of a contention cannot change through migration—i.e. "challeng[ing] the soundness of the information provided [rather than] claim[ing] that necessary information has been omitted"—Petitioner respectfully moves to amend Contention 1 from

[19] March 7, 2024 Board Order at 22.

[20] 10 C.F.R. § 2.309(f)(2), 2.309(c)(1).

[21] Scheduling Order at 2-3.

[22] *See, e.g.*, 2024 FSEIS at 2-38–2-40.

claiming an omission in the 2023 DSEIS to challenging the adequacy of analysis newly included in the 2024 FSEIS.[23] Thus, there is good cause to amend Contention 1.

**2. Contention 1 meets the requirements in 10 C.F.R. § 2.309(f)(1) regarding contention admissibility.**

***AMENDED CONTENTION 1:***

***1-A: THE 2024 FSEIS FAILS TO ADEQUATELY ANALYZE GROUNDWATER CONDITIONS FOR THE "NO ACTION" ALTERNATIVE, WHICH SHOULD BE THE CONDITIONS PRESENT WHEN THE PLANT IS NOT OPERATIONAL.***

***1-B: THE 2024 FSEIS EMPLOYS THE WRONG STANDARD TO DETERMINE THE IMPACT OF THE CCS ON POTABLE WATER.***

***1-C: THE 2024 FSEIS'S ASSESSMENT OF THE IMPACT OF THE PROPOSED ACTION TO GROUNDWATER QUALITY IS INADEQUATE BECAUSE IT UNDERESTIMATES THE IMPACTS ON DRINKING WATER RESOURCES.***

Petitioner respectfully submits a revised version of the previously admitted contention (Contention 1), broken into three sub-issues highlighting three distinct but related ways in which the groundwater analysis in the 2024 FSEIS is inadequate. Petitioner addresses the admissibility criteria for each sub-issue in turn, beginning with Contention 1-A.

***CONTENTION 1-A: THE 2024 FSEIS FAILS TO ADEQUATELY ANALYZE GROUNDWATER CONDITIONS FOR THE "NO ACTION" ALTERNATIVE, WHICH SHOULD BE THE CONDITIONS PRESENT WHEN THE PLANT IS NOT OPERATIONAL.***

1. *Statement of the issue of law or fact to be raised or controverted (10 C.F.R. § 2.309(f)(1)(i))*

As explained below, the NRC Staff has a legal obligation to fully analyze and present to the public and the Board's consideration, the environmental difference between extending the license and continuing the use of the cooling canal system ("CCS") for Units 3 and 4, and declining the application. NRC Staff has failed to do so here, instead it made only a cursory

[23] *Private Fuel Storage, LLC*, LBP-01-23, 54 NRC at 172 n.3.

effort to evaluate the baseline conditions for the no action alternative. This means that the full impacts to groundwater from the proposed action are obscured.

*2. Brief explanation of the basis for the contention (10 C.F.R. § 2.309(f)(1)(ii))*

NEPA requires an agency to "describe the environment of the area(s) to be affected or created by the alternatives under consideration."[24] Among other things, the agency must compare the environmental effects of its proposed action and other reasonable alternatives against a baseline of "no action." 40 C.F.R. § 1502.14(c) specifically requires that an agency "shall" include in the "[a]lternatives" section of an EIS "the no action alternative."[25] The D.C. Circuit will reverse an agency action that "fails to adequately justify or explain its consideration of the environmental baseline."[26]

Establishing appropriate baseline conditions "is critical to any NEPA analysis."[27] EPA requires establishing the baseline conditions of the affected environment as a "practical requirement" of the environmental analysis process.[28] NEPA requires the NRC to identify and explain "the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the

[24] 40 C.F.R § 1502.15

[25] *See Sierra Club v. Mainella*, 459 F. Supp. 2d 76, 83-84; (D.D.C. 2012); *In re Polar Bear Endangered Species Act Listing and 4(d)*, 818 F. Supp. 2d 214, 221 (D.D.C. 2011).

[26] *Mayo v. Jarvis*, 177 F. Supp. 3d 91, 141 (D.D.C. 2016).

[27] *Great Basin Res. Watch*, 844 F.3d 1095, 1101 (9th Cir. 2016). *See also Or. Nat. Desert Ass'n v. Rose*, 921 F.3d 1185, 1190 (9th Cir. 2019) (travel plan decision held unlawful where BLM failed to establish "the physical condition of the routes" and failed to "use any method or estimate—aside from making generic statements about roads in the Steens Mountain area—to establish baseline conditions").

[28] *Oregon Nat. Desert Ass'n v. Jewell*, 840 F.3d 562, 568 (9th Cir. 2016).

decisionmaker and the public."[29] Courts "acknowledge the importance of obtaining baseline condition information before assessing the environmental impacts of a proposed project."[30]

Assessment of the no action alternative "serves as a benchmark"[31] against which an agency measures and evaluates impacts.[32] "Without establishing the baseline conditions which exist" before the project begins, "there is simply no way to determine what effect the proposed [action] will have on the environment and, consequently, no way to comply with NEPA."[33] "[W]ithout [baseline] data, an agency cannot carefully consider information about significant environmental impacts. Thus, the agency fail[s] to consider an important aspect of the problem, resulting in an arbitrary and capricious decision.[34]

In a relicensing case, the no action alternative is not extending the license, which would result in closure of the reactors and ceasing to use the CCS as a heat sink. There is ample precedent demonstrating that an agency's failure to adequately identify and analyze the correct baseline is arbitrary and capricious.

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[29] *City of Grapevine v. Dep't of Transp.*, 17 F.3d 1502, 1506 (D.C. Cir. 1994) (citing 40 C.F.R. § 1502.14).

[30] *Gifford Pinchot*, 2014 WL 3019165, at *28 (D. Or. 2014) (holding that an EA for mineral exploration project failed to obtain and analyze baseline water quality data in violation of NEPA).

[31] *Powder River Basin Resource Council v. United States*, 37 F. Supp. 3d 59, 69 (2014) (citing *Theodore Roosevelt Conservation P'ship v. Salazar,* 744 F. Supp. 2d 151, 160 (D.D.C. 2010), aff'd, 661 F.3d 66 (D.C. Cir. 2011)).

[32] *See Am. Rivers v. FERC*, 201 F.3d 1186, 1195 & n.15 (9th Cir. 2000).

[33] *Half Moon Bay Fisherman's Mktg. Ass'n v. Carlucci*, 857 F.2d 505, 510 (9th Cir. 1988).

[34] *Northern Plains Resource Council, Inc. v. Surface Transp. Bd.*, 668 F.3d 1067, 1085 (9th Cir. 2011). *See also Friends of Back Bay v. U.S. Army Corps of Eng'rs*, 681 F.3d 581, 588 (4th Cir. 2012) ("A material misapprehension of the baseline conditions existing in advance of an agency action can lay the groundwork for an arbitrary and capricious decision.").

An agency's assessment of baseline conditions "must be based on accurate information and defensible reasoning."[35] An "unsupported assumption" is insufficient.[36] To establish a proper baseline, an agency "may estimate" the likely conditions and use modeling or other information from the area or even other similar areas. But any such analysis "must be based on accurate information and defensible reasoning*."*[37]

The D.C. Circuit has specifically recognized that the NRC is required to analyze baseline data,[38] including hydrological data.[39] Courts have consistently found an agency's failure to conduct adequate baseline groundwater studies to result in deficient analysis.[40] In *Idaho Conservation League v. U.S. Forest Service*, a district court concluded that the USFS acted arbitrarily and capriciously by authorizing exploratory mineral drilling without fully analyzing the baseline groundwater and hydrology.[41] The court noted that such analysis should include "a baseline hydrogeologic study to examine the existing density and extent of bedrock fractures, the hydraulic conductivity of the local geologic formations, and [measures of] the local groundwater levels to estimate groundwater flow directions."[42] Similarly, in *Cascade Forest Conservancy v. Heppler*, a district court rejected U.S. Forest Service's extrapolative baseline groundwater analysis because the environmental assessment "fail[ed] to explain why

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[35] *Or. Nat. Desert Ass'n v. Jewell*, 840 F.3d 562, 570 (9th Cir. 2016).

[36] *Id.*

[37] *Great Basin Res. Watch*, 844 F.3d at 1101.

[38] *Natural Resources Defense Council v. U.S. Nuclear Regulatory Comm'n*, 879 F.3d 1202, 1214-15 (D.C. Cir. 2018).

[39] *Oglala Sioux Tribe v. U.S. Nuclear Regulatory Comm'n*, 45 F. 4th 291, 302-03 (D.C. Cir. 2022).

[40] *Gifford Pinchot Task Force v. Perez*, Case No. 03:13-cv-00810-HZ, 2014 WL 3019165, **25-33 (D. Or. July 3, 2014); *Idaho Conservation League v. U.S. Forest Serv.*, Case No. 1:11-cv-00341-EJL, 2012 WL 3758161 (D. Idaho Aug. 29, 2012).

[41] *Idaho Conservation League*, 2012 WL 3758161, at *17.

[42] *Id.* at *16.

the three historical drillholes sampled once in 2014 [were] sufficient to establish an adequate baseline for the entire Project Area," even though the sampled drillholes were in the relevant project area.[43]

An agency cannot rely on future mitigation and monitoring to satisfy its duty to fully analyze the baseline conditions of potentially affected resources. Mitigation alone is insufficient to meet the agency's NEPA obligations to determine the projected extent of the environmental harm to resources before a project is approved. Mitigation may help alleviate impacts, but does serve the requirement to evaluate and understand the impact before approval of the proposed agency action.[44] Instead, reliance on mitigation measures presupposes approval. It assumes that—regardless of what effects construction may have on resources—there are mitigation measures that might counteract the effect without first understanding the extent of the problem.[45]

Here, at a minimum, prior to approving the requested license extension, the NRC must first obtain this required baseline information for all potentially affected resources and subject the information and analysis to public review and comment. [46]

The NRC itself has acknowledged the necessity of conducting an adequate baseline

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[43] *Cascade Forest Conservancy v. Heppler*, Case No. 3:19-cv-00424-HZ, 2021 WL 641614, *20 (D. Or. Feb. 15, 2021); *see also N. Plains Res. Council*, 668 F.3d at 1086 ("The Board contends that it is entitled to rely on this outdated data because 'the physical environment of the area at issue here is substantially the same.' However, the Board does not cite any scientific studies or testimony in the record that supports this conclusion.").

[44] *Northern Plains*, 668 F.3d at 1083 (concluding that an agency's "plans to conduct surveys and studies as part of its post-approval mitigation measures," in the absence of baseline data, indicate failure to take the requisite "hard look" at environmental impacts).

[45] *Gifford Pinchot*, 2014 WL 3019165, at *28-29; *See also Northern Plains*, 668 F.3d at 1084–85; *Idaho Conservation League*, 2012 WL 3758161, at *17 (same).

[46] *Northern Plains*, 668 F.3d at 1083 (internal citations omitted) ("NEPA requires that the agency provide the data on which it bases its environmental analysis. Such analyses must occur before the proposed action is approved, not afterward.").

analysis against which to compare the impacts of the cooling canal system on saltwater intrusion before approval of an increase or extension of impacts at Turkey Point. In a previous Turkey Point proceeding, the Commission approved of the admission of a contention concerning:

> whether the Environmental Assessment contains a sufficient discussion of the current baseline environmental conditions and the reasonably foreseeable environmental impacts of increased temperature and salinity in the cooling canal system on saltwater intrusion arising from migration out of the system and the withdrawal of fresh water from surrounding aquifers to mitigate conditions within the system, and, with respect to this issue, the "reasons why the proposed action will not have a significant effect on the quality of the human environment." We find no error in the Board's holding that CASE has articulated a genuine dispute[.][47]

Other NRC orders have emphasized the importance of baseline groundwater data and analysis.[48]

NRC Staff has a legal obligation to fully analyze and present to the public and for the Board's consideration, the environmental difference between extending the license and continuing the use of the CCS and declining the application. As the Council on Environmental Quality has explained, the no action alternative would mean the proposed activity would not take place, and the resulting environmental effects from taking no action would be compared with the effects of permitting the proposed activity or an alternative activity to go forward.[49]

The baseline analysis here suffers from flaws quite similar to those found in *Am. Rivers & Ala. Rivers All. v. Fed. Energy Regulatory Comm'n*, where an agency was proposing to relicense a hydroelectric project. The D.C. Circuit observed that:

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[47] *In the Matter of Florida Power & Light Co.* (Turkey Point Nuclear Generating Units 3 and 4), CLI-15-25, 82 NRC 389, 406 (Dec. 17, 2015).

[48] *See, e.g.*, *In the Matter of Hydro Resources, Inc*, CLI-06-01, Nuclear Reg. Rep. P 31494 (Jan. 11, 2006).

[49] Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 Fed. Reg. 18,026, 18,027 (Mar. 17, 1981).

> The Biological Opinion itself described certain past harms that triggered ongoing impacts that must be part of the environmental baseline. For example, the Opinion acknowledged that "the *continued* impoundment of these projects results in *continual degradation* of benthic habitats by sedimentation, reducing water velocities, changing flow patterns, and changing water chemistry both above and below dams.[50]

The Court ruled that the Fish and Wildlife Service "acted arbitrarily in establishing the environmental baseline without considering the degradation to the environment caused by the . . . [p]roject's operation and its continuing impacts."[51]

Petitioner's November 26, 2023 comment letter in response to the 2023 DSEIS states:

> To satisfy NEPA's "hard look" requirement and complete an adequate environmental analysis, the NRC must establish the proper environmental baseline . . . . When defining the baseline environment of southeastern Florida in the 2030s through 2050s, the NRC must reassess the projections of both climate science and the groundwater contamination caused by FPL's unique cooling canal system.

The 2024 FSEIS at pages 2-24 to 2-40 discusses the impacts on groundwater quality, incorporating new information that the Petitioner provided regarding groundwater contamination. However, the 2024 FSEIS does not compare groundwater impacts to a no action alternative where the CCS is no longer used as a heat sink. Section 3.2 of the 2024 FSEIS ("Comparison of Alternatives") states that NRC staff evaluated a no action alternative in the 2019 FSEIS, but has not identified any significant new information that would change its evaluation of these discussions. Section 4.6.2 of the 2019 FSEIS states that under the no action alternative, CCS conditions could change, "because less heat would be discharged to the system. This would potentially reduce evaporation resulting in

[50] *Am. Rivers & Ala. Rivers All. v. Fed. Energy Regulatory Comm'n*, 895 F.3d 32, 46 (D.C. Cir. 2018).
[51] *Id.*

less saline conditions that would be more favorable for birds and wildlife."[52] Despite acknowledging the potential benefits of the no action alternative, NRC Staff declined to fulfill their NEPA obligations in the 2019 FSEIS and 2024 FSEIS by failing to objectively analyze, using best available science, how environmental conditions would benefit from the no action alternative. Although this baseline issue is a general issue, this contention concerns only the updated groundwater analysis in the 2024 FSEIS. It is therefore timely.

*3. The issue raised in the contention is within the scope of the proceeding (10 C.F.R. § 2.309(f)(1)(iii)*

In its March 2024 order, the Board found that all five of Petitioner's proposed contentions were within the scope of the proceeding. The Board explained that:

> In both form and substance, Miami Waterkeeper bases its contentions on the Draft SEIS. Although Miami Waterkeeper references documents and repeats arguments that pre-date the Draft SEIS, Miami Waterkeeper makes clear that it remains unsatisfied with the Staff's treatment of these issues in the Draft SEIS.[53]

The scope of this current NRC proceeding with respect to environmental issues is established by 10 C.F.R. Part 51, which requires the NRC Staff to weigh all environmental effects of the proposed action in this proceeding.[54] Contention 1-A, which asserts that NRC Staff failed to adequately consider the difference in terms of groundwater contamination between operating the CCS for 20 more years and not relicensing the plant, is well within the scope of this proceeding.

[52] 2019 FSEIS at 4-49.

[53] March 7, 2024 Board Order at 14-15.

[54] 10 C.F.R. § 51.71 n.3; 10 C.F.R. § 51.94. *See also* 10 C.F.R. §§ 51.21, 51.70-72, 51.92, 51.94, 51.104.

4. *The issue raised in the contention is material to the findings the NRC must make to support the action that is involved in the proceeding (10 C.F.R. § 2.309(f)(1)(iv)))*

Contention 1-A is "material" to the findings the NRC must make. A "material" issue is one that would make a difference in the outcome of the proceeding.[55] "This means that there should be some significant link between the claimed deficiency and either the health and safety of the public or the environment."[56]

Here, Petitioner contests the NRC staff's reliance on an incorrect environmental baseline—which is the basis of its erroneous determination that impacts on groundwater quality will be SMALL or MODERATE.

5. *Concise statement of the alleged facts or expert opinions which support the petitioner's position on the issue and on which the petitioner intends to rely at hearing (10 C.F.R. § 2.309(f)(1)(v))*

The facts supporting the Petitioner's contention are set forth in the Basis Statement in Section 2, above.

6. *A genuine dispute exists with the applicant on a material issue of law or fact (10 C.F.R. § 2.309(f)(1)(vi))*

Petitioner's contention also demonstrates sufficient information to show that a genuine dispute exists with the Applicant on a material issue of law or fact. NRC sets forth factors relevant to determining if a genuine dispute exists when it adopted the current version of 10 C.F.R. § 2.309(f)(1):

> This will require the intervenor to read the pertinent portions of the license application, including the Safety Analysis Report and the Environmental Report, state the applicant's position and the petitioner's opposing view. Where the intervenor believes the application and supporting material do not address a relevant matter, it will be sufficient for the intervenor to explain why the application is deficient.[57]

[55] *Vermont Yankee*, 64 NRC at 149.

[56] *Id.*

[57] Rules for Practice for Domestic Licensing Proceedings—Procedural Changes in the Hearing Process, 54 Fed. Reg. 33,168, 33,170 (Aug. 11, 1989).

Petitioner contests the NRC Staff's reliance in section 2.8.3 of the 2024 FSEIS on an incorrect environmental baseline—which, as discussed in detail in contention 1-C, below, is the basis of its erroneous determination that impacts on groundwater quality will be SMALL or MODERATE.

***AMENDED CONTENTION 1-B:*** ***THE 2024 FSEIS EMPLOYS THE WRONG STANDARD TO DETERMINE THE IMPACT OF THE CCS ON POTABLE WATER.***

1. *Statement of the issue of law or fact to be raised or controverted (10 C.F.R. § 2.309(f)(1)(i))*

The 2024 FSEIS inappropriately used a standard for hypersalinity rather than potability to reach its conclusion that the proposed action will not destabilize important attributes of the potable groundwater resource serving millions of South Florida residents and visitors. Instead of applying any of the federal, state, or local potability thresholds to determine that issue, the NRC Staff instead uses the standard for "hypersaline" water—a standard that, at best, is twice as large as the most permissive potability metric and is many times the County standard for potability. This methodological flaw is foundational and undermines the NRC Staff's ultimate determination that the impact to groundwater quality will be SMALL to MODERATE.[58]

2. *Brief explanation of the basis for the contention (10 C.F.R. § 2.309(f)(1)(ii))*

Under NRC regulations, the impact of a proposed action to groundwater resources is classified by three significance levels: SMALL, MODERATE, and LARGE.

> *SMALL—For the issue, environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource . . . .*
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> *MODERATE—For the issue, environmental effects are sufficient to alter noticeably,*

[58] 2024 FSEIS at 2-40.

*but not to destabilize, important attributes of the resource.*

*LARGE—For the issue, environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.*[59]

In application, this analysis considers two factors in assigning the applicable significance level: (1) the noticeability of the environmental effect, and (2) whether the environmental effect will destabilize an important attribute of the resource. This contention addresses the NRC Staff's assessment of the second factor (destabilizing the resource) for groundwater quality.[60]

Determining whether an "important attribute of [a] resource" will be "destabilized" by an "environmental effect" necessarily looks to how the resource is being used. As NRC Staff acknowledges, the Biscayne Aquifer is classified as a source of potable drinking water for South Floridians,[61] and the "CCS discharges to the Biscayne Aquifer."[62] The 2024 FSEIS further recognizes that the groundwater pollution from the CCS has infiltrated "the potable portion of the Biscayne Aquifer."[63] Clearly, potability is an "important attribute" of the Biscayne Aquifer resource.[64] The EPA has designated the Biscayne aquifer as a sole-source aquifer. Miami-Dade County relies on the Biscayne Aquifer for nearly all of its supply of

[59] 10 C.F.R. Part 51, Subpart A, Appendix B. *See also* 2024 FSEIS at 1-4.

[60] The 2024 FSEIS recognizes, and Miami Waterkeeper agrees, that the impact of the CCS to groundwater quality is clearly noticeable. *See* 2024 FSEIS at 2-39 ("Therefore, the extension of the hypersaline groundwater plume (defined as groundwater with a chloride concentration greater than 19,000 mg/L) beyond the site boundary has altered noticeably the groundwater quality of the potable portion of the Biscayne Aquifer with respect to the designated groundwater use classification. … [T]he plume of hypersaline water from the CCS has measurably altered and degraded groundwater quality in the lower part of the Biscayne Aquifer beyond the CCS and Turkey Point property."); *see also* Attachment A - Expert report of William Nuttle, Ph.D., PEng (May 8, 2024), (hereinafter "May 2024 Nuttle Report").

[61] 2024 FSEIS at 2-24–2-25.

[62] *Id.* at 2-26.

[63] *Id.* at 2-39.

[64] *See* 10 C.F.R. Part 51, Subpart A, Appendix B.

potable water.[65] It follows, then, that the determination of whether the continued CCS operation is "sufficient to destabilize" that drinking water resource must look to whether proposed action will render potable portions of the Biscayne Aquifer non-potable.

The applicable standards for potability are set by Miami-Dade County, the State of Florida, and the EPA. For example, in Miami-Dade County total dissolved solids ("TDS") "shall not be present in a water supply in excess of" 500 mg/L, and chloride cannot exceed 250 mg/L.[66]

The 2024 FSEIS does not employ these standards in its analysis—it does not assess whether the proposed action will result in the Biscayne Aquifer exceeding any of these potable water thresholds. Instead, the 2024 FSEIS analyzes whether "the **hypersaline** groundwater has . . . destabilized the aquifer":

> The NRC staff concludes that the appropriate impact determination for groundwater quality under this scenario is MODERATE, which means that environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource. This impact determination is appropriate because the Biscayne Aquifer is classified as **Class G-III (nonpotable use, with TDS levels of 10,000 mg/L or greater) beneath the Turkey Point site and CCS, but Class-II (potable) to the west of the CCS.** Therefore, the extension of the **hypersaline** groundwater plume (**defined as groundwater with a chloride concentration greater than 19,000 mg/L**) beyond the site boundary has altered noticeably the groundwater quality of the potable portion of the Biscayne Aquifer with respect to the designated groundwater use classification.
> . . .
> Should the hypersaline groundwater plume be fully retracted to within the Turkey Point Units 3 and 4 site boundary, either before or during the SLR term, the NRC staff concludes that the appropriate impact determination for groundwater quality from the continued operation of Turkey Point Units 3 and 4 would be SMALL, which means that environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. This impact determination is appropriate because the Biscayne Aquifer is classified as Class G-III (nonpotable use, with TDS levels of 10,000 mg/L or greater) beneath the Turkey Point site and CCS and so the existence of the hypersaline groundwater

[65] May 2024 Nuttle Report at 6.

[66] Miami-Dade Cnty., Fla., Code § 24-43.3(2)(h) ("Potable Water Standards").

> plume (defined as groundwater with a chloride concentration greater than 19,000 mg/L) in that location would result in environmental effects that are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.[67]

This analysis is materially and methodologically flawed. As noted above, the standard for "hypersaline" water set by the Florida Department of Environmental Protection's 2016 Consent Order is 19,000 mg/L of chloride.[68] Although hypersaline water is certainly non-potable, the standard for hypersalinity is nearly **double** the state classification for potable water use,[69] and **over thirty-eight times** Miami Dade County's potable water standards.[70] In other words, the Staff employed a relaxed standard (hypersalinity) to determine whether the continued CCS operations will destabilize a potable drinking water resource. In doing so, the FSEIS failed to adequately account for how the migration of non-potable saltwater—not just hypersaline water—from the CCS over the SLR term will contribute to the potable portion of the Biscayne Aquifer being rendered non-potable. This foundational flaw in the 2024 FSEIS's methodology undermines both the finding on destabilization and the ultimate conclusion that the impacts to groundwater quality will be SMALL or MODERATE.

3. *The issue raised in the contention is within the scope of the proceeding (10 C.F.R. § 2.309(f)(1)(iii))*

In its March 2024 order, the Board found that all five of Petitioner's proposed contentions were within the scope of the proceeding. The Board explained that:

> In both form and substance, Miami Waterkeeper bases its contentions on the Draft SEIS. Although Miami Waterkeeper references documents and repeats arguments

[67] 2024 FSEIS at 2-39 and 2-40 (emphases added).

[68] *Id.*

[69] 62-520.410(1), F.A.C. Reference Class-G-II for potable water use, groundwater in aquifers with a total dissolved solids content of less than 10,000 mg/L, unless otherwise classified by the Commission.

[70] Miami-Dade Cnty., Fla., Code § 24-43.3(2)(h) ("Potable Water Standards") (referencing a 250 mg/L upper limit of chloride).

> that pre-date the Draft SEIS, Miami Waterkeeper makes clear that it remains unsatisfied with the Staff's treatment of these issues in the Draft SEIS.[71]

The scope of the current NRC proceeding with respect to environmental issues is established by 10 C.F.R. Part 51, which requires the NRC Staff to weigh all environmental effects of the proposed action in this proceeding.[72] Contention 1-B, which asserts that the FSEIS groundwater analysis used the wrong standard for evaluating impacts to a potable water aquifer, is well within the scope of this proceeding.

4. *The issue raised in the contention is material to the findings the NRC must make to support the action that is involved in the proceeding (10 C.F.R. § 2.309(f)(1)(iv)))*

The 2024 FSEIS's failure to utilize the standard for potable water is material to the NRC's ultimate significance level determination of the impact of the proposed action to groundwater quality—a necessary component of the FSEIS. The correct standard from which to whether the proposed action will "destabilize" a sole-source drinking water aquifer are the potability standards established by the federal, state and local governments. By employing the hypersalinity standard, the FSEIS engaged in an improperly relaxed analysis. This resulted in the FSEIS underestimating the impacts to groundwater quality and ultimately assigning the wrong significance level of SMALL to MODERATE.

5. *Concise statement of the alleged facts or expert opinions which support the petitioner's position on the issue and on which the petitioner intends to rely at hearing (10 C.F.R. § 2.309(f)(1)(v))*

The facts supporting Contention 1-B are set forth in the Basis Statement in Section 2, above, and in the expert report of William Nuttle, Ph.D discussing the potential hydrological

[71] March 7, 2024 Board Order at 14-15.

[72] 10 C.F.R. §§ 51.71 n.3, 51.94. *See also* 10 C.F.R. §§ 51.21, 51.70-72, 51.92, 51.94, 51.104.

impacts of the cooling system on the potable water resources that may be affected by any period of extended operation.[73]

6. *A genuine dispute exists with the applicant on a material issue of law or fact (10 C.F.R. § 2.309(f)(1)(vi))*

The dispute raised in Contention 1-B is genuine because the 2024 FSEIS did not employ any of the applicable standards of potability in rendering its conclusion that the proposed action will not destabilize the potable portion of the Biscayne Aquifer, and instead utilized a relaxed "hypersalinity" standard. While the NRC Staff appears to believe this analysis is adequate, Petitioner does not. This dispute is material to the FSEIS's determination of the significance level assigned to groundwater quality impacts, because potential impacts on drinking water resources that serve large populations in South Florida must be fully analyzed before relicensing can proceed.

***AMENDED CONTENTION 1-C:*** ***THE 2024 FSEIS'S ASSESSMENT OF THE IMPACT OF THE PROPOSED ACTION TO GROUNDWATER QUALITY IS INADEQUATE BECAUSE IT UNDERESTIMATES THE IMPACTS ON DRINKING WATER RESOURCES.***

1. *Statement of the issue of law or fact to be raised or controverted (10 C.F.R. § 2.309(f)(1)(i))*

The 2024 FSEIS incorrectly concluded that the impacts of the proposed action on groundwater quality are SMALL to MODERATE.[74] The continued operation of the CCS as a heat sink during the SLR term will produce significant and destabilizing effects on the Biscayne Aquifer, a potable groundwater resource. As such, the FSEIS is inadequate because it

[73] May 2024 Nuttle Report.

[74] 2024 FSEIS at 2-40.

fails to fully evaluate the impacts of the continued operation of the CCS on groundwater resources, thereby underestimating impacts on drinking water resources.

*2. Brief explanation of the basis for the contention (10 C.F.R. § 2.309(f)(1)(ii))*

As set out in detail in the attached expert opinion from Dr. William Nuttle,[75] there is a major concern that FPL's mitigation measures to counteract hypersalinity caused by the continued operation of the cooling canal system as a heat sink is actually increasing the rate at the which the interface between saltwater and freshwater is migrating towards potable water wells that serve large numbers of people in southern Miami-Dade and Monroe counties. To mitigate the hypersaline plume, FPL extracts huge amounts of fresh water from the Upper Floridan Aquifer, and to a lesser extent, the interceptor ditch. This water is pumped into the cooling canals to reduce the average annual salinity to at or below 34 practical salinity units (or "PSU") and thus reduce the hypersalinity within the canals and below them. At the same time, FPL extracts hypersaline water from the Biscayne Aquifer and injects it into the Lower Floridan Aquifer. The effect of this remediation increases the inland movement of the saltwater interface in the Biscayne Aquifer in two ways. First, the extraction of the hypersaline water from the Biscayne Aquifer lowers the head in that area on the inland side of the reactor. Second, adding lower salinity water to the cooling canals increases the head in the canals, leading to the infiltration of larger volumes of saline water into the Biscayne Aquifer. In layman's terms, saline water is being pushed into the Biscayne Aquifer from the cooling canals and then sucked inland by the extraction of the hypersaline water.

In the 2024 FSEIS, NRC Staff focused on hypersaline plume mitigation, but provided fleeting acknowledgement of the transport and fate of the much larger volume of saline water

[75] May 2024 Nuttle Report, included as Attachment A.

emanating from the cooling canal system. Petitioner raised this concern in its comment letter in response to the 2023 DSEIS, and Petitioner's comments are enumerated at A.2.1 of the 2024 FSEIS. Petitioner explains at A-42 that there is an inherent tension between efforts to clean up water quality in the CCS and preventing the spread of saline water.[76] Flushing is the only mechanism that limits the accumulation of salt and other dissolved substances in the CCS, allowing FPL to achieve salinity requirements prescribed by regulators.[77] Petitioner conveyed to NRC Staff that even if the recovery well system works as designed, there will still be a net addition of salt to the Biscayne Aquifer from the cooling canal system, and that this flushing pushes contamination from the CCS into the groundwater, reducing the amount of fresh groundwater available to users in South Florida.

In response to Petitioner's comments, NRC Staff merely notes that "FPL's remedial action is subject to significant ongoing state and local oversight."[78] The NRC Staff claims "that the approval of any changes to this remedial action, or its inclusion as a license condition, is outside NRC's jurisdiction."[79] However, just because the management of this problem is in the hands of the State does not absolve the NRC Staff from assessing the impact of extended operation on groundwater resources. That another governmental agency may have some regulatory authority over a project being considered for a federal action subject to NEPA

[76] *Id.* at A-42, Comment: "The remediation plan for the hypersaline plume adds contamination to groundwater."

[77] *Id.* at 2-26, 2-28, 2-38–2-39 (noting the 2016 FDEP Consent Order objective requiring the CCS salinity to achieve 34 psu or less; also a requirement of the 2022 NPDES permit issued by the State of Florida).

[78] *Id.* at A-45.

[79] *Id.* at A-46.

does not absolve the federal action agency from the requirement to analyze those impacts fully.[80] Federal regulations provide that:

> Compliance with the environmental quality standards and requirements of the Federal Water Pollution Control Act (imposed by EPA or designated permitting states) is not a substitute for, and does not negate the requirement for NRC to weigh all environmental effects of the proposed action, including the degradation, if any, of water quality, and to consider alternatives to the proposed action that are available for reducing adverse effects.[81]

Elsewhere in the 2024 FSEIS, NRC Staff states that:

> [w]hile a flux of water out of the CCS with a salinity of 34 [psu] may not add to the existing hypersaline plume, it may influence the plume's movement, albeit to a small degree. FPL has not provided a detailed analysis comparing hypersaline plume migration with and without the CCS operating.[82]

Moreover, the 2024 FSEIS states that "westward migration of the saltwater interface . . . has historically been attributed, in part, to CCS hypersaline discharges, has also affected the aquifer."[83] Thus, the FSEIS acknowledges that CCS operation is contributing to the inland movement of the saltwater interface, but does little to assess the severity of this problem.

NRC Staff focuses on the hypersaline plume and largely ignores the much greater volume of saline water that is escaping the CCS in vast quantities. They posit that there are two reasonably foreseeable scenarios: (1) the hypersaline plume not expanding overall, but still extending outside of the Turkey Point Units 3 and 4 site boundary and (2) the hypersaline

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[80] *Davis v. Mineta*, 302 F.3d 1104, 1122-23 (10th Cir. 2002); *TOMAC v. Norton*, 240 F. Supp. 2d 45, 50-52 (D.D.C. 2003); *Friends of the Earth v. U.S. Army Corps of Eng'rs*, 109 F. Supp. 2d 30, 43 (D.D.C. 2000); *Sierra Club v. Marsh*, 769 F.2d 868, 877-82 (1st. Cir. 1985); *Natural Resources Defense Council v. Morton*, 458 F.2d 827 (D.C. Cir. 1972). The fact that the Commission is not empowered to implement alternatives does not absolve it from its duty to consider them. *Public Service Co. of New Hampshire* (Seabrook Station, Units 1 & 2), CLI-77-8, 5 NRC 503 (1977).

[81] 10 C.F.R. § 51.71 n.3.

[82] 2024 FSEIS at A-38.

[83] *Id.* at 2-39.

plume being retracted to within the Turkey Point Units 3 and 4 site boundary.[84] They conclude that "[u]nder both reasonably foreseeable scenarios, the staff projects that there will be no additional adverse effect on the beneficial uses of groundwater offsite by existing users because all existing users are located beyond the likely extent of the plume."[85]

The problem raised in this contention illustrates the danger of this narrow approach. In effect, to solve one problem—the hypersaline plume—FPL is exacerbating another, the movement of salt water towards potable water wells that serve about 4 million people.[86] This is a problem that is difficult to solve—but the first step is to do a thorough, integrated analysis of both issues together. To date, the NRC has failed to provide an adequate analysis of this issue.

*3. The issue raised in the contention is within the scope of the proceeding (10 C.F.R. 2.309(f)(iii))*

NRC regulations broadly divide the scope of a license renewal proceeding into (1) safety/aging management issues and (2) environmental impacts. Contention 1-C concerns environmental impacts. The scope of the required environmental review is established by 10 C.F.R. Part 51. This contention is within the scope of the proceeding because it challenges the sufficiency of the environmental analysis in the 2024 FSEIS.

*4. The issue raised in the contention is material to the findings the NRC must make to support the action that is involved in the proceeding (10 C.F.R. § 2.309(f)(1)(iv)))*

Contention 1-C is "material" to the findings the NRC must make.[87] An issue is "material" if "the resolution of the dispute would make a difference in the outcome of the

[84] *Id.* at 2-39.

[85] *Id.*

[86] U.S. Geological Survey, Groundwater Quality in the Biscayne Aquifer, Florida Fact Sheet (FS 2019-3056), (September 16, 2020), *available at* https://pubs.usgs.gov/fs/2019/3056/fs20193056.pdf.

[87] 10 C.F.R. § 2.309(f)(1)(iv).

licensing proceeding."[88] "This means that there must be some link between the claimed error or omission regarding the proposed licensing action and the NRC's role in protecting public health and safety or the environment."[89]

The issue raised in Contention 1-C relates directly to the NRC's role in protecting public health and safety and the environment. NEPA imposes requirements on the NRC to take a "hard look" at potentially significant environmental issues.[90] The failure to comply with these requirements would violate NEPA and is therefore material to the findings NRC must make to support relicensing. Were NRC Staff to remedy the deficiencies that Petitioner identifies, it might conclude that the impacts to groundwater are LARGE.

5. *Concise statement of the alleged facts or expert opinions which support the petitioner's position on the issue and on which the petitioner intends to rely at hearing (10 C.F.R. § 2.309(f)(1)(v))*

NRC staff begins its assessment of the impacts of operating the CCS on groundwater quality with the following:

> Under both reasonably foreseeable scenarios [regarding FPL's groundwater remediation activities], the staff projects that there will be no additional adverse effect on the beneficial use of groundwater offsite by existing users because all existing users are located beyond the likely extent of the [hypersaline] plume.[91]

The Biscayne Aquifer is a surficial aquifer and is designated by the EPA as a sole source aquifer for approximately 4 million people and is thus critical to the region's water supply.[92] Existing users include the operators of municipal wells tapping into the Biscayne Aquifer. Saltwater intrusion threatens municipal water supplies beneath the Model Land Basin

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[88] *Vermont Yankee*, 64 NRC at 149.

[89] *Id.*

[90] 2023 Miami Waterkeeper Petition at 12-34; *see also* Petitioner's Reply Brief at 11-28.

[91] 2024 FSEIS at 2-39.

[92] U.S. Geological Survey, Groundwater Quality in the Biscayne Aquifer, Florida Fact Sheet (FS 2019-3056), (September 16, 2020), *available at* https://pubs.usgs.gov/fs/2019/3056/fs20193056.pdf.

that exists to the immediate west of the CCS. The cooling canal system is recognized as incurring salt water intrusion of the Biscayne Aquifer extending up to 5 miles away.[93] This is because the CCS exerts a major influence on groundwater hydrology in its vicinity: it interacts with the adjacent Model Lands basin through its effects on groundwater in the underlying Biscayne Aquifer.[94] This section discusses the mechanism by which the cooling canal system can affect the adjacent Model Lands basin and nearby public water supply wells.

**i. Municipal wellfields use the Biscayne Aquifer in proximity to the CCS**

The municipal wells nearest the CCS are located at Newton Field, Harris Field, and Witkop Park, approximately 6.8, 7.3, and 7.7 mi, respectively, from the Turkey Point plant site.[95] These municipal wells are located outside of, but proximate to, the Model Land basin, and they communicate with the groundwater beneath the Model Land basin through the highly permeable Biscayne Aquifer.[96]

Wells used for potable water supply in the Biscayne Aquifer are, in general, vulnerable to impact by saltwater intrusion.[97] Protection of the groundwater resource, as a source of potable water, depends on maintaining the position of the interface between freshwater and saltwater, also known as the salt water interface. In particular, assuring the stability of the groundwater resource means preventing the salt water interface from moving further inland.[98]

[93] May 2024 Nuttle Report at 3.

[94] *Id.* at 4.

[95] *Id.* at 6.

[96] *Id.*

[97] *Id.* at 3.

[98] *Id.* at 6.

### ii. The Biscayne Aquifer is sensitive to relatively small changes in hydraulic head and to pollution

The position of the saltwater interface in a surficial coastal aquifer is generally determined by the balance between the hydraulic gradient driving the flow of fresh water to the coast opposed by the flow of sea water inland at the base of the aquifer driven by the difference in density between fresh water and sea water.[99] Relatively small differences in the height of the water table (the hydraulic head), suffice to drive large groundwater fluxes in the Biscayne Aquifer.[100] Proximate to the cooling canal system, the regional hydraulic gradient driving the flow in the Model Land basin is very small, 0.004% to 0.005%.[101]

### iii. The CCS actively exchanges with the Biscayne Aquifer

The CCS functions as an open system from the point of view of water supply: water in the canals actively exchanges with the atmosphere and with groundwater in the underlying Biscayne aquifer and the surface water of Biscayne Bay.[102] The active exchange between the CCS and the surficial aquifer occurs "by design."[103] Historically, the inflow of water from the aquifer into the CCS has been the primary source of makeup water to replace water lost to evaporation in excess of rainfall. The discharge of water from the CCS into the aquifer serves the role of blowdown to control the level of salinity in the CCS, which is increased by evaporation. Active exchange with the aquifer is necessary to maintain the function of the CCS

[99] *Id.*

[100] *Id.* at 4.

[101] *Id.*

[102] *Id.* at 2.

[103] *Id.* at 5 (citing Scroggs letter on dredging, NRC 2018).

to provide cooling for Units 3 and 4. Therefore, the active exchange between the CCS and Biscayne Aquifer is a feature of the CCS and not an unintended consequence.[104]

The operation of the CCS as a heat sink has significant implications for water levels in the CCS. The pumps that circulate water through the nuclear generating plants also alter water levels in the network of cooling canals.[105] Water levels are drawn down at the north end of the return canals (at the plant intakes), and water levels are elevated in the header canal, where the plants discharge water into the CCS. Water levels in the header canal and at the north end of the canals fed by the header canal are raised, and this elevation drives seepage from the CCS into the aquifer, mostly through the bottom of the canals in the northwest corner of the CCS.[106] The operation of the CCS as a heat sink also has significant implications for salinity that is discharged into the aquifer: evaporation from the CCS increases the salinity of water in the CCS that is discharged into the surrounding environment.[107]

The effects of operating the CCS as a heat sink are not confined to the Turkey Point property—they are regional.

#### iv. The CCS increases regional hydraulic head in the direction of the municipal wells

The operation of the CCS has affected the hydrology of the entire Model Land basin.[108] The canals are a dominant feature that define hydrologic conditions in the aquifer at the boundary between the Model Lands basin and Biscayne Bay.[109] As established in previous paragraphs,

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[104] *Id.*

[105] *Id.* at 13.

[106] *Id.*

[107] *Id.* at 5.

[108] *Id.*

[109] *Id.*

relatively small differences in the height of the water table (the hydraulic head) suffice to drive large groundwater fluxes in the Biscayne aquifer. Given the small magnitude of the regional hydraulic gradient, fluctuations in the water table—driven by the shifting balance between rainfall and evaporation in the basin—can result in the temporary reversal of the hydraulic gradient.[110] Thus, the general movement of fresh groundwater through the basin toward the coast is, on occasion, interrupted by periods during which the movement of fresh groundwater is either stagnant or directed inland, away from the coast. During these periods the hydrologic effects of the operation of the CCS can propagate into the Model Land basin.[111]

**v. The CCS's influence on regional hydrology and water quality is significant**

As noted above, the operation of the CCS as a heat sink piles water into the north and west cooling canals, which drives seepage into the Biscayne Aquifer. Rainfall and freshening activities to bring down salinity also drive seepage into the Biscayne Aquifer.[112] Consider that the design of the CCS magnifies the effect of high rainfall events on discharge to the aquifer.[113] Nearly all rainfall from a large event over the CCS is retained within it where it will add directly to the water levels in the canals, as the CCS is currently prevented from discharging water directly to adjacent surface water bodies. The increase in water levels in adjacent wetlands from the same rainfall event is reduced by surface runoff and drainage into Biscayne Bay. Water levels in the saline CCS are therefore increased relative to the position of the fresh water table in the

[110] *Id.*

[111] *Id.* at 5-6.

[112] I*d.* at 21-22.

[113] I*d.* at 15.

Model Land basin. The effect will be to raise the salt water interface and displace it inland beneath the Model Land basin.[114]

By convention, the position where the salt water interface intersects the base of the aquifer is taken as indicative of the position of the salt water interface overall. For this purpose, the inland extent of salt water is defined as the estimated position of the 1,000 mg/L isochlor (referring to chlorinity) as the base of the aquifer.[115]

Chlorinity is closely related to salinity, where salinity measures the concentration of total dissolved solids, and chlorinity measures the concentration of dissolved chloride ions.[116] Typical values for seawater are ~35 parts per thousand total dissolved solids, corresponding to ~35 psu (the conventional measure for seawater salinity), and 19,000 mg/L chlorinity. Hypersaline water is defined as water with chlorinity greater than 19,000 mg/L.[117]

Water in the CCS is required to be at or below 34 practical salinity units—close to the salinity of seawater–per an objective established by the 2016 FDEP 2016 Consent Order. Infiltration of saline water out of the CCS is enormous. Seepage from the CCS into the aquifer has previously been calculated to average 9 million gallons per day (mgd).[118] At this rate, the entire contents of the canals empty into the aquifer every 18 months.[119] It follows that NRC's sole focus on the hypersaline plume neglects the presence of much larger plume of diluted CCS water, with chlorinity less than 19,000 mg/L threshold (salinity less than 34 practical salinity units, or

[114] *Id.*

[115] *Id.* at 10.

[116] *Id.* at 7.

[117] *Id.*

[118] *Id.* at 17.

[119] *Id.*

psu).[120] Yet, NRC is tracking only chlorinity at 19,000 mg/L in its determination as to whether the continued operation of the CCS as a heat sink will affect groundwater quality.[121]

### vi. CCS Operation, including freshening activities, destabilizes the saltwater interface

A 1978 study by Dames and Moore linked changes in the hydraulic gradient caused by changes in CCS water levels to destabilization of the saltwater interface.[122] This study calculated the change in the landward extent of salt water intrusion that would result from a 0.5 foot increase in CCS water level for three hydrologic conditions in the Model Land basin—wet, normal, and dry—corresponding to declining magnitude in values assigned to the regional hydraulic gradient. Results for the study found the inland displacement of the salt water interface at equilibrium are ~1 mile under wet conditions, 3 to 4 miles under normal conditions, and ~7 miles under dry conditions.

The particular results obtained from this calculation are less important than their overall magnitude.[123] The magnitude of the estimated change in the horizontal position of the interface—miles—reflects the inherent sensitivity of the groundwater hydrologic system in the Model Lands basin to relatively small perturbations in water levels.

As predicted by the Dames and Moore study, changes in CCS operation impact local hydrology and destabilize the saltwater interface. FPL's use of the CCS as a heat sink, and its associated requirement to desalinate the canals with freshening water (current allocation is 30

[120] 2024 FSEIS at A-22, A-38, A-42, 2-26, 2-28, 2-30, 2-38, 2-39. 2-67 (noting the 2016 FDEP Consent Order objective requiring the CCS salinity to achieve 34 psu or less; also a requirement of the 2022 NPDES permit issued by the State of Florida).

[121] *Id.* at 2-39 and 2-40.

[122] May 2024 Nuttle Report at 20.

[123] *Id.* at 20.

mgd),[124] alters the CCS water budget and increases discharges to groundwater. These operations result in higher water levels in the CCS, increasing hydraulic head, resulting in *decreased inflows from* the Biscayne Aquifer, *increased outflows to* the Biscayne Aquifer, and an overall increase in net discharge to groundwater.[125]

Petitioner's expert performed a regression analysis on water levels in the CCS, water balance fluxes, and salinity to quantify the change in water level that will result from current and planned future freshening operations.[126] Results indicate that the total increase in water level is 0.38 feet above water levels in the baseline year of 2010. If the new, ~30 mgd freshening limit is applied, then the water level would be 0.52 feet above 2010 levels.[127] This increase in water levels has regional significance. A 0.5-foot increase in CCS water level could decrease the regional gradient by as much as 25%. As established by the Dames and Moore study, the Model Lands basin is inherently sensitive to relatively small perturbations in water levels; thus, the changes in CCS operation can have far-reaching consequences.

Because the CCS contains tritium concentrations hundreds of times greater than background concentrations in the aquifer and surrounding surface waters, detecting the extent of CCS water can be performed by sampling for tritium.[128] There is no other source of tritium at such high concentrations in the region, so sampling for it makes for a reliable indicator of water originating from the CCS in the vicinity of Turkey Point. Regulatory agencies agreed to include tritium as a water quality constituent at a threshold of 20 picocuries per liter to indicate the

[124] 2024 FSEIS at 2-23, acknowledging FPL's annual allocation for freshening to 10,950 million gallons (average rate of 30 mgd) via Turkey Point Site Certification PA03-45F, issued by the FDEP on October 19, 2021.

[125] May 2024 Nuttle Report at 22 (emphasis added).

[126] *Id.* at 23.

[127] *Id.*

[128] *Id.* at 16.

presence of water origination from the CCS in groundwater samples.[129] Dr. Nuttle's expert report explains that:

> In 2014, the USGS reported tritium above the 20 pico Curie per liter threshold in wells G-3699 and G-3855. **This places water originating from the CCS at the leading edge of the salt water interface advancing toward the Newton Wellfield**, Figures 1 and 6. Continued monitoring for tritium by Miami Dade County at G-3699 and another well, G-3966, in the same area shows that **water from the CCS has persisted in the aquifer near and advancing on the Newton Wellfield**, even as CCS water has disappeared in areas to the east and southwest, Figure 7.[130]

In summary, the continued operation of the CCS as a heat sink may cause hydraulic gradient changes throughout the Model Lands basin. The continued operation of the CCS also causes vast quantities of saline water to migrate along that east to west gradient. This threatens local water supplies at nearby wellfields approximately seven miles away. As such, the continued operation of the CCS as a heat sink noticeably destabilizes a critical resource in the public trust: fresh groundwater that supplies drinking water.

6. *A genuine dispute exists with the applicant on a material issue of law or fact (10 C.F.R. § 2.309(f)(1)(vi))*

Petitioner's Contention 1-A demonstrates sufficient information to show that a genuine dispute exists with the Applicant and the NRC Staff on a material issue of law or fact. NRC sets forth factors relevant to determining if a genuine dispute exists when it adopted the current version of 10 C.F.R. § 2.309(f)(1):

> This will require the intervenor to read the pertinent portions of the license application, including the Safety Analysis Report and the Environmental Report, state the applicant's position and the petitioner's opposing view. Where the intervenor believes the application and supporting material do not address a

[129] *Id.*

[130] *Id.* at 17 (internal citations omitted, emphases added).

> relevant matter, it will be sufficient for the intervenor to explain why the application is deficient.[131]

Petitioner contests the NRC Staff's conclusion in Section 2.8 of the 2024 FSEIS "that the impact of CCS operations, including, in part, the continuing operation of Turkey Point Units 3 and 4, during the SLR term on groundwater quality is SMALL to MODERATE."[132] In fact, Petitioner has shown that NRC Staff's cursory analysis of the threat to drinking water resources is inadequate and fails to recognize that continued operation of the CCS would significantly increase the risk to drinking water supplies.

The Board should therefore admit Contentions 1- A, 1-B, and 1-C as amended.

## IV. NEW CONTENTIONS

### A. Overview

Petitioner offers the following new contentions. Each new contention is based on information that did not appear in the 2023 DSEIS or was unavailable at the time Petitioner filed their initial petition to intervene, is raised in timely fashion pursuant to the Board's Scheduling Order, is materially different, and establishes a genuine dispute on a material issue of law or fact that is within the scope of this proceeding.[133]

While Petitioner believes a waiver under 10 C.F.R. § 2.335(b) is not necessary in order for Petitioner assert contentions addressing these issues, we also submit a waiver for Contention 3-B out of an abundance of caution.[111]

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[131] Rules for Practice for Domestic Licensing Proceedings—Procedural Changes in the Hearing Process, 54 Fed. Reg. 33,168, 33,170 (Aug. 11, 1989).

[132] 2024 FSEIS at 2-40.

[133] 10 C.F.R. §§ 2.309(f)(1), 2.309(c)(1).

***CONTENTION 2:*** ***THE 2024 FSEIS'S ANALYSIS OF THE POTENTIAL IMPACTS OF TURKEY POINT'S CONTINUED OPERATION DURING THE RENEWAL PERIOD ON MIAMI CAVE CRAYFISH IS INADEQUATE AND ITS DETERMINATION THAT CONTINUED OPERATION IS UNLIKELY TO ADVERSELY AFFECT OR JEOPARDIZE THE MIAMI CAVE CRAYFISH IS UNSUPPORTED.***

In its March 7, 2024 Order, the Board found Miami Waterkeeper's crayfish-related contention to be "premature based on [a conclusion] that contentions claiming deficiencies from an alleged 'failure to consult' are not ripe if the Staff has not yet completed the relevant [Endangered Species Act ("ESA")] consultation requirements."[134] To similar effect, it concluded that Miami Waterkeeper's NEPA challenge to the agency's failure to take a hard look at impacts on species also "must await an opportunity for the Staff to confer with the Fish and Wildlife Service."[135] The Board specified that Miami Waterkeeper would have "an opportunity to advance any arguments regarding . . . the Miami cave crayfish in a new or amended contention when the Staff issues the Final SEIS."[136]

In line with the Board's earlier decision, Contention 2 now seeks to address the agency's failure to meet legal requirements related to its consultation and analysis of impacts on the Miami cave crayfish. It meets NRC's regulatory requirements for timeliness and admissibility. First, "good cause"—defined as timely and based on new and materially different information—exists to admit Contention 2.[137] Contention 2 also meets the requirements in 10 C.F.R. § 2.309(f)(1) regarding contention admissibility.[138] The Board should therefore admit Contention 2.

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[134] March 7, 2024 Board Order at 30.

[135] *Id.* at 31 n.162.

[136] *Id.* at 31.

[137] 10 C.F.R. §§ 2.309(f)(2), 2.309(c)(1).

[138] *See* March 7, 2024 Board Order at 31 n.162 ("At that time, Miami Waterkeeper must address the general admissibility criteria in 10 C.F.R. § 2.309(f)(1) and the heightened pleading standards for new and amended contentions in 10 C.F.R. § 2.309(c).").

**1. Contention 2 satisfies the "good cause" standard.**

Good cause, which arises where a contention is timely and based on new and materially different information, exists to admit Contention 2.[139] The 2024 FSEIS includes new information that was previously unavailable in the 2023 DSEIS: whereas the 2023 DSEIS did not include any discussion of consultation with the United States Fish and Wildlife Service ("FWS") regarding impacts on the Miami cave crayfish, let alone an analysis of those impacts,[140] the 2024 FSEIS includes a section on the Miami cave crayfish.[141] However, NRC's evaluation of the impacts that Turkey Point's continued operation, including the continued operation of the CCS as a heat sink, will have on the Miami cave crayfish falls well short of requirements under NEPA and the ESA. In its March 7, 2024 Memorandum and Order, the Board held that Miami Waterkeeper would have an opportunity to advance its NEPA and ESA arguments "regarding the Miami cave crayfish in a new or amended contention when the Staff issues the Final SEIS."[142] In short, based both on NRC rules and the Board's prior Memorandum and Order, there is good cause to bring this contention concerning the new analysis of impacts on the Miami cave crayfish that NRC Staff added to its 2024 FSEIS.

**2. Contention 2 satisfies the criteria for admissibility.**

*1. Statement of the issue of law or fact to be raised or controverted (10 C.F.R. § 2.309(f)(1)(i))*

NEPA and NRC regulations require the 2024 FSEIS to consider the effects of Turkey Point's continued operation on important plant and animal habitats, including threatened and

[139] 10 C.F.R. §§ 2.309(f)(2), 2.309(c)(1).

[140] 2023 DSEIS at Appendix E, E-5 to E-6.

[141] 2024 FSEIS at § 2.11.

[142] March 7, 2024 Board Order at 31.

endangered species.[143] In addition, the ESA and its implementing regulations require agencies to confer with the National Marine Fisheries Service or FWS if a proposed action is likely to jeopardize the existence of a species proposed for listing under the ESA.[144] NRC rules specify that site-specific analysis is required to assess the magnitude of impacts of a proposed license extension on endangered, threatened, and protected species:

> The magnitude of impacts on threatened, endangered, and protected species, critical habitat, and essential fish habitat would depend on the occurrence of listed species and habitats and the effects of power plant systems on them. Consultation with appropriate agencies would be needed to determine whether special status species or habitats are present and whether they would be adversely affected by continued operations and refurbishment associated with license renewal.[145]

The 2024 FSEIS acknowledges that relicensing "may affect" the Miami cave crayfish,[146] but it gives inadequate consideration to how the operation of the CCS and its regional hydrologic impacts in the Biscayne Aquifer will affect the crayfish during the twenty-year subsequent license renewal period.

Petitioner notes in its response to the 2023 DSEIS that there is an inherent tension between efforts to clean up water quality in the CCS and preventing the spread of saline water.[147] Petitioner also noted that flushing is the only mechanism that limits the accumulation of salt and other dissolved substances in the CCS, allowing FPL to achieve salinity

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[143] 10 C.F.R. § 51.71 (requiring analysis of Category 2 issues); *see also* 10 C.F.R. Part 51, Subpart A, Appendix B (listing "threatened, endangered, and protected species and essential fish habitat" as a Category 2 issue); 10 C.F.R. § 51.53(c)(3)(ii)(E) ("All license renewal applicants shall assess the impact of … continued operations … on important plant and animal habitats. Additionally, the applicant shall assess the impact of the proposed action on threatened or endangered species.").

[144] 50 C.F.R. § 402.10(a).

[145] 10 C.F.R. § Part 51, Subpart A, Appendix B.

[146] 2024 FSEIS at 2-67.

[147] *Id.* at A-42, Comment: "The remediation plan for the hypersaline plume adds contamination to groundwater."

requirements prescribed by regulators.[148] Petitioner further establishes in Contention 1-C that the infiltration of saline water out of the CCS is enormous and has been previously calculated to average 9 million gallons per day—effectively emptying the contents of the cooling canals into the aquifer every 18 months.[149] Moreover, Petitioner shows in Contention 1-C that CCS operations can cause an inland displacement of the saltwater interface on orders of magnitude (miles) relative to a 0.5 foot increase in the height of the CCS water.[150]

Therefore, NRC Staff's inadequate analysis fails to provide the required "hard look" at environmental impacts required by NEPA. It also undermines the NRC's conclusion under the ESA that the license extension is unlikely to adversely affect or jeopardize the continued existence of the Miami cave crayfish and thus its conclusion that no consultation with FWS is required. These failures violate NEPA, the ESA, and both laws' implementing regulations.

*2. Brief explanation of basis for the contention (10 C.F.R. § 2.309(f)(1)(ii))*

Under NEPA, federal agencies must take a "hard look" at the environmental consequences of their proposed actions.[151] The action agency—here, the NRC—will satisfy the hard look requirement if its analysis "contains sufficient discussion of the relevant issues and

[148] 2024 FSEIS at 2-26, 2-28, 2-38–2-39 (noting the 2016 FDEP Consent Order objective requiring the CCS salinity to achieve 34 psu or less; also a requirement of the 2022 NPDES permit issued by the State of Florida).

[149] May 2024 Nuttle Report at 17.

[150] *Id.* at 20.

[151] 40 C.F.R. § 1502.15 (explaining that an EIS "shall succinctly describe the environment of the area(s) to be affected…[and] may combine the description with evaluation of the environmental consequences"); 40 C.F.R § 1502.16 (defining environmental consequences as "environmental impacts of the proposed action and reasonable alternatives to the proposed action and the significance of those impacts"); 40 C.F.R § 1502.24 (noting "agencies shall prepare draft environmental impact statements concurrent and integrated with environmental impact analyses and related surveys and studies required by all other Federal environmental review laws"). The Commission has consistently emphasized that Council of Environmental Quality ("CEQ") regulations are entitled to persuasive authority. *Pacific Gas & Elec Co.* (Diablo Canyon Nuclear Power Plant, Units 1 and 2), CLI-11-11, 74 NRC 427, 444 (2011) (noting that under its "longstanding policy" the Commission looks "to CEQ regulations for guidance"). *See also* 10 C.F.R. § 51.53(c)(3)(ii)(E).

opposing viewpoints" and if its decision is "fully informed" and "well-considered."[152] While NEPA "does not require agencies to analyze every conceivable aspect of a proposed project,"[153] the CEQ requires action agencies to look at a proposed project's direct,[154] indirect,[155] and cumulative[156] impacts on the environment.[157]

In addition, ESA and NRC rules require an analysis of the effects of a license renewal on species listed or proposed for listing as endangered or threatened under the ESA to determine whether the license renewal is likely to adversely affect or jeopardize the continued existence of the species.[158]

NRC's 2024 FSEIS fails to meet these NEPA requirements because its analysis is neither fully informed nor well-considered, nor does it adequately examine cumulative impacts. In turn, these inadequacies undermine the FSEIS's conclusions that the proposed license extension will neither adversely affect nor jeopardize the continued existence of the

[152] *Fla. Power & Light Co.* (Turkey Point Units 6 and 7), LBP-17-5, 86 NRC 1, 26 (2017).

[153] *Id.* at 16 (citing *Private Fuel Storage, L.L.C.* (Independent Spent Fuel Storage Installation), CLI-02-25, 56 NRC 340, 349 (2002)).

[154] 40 C.F.R. § 1508.1(g)(1) ("Direct effects, which are caused by the action and occur at the same time and place.").

[155] 40 C.F.R. § 1508.1(g)(2) ("Indirect effects, which are caused by the action and are *later in time or farther removed in distance, but are still reasonably foreseeable*. Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems.") (emphasis added).

[156] 40 C.F.R. § 1508.1(g)(3) ("Cumulative effects, which are effects on the environment that result from the *incremental effects of the action when added to the effects of other past, present, and reasonably foreseeable actions* regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative effects can result from *individually minor but collectively significant* actions taking place over a period of time.") (emphasis added).

[157] *See* 40 C.F.R. § 1508.1(g) (defining the scope of effects to be analyzed under the statute).

[158] 50 C.F.R. § 402.10(a); 10 C.F.R. Part 51, Subpart A, Appendix B.

Miami cave crayfish, and thus its determination that further consultation with the FWS is not required.

### i. The 2024 FSEIS fails to adequately evaluate the effects of salinity on the crayfish and its habitat, by considering only the impact of hypersaline water

The 2024 FSEIS notes that "the *hypersaline plume* does not currently overlap with the endemic range of the Miami cave crayfish" and concludes the crayfish therefore "are unlikely to experience measurable effects from saltwater intrusion."[159] The 2024 FSEIS also appears to arbitrarily expand its conclusion that "based on the results obtained to date, it is likely that, with continued freshening of the CCS *to achieve an average annual CCS salinity of 34 psu or less* . . . the operation of Turkey Point Units 3 and 4 during the SLR term would not worsen the hypersaline groundwater plume outside the plant boundary" to the much broader conclusion that "continued CCS freshening would ensure that water originating from the CCS does not influence the Biscayne Aquifer's saltwater/freshwater interface within the species' range."[160] These statements, coupled with NRC Staff's unsubstantiated assumptions that the hypersaline plume will retract as planned, comprise the extent of the 2024 FSEIS's brief, conclusory statements on the effects of salinity on the Miami cave crayfish.

Importantly, however, the crayfish is susceptible to the effects of water salinity at any level above natural freshwater conditions.[161] Although the species's precise salinity tolerance is unknown, FWS concludes it is "highly unlikely" the crayfish "could sustain reproductively successful populations at salinity measures above those evidenced in the natural freshwater

[159] 2024 FSEIS at 2-67 (emphasis added).

[160] *Id.* (emphasis added).

[161] U.S. Fish & Wildlife Serv., Miami Cave Crayfish Species Status Assessment Version 1.2 (Sept. 20, 2023) at 69 (hereinafter "Status Assessment").

aquifer environments from which they have been collected (i.e., ≤0.45 ppt)."[162] In other words, the crayfish cannot reproduce, and therefore survive, even in brackish groundwater. The Species Status Assessment further states that exposure of crayfish to "salinity levels above those of natural habitats causes inhibition of growth, limited to no reproduction, reduced numbers and death of fertile eggs, lower hatching success, and elevated mortality."[163] According to FWS, even if the crayfish in fact have a much higher salinity tolerance of 18 ppt, the species still would be unable to survive in the salinity levels created by saltwater intrusion into the Biscayne Aquifer.[164]

The 2024 FSEIS makes no reference to the crayfish's likely intolerance to salinity conditions above 0.45 ppt or even 18 ppt, instead focusing only on the fact that the hypersaline plume—water with a salinity of 34 psu[165]—does not overlap with the species's endemic range.[166] This demonstrates a fundamental deficiency in the 2024 FSEIS's analysis and a failure to consider science-based standards for determining harmful impacts, as NRC Staff seemingly give no consideration to the nature of the aquifer, nor to well-documented, publicly available FWS findings that suggest the crayfish cannot tolerate even slightly saline conditions. The 2024 FSEIS also fails to consider the concept of a gradient of salinity throughout the aquifer.

The Staff's singular focus on hypersalinity has caused it to disregard the effects of movements of the standard saltwater/freshwater interface that operation of the CCS will cause

[162] Status Assessment at 69.

[163] *Id.*

[164] Status Assessment at 69.

[165] Practical salinity units or "psu" are the equivalent of parts per thousand (or "ppt"). *NASA Salinity Overview: FAQs*, NASA, *available at* https://salinity.oceansciences.org/overview-faqs.htm#.

[166] 2024 FSEIS at 2-67.

during the license plant operation during the extension period. Moreover, Petitioner establishes in Contention 1-C that water from the CCS in USGS wells near the leading edge of the salt water interface is advancing well beyond the Turkey Point property,[167] and that continued monitoring by Miami-Dade County similarly shows by way of tritium that water from the CCS is advancing significantly off-property. The crayfish's Species Status Assessment discusses the high porosity of the Biscayne Aquifer and its susceptibility to saltwater intrusion, adding that the "line" of saltwater intrusion is actually a gradient that "varies in its extent, concentration, and depth over time and distance."[168] Yet at no point does the 2024 FSEIS examine the impacts of Turkey Point's cooling canal system operations on this gradient. The 2024 FSEIS instead effectively assumes—with no explanation for the assumption—that retracting the hypersaline plume as required by FPL's various consent agreements and permits is sufficient to find the crayfish are "unlikely to experience measurable effects from saltwater intrusion."[169] However, the best available information indicates that the crayfish cannot survive in groundwater significantly less saline—50% to an order of magnitude less saline—than the standard represented by the hypersaline plume.[170]

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[167] Reference Contention 1-C: Measurement of tritium in groundwater by the US Geological Survey documented the presence of water above the 20 picocurie per liter threshold–indicating water from the CCS in wells G-3699 and G-3855, near the leading edge of the salt water interface advancing toward the Newton Wellfield in 2014, as shown in the May 2024 Nuttle Report at page 32, Figure 1 and page 37, Figure 6. Continued monitoring by Miami Dade County of G-3699 and another well, G-3966, in the same area documents by way of tritium that water from the CCS has persisted in the aquifer here, advancing on the Newton Wellfield, even as CCS water has disappeared in areas to the east and southwest, as shown in the May 2024 Nuttle Report at page 38, Figure 7. May 2024 Nuttle Report at page 17.

[168] Status Assessment at 66.

[169] 2024 FSEIS at 2-67.

[170] Status Assessment at 69 (finding it "highly unlikely" that the crayfish could survive salinity levels above 0.45 ppt, and acknowledging that even using a much higher target of 18 ppt, "the species is still not predicted to be able to persist in the saline habitats accompanying saltwater incursion into the Biscayne Aquifer").

The 2024 FSEIS effectively seeks to reuse analyses and conclusions devised for a different proceeding to address a different concern: Florida's and Miami Dade County's enforcement action focused on the hypersaline plume created by the CCS, and the need to ensure that hypersaline plume continues to exist only on FPL's Turkey Point property. But those analyses do not answer the question that NRC Staff must address in the FSEIS: the likelihood, extent, and scope of impacts from the continued operation of Turkey Point's CCS as a result of an increase in the extent and degree of brackish and saline water more generally on the Miami cave crayfish and its Biscayne Aquifer habitat.

#### ii. The 2024 FSEIS fails to adequately evaluate impacts on the Miami cave crayfish by failing to consider the cumulative effects of sea level rise together with the salinizing effects of Turkey Point's CCS operations

The FWS's Listing Proposal for the Miami cave crayfish states: "We have determined that the primary threat to Miami cave crayfish is saltwater intrusion caused by sea level rise as a result of climate change."[171] The FWS's Species Status Assessment for the crayfish further notes a second of two primary drivers of saltwater incursion into the crayfish's habitat in the Biscayne Aquifer: seepage from canal systems.[172] The 2024 FSEIS merely states that the crayfish is threatened by "saltwater intrusion associated with sea level rise," along with a short list of other additional threats, including "groundwater contamination by various anthropogenic sources."[173] It does not discuss whether or how the continued operation of the CCS could interact with sea level rise as a result of climate change, exacerbating the extent,

[171] 88 Fed. Reg. 64856 (Sept. 20, 2023).

[172] Status Assessment at 69.

[173] 2024 FSEIS at 2-63.

scope, or longevity of increased regional salinity, as a result of cumulative impacts on the Miami cave crayfish and its habitat.[174]

As discussed above, the 2024 FSEIS's analysis of groundwater salinity effects on crayfish is mainly limited to the effects of the continued operation of the CCS on the hypersaline plume. This analysis entirely ignores: (1) the much larger volume of saline water exiting the CCS as a function of its operations and related freshening; (2) the destabilizing effects that the continued operation of the CCS as a heat sink may cause on the hydraulic gradient throughout the Model Lands basin; and (3) the advancing line of saltwater intrusion moving from the coast inland into Biscayne Aquifer. The FWS Species Status Assessment for the crayfish shows the approximate extent of saltwater intrusion as already extending into known crayfish habitat.[175] Notably, this approximation is based on 2018 data—the current degree of intrusion may be even greater due to increasing sea level rise.[176]

The existing saltwater intrusion conditions must be considered as a cumulative impact, alongside the effects of Turkey Point's continued CCS operations, on the extent and degree of brackish and saline water in the Miami cave crayfish's Biscayne Aquifer habitat. While the 2024 FSEIS's limited groundwater salinity analysis concludes that impacts to the crayfish will

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[174] *See* 40 C.F.R. § 1508.1(g)(3) ("Cumulative effects, which are effects on the environment that result from the *incremental effects of the action when added to the effects of other past, present, and reasonably foreseeable actions* regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative effects can result from *individually minor but collectively significant* actions taking place over a period of time.") (emphasis added).

[175] Status Assessment at 68.

[176] Sweet et. al., *Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines*, National Oceanic and Atmospheric Administration (February 2022), *available at* https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf, at 2-3 and 61; *see also* Status Assessment at 69 ("The two primary processes driving saltwater incursion into the Biscayne Aquifer along the Atlantic Coastal Ridge are seepage from canal systems and encroachment of saltwater from the ocean[.]") (internal citations omitted).

be negligible, it does not adequately consider the cumulative impacts of continued CCS operations, climate change, and the existing degree of saltwater intrusion in Biscayne Aquifer.

### iii. The 2024 FSEIS's analyses underpinning its conclusion that increased salinity and the hypersaline plume are not likely to adversely affect the Miami cave crayfish are deficient

As discussed above, what little analysis NRC does provide in the 2024 FSEIS is based on the unsubstantiated assumption that the impacts of the hypersaline plume are coextensive with the broader salinizing effects of the CCS. The 2024 FSEIS therefore ignores the cumulative effect of continued operation of the CCS together with the impacts of continued sea level rise on the Biscayne Aquifer. These deficiencies are compounded by NRC Staff's assumption in its discussion of impacts on the Miami cave crayfish that the hypersaline plume will retract as planned.[177] Together, these deficiencies render NRC Staff's determination that Turkey Point's continued operation of the CCS and related elevated salinity in the Biscayne Aquifer is not likely to adversely affect the Miami cave crayfish deficient.[178]

It is worth noting that even the 2024 FSEIS's discussion of the species impacts of the hypersaline plume alone on Miami cave crayfish is deficient because it effectively ignores the uncertainty that NRC Staff concede earlier in the document. In its earlier discussion of the potential effects on the hypersaline plume, the 2024 FSEIS acknowledges that "there is uncertainty regarding the groundwater modeling to the start of the SLR term and . . . there is no groundwater modeling to the end of the SLR term, which precludes the staff from reaching

[177] *See* 2024 FSEIS at 2-67 ("NRC staff concludes that based on the results obtained to date, it is likely that, with continued freshening of the CCS to achieve an average annual CCS salinity of 34 psu or less and continued operation of the RWS to halt and retract the westward migration of the hypersaline plume . . . the operation of Turkey Point Units 3 and 4 during the SLR term would not worsen the hypersaline groundwater plume outside the plant boundary, destabilize the groundwater resource, or adversely affect the beneficial uses of groundwater offsite by existing users"); *see also* discussion *supra* in Contentions 1-A, 1-C.

[178] *See* 2024 FSEIS at 2-67.

a definitive conclusion about the likely extent of the hypersaline plume during the SLR term."[179] Moreover, the 2024 FSEIS includes data highlighting evolving uncertainty about the degree of positive impact of ongoing remediation efforts on the hypersaline plume and suggesting that the plume may be expanding in some layers of the aquifer.[180] In addition, the full extent of the crayfish's range remains somewhat uncertain—sampling for the species has been sparse and much of the data used in the 2024 FSEIS is decades old,[181] and FWS's evaluation of the crayfish's known habitat shows it is highly susceptible to saltwater intrusion from both the hypersaline plume and sea level rise.[182] Though the hypersaline plume does not overlap with areas where crayfish has been found to date, the highest levels of porosity within the Biscayne Aquifer are on the Atlantic Coastal Ridge below 16.4 feet in depth,[183] and "the majority of historical collection sites [for crayfish] record specimens from depths below 16.4

[179] *Id.* at 2-38. Staff brush off this uncertainty by noting "a substantial period of time exists to allow the ongoing (or potentially revised) groundwater remediation activities to improve groundwater quality prior to the start to the SLR term." *Id.*

[180] *See, e.g.*, *id.* at Table 2-5 (charting past and current estimates of plume reduction that shows dramatic decline in estimated plume reduction based on new analyses, and even a reversal in plume reduction in recent years); *id.* at 2-30 ("These figures generally indicate that the hypersaline interface is being retracted closer to the CCS boundary for all three depth horizons. Figure 2-8 illustrates that for the middle horizon, the plume in the area northwest of the CCS may have expanded slightly since 2018.").

[181] *Id.* at 2-63 (noting information drawn in NRC's FSEIS analysis is drawn from FWS's Species Status Assessment and the listing proposal); Status Assessment at 19-22 (describing the historical and current range of the crayfish and citing sampling data from 1968, 1992, 2000-2004, 2009, and 2018).

[182] Status Assessment at 17. The Species Status Assessment states, "When reported, the depths from which Miami cave crayfish have been sampled place them within the Miami Limestone or Fort Thompson Formation [within the Atlantic Coastal Ridge] . . . As elsewhere in Miami-Dade County, the Fort Thompson Formation of the Atlantic Coastal Ridge is marked by interconnected networks of well-developed open cavities in the rock, which are so numerous and large . . . that the formation resembles a sponge." *Id.* Comparison of maps in the FSEIS and Status Assessment show the current hypersaline plume extends into portions of the Atlantic Coastal Ridge. *See* Status Assessment fig. 2.5.4. at 16; FSEIS figs. 2-7, 2-8, 2-9 at 2-31, 2-32, 2-33.

[183] Status Assessment at 18.

feet . . . in the area of maximum porosity on the Atlantic Coastal Ridge."[184] Thus this region in the Aquifer—the most likely habitat for crayfish—is also a region in which the effectiveness of ongoing remediation efforts related to the hypersaline plume appear least effective and most uncertain.[185] And yet there is no discussion of these risks in the section of the FEIS addressing impacts on the Miami cave crayfish.

The 2024 FSEIS fails to assess the impact of this lack of information on its analysis of the likely effects of continued operation of the CCS on the Miami cave crayfish and its conclusion that "the hypersaline plume does not currently overlap with the endemic range of the Miami cave crayfish" and that "required continued CCS freshening would ensure that water originating from the CCS does not influence the Biscayne Aquifer's saltwater/freshwater interface within the species' range."[186] This failure further undermines the NRC Staff's determination that Turkey Point's continued operation of the CCS as a heat sink—and its subsequent hydrologic impacts discussed in Contention 1-C and related elevated salinity in the Biscayne Aquifer—is not likely to adversely affect the Miami cave crayfish.[187]

#### iv. The 2024 FSEIS's conclusion that NRC need not confer with FWS is erroneous

NRC Staff conclude in the 2024 FSEIS that Turkey Point subsequent license renewal "may affect, but is not likely to adversely affect" the Miami cave crayfish.[188] Based on this finding, the 2024 FSEIS states, "NRC is not required to confer with the FWS on the Miami

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[184] *Id.*

[185] *Id.*

[186] 2024 FSEIS at 2-67.

[187] Considering the lack of essential information, the FSEIS cannot be "fully informed." Though action agencies are entitled to discretion in selecting the methodology for their environmental impact analysis, that methodology nevertheless must be reasonable. *See Powertech USA, Inc.* (Dewey-Burdoch in Situ Uranium Recovery Facility), LBP-17-9, 86 NRC 167, 191 (2017) (internal citations omitted).

[188] 2024 FSEIS at 2-67.

cave crayfish for this proposed action."[189] In light of the inadequacy of NRC Staff's evaluation of environmental impacts under NEPA—discussed above—this conclusion is unsubstantiated and erroneous.

The numerous deficiencies in the impact analysis cast serious doubt on the accuracy of NRC's "not likely to adversely affect" finding. Agencies are required to use "the best scientific and commercial data available."[190] While agencies are afforded a great deal of deference in areas related to their technical expertise, the ultimate decision must nevertheless be reasonable and reasonably explained.[191] Further, an agency decision may be arbitrary and capricious where it entirely fails to consider an important aspect of the problem.[192] As described above, NRC Staff has entirely failed to consider several important aspects of impacts to the crayfish, including: the cumulative, compounded impacts of rising sea levels and saltwater intrusion with CCS operations; the gradient, dynamic nature of salinity and groundwater movement within an aquifer, particularly within the high-porosity areas that comprise the crayfish's habitat; and the crayfish's likely sensitivity to any higher-than-fresh levels of salinity (not just hypersaline water).

By failing to examine these important aspects of the problem, NRC Staff's analysis is deficient and therefore its conclusion that it need not confer with the FWS on the Miami cave crayfish for this proposed action is erroneous.

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[189] *Id.*

[190] 16. U.S.C. § 1536(a)(2).

[191] *See Oceana v. Pritzker*, 26 F. Supp. 3d 33, 41 (D.D.C. 2014); *Baltimore Gas & Elec. Co. v. Natural Res. Def. Council, Inc.*, 462 U.S. 87, 103 (1983).

[192] *Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co.*, 463 U.S. 29, 43 (1983).

*3. The issue raised in the contention is within the scope of the proceeding (10 C.F.R. § 203.9(f)(1)(iii))*

NEPA, the ESA, and NRC regulations plainly require the 2024 FSEIS to address the effects of Turkey Point's continued operations on threatened, endangered, and protected species, and to consult with the FWS if a proposed action is likely to jeopardize the existence of a species proposed for listing under the ESA.[193] The effects of the continued operation of Turkey Point's CCS on the Miami cave crayfish are therefore within the scope of this proceeding.

*4. The issue raised in the contention is material to the findings the NRC must make to support the action involved in the proceeding (10 C.F.R. § 2.309(f)(1)(iv))*

A contention is "material" to the NRC's duty to make environmental findings if the issue of law or fact it raises "is of possible significance to the result of the proceeding."[194] Material contentions have "some significant link between the claimed deficiency and either the health and safety of the public or the environment."[195] There is a significant link between the issue raised in this contention—NRC's failure to adequately assess the impacts of Turkey Point's operations on a species proposed to be listed as threatened under the ESA and the resulting unsubstantiated and erroneous conclusion that the proposed license extension will not adversely affect or jeopardize the continued existence of the Miami cave crayfish—and "the health and safety of the public or the environment."[196] NRC regulations require the FSEIS to

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[193] 10 C.F.R. § 51.71 (requiring a DSEIS analyze Category 2 issues); *see also* 10 C.F.R. Part 51, Subpart A, Appendix B (listing "threatened, endangered, and protected species and essential fish habitat" as a Category 2 issue).

[194] *Entergy Nuclear Vt. Yankee L.L.C. & Entergy Nuclear Operations* (Vermont Yankee Nuclear Power Station), LBP-04-28, 60 NRC 548, 556–57 (Nov. 22, 2004).

[195] *Id.*; *see also* 10 C.F.R. § 51.53(c)(3)(ii)(E) ("All license renewal applicants shall assess the impact of . . . continued operations . . . on important plant and animal habitats. Additionally, the applicant shall assess the impact of the proposed action on threatened or endangered species[.]"); *see also* 50 C.F.R. § 402.10(a) (requiring federal agencies to confer with the federal wildlife agencies where actions are "likely to jeopardize the continued existence of any proposed species").

[196] *Id.*

include such an analysis. Each aspect of the contention relates directly to an impact on the environment and, thus, is material to the findings the NRC must make to support relicensing.

5. *Concise statement of the alleged facts or expert opinions which support the petitioner's position on the issue and on which the petitioner intends to rely at hearing (10 C.F.R. § 2.309(f)(1)(v))*

Petitioner has outlined the facts supporting its position above, and provides data and analysis from the 2024 FSEIS, the FWS Species Status Assessment for the Miami cave crayfish,[197] and the report of Petitioner's expert, Dr. William Nuttle.[198]

6. *A genuine dispute exists with the applicant on a material issue of law or fact (10 C.F.R. § 2.309(f)(1)(vi))*

As explained above, Petitioner takes issue with NRC's inadequate analysis of Turkey Point's continued CCS operation's impacts on the Miami cave crayfish. Specifically, Petitioner finds NRC Staff's environmental impact analysis deficient under the requirements of NEPA and their determinations that the license extension will not adversely affect or jeopardize the continued existence of the Miami cave crayfish deficient and erroneous under the ESA and NRC rules.

**B. New Contentions 3-A and 3-B**

***CONTENTION 3-A:*** ***THE 2024 FSEIS FAILS TO ADEQUATELY ANALYZE CLIMATE CHANGE-RELATED ENVIRONMENTAL IMPACTS THAT ARE REASONABLY FORESEEABLE TO OCCUR DURING THE SUBSEQUENT LICENSE RENEWAL PERIOD.***

***CONTENTION 3-B:*** ***THE 2024 FSEIS FAILS TO ADEQUATELY UPDATE ITS EVALUATION OF FPL'S SAMA ANALYSIS TO REFLECT THE EFFECTS OF CLIMATE CHANGE ON ACCIDENT RISK.***

[197] U.S. Fish & Wildlife Serv., Miami Cave Crayfish Species Status Assessment Version 1.2 (Sept. 20, 2023).

[198] May 2024 Nuttle Report.

**1. Petitioner satisfies the "good cause" standard for Contentions 3-A and 3-B.**

*1. The information upon which the filing is based was not previously available*

The U.S. Government Accountability Office Report, GAO-24-106326 ("GAO Report" or "the report"), upon which Petitioner relies, was not available until April 2, 2024.[199] Petitioner filed its Petition to Intervene on November 27, 2023[200] and its Reply Brief on January 8, 2024.[201] The GAO Report was not available at the time of Petitioner's Petition or Reply Brief.

*2. The information upon which the filing is based is materially different from information previously available*

Information is "materially different" "[u]nless it looks genuinely plausible that inclusion of an additional factor or use of other assumptions and models may change the cost-benefit conclusions."[202] Materiality in this context "relates to the magnitude of the difference between the previously available information and currently available information."[203]

The GAO Report satisfies the "materially different" requirement because it provides information showing that it is genuinely plausible that consideration of the climate risks and associated environmental impacts identified in the report would change the NRC Staff's conclusions regarding climate change-related environmental impacts. The GAO Report establishes facts that are materially different from the information previously available in

[199] U.S. Government Accountability Office, Nuclear Power Plants: NRC Should Take Actions to Fully Consider the Potential Effects of Climate Change, GAO-24-106326 (Apr. 2, 2024), *available at* https://www.gao.gov/assets/d24106326.pdf (hereinafter "GAO Report").

[200] Miami Waterkeeper Request for Hearing and Petition to Intervene, ADAMS Accession No. ML23331A971 (Nov. 27, 2023).

[201] Reply in Support of Request for Hearing and Petition to Intervene Submitted by Miami Waterkeeper, ADAMS Accession No. ML24008A293 (Jan. 8, 2024).

[202] *See DTE Electric Co.* (Fermi Nuclear Power Plant, Unit 2), LBP-17-1, 85 NRC at 4 (Jan. 10, 2017).

[203] *S. Nuclear Operating Co.* (Vogtle Elec. Generating Plant, Units 3 & 4), LBP-10-01, 71 NRC 165, 183 n.9 (2010).

several ways. The report provides a first-of-its-kind independent assessment of the NRC's need to consider climate-related impacts in relicensing decisions. It contains novel analysis of the effects of climate change on nuclear reactors. It also contains site-specific analysis based on interviews and a site visit to the Turkey Point plant, and conclusions about the specific vulnerability of this plant to climate change.

Contention 3-A also challenges the adequacy of new climate change-related analysis in the 2024 FSEIS that was not available in the 2023 DSEIS.[204]

*3. The filing has been submitted in a timely fashion based on the availability of the subsequent information*

Petitioner submits this contention within a reasonable period after the information on which it is based became available. The Board's April 26, 2024 Memorandum and Order Granting Motion for Extension of Time established a May 8, 2024 deadline for filing of contentions based on the April 2, 2024 GAO Report.[205]

**2. Petitioner satisfies the criteria for admissibility for Contentions 3-A and 3-B.**

Petitioner addresses the admissibility criteria for each sub-contention in turn, beginning with Contention 3-A.

***CONTENTION 3-A:*** ***THE 2024 FSEIS FAILS TO ADEQUATELY ANALYZE CLIMATE CHANGE-RELATED ENVIRONMENTAL IMPACTS THAT ARE REASONABLY FORESEEABLE TO OCCUR DURING THE SUBSEQUENT LICENSE RENEWAL PERIOD.***

In addition to satisfying the "good cause" standard, Petitioner's Contention 3-A meets all six criteria for admissibility as established by 10 C.F.R. § 2.309(f)(1).

[204] 2024 FSEIS at 2-25–240; A-54, E-9–E-11.

[205] Atomic Safety and Licensing Board Panel Memorandum and Order (Granting Motion for Extension of Time), ADAMS Accession No. ML24117A266 (Apr. 26, 2024).

1. *Statement of the issue of law or fact to be raised or controverted (10 C.F.R. § 2.309(f)(1)(i))*

The 2024 FSEIS fails to comply with 10 C.F.R. § 51.71(d) because it does not adequately address the cumulative effects on the environment of operating Units 3 and 4 through the subsequent license extension period. NEPA and NRC's regulations[206] require the FSEIS to include an analysis of the environmental impacts, including any cumulative effects, of the proposed action—here, the impacts of continuing to operate the plant during the 20-year license renewal period.[207] NRC Staff has acknowledged that an EIS should contain a discussion of "the incremental potential environmental impacts of license renewal, including the impacts of climate change during the license renewal period."[208] Cumulative effects are those effects on the environment that result from the incremental effects of the action when added to the effects of other past, present, and reasonably foreseeable actions.[209] The cumulative impacts analysis must account for climate change, including rising sea levels, hurricanes, a hotter climate, and drought.[210] The goal is to identify any "potentially significant

[206] On March 3, 2023, the NRC published a draft rule proposing to amend 10 C.F.R. Part 51 and update the NRC's findings concerning the environmental impacts of renewing the operating license of a nuclear power plant during subsequent license reviews. Renewing Nuclear Power Plant Operating Licenses-Environmental Review, 88 Fed. Reg. 13,329 (Mar. 3, 2023). The proposed rule would add new Category 2 issues to Table B-1, including "climate change impacts on environmental resources." *Id.* at 13,345. The regulatory history of the proposed rule demonstrates that it is a reflection of the Commission's orders in CLI-22–02 and CLI-22-03. *See* Petitioner's Reply Brief at 50-53.

[207] 10 C.F.R. § 51.71(d) ("[T]he draft environmental impact statement will include a preliminary analysis that considers and weighs the environmental effects, including any cumulative effects, of the proposed action[.]"); 10 C.F.R. Pt. 51, Subpt. A, App. B ("Cumulative impacts of continued operations and refurbishment associated with license renewal must be considered on a plant-specific basis. Impacts would depend on regional resource characteristics, the resource-specific impacts of license renewal, and the cumulative significance of other factors affecting the resource.").

[208] NRC Staff's Corrected Response to Petitions to Intervene and Requests for Hearing Filed By (1) Friends of The Earth, Natural Resources Defense Council and Miami Waterkeeper, and (2) Southern Alliance for Clean Energy, ADAMS Accession No. ML18239A458, (Aug. 27, 2018), at 47.

[209] 40 C.F.R. § 1508.1(g)(3).

[210] NUREG 1437, Volume 1 Revision 2, Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, Final Report, ADAMS Accession No. ML23201A224 (Feb. 2024),

impacts" of these cumulative effects.[211] The Commission has ordered NRC Staff to update its regulations to ensure that its evaluation of environmental impacts is "thorough."[212] CEQ guidance, which is entitled to persuasive authority for the NRC,[213] advises agencies to "use the best available information and science when assessing the potential future state of the affected environment in NEPA analyses and providing up-to-date examples of existing sources of scientific information."[214] A failure to take a hard look at cumulative impacts, including those from climate change, violates the NRC's NEPA regulations and, thus, NEPA.

The GAO Report concludes that the effects of climate change, including reasonably foreseeable increases in sea level and air temperature, may have significant adverse impacts on the continued operation of Units 3 and 4. The report further details a number of related environmental impacts that are reasonably foreseeable if FPL continues to operate the plant

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(hereinafter "2024 LR GEIS"), at 4-146. NRC Staff has acknowledged that a hard look should "[i]ncorporate lessons learned and knowledge gained related to environmental issues from ongoing subsequent license renewal reviews (i.e., groundwater quality degradation and threatened, endangered, and protected species of essential fish habitat))." NRC, Rulemaking Plan for Renewing Nuclear Power Plant Operating Licenses— Environmental Review (Rin 3150-Ak32; NRC-2018-0296), SECY-22-0024, ADAMS Accession No. ML22062B643 (Mar. 25, 2022), at 4 (emphasis added). *See also* NRC, Proposed Rule: Renewing Nuclear Power Plant Operating Licenses—Environmental Review (RIN 3150-AK32; NRC-2018-0296), SECY-22-0109, ADAMS Accession No. ML22165A004 (Dec. 6, 2022)

[211] 2024 LR GEIS Report at 4-146.

[212] NRC, Staff Requirements – SECY-21-0066 – Rulemaking Plan for Renewing Nuclear Power Plant Operating Licenses – Environmental Review (RIN 3150 AK32; NRC 2018 0296), ADAMS Accession No. ML22053A308 (Feb. 24, 2022); Renewing Nuclear Power Plant Operating Licenses: Environmental Review, 88 Fed. Reg. 13329 (Mar. 3, 2023) ("Revisions were made to ensure a "thorough" evaluation of the environmental impacts.").

[213] NRC, Rulemaking Plan for Renewing Nuclear Power Plant Operating Licenses—Environmental Review (RIN 3150-AK32; NRC-2018-0296), SECY-22-0024, ADAMS Accession No. ML22062B643, (Mar. 25, 2022), at 4 (emphasis added) (citing *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 350 (1989); *Great Basin Resource Watch v. BLM*, 844 F.3d 1095, 1101 (9th Cir. 2016); *Pacific Gas & Elec Co.* (Diablo Canyon Nuclear Power Plant, Units 1 and 2), CLI-11-11, 74 NRC 427, 444 (2011) (noting that under its "longstanding policy" the Commission looks "to CEQ regulations for guidance").

[214] National Environmental Policy Act Guidance on Consideration of Greenhouse Gas Emissions and Climate Change, 88 Fed. Reg. 1196, 1198 (Jan. 9, 2023).

into the 2050s as sea level rise, flooding, hurricanes, increased temperatures, and droughts worsen due to climate change. In light of this new information, the discussion of "Climate Change Impacts on Environmental Resources" on pages E-8–E-11 of the 2024 FSEIS is inadequate and does not satisfy NEPA.

*2. Brief explanation of the basis for the contention (10 C.F.R. § 2.309(f)(1)(ii))*

GAO's mission is "to provide Congress with fact-based, nonpartisan information that can help improve federal government performance and ensure accountability for the benefit of the American people."[215] In response to a Congressional request to "review the climate resilience of energy infrastructures," the GAO prepared a report titled "Nuclear Power Plants: NRC Should Take Actions to Fully Consider the Potential Effects of Climate Change."[216] The report examines: "(1) how climate change is expected to affect nuclear power plants and (2) what actions NRC has taken to address the risks to nuclear power plants from climate change."[217] The report concludes that "NRC's actions to address risks from natural hazards do not fully consider potential climate change effects."[218]

The GAO Report found that Turkey Point faces a number of interconnected risks: storm surges from more frequent and intense Category 4 and 5 hurricanes, high flood hazard, record-breaking temperatures, and drought.[219] The report identified Turkey Point as among the most vulnerable plants in the country to flood risk due to sea level rise and hurricane storm

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[215] U.S. Government Accountability Office, *About GAO's WatchBlog*, *available at* https://www.gao.gov/blog/about#:~:text=GAO's%20mission%20is%20to%20provide,benefit%20of%20the%20American%20people (last visited May 8, 2024).

[216] GAO Report at "GAO Highlights."

[217] *Id.*

[218] *Id.* The GAO Report states that "NRC officials GAO interviewed said they believe their current processes provide an adequate margin of safety to address climate risks. However, NRC has not conducted an assessment to demonstrate that this is the case." *Id.*

[219] GAO Report at 18.

surges—which the report predicts will intensify in the coming decades.[220] The GAO Report therefore confirms that the climate change-related impacts are reasonably foreseeable to be significant during Turkey Point's subsequent license renewal period. Petitioner discusses these risks and their corresponding environmental impacts in turn.

**i. Flooding risk increased by sea level rise and intensifying hurricanes**

The 2024 FSEIS fails to adequately address the cumulative impacts of operating the Turkey Point plant into the 2050s given the heightened risk of flooding.

The GAO Report found that "[s]ea level rise could affect nuclear power plants by contributing to greater storm surges and flooding."[221] The report's analysis specifically found that Turkey Point plant is located in a high flood hazard area.[222] The report also found that Turkey Point is one of six plants located in an area with exposure to Category 4 and 5 hurricanes.[223] The report further explained that climate change is projected to make hurricanes more frequent and powerful:

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[220] *Id.* at 18.

[221] *Id.* at 22.

[222] *Id.* at 19. n.26. The report explains that GAO staff "analyzed Federal Emergency Management Agency data from 2023. For our analysis, high flood hazard corresponds to areas in 100-year floodplains (areas with a 1 percent or higher annual chance of flooding), moderate flood hazard corresponds to areas in 500-year floodplains (areas with a 0.2 percent or higher annual chance of flooding), and no/low corresponds to areas with minimal, unknown, or other flood hazards, including areas with reduced risk because of levees as well as areas with flood hazard based on future conditions, such as the future implementation of land-use plans." *Id.*

[223] *Id.* at 21 n.28 ("Our analysis of NOAA storm surge data is based on a model that estimates the maximum extent of storm surge at high tide. NOAA provides estimates of hurricane storm surge using a model called Sea, Lake, and Overland Surges from Hurricanes. This model includes hypothetical hurricanes under different storm conditions, such as landfall location, trajectory, and forward speed. Hurricanes reaching Category 3 and higher are considered major hurricanes because of the potential for significant loss of life and damage. In our analysis, we used the maximum extent of storm surge from Category 1 hurricanes (the lowest possible category) and Category 5 hurricanes (the highest possible category) to show a range of potential climate change effects. Category 4 hurricanes carry sustained winds of 130–156 miles per hour. Category 5 hurricanes have sustained winds exceeding 156 miles per hour.").

> Climate change leads to warmer ocean surface temperatures. This, in turn, makes hurricanes more powerful because the temperature increase causes more water to evaporate from the ocean. Evaporation adds moisture to the air, and warmer air temperatures can hold more water vapor. The increased moisture in the air leads to more intense rainfall. In a hurricane, spiraling winds draw moist air toward the center, fueling the thunderstorms that surround it.[224]

The GAO Report therefore categorizes the Turkey Point plant as high risk for hurricane storm surges.[225]

NEPA does not require that an outcome be certain to occur in order to mandate that an agency consider its impacts. Instead, NEPA mandates consideration of all "reasonably foreseeable environmental impacts."[226] The GAO Report provides myriad information demonstrating the reasonably foreseeable risk of overtopping of the Turkey Point CCS—which falls into the highest risk categories for both flood hazard level and hurricane storm surge risk.[227] The GAO Report found that in addition to facing 0.9 to 1.6 feet of sea level rise in the coming 25 years alone, the Turkey Point plant was at a high flood risk and high risk of storm surge, especially as climate change renders hurricanes more powerful that release greater quantities of rain.[228] While the reactors are elevated 22 feet,[229] the CCS itself is at sea level and

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[224] *Id.* at 21 n.30.

[225] *Id.* at 22, 55 ("To determine if a plant exists in an area with exposure to hurricane storm surge, we identified overlap between a 0.5-mile radius around nuclear power plant coordinates provided by the Nuclear Regulatory Commission and storm surge data. Overlap indicates that a facility is located in an area that may be affected by the selected hazard. *See* Appendix I for more details on our data analysis. To show exposure to hurricane storm surge, we use the National Oceanic and Atmospheric Administration's Sea, Lake, and Overland Surges from Hurricanes Model, which estimates storm surge heights resulting from the various categories of hurricanes. This analysis does not account for any protective measures plants may have taken to mitigate the risk of selected natural hazards.").

[226] *In the Matter of Pa'ina Hawaii, LLC*, CLI-10-18, 72 NRC 56 (2010).

[227] GAO Report at 23, 55.

[228] *Id.* at 21 n.30.

[229] FPL Turkey Point Units 3 & 4 Fact Sheet, *available at* https://www.fpl.com/content/dam/fplgp/us/en/clean-energy/pdf/turkey-point-factsheet.pdf (last visited May 6, 2024).

sits on the shore of Biscayne Bay.[230] The canals are only 1-3 feet deep[231] and are protected by perimeter berms that vary in height from 4 to 10 feet.[232] In the event of a storm surge, it is reasonably foreseeable that the canals would be overtopped or breached. Overtopping would mean that the surface waters of the cooling canal will flow into Biscayne Bay National Park, carrying with it thermal pollution, and high levels of tritium, phosphorus, and salt-concentrated waters. The risk of overtopping is not merely hypothetical—in 2017, Hurricane Irma's storm surge overtopped the protective berm that surrounds the CCS.[233]

The GAO Report therefore contains portions of the site-specific analysis of climate change-related impacts that Petitioner has been urging NRC Staff to complete since 2018[234]—and NRC Staff must consider this information in order to provide adequate analysis under NEPA.

The 2024 FSEIS's current analysis of these issues is deficient. The FSEIS does not adequately consider the cumulative effects of increased flooding due to climate change, which the GAO Report demonstrates is reasonably foreseeable. At the urging of Petitioner,[235] NRC Staff revised Appendix E to acknowledge current sea level rise projections.[236] Yet this discussion is cursory: NRC Staff briefly describes the Fifth National Climate Assessment and

[230] NUREG-1437 Supplement 5, Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 5, Regarding Turkey Points Units 3 and 4, Final Report, ADAMS Accession No. ML020280119 (Jan. 2002), at 2-1.

[231] *Id.* at 2-7.

[232] 2019 FSEIS at 3-8.

[233] May 2024 Nuttle Report at 21.

[234] Request for Hearing and Petition to Intervene Submitted by Friends of the Earth, Natural Resources Defense Council, and Miami Waterkeeper, ADAMS Accession No. ML18213A418 (August 1, 2018), at 31-57.

[235] 2023 Miami Waterkeeper Petition at 50-52.

[236] 2024 FSEIS at A-54, E-9–E-11.

the Interagency Sea Level Rise Scenario Tool and notes that these projections "vary from that discussed and presented in the 2019 FSEIS." NRC Staff then summarily concludes that these projections do "not paint a seriously different picture from what was considered in the 2019 FSEIS"—without explaining how they reached this conclusion or whether they conducted any site-specific analyses using this data.[237] Thus, although the 2024 FSEIS acknowledges that "[t]he Fifth National Climate Assessment reports that sea level rise will continue to cause permanent inundation and an increase in the severity of E-10 coastal flooding"[238]—an alarming prediction—it does not consider the cumulative effects of such events or analyze the impacts of overtopping the Unit 3 and 4 cooling canal system.[239] The discussion of cumulative impacts in Section 4.16 of the 2019 FSEIS, upon which the 2024 FSEIS relies, is inadequate for the same reasons.[240]

The 2024 FSEIS's analysis of the effects of intensifying hurricanes on the environmental impacts of continued operation is similarly lacking. The FSEIS briefly summarizes recent reports on climate change, which explain that "hurricanes have been intensifying more rapidly and causing heavier rainfall and high storm surges."[241] Yet this marks the end of the 2024 FSEIS's discussion of hurricane-related environmental impacts,[242]

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[237] *Id. See also id.* at A-37 ("[T]he information used in the 2019 FSEIS was reasonable and that applying the new information would not lead to the staff making a different finding regarding the environmental impacts of the proposed continued operation of Turkey Point during the SLR term."); *id.* at A-53 ("[T]he staff identified no new information related to cumulative impacts on water resources (including impacts from climate change) that would change the conclusions reached in the FEIS.").

[238] *Id.* at E-9–E-10.

[239] *Id.* at E-8–E-11.

[240] *See* 2019 FSEIS at 4-125 to 4-143.

[241] 2024 FSEIS at E-10.

[242] *Id.* at 2-44 mentions the term "storm surge" but does not discuss their specific effects. The 2024 FSEIS A-26 mentions storm surges in the context of crocodile habitat.

despite a number of comments urging NRC Staff to seriously consider the effects of hurricanes and associated storm surges.[243]

Nor is NRC Staff's NEPA burden satisfied by the allegedly "extensive" discussion of climate change impacts on groundwater in the 2019 FSEIS.[244] Commission orders CLI-22-02 and CLI-22-03 found that the 2019 FSEIS did not adequately analyze environmental impacts on a site-specific basis and ordered NRC Staff to draft the 2024 FSEIS to cure those very deficiencies.[245]

The novel, site-specific analysis provided by the GAO Report constitutes the exact sort of analysis that NRC Staff ought to undertake—and demonstrates why the 2024 FSEIS's discussion of these issues is inadequate, given the significant environmental risks that intensifying hurricanes and the associated flooding pose.

**ii. Hurricanes**

The 2024 FSEIS fails to adequately address the hurricane-related impacts of operating the Turkey Point plant into the 2050s. According to the GAO Report, hurricanes not only increase flood and storm surge risks—they also increase the risk of a nuclear release. The report warns that "[h]igh winds from hurricanes can generate projectiles capable of damaging parts of nuclear power plants and electricity transmission lines that provide nuclear power plants with power."[246] The report further explains that:

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[243] For example, EPA urged NRC Staff to "provide a more detailed description of climate models used for determining storm surge and flooding." 2024 FSEIS at A-28. *See also id.* at A-50–52 (Petitioner's comments regarding storm surges).

[244] *See* 2024 FSEIS at A-53.

[245] Commission Memorandum and Order, CLI-22-02 (Feb. 24, 2022); Commission Memorandum and Order, CLI-22-03 (Feb. 24, 2022).

[246] GAO Report at 20.

> [T]he loss of power and ability to pump cooling water can have a significant adverse impact on a plant's ability to safely shut down and maintain safe shutdown conditions. This could result in damage to a reactor's core and **potentially release radiological material into the environment**.[247]

The likelihood of widespread power outages affecting nuclear plants is projected to increase as climate change destabilizes the electricity grid.[248] A release of radiological material would endanger public safety and damage the environment.[249]

As discussed above, the 2024 FSEIS's analysis of the effects of intensifying hurricanes on the environmental impacts of continued operation is deficient. The FSEIS briefly summarizes recent reports on climate change, which explain that "hurricanes have been intensifying more rapidly and causing heavier rainfall and high storm surges,"[250] but provides no further analysis hurricane-related environmental impacts.[251]

### iii. Rising temperatures and drought

The 2024 FSEIS fails to adequately address the temperature and drought-related impacts of operating the Turkey Point plant into the 2050s. The GAO Report explains that "the effects of climate change on maximum temperatures are projected to be most severe in the South[.]"[252] The report finds that Turkey Point is particularly vulnerable to rising temperatures.

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[247] *Id.* at 9 (emphasis added).

[248] *Id.* at 8 n.11 ([C]limate change is expected to affect every aspect of the electricity grid—from generation, transmission, and distribution, to demand for electricity. We found that power outages can have significant cascading effects on critical sectors and electric service disruptions can significantly affect the reliability of other parts of the energy sector. These losses are of special concern because outages caused by climate effects can be widespread and affect large geographic areas all at once[.]") (citing Department of Energy. GAO, Electricity Grid Resilience: Climate Change Is Expected to Have Far-Reaching Effects and DOE and FERC Should Take Actions, GAO-21-346 (Washington, D.C.: March 5, 2021)).

[249] *Id.* at 9 (emphasis added).

[250] 2024 FSEIS at E-10.

[251] *Id.* at 2-44 mentions the term "storm surge" but does not discuss their specific effects. The 2024 FSEIS at A-26 mentions storm surges in the context of crocodile habitat.

[252] GAO Report at 15.

It projects that maximum daily temperatures at the plant will increase 2.91 to 3.75°F between 2036-2065, and predicts that the maximum temperature at the plant will exceed historic levels 54 to 80 days annually.[253]

The GAO Report warns that these rising temperatures could exacerbate the risk of saltwater intrusion contaminating local drinking aquifers. Based on interviews with Turkey Point personnel and a review of NRC documents, the GAO finds that:

> High temperatures and drought conditions at Turkey Point Nuclear Generating Station potentially created risks to local drinking water sources when decreased water levels and increased evaporation rates led to higher salinity in the cooling canals. Higher salinity levels made the water denser, causing it to sink below the canals that contain it. This could have led to intrusion of higher salinity water into the areas of the Biscayne Aquifer, a source of drinking water for the Miami-Dade area.[254]

The report further explains that sea level rise could exacerbate saltwater intrusion into both cooling canals and drinking aquifers, especially during dry periods.[255] According to NOAA officials, "Turkey Point Nuclear Generating Station is an example of a plant where, if unaddressed, sea level rise could lead to saltwater intrusion into the plant's cooling canals."[256] The report notes that "saltwater intrusion into groundwater aquifers can degrade the quality of groundwater used for potable and service water at nuclear power plants."[257] Thus, whereas the Board previously dismissed Petitioner's concerns regarding the effects of rising temperatures, citing a lack of evidence that the rising temperature would increase salinity levels to the extent

[253] *Id.* at 55.

[254] *Id.* at 15. The report also noted that "higher than-usual ambient air temperatures may increase the temperature of water used for cooling." *Id.* at 14.

[255] *Id.* at 23.

[256] *Id.* at 23 n.31.

[257] *Id.* at 23 n.34 (citing NRC's Generic Environmental Impact Statement for License Renewal of Nuclear Plants).

that would affect the environment,[258] the GAO Report has specifically warned that such impacts are reasonably foreseeable.[259]

It follows that, as temperatures rise, water will evaporate more quickly. Evaporation of CCS water removes waste heat produced by the power plants, and in doing so, concentrates dissolved salts in the water. As the main source of water into the CCS is rainfall, drought only exacerbates this problem. For example, in 2014 and 2015, South Florida experienced a drought and the salinity levels reached approximately 90 psu.[260]

Unusually high temperatures and salinity in the CCS have already triggered emergency actions. In 2014, an uprate increased the plant's power-generating capacity.[261] This correlated to increasing water temperatures in the CCS.[262] Concerns regarding the unusually high temperatures and salinity in the CCS reached a flashpoint following the uprate: in August 2014, the plant operator reduced power at Turkey Point Units 3 and 4 due to excessive heat sink temperature in the CCS.[263] Likewise, the South Florida Water Management District issued an emergency order approving the use of water from the nearby L-31E canal to freshen the CCS.[264] Following the emergency order, the District approved a separate authorization in 2015

[258] March 7, 2024 Board Order at 28-29.

[259] GAO Report at 15, 23.

[260] 2019 FSEIS at 3-56.

[261] David Chin, *The Cooling Canal System at the FPL Turkey Point Power Station* (2016), *available at* https://www.miamidade.gov/environment/library/reports/cooling-canal-system-at-the-fpl-turkey-point-power-station.pdf, at 1.

[262] *Id.*

[263] NUREG-1437, Volume 1, Revision 2 GEIS - Draft Report for Comment, February 2023, at 3-42.

[264] Miami Dade County, *Report on Recent Biscayne Bay Water Quality Observations associated with Florida Power and Light Turkey Point Cooling Canal System Operations* (Mar. 7, 2016), at 4.

to allow the plant operator to pump up to 18,300 million gallons annually (up to 100 million gallons per day) of L-31E fresh water into the CCS.[265]

In order to comply with the state Consent Order, FPL currently draws water from the Upper Floridan Aquifer in order to dilute and freshen the CCS water. In 2021, FPL more than doubled its allotment of Upper Floridian in order to comply with the 34 psu limit set by the state's 2016 Consent Order.[266] These freshening activities increase the volume of water in the unlined CCS—and therefore the amount of water that leaches into the ground and toward the drinking aquifer.

If temperatures continue to increase at Turkey Point and droughts become more frequent[267]—as the GAO Report predicts they will[268]—FPL would need to withdraw even more Upper Floridan Aquifer Water to cool and maintain its legally-mandated 34 PSU salinity limit. The GAO Report therefore demonstrates that it is reasonably foreseeable that higher temperatures and drought will increase evaporation in the CCS to an extent that would increase the CCS salinity to a level that would affect the environment.

In light of the information provided by the GAO Report, it is clear that the 2024 FSEIS fails to adequately consider the cumulative impacts of rising temperatures and drought. The discussion of rising temperatures and CCS evaporation in the 2024 FSEIS is cursory and general. The FSEIS states generally that a variety of factors, including air temperature and precipitation, affect the CCS temperature.[269] NRC Staff briefly describes FPL's efforts to

[265] SFWMD Permit No. 13-05856-W (June 1, 2015).

[266] 2024 FSEIS at 2-23, 2-26.

[267] The CCS and surrounding environment are already experiencing the effects of these rising temperatures. In 2014, FPL requested and received emergency permission to increase the CCS's running temperature by 4°F due to elevated temperatures. Miami Waterkeeper 2023 Petition at 57-59.

[268] GAO Report at 16, 35, 40.

[269] 2024 FSEIS at 2-24, 2-44.

improve water quality and thermal conditions, although it does not mention salinity levels or evaporation.[270] NRC Staff acknowledges the "increases include total dissolved solids (TDS) primarily due to water losses to evaporation."[271] Section 2.8.3.1 adds new discussion regarding FPL's salinity management program, which was not included in the 2023 DSEIS.[272] The new analysis notes that in 2021 FPL's Upper Floridian Aquifer allocation was increased "to manage larger rainfall/evaporation deficits"[273] The NRC Staff acknowledges that droughts have affected the CCS in the past, [274]and that "the CCS, partially through the continued operation of Turkey Point Units 3 and 4, may potentially influence the extent of the hypersaline groundwater plume due to changes in CCS seepage, particularly if CCS salinity levels are higher than 34 psu."[275] Yet NRC Staff does not discuss how rising temperatures and drought caused by climate change will affect groundwater quality and to what extent.[276] The 2024 FSEIS's analysis therefore remains inadequate.

In its comments on GAO's draft report, NRC Staff stated that the agency's mission "is focused on nuclear safety; as such, we cannot impose requirements that would increase energy resilience or require consideration of potential future climate impacts without a sufficient

[270] *Id.* at 2-43–2-45.

[271] *Id.* at 2-24.

[272] *Id.* 2-25–2-40.

[273] *Id.* at 2-26. The 2024 FSEIS also briefly discusses salinity and temperature in the context of eutrophication and fish disease and mentions how changing temperature can affect aquatic organisms. *Id.* at 2-52–2-55.

[274] *Id.* at 2-22 ("Although FPL initially believed that the freshening actions that it had taken were effective in moderating CCS salinity, it later determined that additional freshening was needed to replace evaporative losses during drought periods and to achieve and maintain an average annual salinity at or below 34 practical salinity units (psu), as required by the 2016 FDEP Consent Order.").

[275] *Id.* at 2-28.

[276] *Id.*

nuclear safety justification."[277] This is a troubling misstatement of NRC's mission, which explicitly includes protecting public health and the environment.[278] Nuclear safety, public health, and environmental protection go hand in hand. Regardless, NEPA and NRC regulations require the agency to take a hard look at the environmental impacts of continued plant operation, including climate-change related impacts. Yet, as explained above, NRC Staff has failed to do so here.

*3. The issue raised in the contention is within the scope of the proceeding (10 C.F.R. § 2.309(f)(1)(iii))*

In its March 2024 order, the Board found that all five of Petitioner's proposed contentions were within the scope of the proceeding. The Board explained that:

> In both form and substance, Miami Waterkeeper bases its contentions on the Draft SEIS. Although Miami Waterkeeper references documents and repeats arguments that pre-date the Draft SEIS, Miami Waterkeeper makes clear that it remains unsatisfied with the Staff's treatment of these issues in the Draft SEIS.[279]

The scope of the current NRC proceeding with respect to environmental issues is established by 10 C.F.R. Part 51, which requires the NRC Staff to weigh all environmental effects of the proposed action in this proceeding.[280] Contention 3-A, which asserts that NRC Staff failed to adequately consider the cumulative climate change-related environmental impacts of continuing to operate the plant into the 2050s, is well within the scope of this proceeding.

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[277] GAO Report at 65.

[278] Nuclear Regulatory Commission, *About NRC*, *available at* https://www.nrc.gov/about-nrc.html (last updated May 1, 2024) ("The U.S. Nuclear Regulatory Commission (NRC) was created as an independent agency by Congress in 1974 to ensure the safe use of radioactive materials for beneficial civilian purposes while protecting people and the environment.").

[279] March 7, 2024 Board Order at 14-15.

[280] 10 C.F.R. §§ 51.71 n.3, 51.94. *See also* 10 C.F.R. §§ 51.21, 51.70-72, 51.92, 51.94, 51.104.

*4. The issue raised in the contention is material to the findings the NRC must make to support the action that is involved in the proceeding (10 C.F.R. § 2.309(f)(1)(iv))*

Contention 3-A is "material" to the findings the NRC must make. A "material" issue is one that would make a difference in the outcome of the proceeding.[281] "This means that there should be some significant link between the claimed deficiency and either the health and safety of the public or the environment."[282]

The GAO Report shows that climate change will exacerbate a number of issues that NRC Staff has previously assessed (albeit in a cursory manner). This new, independent analysis, far from "fine-tuning" existing information in the FSEIS,[283] could alter the outcome of the proceeding. The GAO Report, which is the product of congressional inquiry and years of expert analysis, represents the type of "significant new information" that could "change the NRC staff's conclusions concerning Category 2 issues (specific to individual nuclear power plants) in the FSEIS."[284] Were NRC Staff to take a hard look at the information provided in the GAO Report regarding the environmental impacts of continued plant operating as flooding increases and temperatures rise, it might agree with the GAO Report's findings that these impacts are reasonably foreseeable to be significant. Given the NRC's mandate to protect public health and safety and the environment, NRC might decide to deny the license renewal or impose operating conditions that would mitigate these impacts.

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[281] *In the Matter of Entergy Nuclear Vermont Yankee, LLC & Entergy Nuclear Operations, Inc.* (Vermont Yankee Nuclear Power Station), 64 NRC 131, 149 (Sept. 22, 2006).

[282] *Id.*

[283] *See* March 7, 2024 Board Order at 27.

[284] 2024 FSEIS at E-1.

5. *Concise statement of the alleged facts or expert opinions which support the petitioner's position on the issue and on which the petitioner intends to rely at hearing (10 C.F.R. § 2.309(f)(1)(v))*

Petitioner has outlined the facts supporting our position above. In support of Contention 3-A, Petitioner attaches the GAO Report.

6. *A genuine dispute exists with the applicant on a material issue of law or fact (10 C.F.R. § 2.309(f)(1)(vi))*

Contention 3-A also demonstrates sufficient information to show that a genuine dispute exists with the Applicant on a material issue of law or fact. NRC set forth factors relevant to determining if a genuine dispute exists when it adopted the current version of 10 C.F.R. § 2.309(f)(1):

> This will require the intervenor to read the pertinent portions of the license application, including the Safety Analysis Report and the Environmental Report, state the applicant's position and the petitioner's opposing view. Where the intervenor believes the application and supporting material do not address a relevant matter, it will be sufficient for the intervenor to explain why the application is deficient.[285]

As described in detail above, Petitioner attests that NRC Staff's analysis of cumulative impacts in Section 4.16 of the 2019 FSEIS, which the 2024 FSEIS relies upon, is inadequate in light of new information provided by the GAO Report, and thus so is the 2024 FSEIS.

***CONTENTION 3-B: THE 2024 FSEIS FAILS TO ADEQUATELY UPDATE ITS EVALUATION OF FPL'S SAMA ANALYSIS TO REFLECT THE EFFECTS OF CLIMATE CHANGE ON ACCIDENT RISK.***

In addition to satisfying the "good cause" standard, as discussed above, Contention 3-B meets all six criteria for admissibility as established by 10 C.F.R. § 2.309(f)(1).

[285] Rules for Practice for Domestic Licensing Proceedings—Procedural Changes in the Hearing Process, 54 Fed. Reg. 33,168, 33,170 (Aug. 11, 1989).

*1. Statement of the issue of law or fact to be raised or controverted (10 C.F.R. § 2.309(f)(1)(i))*

To prepare a NEPA-compliant environmental impact statement during a license renewal application, an applicant must "consider the environmental impacts of severe accidents at nuclear power plants, their probability of occurrence, and potential means available to mitigate those accidents in severe accident mitigation alternatives ('SAMA') analyses."[286] SAMA analysis is designed to evaluate the risk of beyond-design basis severe accidents and determine whether mitigation measures are warranted.[287] "NEPA calls for the disclosure of potential adverse effects and a discussion of potential mitigation measures" in order to "assure that the agency and the public will have relevant information on the potential impacts of a proposed action[.]"[288] The Commission classifies SAMA analysis as a Category 2 issue that must be evaluated on a site-specific basis.[289] Thus, in order to comply with NEPA, FPL must disclose, and NRC Staff must review and audit, the risks of a severe accident posed by running a now 52-year old plant—and one that is particularly vulnerable to damage from hurricanes and sea level rise—into the 2050s.

The 2024 FSEIS has not yet been updated to reflect the new and significant information concerning climate change-related severe accident risks in the GAO Report, and therefore falls short of what NEPA requires.

[286] 2024 FSEIS at D-1.

[287] *Id.* at A-5.

[288] *In the Matter of Entergy Nuclear Operations, Inc.* (Indian Point, Units 2 and 3), CLI-16-10, 83 NRC 494 (June 2, 2016).

[289] *See* 10 C.F.R. Part 51, Appendix B.

*2. Brief explanation of the basis for the contention (10 C.F.R. § 2.309(f)(1)(ii))*

The 2024 FSEIS purports to "evaluate, on a site-specific basis, all of the SAMA-related environmental impacts of continued operations during the SLR term" from 2032 to 2053.[290] Yet FPL has not updated its SAMA evaluation to reflect the current climate change projections—claiming to have identified "*no new and significant information regarding uncertainties*" during its SAMA audit or scoping process that would alter the conclusions it made in 1996 or 2013.[291] NRC Staff does not mention any resources related to climate-risks among the materials they reviewed to make this determination.[292]

The 2024 FSEIS therefore concludes that "the probability-weighted consequences of severe accidents from continued nuclear power plant operations at Turkey Point during the SLR term would be SMALL."[293] And in turn, NRC Staff reasons: "Given . . . the fact that no potentially cost-beneficial SAMAs were identified during the Turkey Point initial license renewal review, it is unlikely that FPL would have found any potentially cost-beneficial SAMAs for the SLR term."[294] NRC Staff therefore concludes that "there is no new and significant information regarding any potentially cost-beneficial SAMAs that would substantially reduce the risks of a severe accident at Turkey Point."[295]

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[290] 2024 FSEIS at D-2.

[291] *Id.* at D-6 (emphasis added).

[292] *Id.* at D-3 ("The sources of new information were those that the NRC staff determined to be important to severe accident impacts and included new internal events, new external events, new source term information, use of the Biological Effects of Ionizing Radiation (BEIR) VII report (National Resource Council 2006) risk coefficients, spent fuel pool accidents, higher fuel burnup, low power and shutdown events, and population increase.").

[293] *Id.* at D-6.

[294] *Id.* at D-5.

[295] *Id.* at D-6.

NRC Staff's circular reasoning is troubling in light of the GAO Report, which identifies a multitude of ever-increasing risks that climate change poses to safe operation of the Turkey Point plant in the coming decades.[296] The report identifies how climate change exacerbates a number of risks to nuclear plants, and identifies Turkey Point as at the highest risk level for each of these.[297] The GAO Report, published a few days after the publication of the 2024 FSEIS, provides new and significant information that calls into question NRC Staff's conclusion. The report warns that NRC's licensing processes "do not fully consider the potential effects of climate change."[298]

**i. Flooding-related risks**

The 2024 FSEIS fails to adequately update its SAMA evaluation to reflect the flooding-related effects of climate change on accident risk. The GAO Report found that:

> Flooding could pose risks to nuclear power plants by, among other things, diminishing a plant's cooling capacity. Flooded roads could prevent personnel, equipment, and supplies from reaching a plant. Flooding could also cause damage to buildings, equipment, and electrical systems that could require a plant to curtail operations or shut down.[299]

The report found that sea level rise is likely to exacerbate storm surges and flooding.[300]

The flooding associated with hurricanes and sea level rise increases the risk of a nuclear release. The GAO Report explains that by exposing the facility to salt water for prolonged periods, flooding could "degrade or corrode a cask's exterior, potentially posing risks to the environment and human health."[301] The report also warns that "flood waters could

[296] GAO Report.

[297] *Id.* at 55.

[298] *Id.* at 34.

[299] *Id.* at 19.

[300] *Id.* at 22.

[301] *Id.* at 19.

interfere with heat removal from spent fuel pools by blocking ventilation ports with water."[302] Turkey Point's high vulnerability to hurricane storm surges and potential exposure to extreme weather events makes this particularly troubling, as casks of spent nuclear fuel may remain on site at the Turkey Point long after a plant's closure, since "the United States does not have a consolidated storage facility or repository where plants can send their spent fuel during operations or after a plant shuts down."[303] and decommissioning a nuclear plant can take up to 60 years.[304] Therefore, these casks could be exposed to corrosive salt water and potential leaks well past the 2050s, when flood risks are even higher.[305]

**ii. Hurricane-related risks**

The 2024 FSEIS fails to adequately update its SAMA evaluation to reflect the hurricane-related effects of climate change on accident risk. The GAO categorizes the Turkey Point plant as high risk for exposure to Category 4 and 5 hurricanes. In addition to contributing to storm surges and flood risks (see above), the report found that "[h]igh winds from hurricanes can generate projectiles capable of damaging parts of nuclear power plants and electricity transmission lines that provide nuclear power plants with power." The report explains that:

> To operate the cooling pumps and other systems that manage the water that reactors rely on for key safety and operational functions, nuclear plants need a reliable source of power. Nuclear power plants typically rely on the electricity grid to which the plant is connected for offsite power. However, if a plant loses access to offsite power, it must rely on backup power sources, such as diesel generators, to power cooling pumps. The loss of power and ability to pump cooling water can have a significant adverse impact on a plant's ability to safely shut down and maintain safe

[302] *Id.* at 19.

[303] *Id.* at 9 n.14.

[304] *Backgrounder: Decommissioning Nuclear Power Plants*, ADAMS Accession No. ML040340625 (May 1, 2013).

[305] GAO Report at 9.

> shutdown conditions. This could result in damage to a reactor's core and *potentially release radiological material into the environment.*[306]

The likelihood of widespread power outages affecting nuclear plants is projected to increase as climate change destabilizes the electricity grid.[307] The GAO report explains that such outages

> can have significant cascading effects on critical sectors and electric service disruptions can significantly affect the reliability of other parts of the energy sector. These losses are of special concern because outages caused by climate effects can be widespread and affect large geographic areas all at once[.][308]

Yet NRC Staff claims that climate change impacts on power disruptions and cooling demands are outside the scope of the environmental review[309]—despite the fact that such power disruptions could lead to a nuclear release, with serious environmental impacts.[310]

### iii. Temperature-related risks

Additionally, the 2024 FSEIS fails to adequately update its SAMA analysis to reflect the temperature-related effects of climate change on accident risk. The GAO Report warns that:

> Higher temperatures in the bodies of water into which nuclear power plants discharge cooling water may also require a plant to limit or temporarily stop operations to comply with laws designed to protect aquatic ecosystems and wildlife. In addition, high temperatures can also degrade the performance or cause failure of pumps and other equipment, reduce the lifetime of plant components, and reduce the overall efficiency of power plants. Warmer temperatures may also

[306] *Id.* at 8-9 (emphasis added).

[307] *Id.* at 8 n.11 ([C]limate change is expected to affect every aspect of the electricity grid—from generation, transmission, and distribution, to demand for electricity. We found that power outages can have significant cascading effects on critical sectors and electric service disruptions can significantly affect the reliability of other parts of the energy sector. These losses are of special concern because outages caused by climate effects can be widespread and affect large geographic areas all at once[.]") (citing Department of Energy. GAO, Electricity Grid Resilience: Climate Change Is Expected to Have Far-Reaching Effects and DOE and FERC Should Take Actions, GAO-21-346 (Washington, D.C.: March 5, 2021)).

[308] *Id.* at 8.

[309] 2024 FSEIS at A-36–A-37.

[310] GAO Report at 8-9 (emphasis added).

> increase levels of certain algae or other biological material which can block cooling water systems and lead to reduced production or a temporary plant shutdown.[311]

NRC Staff does not adequately examine how climate change increases temperature-related accident risks.

### iv. Inadequacies of NRC's relicensing process

In addition to identifying a number of ways that climate change increases the likelihood of a severe accident, the GAO Report specifically identifies ways that the NRC's relicensing processes fail to take these into account. The report identifies license renewals as a particular area of concern, explaining that:

> Following an initial 40-year licensing period, NRC does not reevaluate natural hazard risks, including climate-related risks, to update the safety reviews required for the license renewal process. NRC's license renewal process focuses on evaluating and managing the effects of aging on the extended operations of nuclear power plants and considers the original licensing basis in that context. As of January 2024, NRC had issued license renewals to 49 of the 54 operating nuclear power plants, meaning most plants are operating on the basis of assessments of natural hazard risk that are over 40 years old.[312]

The relicensing process therefore does not use climate projections data to assess climate risks, instead relying on historical data to extrapolate potential risks.[313] The report notes that although "NRC required licensees to assess flooding risk and enhance safety and emergency equipment, . . . NRC did not require licensees to use climate projections data to assess future flooding risks as part of these assessments."[314] This means that probabilistic risk assessments like SAMA do not adequately consider the risks posed by climate change, since that historical

[311] *Id.* at 14.

[312] *Id.* at 36.

[313] *Id.* at 36.

[314] *Id.* at 36-37.

data does not reflect the ways that climate change is disrupting historical weather patterns and increasing accident risks. The report concludes that:

> Without incorporating the best available information into its licensing and oversight processes, it is unclear whether the safety margins for nuclear power plants established during the licensing period—in most cases over 40 years ago—are adequate to address the risks that climate change poses to plants.[315]

NRC need not wait to formally change its regulations in order to begin using climate projections in its SAMA evaluation, as "NRC regulations do not preclude NRC from using climate projections data, and new sources of reliable projected climate data are available to NRC."[316]

*3. The issue raised in the contention is within the scope of the proceeding (10 C.F.R. § 2.309(f)(1)(iii))*

In its March 2024 order, the Board found that all five of Petitioner's proposed contentions were within the scope of the proceeding. The Board explained that:

> In both form and substance, Miami Waterkeeper bases its contentions on the Draft SEIS. Although Miami Waterkeeper references documents and repeats arguments that pre-date the Draft SEIS, Miami Waterkeeper makes clear that it remains unsatisfied with the Staff's treatment of these issues in the Draft SEIS.[317]

The scope of this current NRC proceeding with respect to environmental issues is established by 10 C.F.R. Part 51, which requires the NRC Staff to weigh all environmental effects of the proposed action in this proceeding.[318] Accident risks are a lawful subject of NEPA review.[319] Contention 3-B, which asserts that NRC Staff has failed to adequately update its SAMA

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[315] *Id.* at 39.

[316] *Id.* at 39.

[317] March 7, 2024 Board Order at 14-15.

[318] 10 C.F.R. §§ 51.71 n.3, 51.94. *See also* 10 C.F.R. §§ 51.21, 51.70-72, 51.92, 51.94, 51.104.

[319] *See State of New York. v NRC,* 681 F.3d 471, 478 (2012) ("Under NEPA, an agency must look at both the probabilities of potentially harmful events and the consequences if those events come to pass").

evaluation to account for new and significant information of climate change-related risks provided in the April 2, 2024 GAO Report, is well within the scope of this proceeding.

*4. The issue raised in the contention is material to the findings the NRC must make to support the action that is involved in the proceeding (10 C.F.R. § 2.309(f)(1)(iv))*

A "material" issue is one that would make a difference in the outcome of the proceeding.[320] "This means that there should be some significant link between the claimed deficiency and either the health and safety of the public or the environment."[321] NRC Staff explains that:

> In its evaluation of the significance of new information related to plant-specific SAMA analyses, the NRC staff considers new information to be significant if it provides a seriously different picture of the impacts of the Federal action under consideration. Thus, for mitigation alternatives such as SAMAs, "new information is significant if it indicates that a mitigation alternative would substantially reduce an impact of the Federal action on the environment. Consequently, with respect to SAMAs, new information may be significant if it indicates that a given potentially cost-beneficial SAMA would substantially reduce the impacts of a severe accident or the probability or consequences (risk) of a severe accident occurring.[322]

The information in the GAO Report is new and significant: it provides a "seriously different picture" than the current FSEIS evaluation of the risk of a severe accident in coming years. The report identifies Turkey Point to be at the highest risk level for flooding and high-intensity hurricanes—and warns of the increasing risk of severe accidents due to climate change.[323] The 2024 FSEIS and its SAMA evaluation do not address how climate change will affect the risk of flooding, hurricane, or temperature-related severe accidents. If NRC Staff were to update the SAMA evaluation to reflect the risks identified in the GAO Report, it might

[320] Rules for Practice for Domestic Licensing Proceedings—Procedural Changes in the Hearing Process, 54 Fed. Reg. 33,168, 33,172 (Aug. 11, 1989).

[321] *Vermont Yankee*, 60 NRC 548, 557 (Nov. 22, 2004).

[322] 2024 FSEIS at D-4.

[323] GAO Report at 55.

very well "call into question the [FSEIS's] overall conclusions regarding the probability-weighted consequences of potential severe accidents."[324] FPL might then be required to conduct a cost-benefit analysis of potential mitigation measures "that would substantially reduce the impacts of a severe accident or the probability or consequences (risk) of a severe accident occurring"—thereby "substantially reduc[ing]" the impact of operating Turkey Point into the 2050s on the environment.[325]

5. *Concise statement of the alleged facts or expert opinions which support the petitioner's position on the issue and on which the petitioner intends to rely at hearing (10 C.F.R. § 2.309(f)(1)(v))*

In support of Contention 3-B, Petitioner submits the GAO Report. Key facts from the report are provided above.

6. *A genuine dispute exists with the applicant on a material issue of law or fact (10 C.F.R. § 2.309(f)(1)(vi))*

As explained above, Petitioner takes issue with the inadequate SAMA evaluation in the 2024 FSEIS at pages D-2–D-7.

The 2024 FSEIS dismisses commenters' "concerns that this site-specific EIS does not address the impacts of climate change on safe operation of the facility or adaptation of the facility in response to climate change." Instead, NRC Staff asserts that site-specific environmental conditions were considered when Turkey Point was sited, that the plant was designed to withstand flooding, and that FPL has demonstrated that it will adequately manage any aging effects during its extended operation.[326] These blanket assurances are no substitute

[324] *In the Matter of Entergy Nuclear Operations, Inc.* (Indian Point, Units 2 and 3), CLI-16-10, 83 NRC 494 (June 2, 2016).

[325] 2024 FSEIS at D-5 ("Applicants that are able to demonstrate through the Stage 1 screening process that there is no potentially significant new information are not required to perform the Stage 2 or Stage 3 assessments.").

[326] *Id.* at A-34 to A-35.

for a full NEPA analysis of climate impacts, given that the plant was sited and designed in the 1960s, before scientific consensus around anthropogenic climate change had emerged.

In response to comments urging it to employ the current federal flood risk management practices, NRC Staff effectively argues that because the Turkey Point plant's operating license requires it to take steps to protect public safety, NRC Staff need not consider the latest data on flood risks yet.[327] Not so. NRC Staff's SAMA evaluation must ensure that the analysis accounts for the risks of severe accidents and their environmental consequences.[328] Indeed, the Third Circuit rejected NRC's Final Environmental Impact Statement for the Limerick power plant as inadequate under NEPA because it did not include "the requisite careful consideration of the environmental consequences [of severe accidents]."[329]

The 2024 FSEIS also asserts that "the implications of long-term climate change on plant operations and adjustments or preparations by licensees to a new or changing environment are outside the scope of the NRC's license renewal environmental review, which documents the potential environmental impacts of continued reactor operations."[330] Yet the implications of climate change are no longer remote risks. Turkey Point is already

[327] *Id.*at A-35 ("Further, operating plants must deal with the effects of climate change (e.g., sea level rise) as required by the NRC's regulations in 10 CFR Part 50 and the requirements of their licenses, including technical specifications, to provide reasonable assurance that the activities authorized by the license can be conducted without endangering the health and safety of the public, and to adequately manage the effects of aging so that structures, systems, and components that are important to safety will continue to perform their intended functions for the period of extended operation, as required in 10 CFR Part 54 A plant's current licensing basis is subject to NRC oversight and all times and is separate from license renewal licensing actions. Accordingly, no changes were made to this site-specific EIS as a result of this comment.").

[328] *Id.* at D-1.

[329] *Limerick Ecology Action, Inc. v. NRC,* 869 F.2d 719, 723 (3d Cir. 1989).

[330] 2024 FSEIS at A-5. Elsewhere, the 2024 FSEIS states that "the effects of climate change on Turkey Point Units 3 and 4 structures, systems, and components are outside the scope of the license renewal environmental review." *Id.* at A-34 and A-35.

experiencing the effects of climate change.[331] The 2024 FSEIS must consider the "reasonably foreseeable" environmental impacts of operating the plant into the 2050s. And SAMA analysis is specifically designed "to address alternatives to further mitigate the potential environmental impacts from postulated beyond-design-basis severe accidents"[332]—the likelihood of which is ever increasing due to climate-related risks.[333]

Petitioner has satisfied the admissibility criteria, and the Board should therefore admit Contentions 3-A and 3-B.

## V. CONCLUSION

For the foregoing reasons, Petitioner has demonstrated that our amended contention and new contentions are admissible, and we are entitled to a hearing on these contentions.

Respectfully submitted,

*/Signed (electronically) by/ Cameron Bills*
Cameron Bills
Miami Waterkeeper
PO Box 141596
Coral Gables, FL 33114-1596
Phone: (305) 905-0856
Email: cameron@miamiwaterkeeper.org

Richard Webster
Law Office of Richard Webster
133 Wildwood Avenue
Montclair, NJ 07043
Phone: (202)-630-5708
Email: rwebster463@gmail.com

*Counsel for Miami Waterkeeper*

[331] *See* Contention 3-A at 57, where Petitioner discussed how temperatures have affected CCS in the past and Hurricane Irma led to overtopping.

[332] 2024 FSEIS at A-5.

[333] GAO Report.

**UNITED STATES OF AMERICA**
**NUCLEAR REGULATORY COMMISSION**

**BEFORE THE ATOMIC SAFETY AND LICENSING BOARD**

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|---|---|---|
| In the Matter of: | ) | |
| | ) | |
| FLORIDA POWER & LIGHT COMPANY | ) | Docket No. 50-250-SLR-2 |
| | ) | Docket No. 50-251-SLR-2 |
| (Turkey Point Nuclear Generating Units 3 and 4) | ) | |
| | ) | May 8, 2024 |
| (Subsequent License Renewal Application) | ) | |

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## CONSULTATION CERTIFICATION

Pursuant to 10 C.F.R. § 2.323(b), I certify that Miami Waterkeeper made a sincere effort to contact the other participants in this proceeding and resolve the issues raised in the above motion. The NRC Staff does not oppose the filing by Miami Waterkeeper of a motion for leave to file new or amended contentions to the extent that such a filing is consistent with the Board's Initial Scheduling Order dated March 26, 2024 and Memorandum and Order (Granting Motion for Extension of Time) dated April 26, 2024. Consistent with 10 C.F.R. § 2.309(i), the Initial Scheduling Order dated March 26, 2024, and the Memorandum and Order (Granting Motion for Extension of Time), the Staff reserves the right to file an answer to the motion. FPL reserves the right to respond to and/or oppose Miami Waterkeeper's motion.

*/Signed (electronically) by/ Cameron Bills*

Cameron Bills
Miami Waterkeeper
PO Box 141596
Coral Gables, FL 33114-1596
Phone: (305) 905-0856
Email: cameron@miamiwaterkeeper.org

Richard Webster
Law Office of Richard Webster
133 Wildwood Avenue
Montclair, NJ 07043
Phone: (202) 630-5708
Email: rwebster463@gmail.com

*Counsel for Miami Waterkeeper*

**UNITED STATES OF AMERICA**
**NUCLEAR REGULATORY COMMISSION**

**BEFORE THE ATOMIC SAFETY AND LICENSING BOARD**

| | | |
|---|---|---|
| In the Matter of: | ) | |
| | ) | |
| FLORIDA POWER & LIGHT COMPANY | ) | Docket No. 50-250-SLR-2 |
| | ) | Docket No. 50-251-SLR-2 |
| (Turkey Point Nuclear Generating Units 3 and 4) | ) | |
| | ) | May 8, 2024 |
| (Subsequent License Renewal Application) | ) | |

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## CERTIFICATE OF SERVICE

Pursuant to 10 C.F.R. § 2.305, I certify that, on this date, the foregoing "*Miami Waterkeeper's Motion to Admit Amended and New Contentions in Response to NRC Staff's Final Site-Specific Environmental Impact Statement*" was served upon the Electronic Information Exchange ("EIE," the NRC's E-Filing System), in the above-captioned docket, which to the best of my knowledge resulted in transmittal of same to those on the EIE Service List for the captioned proceeding.

*/Signed (electronically) by/ Cameron Bills*

Cameron Bills
Miami Waterkeeper
PO Box 141596
Coral Gables, FL 33114-1596
Phone: (305) 905-0856
Email: cameron@miamiwaterkeeper.org

Richard Webster
Law Office of Richard Webster
133 Wildwood Avenue
Montclair, NJ 07043
Phone: (202) 630-5708
Email: rwebster463@gmail.com

*Counsel for Miami Waterkeeper*

# ATTACHMENT A

**UNITED STATES OF AMERICA**
**NUCLEAR REGULATORY COMMISSION**

**BEFORE THE ATOMIC SAFETY AND LICENSING BOARD**

| | | |
|---|---|---|
| In the Matter of: | ) | |
| | ) | |
| FLORIDA POWER & LIGHT COMPANY | ) | Docket No. 50-250-SLR-2 |
| | ) | Docket No. 50-251-SLR-2 |
| (Turkey Point Nuclear Generating Units 3 and 4) | ) | |
| | ) | May 8, 2024 |
| (Subsequent License Renewal Application) | ) | |

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**EXPERT REPORT OF WILLIAM NUTTLE, PH.D, PEng (Ontario)**

I have been retained by the Petitioner in this matter to offer expert testimony. The following is my written report.

William K. Nuttle
May 8, 2024

# Impacts on Groundwater Resources Assessed in the Final Environmental Impact Statement for Turkey Point License Renewal

Report prepared for:
Miami Waterkeeper

By:
William K. Nuttle, PH.D, PEng (Ontario)

8 May 2024

## Summary

The Cooling Canal System (CCS) at the Turkey Point Power Station provides cooling for two nuclear-powered thermo-electric generating units, Units 3 and 4. The Turkey Point plant is located on the shore of Biscayne Bay, immediately adjacent to Biscayne National Park and about 25 miles southwest of Miami. The CCS consists of a system of shallow canals that cover an area of approximately 6,100 acres, two miles wide by five miles long, Figure 1.

The CCS functions as an open system from the point of view of water supply. Water in the canals actively exchanges with the atmosphere and with groundwater in the underlying Biscayne aquifer and the surface water of Biscayne Bay. The Biscayne aquifer is a surficial, i.e. water-table, aquifer comprised of very porous limestone that has a thickness of about 100 feet at the location of the CCS. The Biscayne aquifer is the major source of drinking water for Monroe County and communities in south Miami-Dade County.

FPL has applied to the US Nuclear Regulatory Commission to renew its license to operate the Turkey Point Power Station and continue the operation of the CCS beyond the term of its current license. As part of its review of FPL's application, NRC staff must assess the impact of continued operation of the CCS on groundwater resources. NRC staff assesses this impact as SMALL to MODERATE.[1] In the justification given for this assessment, NRC staff discount the potential impacts of CCS operations on adjacent municipal water supply wells.

I believe that NRC staff has erred in this assessment. I have reviewed the materials developed by NRC staff as part of their review, materials provided by FPL in support of their application, annual reports from the environmental monitoring program conducted by FPL in and around the CCS, the most recent annual report of FPL's groundwater remediation program at the CCS site, and various other studies concerning the interaction of the CCS with groundwater. Based on this information, I believe that NRC staff has not considered fully the impacts that operation of the CCS has at the scale of the region that encompasses both the CCS and the adjacent water supply wells.

[1] NRC 2024

In this report, I identify shortcomings in NRC staff's assessment of the impacts of CCS operations on groundwater resources, and I identify a mechanism by which CCS operations influence groundwater hydrology on a regional scale that is not considered by NRC staff in their assessment. Finally, I provide a preliminary assessment of the regional impact of recent and planned changes in CCS operations. My assessment confirms the opinion of others that CCS operations threaten the use of adjacent municipal water supply wells. My findings indicate that the potential regional impact of continued operation of the CCS on groundwater resources is large enough to merit further investigation.

## *1) The assertion that the CCS will not impact municipal wells is not supported by the information presented.*

NRC staff opens its assessment of the impacts of operating the CCS on groundwater quality with the statement that:

*"Under both reasonably foreseeable scenarios [regarding FPL's groundwater remediation activities], the staff projects that there will be no additional adverse effect on the beneficial use of groundwater offsite by existing users because all existing users are located beyond the likely extent of the plume."*[2]

The existing users in question are municipal wells that tap the Biscayne Aquifer in the vicinity of the Turkey Point power plant. In general, wells used for potable water supply in the Biscayne Aquifer are vulnerable to salt water intrusion. The CCS is responsible for causing salt water intrusion reaching up to 5 miles away in the direction of the municipal wells. Therefore, it must be assumed that continued operation of the CCS will have adverse effect on adjacent potable water supplies unless robust evidence is developed that this will not occur. Such evidence is lacking in the information that NRC staff presents in support of their assessment. Here I review the factors that must be considered in assessing the impact of the CCS on salt water intrusion threatening adjacent municipal wells, and I show that the information developed by NRC staff falls short of what is required for a complete assessment.

[2] NRC 2024, page 2-39

### *Setting: the CCS has a large hydrologic footprint in a small, hydrologically sensitive basin.*

The cooling canal system (CCS) at FPL's Turkey Point facility covers an area of 6,100 acres, roughly 2 miles by 5 miles, along the coast of Biscayne Bay formerly occupied by mangrove swamp and salt marsh, Figure 1. Units 3 and 4, which rely on the CCS for cooling, are located at the northeast end of the CCS between the CCS and Biscayne Bay. Units 3 and 4 discharge heated water into the header canal, which runs across the north end of the CCS and distributes water into a series of, ultimately, 32 canals that carry the water south. Water from these canals is collected in the collector canal and carried east into a series of 7 canals that return the cooled water north to the intakes at Units 3 and 4. Cooling is accomplished through the processes of evaporation, conduction, and net radiation to the atmosphere, of which evaporation is the most important process.[3]

The CCS interacts with the Model Land hydrological basin through its effects on groundwater in the underlying Biscayne Aquifer. The Model Land basin is delineated on the north by Palm Drive, on the east by the L-31E levee, on the southwest by Card Sound road, and US Route 1 on the west. The land surface in the basin is flat and low lying, generally less than 2 feet above sea level.[4] Land use in most of the basin is classed as marl prairie wetland. Some agriculture exists in the western part of the basin, and there is a limited amount of urban development along US Route 1. The Model Land basin is hydrologically isolated from the surface flows from the Everglades[5] that provide an important supplement to the fresh water budget in other areas of the southeast Florida coast, north of the Model Land basin.

The Biscayne Aquifer extends beneath the full extent of the Model Land basin, the CCS, and continues under Biscayne Bay. The Biscayne Aquifer is one of the most permeable aquifers in the world.[6] This means that relatively small differences in the height of the water table, or hydraulic head, suffice to drive large groundwater fluxes. Fresh groundwater in the Model Land basin flows generally southeasterly from areas recharged by seepage from the L-31W and C-111 canals and by the infiltration from rainfall on the higher ground around Homestead and Florida City toward Biscayne Bay. The regional hydraulic gradient driving this flow is very small, 0.004% to 0.005%.[7]

[3] Chin 2016
[4] Prinos et al. 2014
[5] NRC 2016
[6] FPL 2018
[7] Chin 2016

The CCS exerts a major influence on groundwater hydrology in its vicinity. The CCS occupies about one fifth of the combined area of the Model Land basin and the coastal area east of the L-31E levee. It comprises about two thirds of the boundary between the Model Land basin and Biscayne Bay. The CCS affects the hydrology and groundwater quality of the Biscayne aquifer.[8] The operation of the CCS to provide cooling for Units 3 and 4 alters water levels and water quality in the CCS. Water levels are raised in the north, where heated water is discharged from the plants, and in the canal flowing south along the west side of the CCS, and water levels on the east side, near the plant intakes, are drawn down. This drives an active exchange of water between the cooling canals and the underlying aquifer. Saline groundwater drawn into the CCS from beneath Biscayne Bay is an important source of water needed to make up the difference between evaporation and rainfall. Evaporation increases the salinity of water in the CCS that is discharged to the aquifer.

The active exchange between the CCS and the aquifer occurs "by design".[9] Historically, the inflow of water from the aquifer has been the primary source[10] of makeup water to replace water lost to evaporation in excess of rainfall. The discharge of water from the CCS into the aquifer serves the role of blowdown to control the level of salinity in the CCS, which is increased by the evaporation. Active exchange with the aquifer is necessary to maintain the function of the CCS to provide cooling for Units 3 and 4. In response to the crisis of high temperatures and spiking salinity experienced in 2014 FPL took actions specifically intended to enhance exchange with the aquifer. Therefore, active exchange with groundwater is a feature of the CCS, not an unintended consequence.

The hydrology of the entire Model Land basin is affected by the operation of the CCS. The CCS is a dominant feature that defines hydrologic conditions in the aquifer at the boundary between the Model Lands basin and Biscayne Bay. Owing to the small magnitude of the regional hydraulic gradient, fluctuations in the water table, driven by the shifting balance between rainfall and evaporation in the basin, can result in the temporary reversal of the hydraulic gradient.[11] For example, a reversal of the regional hydraulic gradient was triggered by a memorable drought in 1971. The water table in the Everglades, west of the Model Land basin, dropped to 1 foot below sea level in April, the end of the dry season, allowing salt water to move inland from the coast.[12] Therefore, the general movement of fresh groundwater through the basin toward the coast is on occasion interrupted by periods during which the movement of fresh groundwater is either stagnant or directed inland, away from the coast. During these periods the hydrologic effects of

[8] NRC 2019, NRC 2018
[9] Scroggs 2014, NRC 2018
[10] Water added for freshening, beginning in or around 2015, provides a supplemental source of makeup water. Thus it supplements the roles played by the exchange with the aquifer, but it does not replace it.
[11] Chin 2016
[12] Benson and Gardner 1974.

the operation of the CCS, which is largely unaffected by drought, can propagate into the Model Land basin.

### *Stability of the groundwater resource depends on two things: the water table and salinity.*

Salt water intrusion beneath the Model Land basin threatens municipal water supplies. Of concern are municipal wells providing potable water for Miami-Dade County and the Florida Keys, in Monroe County.[13] The EPA has designated the Biscayne aquifer as a sole-source aquifer. Miami-Dade County relies on the Biscayne Aquifer for nearly all of its supply of potable water. The municipal wells located nearest the CCS are located at Newton Field, Harris Field and Witkop Park in Homestead, approximately 6.8, 7.3, and 7.7 mi, respectively, from the Turkey Point plant site. The municipal water supply for the Florida Keys comes from Biscayne aquifer wells and an Upper Floridan aquifer well located west of Florida City, approximately 9 mi west of the plant site. These municipal wells are located outside of, but proximate to, the Model Land basin (Figure 1), and they communicate with the groundwater beneath the Model Land basin through the permeable Biscayne Aquifer.

As elsewhere along the southeast Florida coast, groundwater in the Biscayne Aquifer beneath the Model Land basin is stratified by density. A layer of fresh water at the surface of the aquifer lies over denser, saline water at the bottom of the aquifer. Saline water extends inland along the base of the aquifer from the Biscayne Bay shoreline across about two thirds the width of the Model Land basin to the position identified as the inland extent of salt water in Figure 1. Protection of the groundwater resource, as a source of potable water, depends on maintaining the position of the interface between fresh water and salt water, e.g. the salt water interface (Figure 2). In particular, assuring the stability of the groundwater resource means preventing the salt water interface from moving further inland.

In general, the position of the salt water interface in a surficial coastal aquifer is determined by the balance between the hydraulic gradient driving the flow of fresh water to the coast and an opposing flow of sea water at the base of the aquifer, driven by the difference in density between fresh water and sea water. The Gyben Herzberg relationship describes the position of the salt water interface under the ideal condition of static equilibrium between fresh and salt water in the aquifer.

The Gyben Herzberg relationship calculates the depth z, below mean sea level, to the salt water interface in a coastal aquifer as the height of the fresh water table above sea level, h, multiplied by a factor computed from the densities of fresh water and seawater.[14] Therefore, under equilibrium conditions, the position of the salt water interface below sea level mirrors the

[13] NRC 2016
[14]

position of the water table above sea level but amplified by a multiplier that depends on the densities of fresh groundwater and the invading salt water. For fresh water with a density of ~1000 kg/m$^3$ and sea water with a density of ~1025 kg/m$^3$ the multiplier is ~40.

From the Gyben Herzberg relationship, we can discern two principles that are fundamental to assessing the stability of the salt water interface, and thus the stability of the groundwater resource in the Model Lands basin:

The **first principle** is that the position of the salt water interface depends on two independent conditions: 1) the position of the water table relative to sea level, and 2) the contrast in the density of the intruding saline water relative to the density of fresh water. The position of the water table depends in turn on a host of factors related to the extent, geometry, and hydraulic properties of the aquifer, the components of the water balance that determine the recharge to the aquifer that sustains the flow of fresh water to the coast, and fluctuations in sea level. In this report, I refer to the regional hydraulic gradient that drives the flow of fresh water to the coast simply as the water table.

The **second principle** is that no equilibrium position of the salt water interface exists where the water table is located below mean sea level, i.e. the mean level of the salt water body that is the source of salt water intruding into the aquifer. The fresh groundwater resource is inherently unstable under this condition. Salt water will move in to fill the aquifer up to the level of mean sea level, impeded only by the time required to displace the fresh water in the aquifer. This will occur as salt water first moving beneath the fresh water and then pushing it to the surface of the aquifer, where it will be lost either by evaporation or by exfiltration at the ground surface and runoff into Biscayne Bay.

By convention, the position where the salt water interface intersects the base of the aquifer is taken as the inland extent of salt water.[15] For this purpose, the interface is defined, in terms of chlorinity, by the location of the 1000 mg/L isochlor. EPA has established 250 mg/L as the standard for drinking water. Chlorinity is closely related to salinity; where salinity measures the concentration of total dissolved solids, chlorinity measures the concentration of dissolved chloride ions. Typical values for seawater are ~35 parts per thousand total dissolved solids, corresponding to ~35 PSU (practical salinity units, the conventional measure for seawater salinity), and 19,000 mg/L chlorinity. Hypersaline water, as discussed below, is defined as water with chlorinity greater that 19,000 mg/L. Seawater and hypersaline water are considered to be non potable.

The ideal condition of static equilibrium rarely occurs, if ever. The balance between the seaward flow of fresh water acting against the denser, saline water pressing inland is dynamic in nature.

[15] Prinos et al. 2014.

The position of the water table fluctuates on daily, seasonal, and year-to-year timescales in response inputs from rainfall, water loss via evapotranspiration, and drainage toward Biscayne Bay assisted and controlled by canals. A lowering of the water table, that is a decrease in the fresh water gradient, allows salt water to move into the aquifer, displacing fresh water and moving the salt water interface inland. Conversely, an increase in the fresh water hydraulic gradient will push the salt water interface seaward.[16] The heterogeneity of the aquifer, especially the existence of preferred paths for water movement also plays a role.

Experience has shown that the Gyben Herzberg relationship has value in establishing the location about which the salt water interface moves in response to variable hydrologic conditions.[17] On this basis, the two principles derived from it, above, provide the basis for assessing impacts on the stability of the salt water interface and thus of the groundwater resource. An assessment of the impact of the operation of the CCS on the saltwater interface must consider both its effects on the water table and its effects on salinity.

### *Remediation of the hypersaline plume is only half the story.*

NRC staff relies primarily on information provided by FPL in assessing the impact of the CCS on groundwater resources. This information is produced as the result of two activities: 1) an environmental monitoring program, first established in 2009 for purpose of detecting adverse environmental impacts of the uprate of units 3 and 4, and 2) a groundwater remediation program prescribed by a consent order from the Florida Department of Environmental Protection in 2016.[18] The monitoring program continued and expanded a groundwater monitoring program begun in the 1970s when operation of the CCS started. Subsequently, the environmental monitoring program was further modified to serve the requirements of the 2016 consent order.

[16] NRC 2016, Chin 2016
[17] Black et al. 1953
[18] FDEP 2016

While these activities generate extensive information that is relevant to the impact of the CCS on groundwater resources, the mandate for these activities is to serve the specific objectives of the 2016 consent order. These are "to remediate the CCS contribution to the hypersaline plume, reduce the size of the hypersaline plume, and prevent future harm to waters of the State."[19]

In practice, monitoring and remediation activities have focused on the first two objectives: reducing salinity in the CCS to eliminate the discharge of hypersaline water into the aquifer, and retracting the hypersaline plume in the aquifer back to the boundaries of the CCS. This much is evident from reading the table of contents of the latest annual report on remediation activities.[20] Success in meeting the first two objectives is deemed sufficient to meet the third, more expansive objective to prevent future harm to waters of the State.

Consequently, the information generated by the annual monitoring program and the groundwater remediation is limited in scope by the particular requirements of the 2016 consent order. Care must be exercised in relying on this information for other purposes, such as assessing the impact of the operation of the CCS on adjacent users of groundwater and on groundwater resources generally.

For example, the consent order defines the term "salt water interface" as "the intersection of class G-Il and G-Ill groundwaters," where G-II and G-III refer to the groundwater classification scheme used by the Department of Environmental Protection. G-II groundwater is defined as potable water with a concentration of total dissolved solids less than 10,000 mg/l, and G-III groundwater is defined as non potable water in an unconfined aquifer with a concentration of total dissolved solids greater than 10,000 mg/l.

By contrast, the US Geological Survey defines "salt water interface" in more general terms as: "A zone of transition between intruded saltwater and freshwater in the aquifer. Sometimes this interface is sharp. Often this interface is diffuse and allows mixing between the two masses of water." [21]

[19] FDEP 2016
[20] FPL 2023b
[21] Prinos et al. 2014

In both cases, the term "salt water interface" is distinct from the term "inland extent of salt water" that refers to the position of the salt water interface reduced to two dimensions on a map. For this purpose, the inland extent of salt water is defined as the estimated position of the 1,000 mg/l isochlor (referring to chlorinity) at the base of the aquifer.[22]

The boundaries of the compliance area defined for compliance with the 2016 consent order illustrate graphically the limitations on the information that is produced by FPL's annual monitoring program and groundwater remediation program, Figure 3. The compliance area corresponds to the area covered by the aerial survey used to map the extent of the hypersaline plume. The position of the salt water interface, as indicated by the landward extent of salt water intrusion, is located far outside the western boundary of the compliance area, Figures 1 and 4. With respect to the assessment by NRC staff, it is perhaps more correct to say that all existing users are located beyond the compliance area established for the 2016 consent order.

Consideration for the position of the salt water interface is absent from the information produced by the annual monitoring program and the groundwater remediation program. FPL uses three tools to assess the progress of the groundwater remediation: groundwater monitoring, aerial electromagnetic surveys of the hypersaline plume, and groundwater modeling. None of these address changes in the position of the saltwater interface.

A search for references to "groundwater interface" in the body of the 2023 Remedial Action Annual Status Report turns up 21 instances. Of these, 15 refer to the hypersaline interface. Of the 6 that relate to the saltwater interface: one is in reference to the location of monitoring wells; one is in reference to mitigation alternatives considered but rejected; one is in reference to the attribution study conducted during the planning of the remediation program; and three reiterate the assertion that eliminating hypersalinity will "remove the influence of discharged CCS water on the saltwater interface without creating adverse environmental impacts,"[23] quoting almost verbatim from the 2016 consent order.

The discharge of hypersaline water into the aquifer is clearly implicated as a mechanism by which the CCS has driven saltwater intrusion beneath the Model Land basin. Undoubtedly, eliminating further discharge of hypersaline water into the aquifer and removing the hypersaline water present in the aquifer are necessary steps toward eliminating the influence of the CCS on the salt water interface. But, these actions are not sufficient to assure this result.

[22] Prinos et al 2014
[23] FPL 2023b

There are more factors that must be considered. In the preceding section, I argue that two sets of factors affect the position of the salt water interface. Both sets of factors must be considered when assessing the impacts of the operation of the CCS on the saltwater interface, the stability of the groundwater resource, and potential impacts on existing users.

Information on the effect that the CCS has on the water table is absent from the material assembled by NRC staff in support of their assessment. At best, the information developed from FPL's annual monitoring program and groundwater remediation program allow for the assessment of impacts on the salt water interface related to changes in salinity caused by the CCS. But, a complete assessment must also consider various mechanisms by which the operation of the CCS impacts the regional hydraulic gradient in the Model Lands basin.

### *Reference to the historic position of the salt water interface is misleading.*

Although scant attention is paid to the current and future positions of the salt water interface in FPL's annual monitoring and groundwater remediation programs, the historic position of the salt water interface plays an important role. NRC has compiled a record mapped positions of the inland extent of salt water beneath the Model Land basin for the period 1951 through 2008, Figure 4.

This compilation provides a point of reference for assessing the impact that the operation of the CCS has had on salt water intrusion in the Model Land basin. In particular, the line labeled "1971" indicates the estimated landward extent of salt water immediately before the CCS was constructed and put into operation. However, this figure is misleading in two ways. The first is a minor annoyance, but the second is more substantial.

First, the figure is in error in identifying the source for the 1971 extent of salt water intrusion. The source cited in Note 2 is a report published in 1951, 20 years prior to the date indicated in the figure. I believe that the correct citation for the inland extent of salt water in 1971 is a report entitled "The 1971 Drought in South Florida and Its Effect on the Hydrologic System".[24]

Second, the inland extent of salt water in 1971 represents the response of the salt water interface to a "notable drought"[25] rather than normal conditions prior to the effect of the CCS. Extremely low rainfall during the dry season in the spring of 1971 caused a drawdown of the water table to as much as 1 foot below sea level in the Everglades, west of the Model Land basin. The regional hydraulic gradient was reversed for an extended period of time, destabilizing the salt water interface throughout the region, drawing salt water into the aquifer.

[24] Benson and Gardner 1974
[25] Benson and Gardner 1974

A study by Dames and Moore in 1978 placed the pre-project position of the salt water interface at the bottom of the aquifer in the vicinity of the monitoring well G-28. (See the upper panel of Figure 5.) The purpose of the Dames and Moore study was to assess the probable future impact of the operation of the CCS on salt water intrusion beneath the Model Land basin. The G-28 well is located along Tallahassee Road, about 2 miles east of the estimated inland extent of salt water in 1971.

This difference in the estimated positions of the salt water interface prior to the CCS provides an indication of the sensitivity of the salt water interface in the Model Land basin to perturbations in the water table related to rainfall. Although, the drought during the spring of 1971 was "notable," it was not especially severe, and the regional hydrologic system recovered by the end of the following wet season.[26]

### *Operation of the CCS affects the water table in multiple ways.*

The role of canals as a cause of salt water intrusion has been known for a least 70 years. Canals cause salt water intrusion through encroachment and overdrainage.[27] Encroachment effectively allows for the rapid movement of salt water inland via surface pathways, effectively displacing the coastal boundary to the interior of the aquifer. Overdrainage draws down the water table, decreasing its height above sea level, thus allowing the salt water interface to migrate upward and inland in accordance with the Gyben Herzberg relationship.

Both of these mechanisms apply to the CCS; however, the design and operation of the CCS introduce several other mechanisms that are unique to the CCS. Here, I briefly describe mechanisms through which the operation of the CCS can impact salt water intrusion by changing the configuration of the water table. These mechanisms alter the water budget in some way, thus their impact on the salt water interface is from their effect on the water table. The possible contribution of each of these mechanisms must be considered in any assessment of the total impact of the CCS on salt water intrusion.

#### Encroachment

Construction of the CCS created a system of shallow surface water canals initially filled by water with a salinity close to the salinity of Biscayne Bay. The expected effect was to effectively displace the coastline and the salt water interface inland by about 2 miles, the width of the CCS. (See the lower panel in Figure 5.)[28] However, as the site of the CCS was originally mangrove swamp and salt marsh it is likely that the effective location of the coast prior to the construction of the CCS was already inland from the coast, mitigating the effect of encroachment that occurred with the construction of the CCS.

[26] Benson and Gardner 1974
[27] Black and Brown 1953
[28] Dames and Moore 1978

### Water levels altered by operation of the circulating water pumps

The pumps that circulate water through the power plants for cooling also alter water levels in the network of canals. Water levels are drawn down at the north end of the return canals, at the plant intakes, and water levels are elevated in the header canal, where the plants discharge water into the CCS. The difference in water levels between the plant discharge and intake points is around 0.5 feet under normal operation conditions. Water levels near the plant intakes are usually lower than the water level in Biscayne Bay, and this draws groundwater into the CCS from beneath the bay. Water levels in the header canal and at the north end of the canals it feeds are raised, and this drives the discharge of water from the CCS into the aquifer, mostly through the bottom of the canals in the northwest corner of the CCS. Water levels at the south end of the CCS generally are nearly equal to water levels in Biscayne Bay and the adjacent wetlands, which reduces the degree to which water is exchanged with the aquifer.

The effect of the circulating water pumps is to raise water levels along the north and western boundaries of the CCS and enhance recharge to the aquifer. Both processes will have the effect of raising the level of the water table outside the CCS, decreasing the regional hydraulic gradient and displacing the salt water interface inland.[29]

### Operation of the Interceptor Ditch

Water is pumped out of the Interceptor Ditch (ID) as needed to maintain water levels in the ID lower than water levels in the L-31E canal. This is supposed to assure that the direction of groundwater flow is always from the west toward the CCS. In practice, the ID has failed to prevent the westward movement of the dense hypersaline plume along the bottom of the aquifer, ~ 100 feet below the land surface. The ID is too shallow, ~20 feet deep, to retard the horizontal movement of water deep in the aquifer, especially under the conditions where flow in the aquifer is stratified.

Beyond problems arising from its failure to retard the westward movement of CCS water, operation of the ID represents a large, undocumented withdrawal of water from the layer of fresh water at the surface of the Biscayne Aquifer, west of the CCS, which overlies the saline water at depth. Water pumped out of the ID is a mixture of saline water from the CCS and fresh groundwater flow from west of the ID. The impact of pumping on the water table is exacerbated by the fact that pumping from the ID occurs predominantly during the dry season, January through May. This is when the water table is at its seasonal low, and hydraulic gradients conducive for flow from the CCS inland toward the L-31E canal exist.

[29] Dames and Moore 1978

NRC 2024[30] catalogs withdrawals from groundwater at the Turkey Point site for the purpose of systematically assessing their impact on the groundwater resource. However, the withdrawal of fresh groundwater from the Model Land basin as a consequence of the operation of the ID is missing both from Table 2-4 and from the assessment by NRC staff. Therefore, the assessment of the impact of CCS operations on groundwater resources is incomplete in this regard.

The amount of freshwater withdrawn by the ID pumps can be estimated from the ID pumping rate and salinity data collected for the ID and the L-31E canal. On any day, the amount of water pumped from the ID, $Q_{ID}$, is the sum of an amount of water that has entered the ID from the west, from $Q_{L31}$, and an amount of water recycled from the CCS, $Q_{RW}$;

$$Q_{ID} = Q_{L31} + Q_{RW}. \qquad \text{Equation 1}$$

Similarly, the amount of salt in the water pumped from the ID is the sum of an amount carried into the ID in groundwater flow from the west and in the flow of recycled water from the CCS;

$$Q_{ID}S_{ID} = Q_{RW}S_{CCS} + Q_{L31}S_{L31}. \qquad \text{Equation 2}$$

From these two equations, one can derive the following formula to calculate the portion of the total daily ID pumping that is fed by groundwater flow from the west:

$$Q_{L31} = Q_{ID}[(S_{CCS} - S_{ID}) / (S_{CCS} - S_{L31})] \qquad \text{Equation 3}$$

The daily rates of pumping from the ID, QID, and the salinity of water in the ID, SID , are measured. The salinity measured in the L-31E canal can be taken as representative of the salinity of water flowing into the ID from the west. Shallow groundwater west of the CCS is not totally fresh, as a consequence of infrequent flooding of the wetlands there by water from Biscayne Bay. The salinity of water below the CCS is taken to be 60 gm/l, which reflects the long-term, stable average of salinity measured in a shallow well in the center of the CCS.[31]

Based on these data, calculations reveal that ID pumping removes about 3.5 mgd of fresh groundwater from the Biscayne aquifer west of the CCS. This is the average of the amount of freshwater extracted calculated using Equation 3 applied with daily values of pumping rate and salinity, Table 1. The pumping rate varies from day to day, and salinity in the ID tends to be higher on days with higher rates of pumping.

[30] NRC 2024; table 2.4, page 2-17
[31] TPGW-13

This rate of extraction is large relative to other withdrawals from the aquifer. Nearby well fields operated by public water utilities[32] withdraw 2 mgd (Florida City), 11 mgd (Homestead), and 17 mgd (FKAA). The withdrawal of freshwater as a consequence of ID operations also is not documented by the current regional water supply plan.

### Rainfall capture and enhanced recharge

Rainfall events raise water levels in the CCS and drive the discharge of water into the aquifer.[33] The design of the CCS magnifies effect of high rainfall events on discharge to the aquifer. The CCS is prevented from discharging water directly to adjacent surface water bodies. Therefore, all the rainfall from a large event is retained within the CCS where nearly all of it will add directly to the water levels in the canals.

A high rainfall event can raise water levels significantly throughout the CCS over a short period of time, increasing discharge into the aquifer. For example, on 23 March 2024 the CCS received 10 inches of rainfall in one day.[34] Other notable rainfall events occurred in 2015 and 2017. Discharge from the CCS into the aquifer increase generally throughout the CCS in the days immediately following a large rainfall event. Sometimes the usual inflow from Biscayne Bay is reversed so that CCS water discharges through the aquifer into Biscayne Bay.

The same high rainfall event will raise water levels in adjacent wetlands; however the response will be less than inside the CCS. Runoff will remove a large portion of the rainfall into Biscayne Bay, and this reduces the effect of rainfall on water levels in the wetlands of the Model Land basin. As a result, water levels in the saline CCS are increased relative to the position of the fresh water table. The net effect will be to raise the salt water interface and displace it inland beneath the Model Land basin.

### Water added for freshening

The addition of water for the purpose of reducing salinity in the CCS will raise water levels in the CCS relative to the water table in the adjacent wetlands with an effect similar to the effect of rainfall capture. I estimate the magnitude of the average increase in water levels that has occurred since freshening occurred in the following section of this report.

[32] SFWMD 2013
[33] Chin 2016
[34] https://www.local10.com/weather/2024/03/23/flood-watch-in-effect-miami-dade-gets-lightining/

## *2. Impact of CCS operation on movement of the salt water interface cannot be dismissed a priori.*

### *CCS water is found throughout the saline portion of the aquifer nearly up to the salt water interface.*

Data gathered from monitoring wells document the presence of groundwater originating from the CCS throughout the Model Land basin nearly up to the landward extent of salt water intrusion, (Figures 1, 6 and 7). This is consistent with the CCS being a primary cause of salt water intrusion.

Tritium is a reliable indicator of water originating from the CCS in the vicinity of Turkey Point.[35] Water in the CCS contains tritium in concentrations[36] hundreds of times greater than the background concentrations in the aquifer and in surrounding surface waters. No other source of tritium at such high concentrations exists in the region. Therefore, measured concentrations of tritium above background levels indicates the presence of water from the CCS. For this reason, the agencies cooperating in the design of FPL's monitoring program for the CCS agreed to include tritium as a water quality constituent that is routinely measured.

The agencies agreed that a threshold concentration of 20 pico Curies per liter would indicate the presence of water originating from that CCS in groundwater samples. This threshold applies only to groundwater samples taken at depth in the aquifer. The use of tritium to trace water movement in surface water and in near-surface groundwater is confounded by the fact that the atmosphere provides an alternative pathway for the movement of tritium from the CCS and deposition in shallow groundwater, surface water, and the soil in the vicinity of the CCS.

The presence of CCS water in the aquifer is documented extensively by FPL's annual monitoring program, Figure 6. In recent years, tritium concentrations have dropped below the detection threshold in wells at the northern and southwestern periphery of the monitoring network. This may reflect the effect of the RWS on the recovery of hypersaline water shrinking the plume of CCS water in the aquifer. But, it could also be related increased rainfall recharging the aquifer and displacing the salt water interface toward Biscayne Bay.

[35] Janzen and Krupa 2011
[36] Typical values for tritium concentration in the CCS are between 2000 to 18000 pCi/l.

In 2014, the USGS reported tritium above the 20 pico Curie per liter threshold in wells G-3699 and G-3855.[37] This places water originating from the CCS at the leading edge of the salt water interface advancing toward the Newton Wellfield, Figures 1 and 6. Continued monitoring for tritium by Miami Dade County at G-3699 and another well, G-3966, in the same area shows that water from the CCS has persisted in the aquifer near and advancing on the Newton Wellfield, even as CCS water has disappeared in areas to the east and southwest, Figure 7.

### *The volume of CCS water present in the aquifer exceeds the capacity of the RWS.*

Between 2009 and 2015 I was hired work with the team at the South Florida Water Management District tasked with reviewing the early results from FPL's annual monitoring program. In 2013 the monitoring program had produced enough data to be able to begin to understand how much water the CCS was discharging into the aquifer and where it had gone.

Initial estimates of the rate of discharge from the CCS into the aquifer averaged about 9 mgd for the first year or 18 months of data. At this rate the entire contents of the canals empty into the aquifer every 18 months.

The team was able to map the extent of plume of CCS water that had intruded into the aquifer west of the CCS. The map assigned a percentage of CCS water to every point in the aquifer based on the distinct chemical composition of CCS water, which combines concentrations of major ions and tritium. Based on this map, the team was able to estimate the total volume of CCS water present in the aquifer west of the CCS in 2013 – 123 billion gallons. This is equal to about 40 years of "leakage" from the CCS at the rate of 9 mgd.

The magnitude of contamination in the aquifer by CCS water is beyond the ability of the RWS to fully remediate. Removing 123 billion gallons of water from the aquifer at the current rate of pumping removing 123 billion gallons would take about 30 years. This does not account for the fact that the CCS has continued to discharge water into the aquifer since 2013 and the fact that much of the CCS water has been diluted by mixing with water from other sources, so that removing all of the CCS water would require removing a much larger volume of water. Even if is successful, FPL's remediation program, mandated by the Department of Environmental Protection through the 2016 consent order, will leave most of the CCS water that has escaped west of the Interceptor Ditch in the aquifer where it contributes to increasing salinity by mixing with fresh water and displacing the salt water interface further inland.

[37] Prinos et al. 2014

### *CSS is regarded as a cause of salt water intrusion that threatens municipal wellfields.*

Beginning in 2012, the USGS has been tracking the movement of the salt water interface in the vicinity of the Newton wellfield, Figure 1. Prinos (2016)[38] states that "Given the stated assumptions, the saltwater interface may move under the Newton well field by 2026." Detection of tritium in excess of the 20 pico Curie per liter threshold in monitoring well G-3699, first in 2014 and continuing to the present day (Figure 7) places water originating from the CCS at the vanguard of the advancing salt water interface that is encroaching on the Newton wellfield.

Miami-Dade County and SFWMD identify Newton, Homestead, Florida City, and FKAA wellfields as at risk to salt water intrusion.[39] The US Geological Survey writes that "hypersaline water [from the CCS] may be contributing to saltwater encroachment in area of the Newton wellfield.[40]

Hydrogeologists working for the Florida Keys Aqueduct Authority assess the threat posed by the CCS as the "single most damaging source of groundwater pollution threatening the authority's wellfield." [41]

### *Two studies evaluate the effects of hypersalinity in the CCS on the salt water interface.*

Two modeling studies have investigated the relative effect on salt water intrusion of the salinity of water discharged from the CCS into the aquifer. Both confirm that the extent of salt water intrusion is much greater when the CCS is a source of hypersaline water, nominally set at twice sea water salinity, as compared to the hypothetical case in which water in the CCS is maintained at sea water salinity.

[38] Prinos 2016
[39] MDC 2016
[40] Prinos 2014, and Hughes et al 2009
[41] McThenia et al. 2017

Hughes et al.[42] conducted a speculative modeling study of the interaction between the CCS and the Biscayne Aquifer to examine various aspects of the initiation of a plume of heated, saline water into the aquifer, its growth and intrusion into a freshwater coastal aquifer. The study used a two dimensional density-dependent groundwater model to simulate conditions in a vertical plane cut through the aquifer. It examined the sensitivity of the plume's behavior to various assumptions about the hydraulic parameters of the aquifer. The contrast between the extent of salt water intrusion that occurs under hypersaline versus seawater-saline conditions was striking; the extent of salt water intrusion that occurred under hypersaline conditions was 6 times greater than intrusion under conditions of seawater salinity in one of the cases examined. The extent of intrusion also was found to be sensitive to the assumed aquifer properties.

Andersen and Ross[43] conducted an applied modeling study for FPL to satisfy the condition of the 2016 consent order. The purpose of this study was to investigate the relative contributions of the CCS compared to other factors recognized as contributing to salt water intrusion. This study is sometime referred to as the attribution study. A three dimensional density-dependent groundwater model was first calibrated to simulate the historical development of salt water intrusion beneath the Model Land basin. The results of the historical base case were compared to results from a series of hypothetical simulations in which the influence of various factors were explored, separately.

The factors examined for their influence on salt water intrusion were:

- Operation of the FPL Cooling Canal System (CCS);
- Sea level rise;
- Changes in land use:
- Decadal-scale changes in precipitation recharge;
- Construction of drainage structures and changes to drainage practices;
- Construction and operation of controlled freshwater canals;
- Changes to groundwater use (changes to the operation and capacity of nearby wellfields); and
- Management and operation of mining practices west of the CCS.

The effect of operation of the CCS was investigated by comparing the results of the historical base case, in which the CCS was modeled as hypersaline, with the hypothetical case in which salinity in the CCS is held at seawater salinity. The result of this comparison showed that operation the CCS at seawater salinity would reduce salt water intrusion relative to operation under hypersaline conditions. Comparison of the effects obtained for each of the factors showed that the operation of the CCS has the largest impact on salt water intrusion of all the factors examined.

[42] Hughes et al. 2009
[43] Andersen and Ross 2018

Significantly, with respect to the topic of this report, the model simulations performed for the attribution study did not explore the impact on salt water intrusion of changes in the operation of the CCS that would affect the water table primarily, such as the effect of freshening activities increasing water levels in the CCS.

### *A study by Dames and Moore evaluates the impact of changes to the water table on the salt water interface.*

Early in the operational history of the CCS, soon after its construction, Dames and Moore was engaged to assess the likely impact of the operation of the CCS on salt water intrusion.[44] One of the factors they considered was the impact that increasing water levels in the CCS might have. Their analysis assumed that an increase in water level in the CCS would be matched by a similar increase in water level in the wetland to the west of the CCS, Figure 8. An increase in the water table next to the CCS would have the effect of reducing the regional hydraulic gradient. That combined with what is effectively an increase in mean sea level in the sense of the Gyben Herzberg relationship (Figure 2) results in a landward shift in the equilibrium position of the salt water interface.

The Dames and Moore study calculated the change in the landward extent of salt water intrusion that would result from a 0.5 foot increase in CCS water level for three hydrologic conditions in the Model Land basin, wet, normal, and dry, corresponding to declining magnitude in values assigned to the regional hydraulic gradient. Estimates for the inland displacement of the salt water interface at equilibrium are ~1 mile under wet conditions, 3 to 4 miles under normal conditions, and ~7 miles under dry conditions.

The particular results obtained from this calculation are less important than the magnitude of the predicted changes, overall. The underlying model neglects the effects of several factors that will affect the behavior of the groundwater system under actual conditions. For one thing, the model does not account for the effect that operation of the interceptor ditch has moderating the relationship between water levels in the CCS and groundwater levels in the wetlands of the Model Land basin. The magnitude of the estimated changes in the horizontal position of the interface – miles – reflects the inherent the sensitivity of the groundwater hydrologic system in the Model Lands basin to relatively small perturbations in water levels.

[44] Dames and Moore 1978

## *3) Adding water to the CCS to reduce salinity increases water levels in the CCS enough to alter the regional gradient in hydraulic head, displacing the salt water interface inland and threatening municipal wellfields.*

Water levels in CCS vary constantly as a consequence of the influence of weather and of fluctuations in water levels in Biscayne Bay and adjacent wetlands, acting through the hydraulic connection provided by the aquifer. Beginning in 2010, FPL has conducted extensive monitoring[45] of water levels and water quality in the CCS, the Biscayne aquifer, Biscayne Bay and adjacent wetlands. During this period the average water level of the CCS has fluctuated by as much as 3 feet, and the volume of the CCS has fluctuated between 4 billion and 8 billion gallons,[46] Figure 10.

Two high water events stand out in the record of fluctuating water levels and volume. The first occurred in 2015. FPL began adding water to the CCS from the L-31E canal in the fall of 2015 for the purpose of reducing the high values of salinity experienced in 2014. This had the effect of raising water levels moderately. Then a week of rain in December 2015 brought water levels to a record high level, reducing greatly reducing salinity in the process. The second, in 2017, corresponds to the passage of Hurricane Irma. Rain in advance of the storm, then during the passage of the hurricane, storm surge overtopping the protective berm that surrounds the CCS filled the canals to capacity.

### *Freshening increases discharge to groundwater.*

Historically, rainfall and evaporation have been the major inflow to and outflow from the CCS, respectively. Other sources of water include relatively small amounts of water discharged from the plant facilities onsite, pumping from the Interceptor Ditch, and water added to reduce salinities in the CCS, i.e. freshening. Discharge to groundwater is the only other outflow from the CCS, as surface water is prevented from entering or leaving the CCS.

The exchange of water between the CCS and the aquifer occurs as both discharge into the aquifer from the CCS and inflows into the CCS from the aquifer. The exchange of water between the CCS and the aquifer varies over time and with location in the CCS. The monitoring program estimates water fluxes between the CCS and groundwater for different parts of the CCS on a daily basis. For the purposes of summarizing the water budget in Table 2, all the separate groundwater fluxes are combined to compute an annual net flux into the Biscayne Aquifer as an

[45] The monitoring program first described in SFWMD 2009 has been expanded to serve the requirements of the 2016 consent order, FDEP 2016.

[46] FPL calculates the volume of the CCS daily, based on measured water levels, as part of their compilation of the water and salt budgets reported by FPL in annual reports of the monitoring program, c.f. FPL 2023a and reports from prior years.

outflow from the CCS. Negative values of net discharge to groundwater means that exchanges with the aquifer resulted in a net inflow of water to the CCS for the year.

Over the long-term, inflows of water from rainfall and other water additions will be balanced by outflows from evaporation and net discharge to groundwater. Small imbalances can occur on an annual basis, resulting in a change in the water stored in the CCS. This is reflected in changes in volume and water level over the course of a year. Exchange with groundwater regulates changes in the volume of the CCS. An increase in volume results in higher water levels and increased hydraulic head, resulting in decreased inflows, increased outflows, and an overall increase in net discharge to groundwater. A decrease in volume has the opposite effect, resulting in a decrease in net discharge to groundwater or a net gain of water from the aquifer. Thus, year-to-year changes volume will even out over time; the fluxes of water into and out of storage will tend toward zero; and inputs from rainfall and other water additions will be balanced by evaporation and net discharge to groundwater.

Beginning in 2015, freshening activities have altered the water budget. FPL describes freshening activities as using fresher water sources, such as brackish water from the Upper Floridan Aquifer, to replace freshwater evaporated from the CCS and thereby reduce the average annual CCS salinity.[47] The Consent Order directs FPL to "cease discharges from the CCS that impair the reasonable and beneficial use of adjacent G-II ground waters to the west of the CCS" by reducing the average annual salinity to 34 psu.

In 2016/7, FPL began adding low-salinity water from the Upper Floridan Aquifer as part of its program to bring salinity in the CCS down to 34 psu, eliminating hypersaline conditions. This has had the expected long-term effect of increasing net discharge to groundwater; long-term average rainfall and evaporation remaining unchanged. Fluctuations occurred during the extremely wet periods of 2015-16 and 2017-18, but the increase in net discharge to groundwater is clear, Figure 11.

### *Freshening increases CCS water levels.*

Freshen the CCS affects water levels in two ways. One is related to the increase in net discharge to groundwater caused by adding water to the CCS. The second is related to the decrease in salinity. Both contribute to the long-term trend of increasing water levels in the CCS seen beginning in 2016, Figure 12. The observed change in water level between 2016 and 2023 associated with this long-term trend is amounts to an increase of 0.33 feet.

Water levels increase with increased net discharge to groundwater because both the increase in discharge out of the CCS into the aquifer and the decrease in discharge from the aquifer into the CCS require an increase in hydraulic head in the CCS relative to the surrounding aquifer.

[47] FPL 2023b

Increasing the level of water in the CCS increases hydraulic head, all other factors being the same.

Water levels increase with decreasing salinity due to the effect of salinity on the density of water. Consider, for example, the discharge into the aquifer through the bottom of the CCS, which is where most of the discharge to groundwater occurs. The equations for groundwater flow relate flow to a difference in hydraulic head; however, it is understood that water movement through a porous medium is driven by a difference in pressure. Decreasing salinity makes the water in the CCS less dense, lighter, decreasing pressure it exerts on the bottom of the CCS, which is the driving force moving water into the aquifer. In order to maintain the same rate of discharge to groundwater, the depth of water of the less dense water must increase to compensate for the lower density of the water column

I used multiple regression analysis applied to a 4.5-year record[48] of changes in water levels in the CCS, the water balance fluxes, and salinity to quantify the change in water level that will result from planned current and planned future freshening operations. The purpose of this analysis is to estimate the magnitude of the change in CCS water level that will result from freshening and assess its impact on the salt water interface. I also included Biscayne Bay water level in the analysis because evidence shows that water levels in the CCS respond to changes to bay water levels.

I assembled data from the Water and Salt budget compilations included in the FPL annual monitoring reports[49] into a Microsoft Excel spreadsheet, and I used the native regression routine to perform the analysis. The results are reported in Table 3.

The expected change in water levels resulting from current and planned changes in CCS operation can be calculated using the coefficients determined from the regression analysis. Taking ~2010 as the baseline, current operations in 2023 have increased the net water inputs by ~14 mgd and decreased salinity by ~30 psu. The addition of water for freshening has increased water levels by 0.116 feet (14 mgd multiplied by 0.00832), and the resulting decrease in salinity has increased water levels by 0.266 feet (-30 psu multiplied by -0.0089) for a total increase in CCS water level of 0.38 feet.

FPL has announced plans to increase the amount of water added for freshening to ~30 mgd. Compared to water levels in the CCS prior to the start of freshening activities, the total increase in water level expected as the result of current and planned future freshening operations is 0.52 feet.

[48] January 2016 through May 2020
[49] C.f. FPL 2023a and annual reports from prior years.

### *The estimated increase in CCS water levels is significant at a regional level.*

The significance of changes in CCS water level of this magnitude, i.e. 0.38 feet now and 0.52 feet in the future, can be judged by comparison with the gradient in hydraulic head driving fresh water flow to the coast across the entire Model Land basin, Figure 13. In around 2013, FPL implemented a 2-D, density dependent groundwater model to assess the effectiveness of reducing salinity in the CCS on mitigating the impacts the plume of CCS water advancing westward beneath the Model Land basin. Water levels prescribed as boundary conditions on groundwater flow in this model are summarized in Figure 13, taken from Giddings (2013)[50] who reviewed FPL's model application for the South Florida Water Management District.

The regional gradient in hydraulic head is determined by the difference in water levels prescribed at the western boundary of the model, i.e. the L-31W canal, and the L-31E canal, that is ~2 feet. Assuming that changes in water level in CCS are reflected by similar increases in the fresh water table in the wetlands immediately adjacent to the CCS, as proposed in the analysis by Dames and Moore (1978)[51], a 0.5 foot increase in CCS water level could decrease the regional gradient by as much as 25 percent. Reading from the results presented in Dames and Moore (1978), a 0.5 foot increase in CCS water level can be expected to displace the position of the salt water interface to the west between ~1 mile, under wet, high regional gradient conditions, and ~7 miles, under dry, low regional gradient conditions. (See Figure 9)

[50] Giddings 2013
[51] Dames and Moore 1978

## *4) Closing down the CCS will mitigate saltwater intrusion in the Model Land basin and decrease threats to municipal wells.*

Discontinuing the operation of the CCS would end its contribution to salt water intrusion beneath that Model Land basin that threatens municipal water supply wells. Discontinuing the operation of the CCS as a heat sink for Units 3 and 4 by turning off the circulating water pumps, discontinuing the addition of water from the Upper Floridan Aquifer for freshening, and establishing free, open communication between the canals and Biscayne Bay would equilibrate water levels with Biscayne Bay, and end the active discharge of water from the CCS into the aquifer that feeds salt water intrusion into the Biscayne Aquifer. Under current operations in the period June 2016 through May 2020, the period for which water level data are available to me from the annual monitoring program, water levels in the header canal were about 0.3 feet above the level of Biscayne Bay.

Equilibrating water levels in the CCS with water levels in Biscayne Bay would reduce, perhaps eliminate, the active discharge of water into the aquifer, and it would contribute to increasing the regional hydraulic head driving the flow of fresh groundwater to the coast. The increase in the regional hydraulic head gradient would reverse salt water intrusion, at least for a little while, buying time until sea level rise catches up and returns water levels in the decommissioned CCS canals to their present levels.

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**Table 1: Estimated rates for the withdrawal of freshwater from the Biscayne aquifer from pumping the Interceptor Ditch. Data are for the period January 2015 through November 2017.**

| | Calculated fresh water flow (mgd) | Measured ID Pump Rate (mgd) | ID salinity | L-31E salinity |
|---|---|---|---|---|
| Average | 3.45 | 4.01 | 6.11 | 1.51 |
| Standard deviation | 8.53 | 9.63 | 3.85 | 1.44 |
| Maximum | 161.19 | 168.60 | 20.13 | 6.76 |
| Minimum | 0.00 | 0.00 | 1.92 | 0.27 |

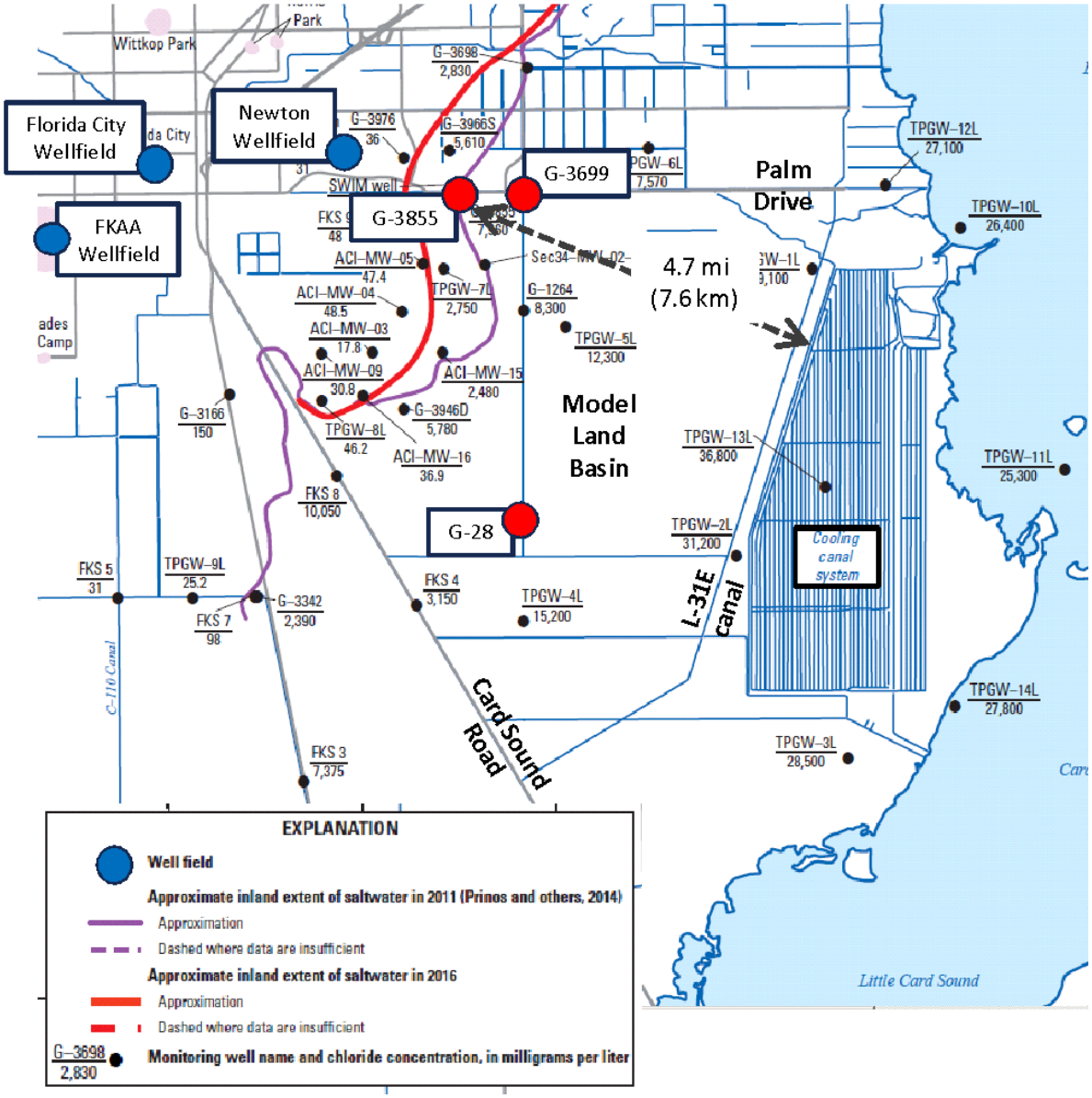
**Table 2: Main components of the CCS water budget compiled from annual monitoring reports. Periods with extraordinarily high inputs of water are highlighted.**

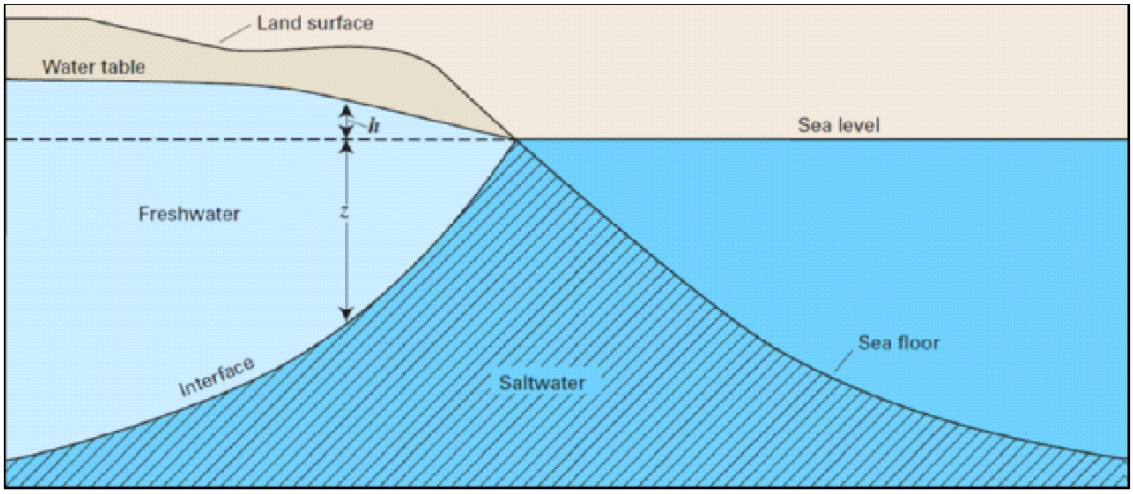
| Period June to May | Inflows (mgd) | | Outflows (mgd) | | Stored (mgd) |
|---|---|---|---|---|---|
| | Rainfall | Other Sources | Evaporation | Net Discharge to Groundwater | |
| 2011-12 | 26.6 | 7.0 | 35.4 | -4.2 | 2.5 |
| 2012-13 | 19.5 | 4.7 | 31.7 | -8.1 | 0.6 |
| 2013-14 | 16.8 | 3.2 | 42.8 | -19.0 | -3.8 |
| 2014-15 | 17.6 | 16.2 | 41.8 | -8.3 | 0.2 |
| 2015-16 | 26.9 | 28.9 | 39.1 | 17.2 | -0.4 |
| 2016-17 | 16.6 | 16.7 | 35.8 | -6.8 | 4.3 |
| 2017-18 | 25.7 | 20.0 | 41.0 | 3.5 | 1.2 |
| 2018-19 | 16.4 | 14.9 | 35.7 | -2.3 | -2.2 |
| 2019-20 | 20.4 | 18.2 | 38.1 | -2.8 | 3.4 |
| 2020-21 | 24.9 | 17.3 | 35.9 | 9.5 | -3.1 |
| 2021-22 | 23.9 | 16.4 | 35.9 | 3.4 | 1.0 |
| 2022-23 | 30.2 | 16.2 | 41.5 | 4.0 | 1.0 |

**Table 3: Results from multiple regression to determine the effect of net water supply, Biscayne Bay water level, and average salinity on water level in the CCS. Data are from the period January 2016 through May 2020.**

| SUMMARY OUTPUT | | | | |
|---|---|---|---|---|
| *Regression Statistics* | | | | |
| Multiple R | 0.835818 | | | |
| R Square | 0.698592 | | | |
| Adjusted R Square | 0.679353 | | | |
| Standard Error | 0.181956 | | | |
| Observations | 51 | | | |
| | | | | |
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
| Intercept | 0.58299 | 0.176058 | 3.311353 | 0.00179 |
| net water supply (mgd) | 0.008315 | 0.001441 | 5.772036 | 5.95E-07 |
| Biscayne Bay level (ft) | 0.535857 | 0.079892 | 6.707309 | 2.27E-08 |
| CCS avg salinity (PSU) | -0.00887 | 0.003275 | -2.70877 | 0.009392 |

**Figure 1: Location of the Turkey Point cooling canals (CCS) showing the main features of the Model Lands hydrologic basin and the location of nearby municipal wellfields (blue), the positions of the salt water interface in 2014 (purple) and 2016 (red), and monitoring wells. Water originating from the CCS has been detected in groundwater at the wells shown in red, as indicated by the presence of tritium in excess of 20 pico Curies per liter. (This figure is adapted from Prinos 2017.)**






Source: Barlow 2003

**Figure 3-16 Generalized Diagram of the Freshwater-Saltwater Interface in a Coastal Water Table Aquifer**

**Figure 3: Diagram showing the extent of the compliance area defined for compliance with the 2016 consent order, in orange. The approximate location of the G-28 monitoring well is added here to aid in comparing the position of the western boundary of the compliance area with the inland extent of salt water intrusion shown in Figures 1, 4 and 5. (This figure is modified from NRC 2024.)**

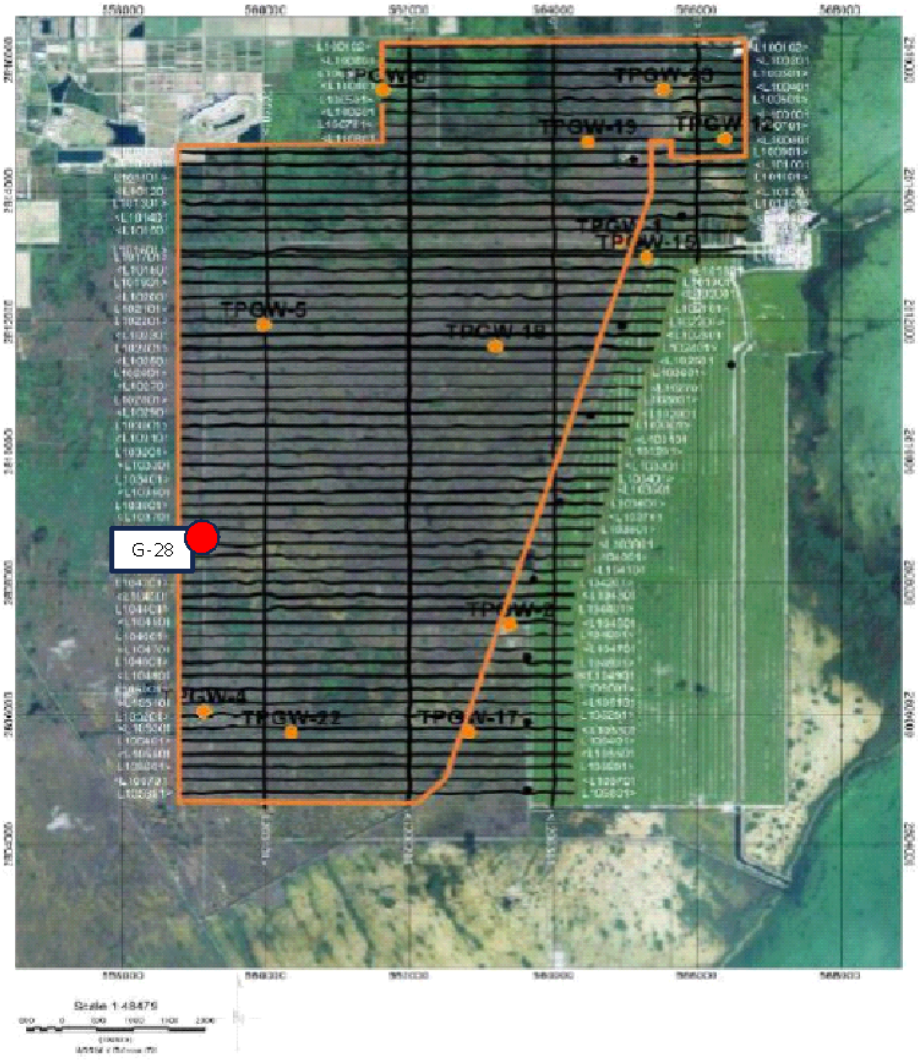



Figure 2-6 Aerial Electromagnetic Flight Lines from 2023 Study Represented by Black Lines, and Orange Lines Representing Monitoring Well Locations and Compliance Area Boundary. (Source FPL 2023e; Figure 4.3-1)

**Figure 4: Historic positions of the salt water interface in the Model Land Area referenced by FPL. (This figure is based on Figure 2-22 in NRC 2016.)**

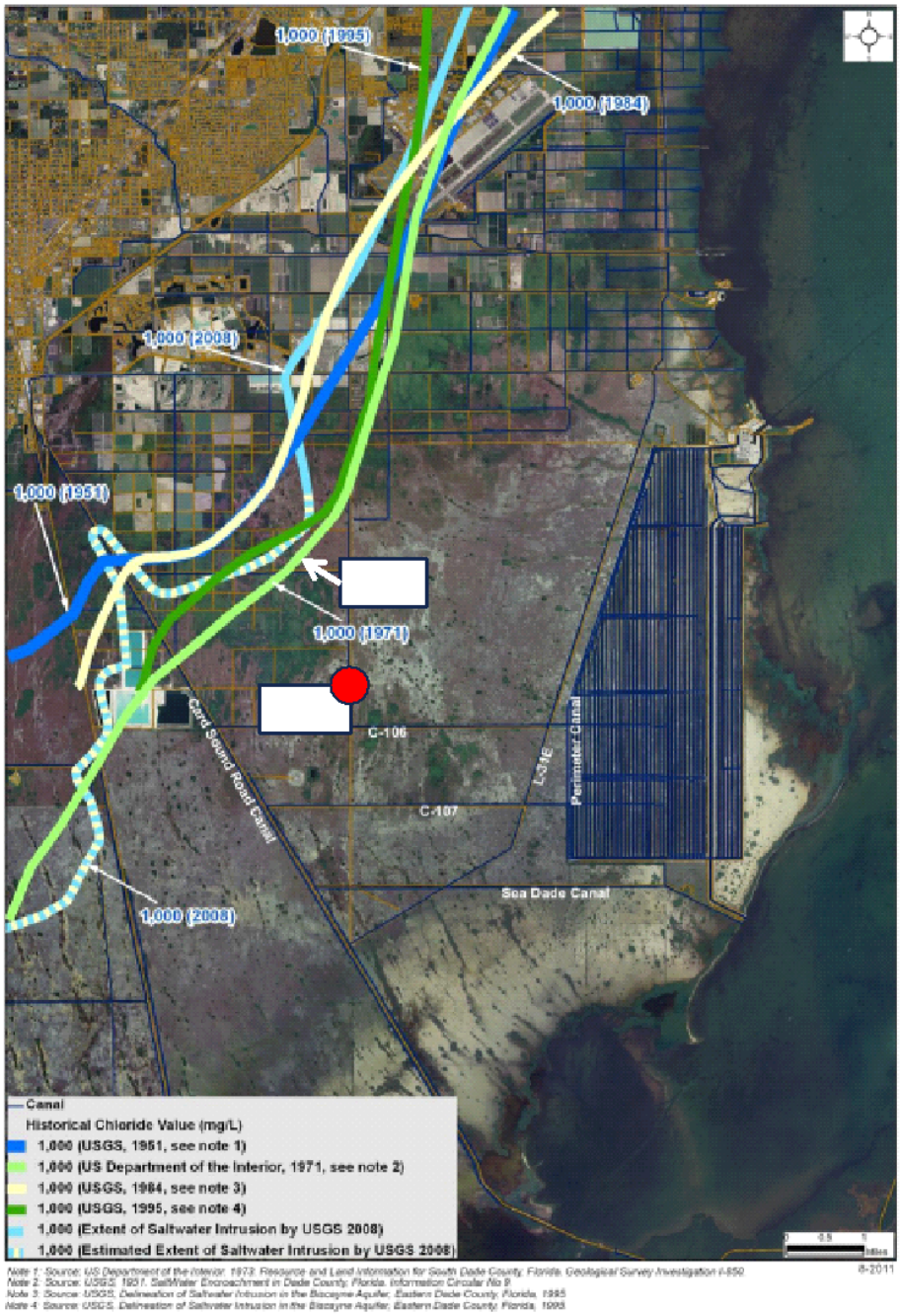


**Figure 5: Cross section through the Biscayne Aquifer at the CCS showing the position of the salt water interface prior to building the CCS (upper panel) and the projected position of the interface some time after completion of the CCS, when equilibrium of the interface has been reestablished (lower panel). (Figure adapted from figures 6.7 and 6.8 in Dames and Moore 1978)**

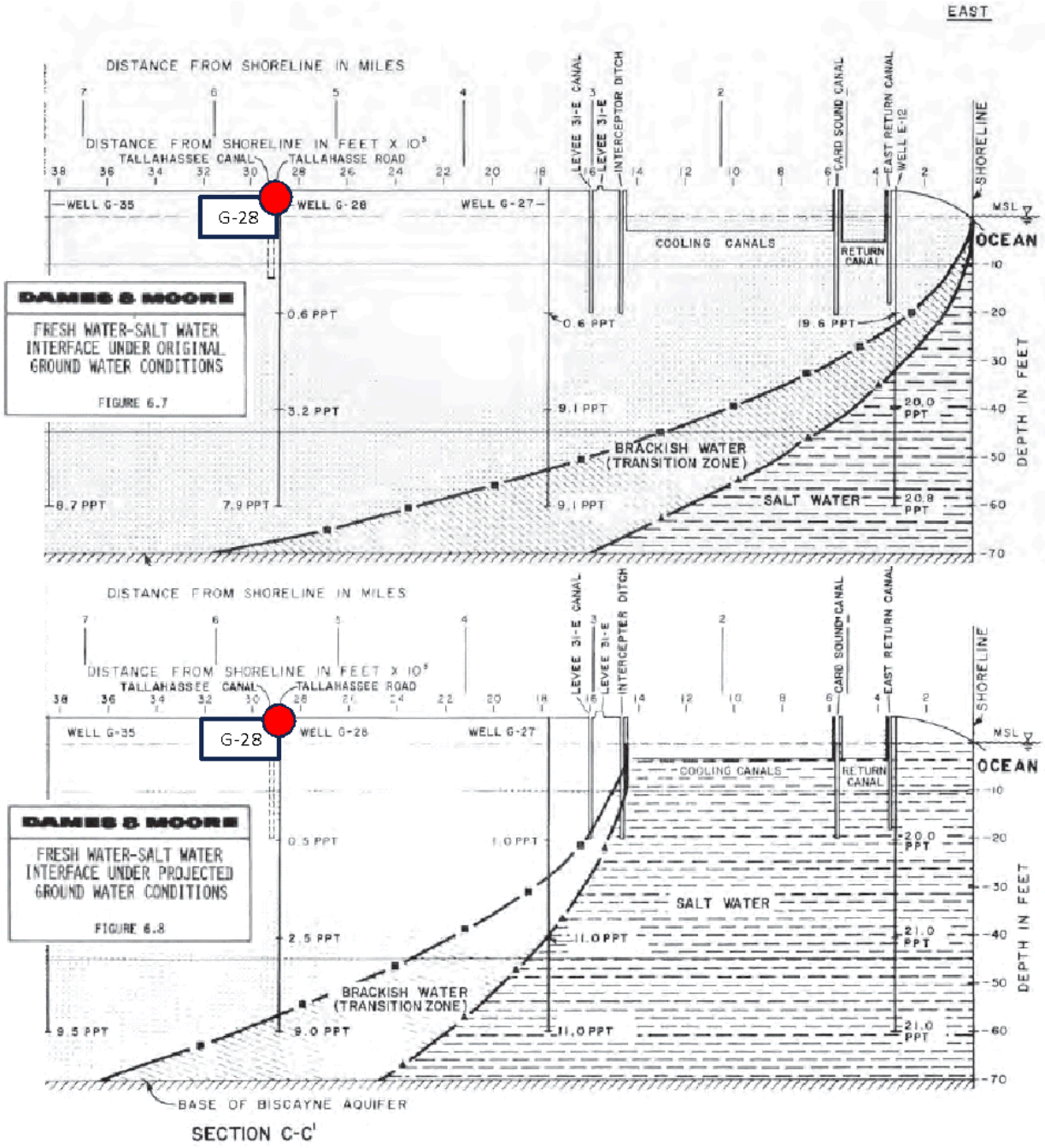
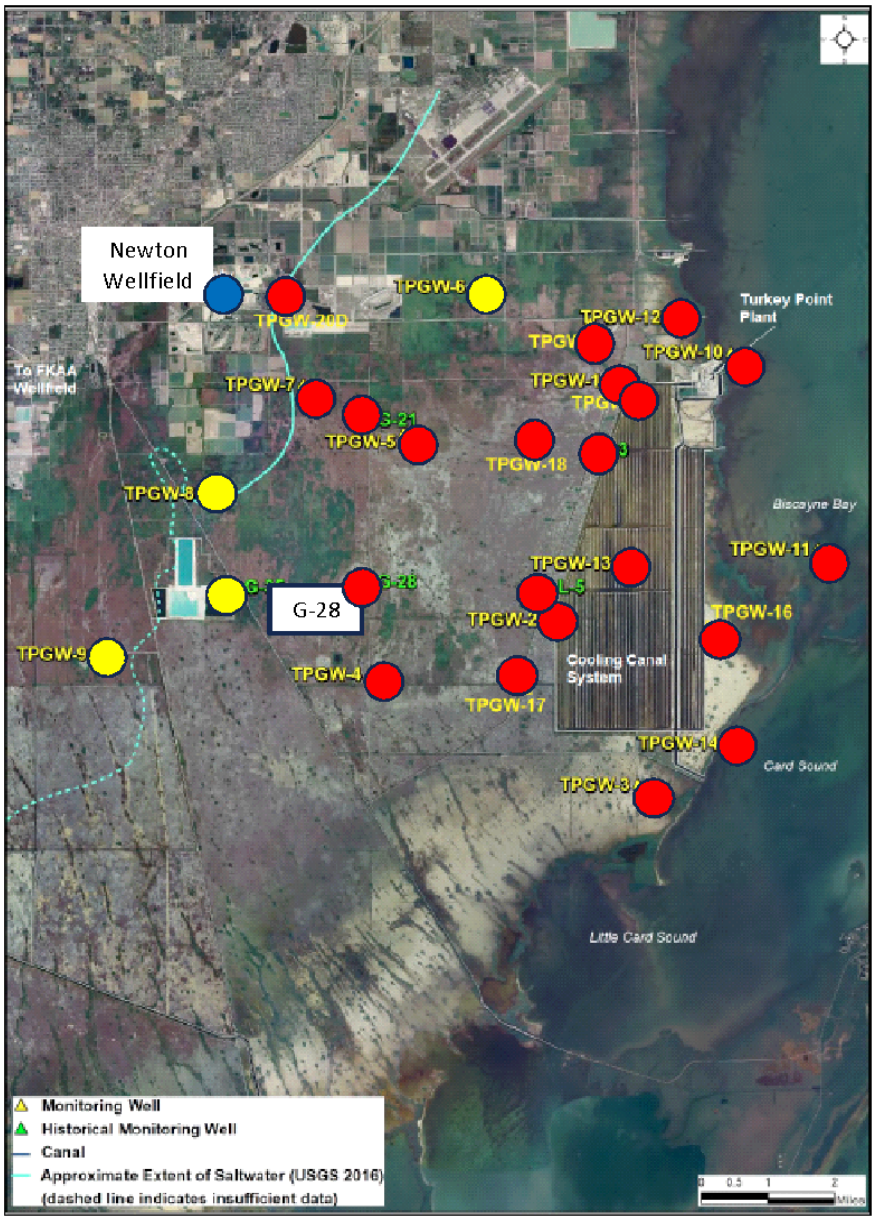


**Figure 6: Locations in the FPL groundwater monitoring network reporting the presence of CCS water, as indicated by tritium concentrations in excess of 20 pico Curies per liter, in the 2023 annual monitoring report[52] (shown in red). Locations where tritium has been found above this threshold in the past, but not in the latest reporting period, are shown in yellow. (This figure is adapted from NRC 2019.)**

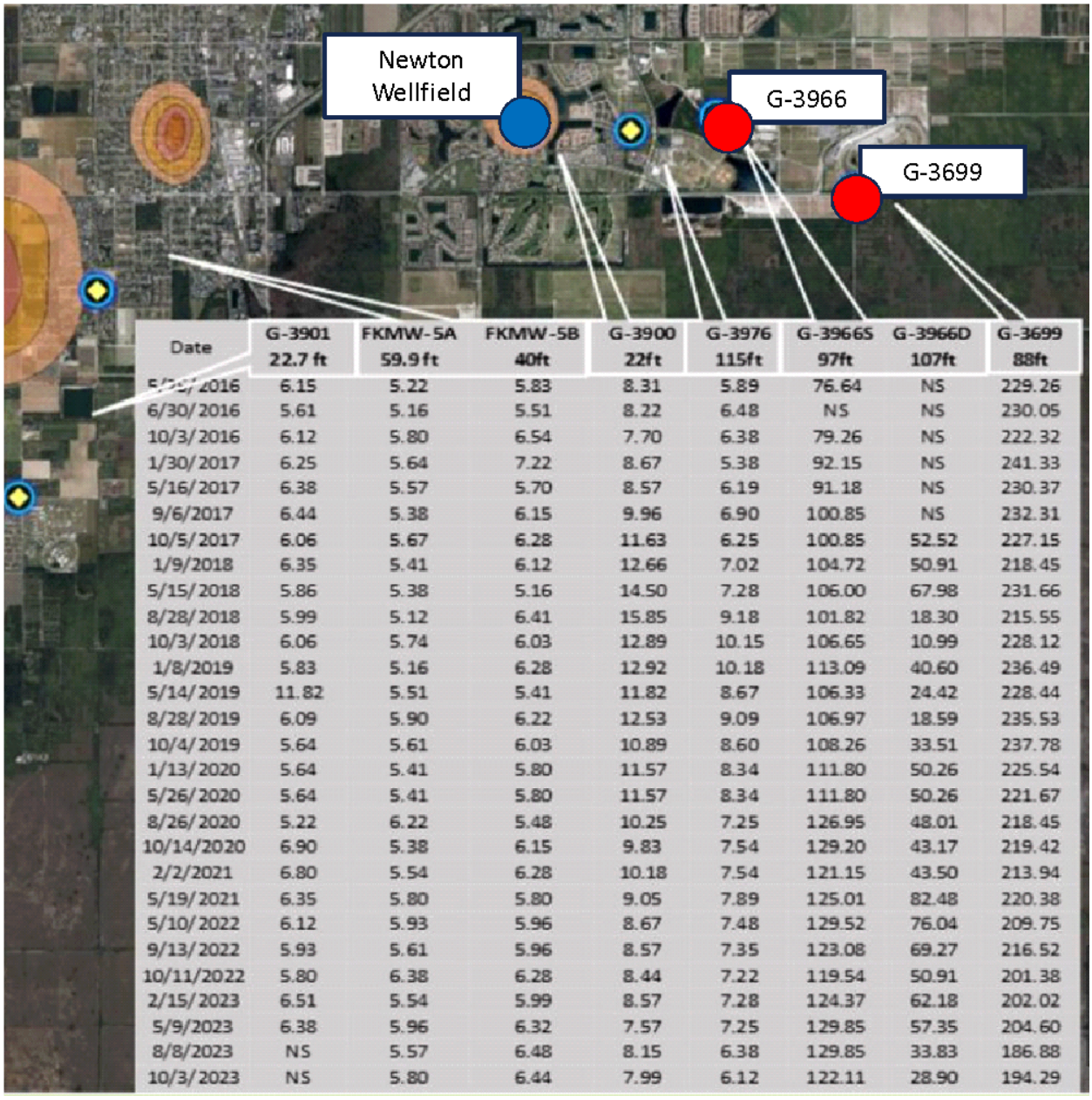



Source: Modified from FPL 2018o: Fig. 1.1-2 and FPL 2018p: Fig. 2.4-1

**Figure 3-17 Groundwater Monitoring Locations and Saltwater Interface, Turkey Point Site**

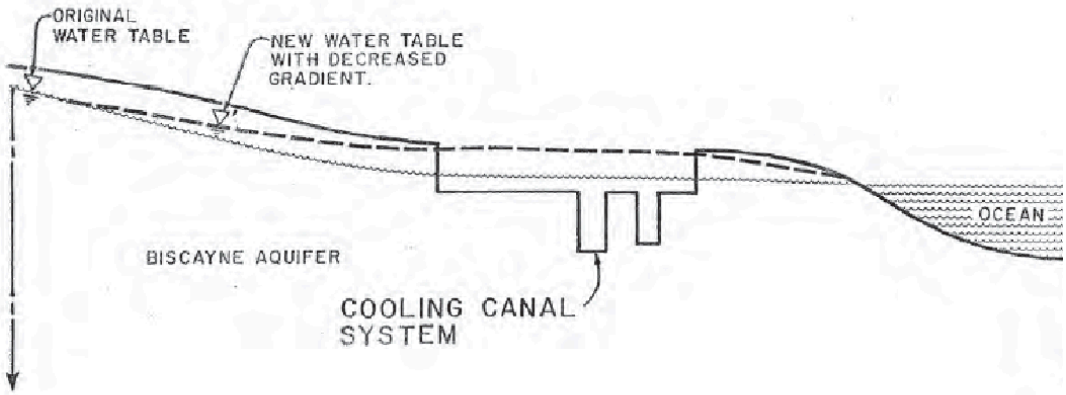
[52] FPL 2023 annual monitoring report

**Figure 7: Data collected by Miami-Dade County shows that water originating from the CCS persists in the aquifer after its first detection in wells near the Newton municipal wellfield. The presence of CCS water in groundwater is indicated by tritium concentrations in excess of 20 pico Curies per liter. (This figure is adapted from a figure provided by Miami-Dade County.)**




| Date | G-3901 22.7 ft | FKMW-5A 59.9 ft | FKMW-5B 40ft | G-3900 22ft | G-3976 115ft | G-3966S 97ft | G-3966D 107ft | G-3699 88ft |
|---|---|---|---|---|---|---|---|---|
| [illegible]/2016 | 6.15 | 5.22 | 5.83 | 8.31 | 5.89 | 76.64 | NS | 229.26 |
| 6/30/2016 | 5.61 | 5.16 | 5.51 | 8.22 | 6.48 | NS | NS | 230.05 |
| 10/3/2016 | 6.12 | 5.80 | 6.54 | 7.70 | 6.38 | 79.26 | NS | 222.32 |
| 1/30/2017 | 6.25 | 5.64 | 7.22 | 8.67 | 5.38 | 92.15 | NS | 241.33 |
| 5/16/2017 | 6.38 | 5.57 | 5.70 | 8.57 | 6.19 | 91.18 | NS | 230.37 |
| 9/6/2017 | 6.44 | 5.38 | 6.15 | 9.96 | 6.90 | 100.85 | NS | 232.31 |
| 10/5/2017 | 6.06 | 5.67 | 6.28 | 11.63 | 6.25 | 100.85 | 52.52 | 227.15 |
| 1/9/2018 | 6.35 | 5.41 | 6.12 | 12.66 | 7.02 | 104.72 | 50.91 | 218.45 |
| 5/15/2018 | 5.86 | 5.38 | 5.16 | 14.50 | 7.28 | 106.00 | 67.98 | 231.66 |
| 8/28/2018 | 5.99 | 5.12 | 6.41 | 15.85 | 9.18 | 101.82 | 18.30 | 215.55 |
| 10/3/2018 | 6.06 | 5.74 | 6.03 | 12.89 | 10.15 | 106.65 | 10.99 | 228.12 |
| 1/8/2019 | 5.83 | 5.16 | 6.28 | 12.92 | 10.18 | 113.09 | 40.60 | 236.49 |
| 5/14/2019 | 11.82 | 5.51 | 5.41 | 11.82 | 8.67 | 106.33 | 24.42 | 228.44 |
| 8/28/2019 | 6.09 | 5.90 | 6.22 | 12.53 | 9.09 | 106.97 | 18.59 | 235.53 |
| 10/4/2019 | 5.64 | 5.61 | 6.03 | 10.89 | 8.60 | 108.26 | 33.51 | 237.78 |
| 1/13/2020 | 5.64 | 5.41 | 5.80 | 11.57 | 8.34 | 111.80 | 50.26 | 225.54 |
| 5/26/2020 | 5.64 | 5.41 | 5.80 | 11.57 | 8.34 | 111.80 | 50.26 | 221.67 |
| 8/26/2020 | 5.22 | 6.22 | 5.48 | 10.25 | 7.25 | 126.95 | 48.01 | 218.45 |
| 10/14/2020 | 6.90 | 5.38 | 6.15 | 9.83 | 7.54 | 129.20 | 43.17 | 219.42 |
| 2/2/2021 | 6.80 | 5.54 | 6.28 | 10.18 | 7.54 | 121.15 | 43.50 | 213.94 |
| 5/19/2021 | 6.35 | 5.80 | 5.80 | 9.05 | 7.89 | 125.01 | 82.48 | 220.38 |
| 5/10/2022 | 6.12 | 5.93 | 5.96 | 8.67 | 7.48 | 129.52 | 76.04 | 209.75 |
| 9/13/2022 | 5.93 | 5.61 | 5.96 | 8.57 | 7.35 | 123.08 | 69.27 | 216.52 |
| 10/11/2022 | 5.80 | 6.38 | 6.28 | 8.44 | 7.22 | 119.54 | 50.91 | 201.38 |
| 2/15/2023 | 6.51 | 5.54 | 5.99 | 8.57 | 7.28 | 124.37 | 62.18 | 202.02 |
| 5/9/2023 | 6.38 | 5.96 | 6.32 | 7.57 | 7.25 | 129.85 | 57.35 | 204.60 |
| 8/8/2023 | NS | 5.57 | 6.48 | 8.15 | 6.38 | 129.85 | 33.83 | 186.88 |
| 10/3/2023 | NS | 5.80 | 6.44 | 7.99 | 6.12 | 122.11 | 28.90 | 194.29 |

**Figure 8: Adjustment in the position of the fresh water table that will occur as the result of increasing water levels in the CCS. (This figure is adapted from figure 7.3 in Dames and Moore 1978.)**




SCHEMATIC CROSS SECTION ILLUSTRATING EFFECT
OF RAISING COOLING CANAL SYSTEM WATER
LEVELS ON THE FRESH WATER HYDRAULIC GRADIENT.

**Figure 9: Calculated position of the salt water interface, at equilibrium, at the base of the Biscayne (in miles from the CCS, shown on the horizontal axis) that will result from an increase in the water level in the CCS (in feet, show on the vertical axis) for dry (upper panel), average (middle panel), and wet conditions (lower panel). (Figure 7.4 from Dames and Moore 1978.)**

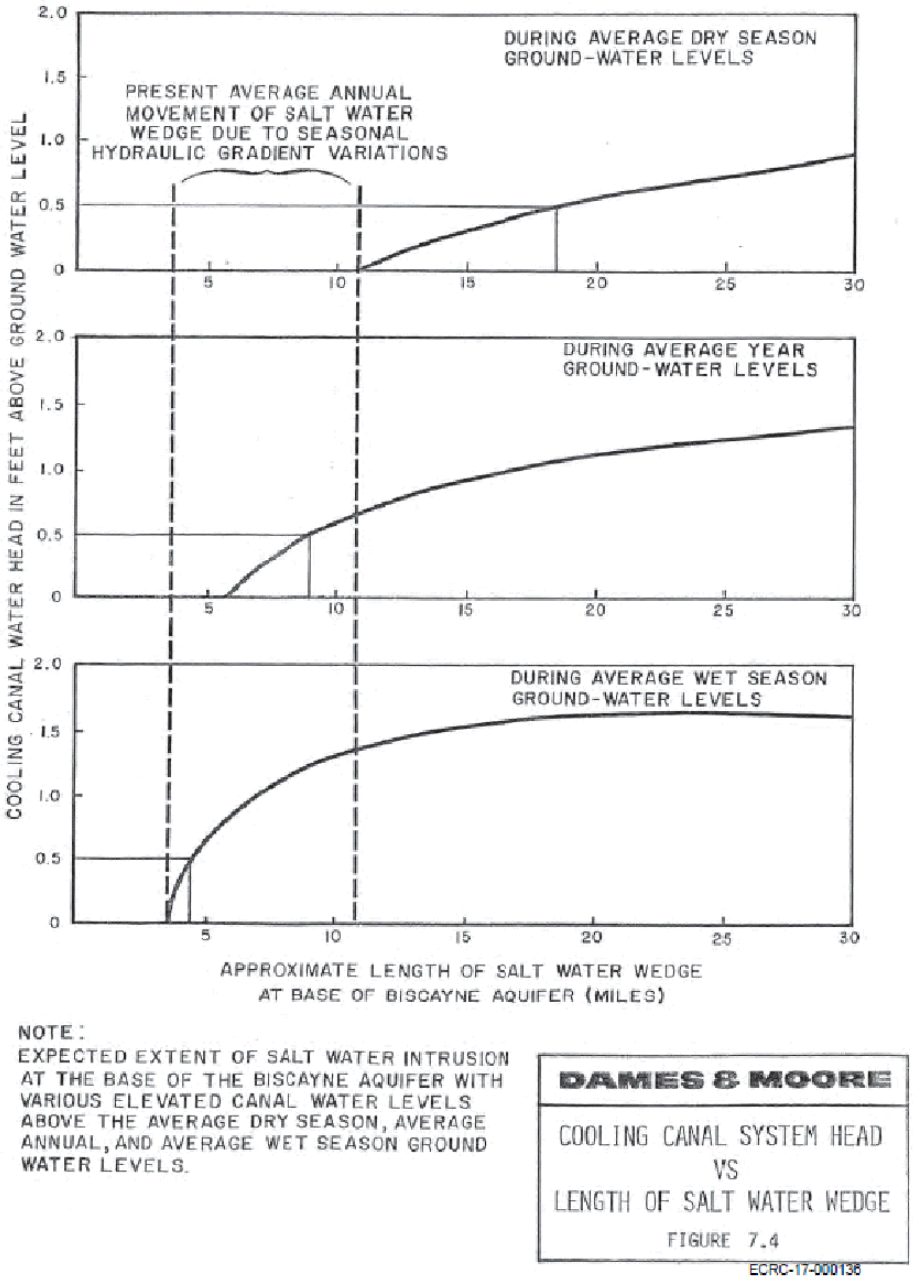


**Figure 10: The volume of water contained in the CCS changes constantly in response to rainfall, water inputs from other sources, and the loss of water through evaporation. Water exchange between the CCS canals and the underlying aquifer sometimes adds water and sometimes removes water from the CCS. Measured changes in CCS volume combined with measurements and estimates of rainfall, other water inputs, and evaporation make it possible to calculate the volume of water exchanged with the aquifer on a daily basis.**

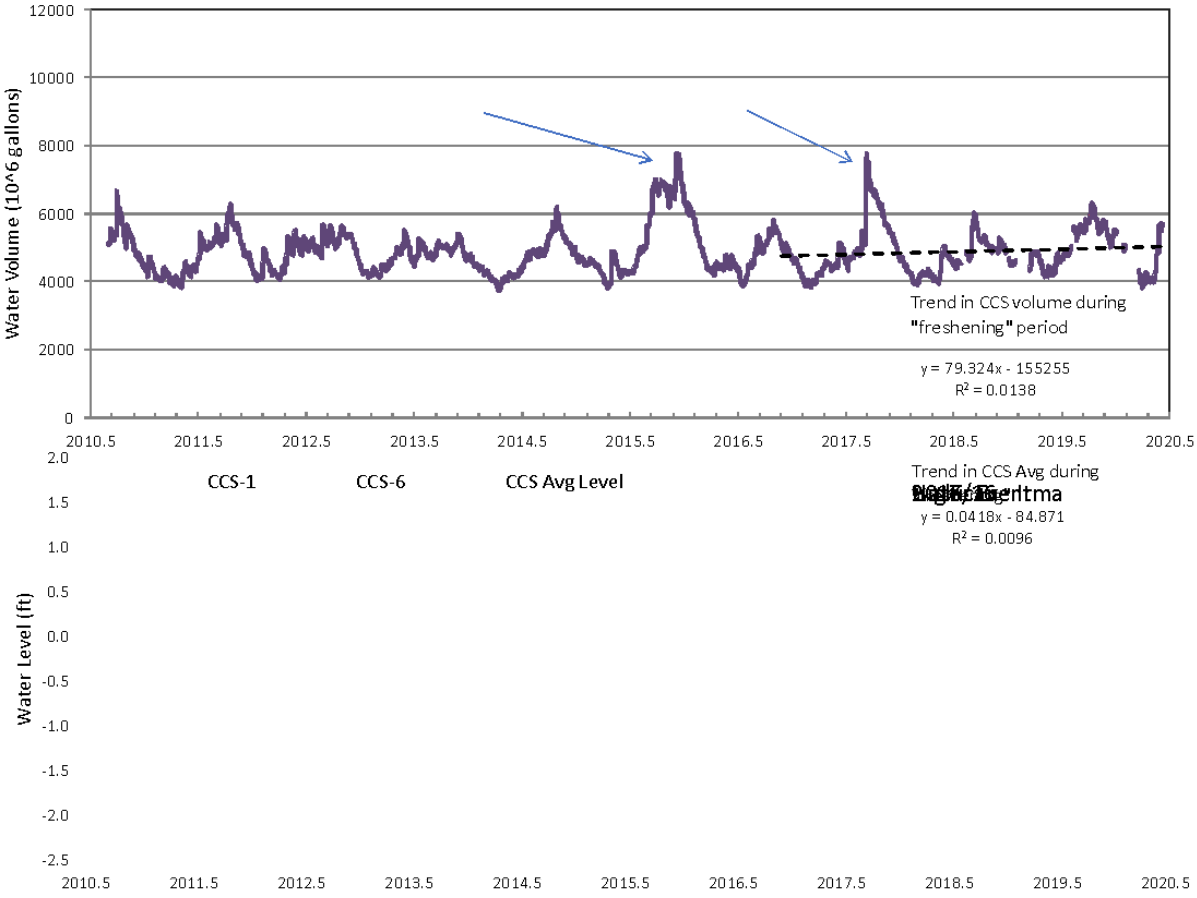


**Figure 11: Net discharge from the CCS into the Biscayne Aquifer has increased as a result of freshening activities that began in 2015. The shaded areas indicate the range defined by the calculated average of annual net discharge plus and minus one standard error in the periods prior to and following the 2015-16 reporting period. The 2015-16 reporting period is excluded because net discharge in that year was affected by high rainfall in and by the addition of a higher amount of water for freshening than in subsequent years.**

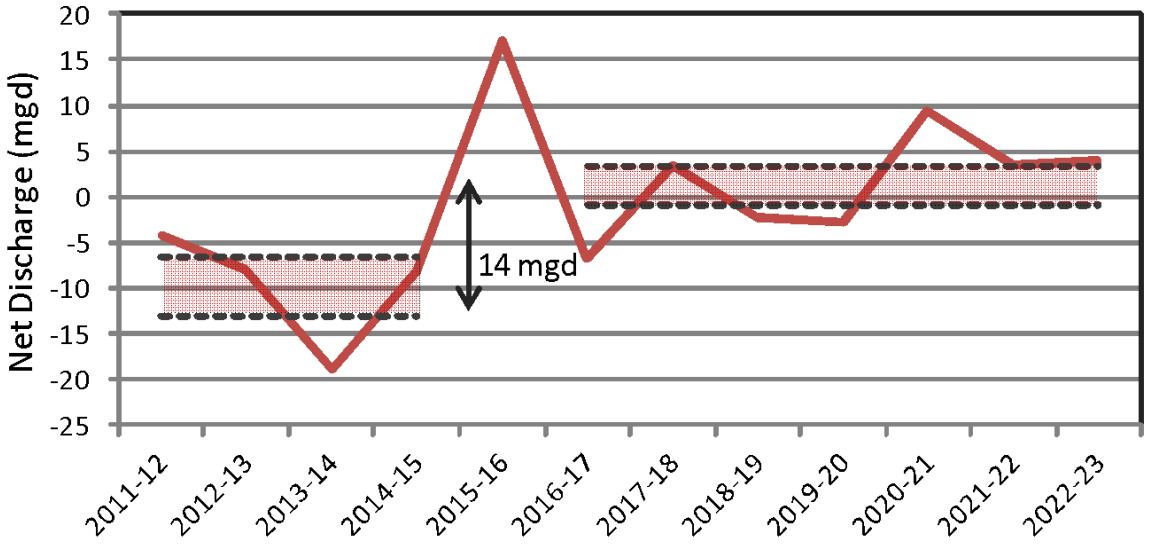


**Figure 12: Monthly average CCS water level measured at the northwest corner showing the trend of increasing water level 2016 through mid-2023.**

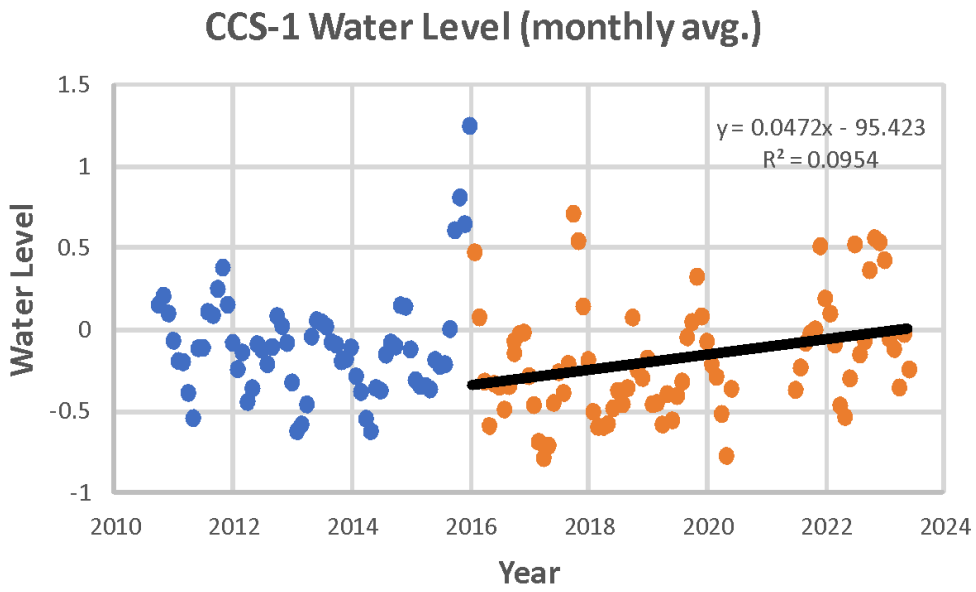


**Figure 13: Projected increase in CCS water levels compared with water levels prescribed as boundary conditions in the groundwater model implemented by FPL in 2013. (This figure is adapted from Figure 3 in Giddings 2013)**

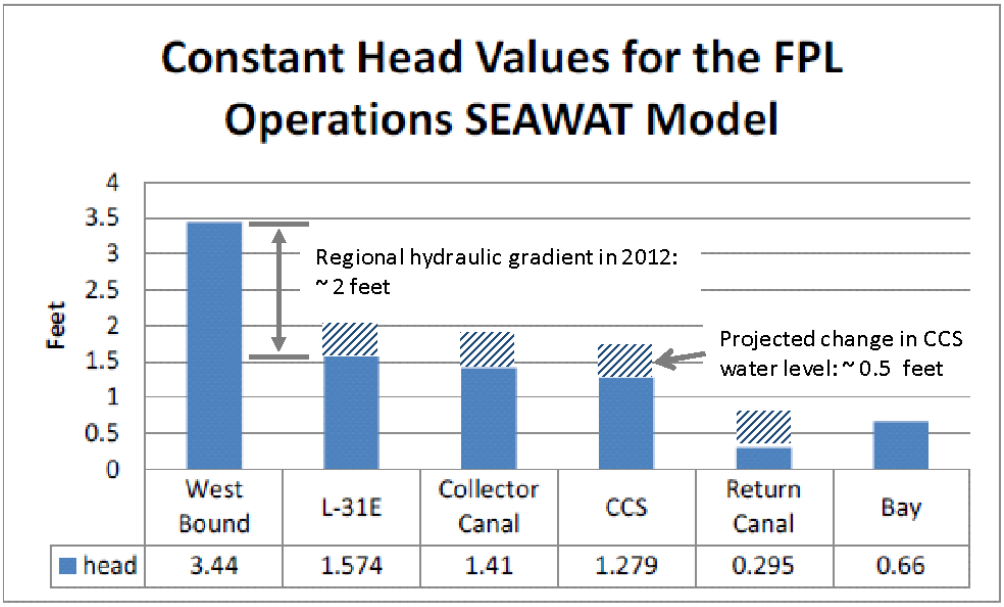



**Figure 3. FPL Canal Stages for the Operations Model submitted to SFWMD.**

# Curriculum Vitae

William K. Nuttle, PhD, PEng

11 Craig Street
Ottawa, Ontario
Canada K1S 4B6
wknuttle@gmail.com

## Profile

William K. Nuttle has 35 years of experience working with water managers, engineers, Earth scientists and ecologists in planning research and in interpreting and applying science to restore ecosystems and manage natural resources. Dr. Nuttle has coordinated large-scale ecosystem research programs in South Florida and Louisiana, and he provides expert advice and legal testimony on matters of coastal hydrology. Dr. Nuttle was director of Everglades Department for the South Florida Water Management District in 2000-2001. Prior to that he served as Executive Officer for the Florida Bay Science Program. Dr. Nuttle received his M.S. and Ph.D. (1986) degrees in civil engineering from the Massachusetts Institute of Technology and his BSCE from the University of Maryland.

## Education

| | |
|---|---|
| 1986 | PhD, Civil Engineering, Massachusetts Institute of Technology, 1986 |
| 1982 | MS, Civil Engineering, Massachusetts Institute of Technology, 1982 |
| 1980 | BS, Civil Engineering, University of Maryland, 1980 |

## Career Summary

| | |
|---|---|
| 1986 - | Consultant in Environmental Science, Hydrology, and Water Resources |
| 2013 - | Consultant, Integration and Application Network, Center for Environmental Science, University of Maryland |
| 2009 - 2012 | Executive Officer, South Florida MARES Project |
| 2000 - 2001 | Director, Everglades Department, Division of Watershed Research and Planning, South Florida Water Management District |
| 1998 - 2000 | Executive Officer, Science Program for Florida Bay and Adjacent Marine Systems |
| 1997 | Lecturer, Environmental Science Program, Carleton University, Ottawa, Ontario |
| 1991 - 1993 | Associate, Rawson Academy of Aquatic Science, Ottawa, Ontario |
| 1990 - 1991 | Assistant Professor (Research), Memorial University of Newfoundland |
| 1986 - 1989 | Assistant Professor, University of Virginia |

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# ATTACHMENT B

United States Government Accountability Office

Report to Congressional Requesters

April 2024

# NUCLEAR POWER PLANTS

# NRC Should Take Actions to Fully Consider the Potential Effects of Climate Change

GAO-24-106326

GAO Highlights

Highlights of GAO-24-106326, a report to congressional requesters

April 2024

# NUCLEAR POWER PLANTS

## NRC Should Take Actions to Fully Consider the Potential Effects of Climate Change

## Why GAO Did This Study

NRC licenses and regulates the use of nuclear energy to provide reasonable assurance of adequate protection of public health and safety, to promote the common defense and security, and to protect the environment. Like all energy infrastructure, nuclear power plants can be affected by disruptions from natural hazards, some of which are likely to be exacerbated by climate change. Most commercial nuclear plants in the United States were built in the 1960s and 1970s, and weather patterns and climate-related risks to these plants have changed since their construction.

GAO was asked to review the climate resilience of energy infrastructure. This report examines (1) how climate change is expected to affect nuclear power plants and (2) NRC actions to address risks to nuclear power plants from climate change. GAO analyzed available federal data and reviewed regulations, agency documents, and relevant literature. GAO interviewed officials from federal agencies, including NRC, the Department of Energy, and the National Oceanic and Atmospheric Administration, and knowledgeable stakeholders from industry, academia, and nongovernmental organizations. GAO also conducted site visits to two plants.

## What GAO Recommends

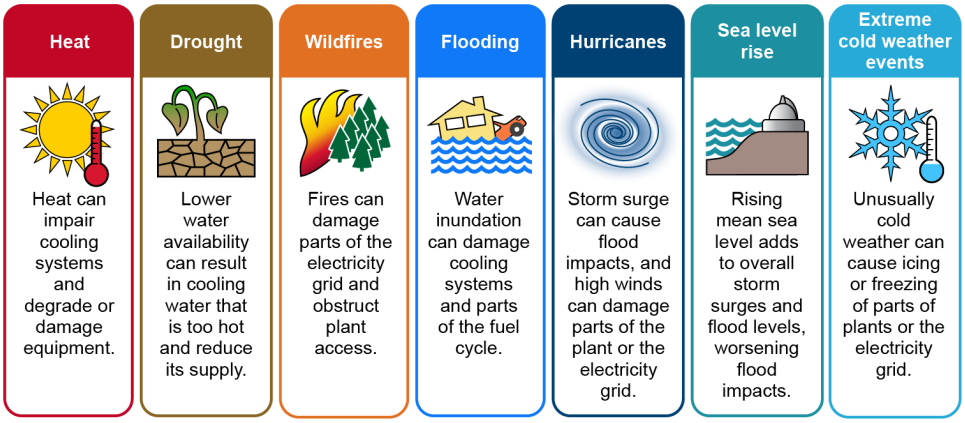
GAO is making three recommendations, including that NRC assess whether its existing processes adequately address climate risks and develop and implement a plan to address any gaps identified. NRC said the recommendations are consistent with actions that are either underway or under development.

View GAO-24-106326. For more information, contact Frank Rusco at (202) 512-3841 or ruscof@gao.gov.

## What GAO Found

Climate change is expected to exacerbate natural hazards—including heat, drought, wildfires, flooding, hurricanes, and sea level rise. In addition, climate change may affect extreme cold weather events. Risks to nuclear power plants from these hazards include loss of offsite power, damage to systems and equipment, and diminished cooling capacity, potentially resulting in reduced operations or plant shutdowns.

**Examples of Natural Hazards that May Pose Risks to Nuclear Power Plants**




Sources: Nuclear Regulatory Commission documents; summary of literature; GAO (icons). | GAO-24-106326

The Nuclear Regulatory Commission (NRC) addresses risks to the safety of nuclear power plants, including risks from natural hazards, in its licensing and oversight processes. Following the tsunami that led to the 2011 accident at Japan's Fukushima Dai-ichi nuclear power plant, NRC took additional actions to address risks from natural hazards. These include requiring safety margins in reactor designs, measures to prevent radioactive releases should a natural hazard event exceed what a plant was designed to withstand, and maintenance of backup equipment related to safety functions.

However, NRC's actions to address risks from natural hazards do not fully consider potential climate change effects. For example, NRC primarily uses historical data in its licensing and oversight processes rather than climate projections data. NRC officials GAO interviewed said they believe their current processes provide an adequate margin of safety to address climate risks. However, NRC has not conducted an assessment to demonstrate that this is the case. Assessing its processes to determine whether they adequately address the potential for increased risks from climate change would help ensure NRC fully considers risks to existing and proposed plants. Specifically, identifying any gaps in its processes and developing a plan to address them, including by using climate projections data, would help ensure that NRC adopts a more comprehensive approach for assessing risks and is better able to fulfill its mission to protect public health and safety.

# Contents

## Abbreviations

| | |
|---|---|
| FLEX | Diverse and Flexible Coping Strategies |
| NCA | National Climate Assessment |
| NOAA | National Oceanic and Atmospheric Administration |
| NRC | Nuclear Regulatory Commission |
| POANHI | Process for the Ongoing Assessment of Natural Hazard Information |
| SAFER | Strategic Alliance for FLEX Emergency Response |

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

April 2, 2024

The Honorable Joe Manchin III
Chairman
Committee on Energy and Natural Resources
United States Senate

The Honorable Tom Carper
Chairman
Committee on Environment and Public Works
United States Senate

Since 1990, nuclear energy has accounted for about 20 percent of the electricity generated in the United States. In 2022, nuclear energy provided nearly half of our nation's carbon-free electricity, making it the largest domestic source of carbon-free energy. Nuclear power plants emit no carbon dioxide during operations and, unlike many sources of renewable energy, typically operate around the clock, producing on average above 90 percent of their generating capacity.

However, nuclear power plants can be affected by natural hazards—including heat, drought, wildfires, flooding, hurricanes, sea level rise, and extreme cold weather events—some of which are expected to be exacerbated by climate change, with effects varying by region. Most commercial nuclear power plants in the United States were licensed and built in the 1960s and 1970s, and the risks to plants' safety and operations from natural hazards have changed since their construction.

The Nuclear Regulatory Commission (NRC) is responsible for regulating the civilian use of radioactive materials to promote the nation's common defense and security, provide reasonable assurance of adequate protection of public health and safety, and protect the environment. As electricity demand in the United States is expected to continue to grow over the coming decades, Congress and others are turning to nuclear power as one means of meeting the increased demand while reducing carbon emissions. For example, in recent years, Congress has provided incentives for the continued operation of existing nuclear power plants

and for the construction of new plants, which, if licensed, could operate into the next century.[1]

You asked us to review the climate resilience of energy infrastructure. This report focuses on nuclear power plants' resilience to climate change and examines (1) how climate change is expected to affect nuclear power plants and (2) what actions NRC has taken to address the risks to nuclear power plants from climate change.

To address both objectives, we interviewed officials from NRC headquarters and its four regional offices, NRC resident inspectors, and officials from the Department of Energy—including the Office of Nuclear Energy and the Idaho National Laboratory—the Federal Energy Regulatory Commission, the Federal Emergency Management Agency, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Forest Service. In addition, we interviewed a nongeneralizable sample of nine stakeholders knowledgeable about nuclear power plant operations and safety, climate change, and resilience measures. We also visited two selected nuclear power plants—Palo Verde Nuclear Generating Station in Buckeye, Arizona, and Turkey Point Nuclear Generating Station in Homestead, Florida—and interviewed plant staff and NRC resident inspectors at these plants. We selected these plants because of their exposure to a variety of natural hazards that may be exacerbated by climate change and regional diversity. Findings from selected stakeholder interviews and site visits are not generalizable to all stakeholders and sites.

To examine how climate change is expected to affect nuclear power plants, we conducted a literature review of articles and reports related to the effects of climate change on nuclear power plants. On the basis of this method, we identified and used 36 articles to support the findings in our report. We also reviewed the fourth and fifth U.S. Global Change

[1]NRC has efforts underway to support the licensing of advanced nuclear reactors—nuclear fission reactors that may offer significant improvements over the most recent generation of nuclear fission reactors and may involve first-of-a-kind designs—which, according to NRC officials, contribute to climate resilience by supporting an alternative to fossil-fuel-based power plants. For more information on NRC's licensing of advanced nuclear reactors, see GAO, *Nuclear Power: NRC Needs to Take Additional Actions to Prepare to License Advanced Reactors,* GAO-23-105997 (Washington, D.C.: July 27, 2023).

Research Program's National Climate Assessments (NCA),[2] federal data on natural hazards, and prior GAO reports.

Additionally, we identified and obtained national-level data sets from relevant federal agencies for six of the seven natural hazards identified by the NCA and our literature review as likely to be exacerbated by climate change: extreme heat, extreme cold, wildfires, flooding, storm surge from hurricanes, and sea level rise.[3] For heat, cold, and sea level rise, we used data that are based on climate scenarios. For heat and cold, we analyzed the projected exposure of nuclear power plants to those hazards.[4] For wildfires, hurricane storm surge, and flooding, we used data that are based on current and past conditions.[5] We assessed the reliability of the data sources used and found the data to be sufficiently reliable for the purposes of our reporting objectives. For more detailed information on our scope and methodology, and the steps we took to assess the reliability of the data used in this report, see appendix I. For more detail on data sources used in this report, see appendix II.

In addition, we obtained NRC data on the location of all 54 operating U.S. nuclear power plants as well as on the 21 shutdown nuclear power plants

[2]U.S. Global Change Research Program, *Fifth National Climate Assessment*, (Washington, D.C.: 2023); U.S. Global Change Research Program, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, vol. II (Washington, D.C.: 2018).

[3]To identify and select national-level data sets, we used information from the NCA. The fifth NCA was released on November 14, 2023, after we had obtained and analyzed the hazard data sets. We reviewed relevant sections from the fifth NCA and did not identify major differences in the predicted or projected trends for the selected natural hazards. We did not analyze drought data because we were unable to identify national-level geospatial data that was both relevant to nuclear power plants and sufficiently reliable for our purposes.

[4]To analyze projected exposure to heat and cold hazards, we used data from the fourth NCA on the projected exposure to maximum and minimum temperatures by the midcentury (i.e., 2036–2065). We selected data using the projected change by the midcentury time frame under both a low- and high-emission scenario to show the range of potential projected change to selected natural hazards. The midcentury time frame was selected because it captures potential hazard effects during the period in which most U.S. nuclear power plants are likely to remain operational.

[5]To analyze exposure to floods, we used 2023 data from the Federal Emergency Management Agency that categorize flood exposure as a high, moderate, minimal, other, or unknown flood hazard. To analyze exposure to hurricane storm surge, we used NOAA data on storm surge exposure from Category 1 hurricanes (the lowest possible category) and Category 4 or 5 hurricanes (the highest possible categories) to show a range of potential climate change effects. To analyze exposure to wildfires, we used 2023 data from the U.S. Forest Service on wildfire hazard potential.

that have spent nuclear fuel stored onsite in spent fuel pools or in dry cask storage.[6] We analyzed these data using mapping software to identify nuclear power plants located in areas that may be affected by selected natural hazards. We determined that the data were sufficiently reliable for the purposes of our reporting objectives.

To examine NRC's actions to address risks to nuclear power plants from climate change, we reviewed relevant laws and regulations; agency guidance and documents, including NRC's 2022–2026 Strategic Plan; NRC office instructions; and the NRC inspection manual on adverse weather protection.[7] We also reviewed GAO's *Standards for Internal Control in the Federal Government*.[8]

We conducted this performance audit from November 2022 to April 2024 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[6]When a company decides to shut down a nuclear power plant permanently, the facility must be decommissioned by safely removing it from service and reducing residual radioactivity to a level that permits release of the property and termination of the operating license. NRC regulates the decommissioning a nuclear power plant and any spent nuclear fuel that will remain on site. See 10 C.F.R. pt. 20, subpt. E; 10 C.F.R. §§ 50.75, 50.82, 51.53, 51.95. For the purposes of this report, we use the term "shutdown" to refer to plants at various stages of decommissioning, including those in the process of decommissioning and those already decommissioned, with spent nuclear fuel stored onsite. Spent nuclear fuel is the fuel that has been removed from commercial nuclear power reactors after it has been used to produce electricity. Spent nuclear fuel is initially stored immersed in pools of water designed to cool and isolate it from the environment. Water circulates in the pools to remove the heat generated from the radioactive decay. Industry practice has been to store the spent nuclear fuel in these pools for at least 5 years or until the fuel has cooled enough to be transferred to dry cask storage. Dry cask storage consists of a steel canister that holds the fuel assemblies, protected by an outer cask made of steel and concrete designed to cool the fuel and provide shielding from its radiation. We also obtained data on the location of the two Strategic Alliance for FLEX Emergency Response (SAFER) centers that maintain emergency equipment that can be provided to plants as a backup to the plants' onsite primary backup equipment.

[7]NRC, *Strategic Plan Fiscal Years 2022-2026,* NUREG-1614, Vol. 8 (Washington, D.C.: April 2022). See also, NRC, *Inspection Manual: Adverse Weather Protection,* Inspection Procedure 71111, Attachment 01 (Washington, D.C.: Jan. 1, 2018).

[8]GAO, *Standards for Internal Control in the Federal Government*, GAO-14-704G (Washington, D.C.: Sept. 10, 2014).

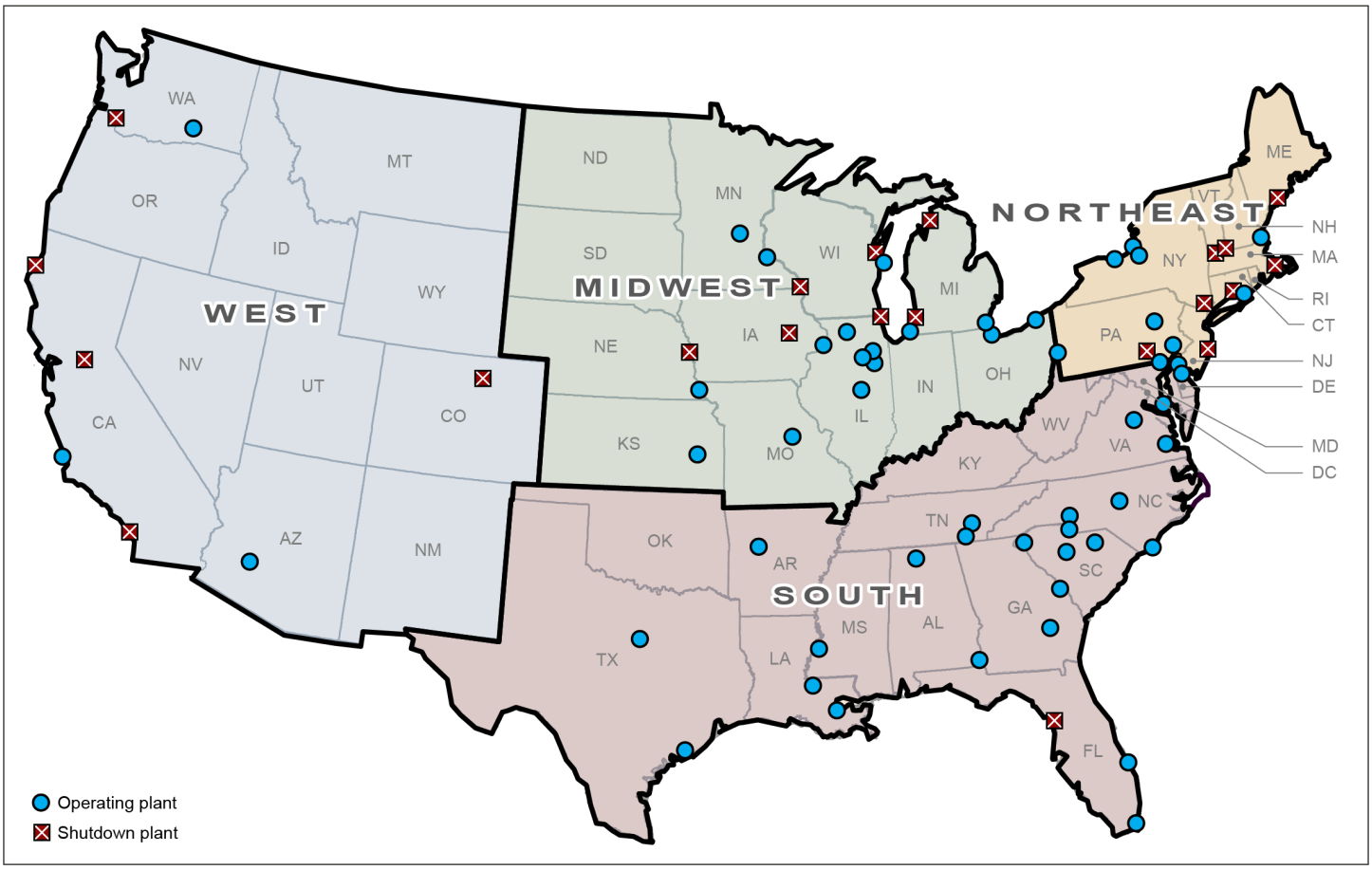
# Background

## The Nuclear Power Industry and U.S. Plant Operations

Private companies own nearly all nuclear power plants in the United States. As of August 2023, the United States had 93 operating commercial nuclear reactors with an average age of about 42 years old, according to the U.S. Energy Information Administration. These reactors are located at 54 nuclear power plants in 28 states.[9] In addition, as of July 2023, there were 21 shutdown plants that have spent nuclear fuel stored onsite in spent fuel pools or in dry casks. See figure 1 for the locations and regions of operating and shutdown nuclear power plants by U.S. Census region.

[9]According to the U.S. Energy Information Administration, nuclear reactors are machines that contain and control nuclear chain reactions while releasing heat at a controlled rate. A nuclear power plant uses the heat that a nuclear reactor produces to turn water into steam, which then drives turbine generators that generate electricity.

**Figure 1: Map of Operating and Shutdown Nuclear Power Plants by U.S. Census Region**




Sources: GAO analysis of U.S. Census Bureau and Nuclear Regulatory Commission data; U.S. Census Bureau (map). | GAO-24-106326

Note: This map includes 75 U.S. nuclear power plants—54 operating plants and 21 shutdown plants with spent nuclear fuel onsite.

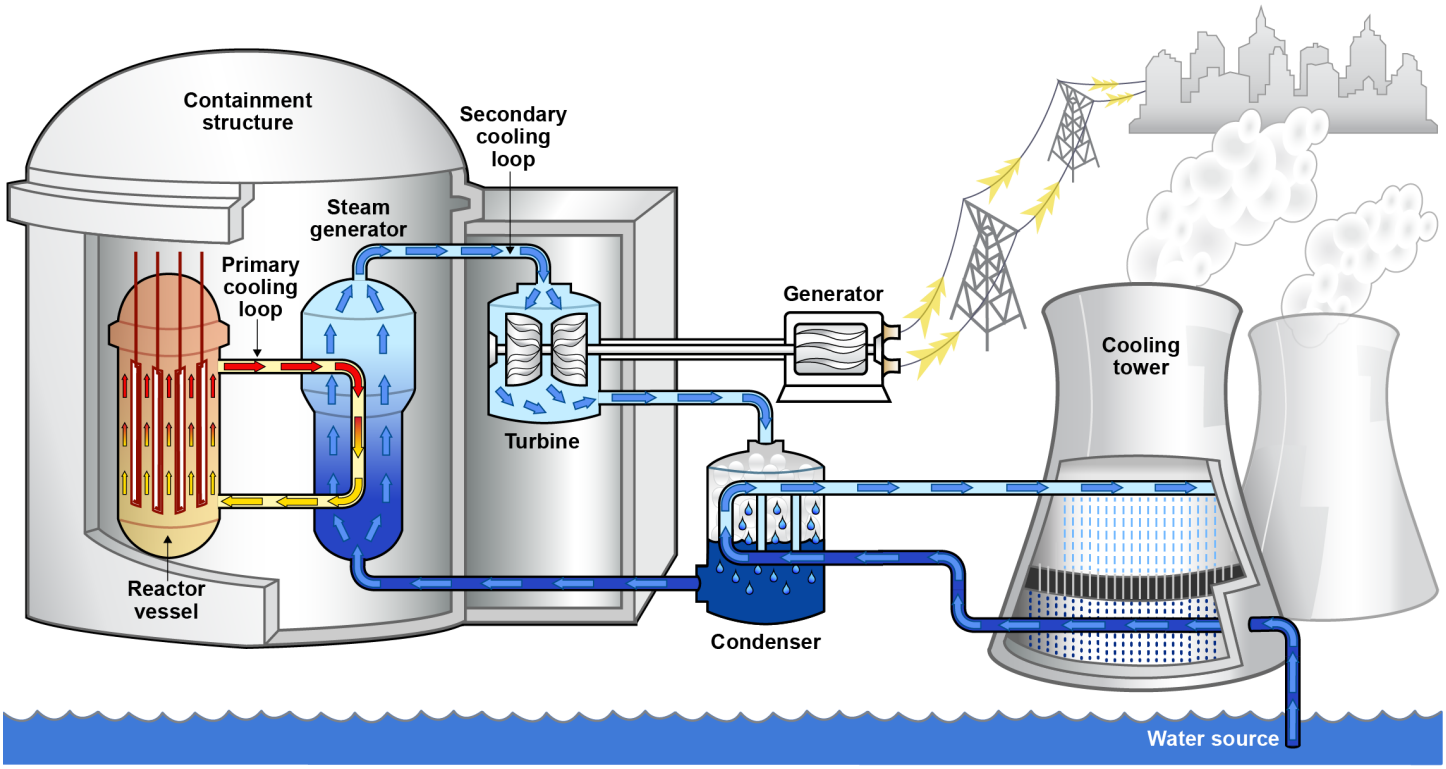
Nuclear reactors rely on technologies to initiate and control chain reactions that produce heat through a physical process called fission—whereby atoms are split to release energy. All commercial nuclear power reactors in the United States use uranium as fuel and are light water reactors, which means they use water as both a coolant and moderator to

serve critical safety and operations functions.[10] Nuclear power plants use water during normal operations to absorb the heat that is left over after making electricity and to cool the equipment and buildings used in generating that electricity. In the event of an accident, nuclear power plants also need water to remove the heat produced by the reactor core, even when it is temporarily shut down. Water is also used to cool spent fuel once it is removed from the reactor core. Because light water reactors rely on water for key safety and operational functions, nuclear power plants are typically located next to lakes, rivers, or oceans.

There are two types of light water reactors in the United States—pressurized water reactors and boiling water reactors. Pressurized water reactors, the predominant type of light water reactor in the United States, use steam generators to transfer the heat created by fission from the primary coolant loop to the secondary coolant loop, creating steam in the secondary loop that spins a turbine and generates electricity. Boiling water reactors, which constitute a third of the operating reactors in the United States, do not use steam generators or have secondary loops. Instead, the steam is generated directly inside the reactor vessel. See figure 2 for an overview of a nuclear power plant's components for a pressurized water reactor.

[10]The commercial nuclear power reactors currently operational in the United States are known as "light water reactors," meaning reactors that use ordinary water to cool and moderate the reactor, as opposed to heavy water, which contains deuterium, an isotope of hydrogen.

**Figure 2: Nuclear Power Plant Components and Operations for a Pressurized Water Reactor**




Sources: GAO illustration and analysis of Department of Energy and Nuclear Regulatory Commission documentation. | GAO-24-106326

Note: This illustration depicts a pressurized water reactor, the predominant reactor type in the United States. Boiling water reactors, which constitute a third of the operating reactors in the United States, do not use steam generators or have secondary loops. Boiling water reactors boil water directly inside the reactor vessel to produce steam.

To operate the cooling pumps and other systems that manage the water that reactors rely on for key safety and operational functions, nuclear plants need a reliable source of power. Nuclear power plants typically rely on the electricity grid to which the plant is connected for offsite power.[11]

[11]As we reported in 2021, climate change is expected to affect every aspect of the electricity grid—from generation, transmission, and distribution, to demand for electricity. We found that power outages can have significant cascading effects on critical sectors and electric service disruptions can significantly affect the reliability of other parts of the energy sector. These losses are of special concern because outages caused by climate effects can be widespread and affect large geographic areas all at once, according to the Department of Energy. GAO, *Electricity Grid Resilience: Climate Change Is Expected to Have Far-Reaching Effects and DOE and FERC Should Take Actions,* GAO-21-346 (Washington, D.C.: March 5, 2021).

However, if a plant loses access to offsite power, it must rely on backup power sources, such as diesel generators, to power cooling pumps. The loss of power and ability to pump cooling water can have a significant adverse impact on a plant's ability to safely shut down and maintain safe shutdown conditions. This could result in damage to a reactor's core and potentially release radiological material into the environment.

## NRC's Role

NRC is an independent federal agency, headed by five commissioners, responsible for permitting the construction and licensing of commercial nuclear power reactors and regulating and overseeing their security and safe operation.[12] NRC can issue a license to operate a nuclear power reactor for up to 40 years and can renew a license for up to 20 additional years. A renewed license may be subsequently renewed for up to another 20 years, allowing a reactor to operate for up to a total of 80 years. As of December 2023, NRC had issued subsequent license renewals for six reactors at three nuclear power plants in the United States.[13] Spent nuclear fuel may remain onsite long after a plant shuts down.[14]

As part of NRC's process for issuing construction permits and licenses for nuclear power plants, agency staff conduct safety and environmental reviews. As part of the safety review, NRC reviews a plant's design to ensure it meets the technical specifications required for the safe operation of the plant. Specifically, NRC's reactor design criteria require that important safety systems, structures, and components are designed to withstand the effects of natural hazards, including climate-related hazards

[12]NRC's mission is to regulate the civilian use of radioactive materials, to provide reasonable assurance of adequate protection of public health and safety, to promote the common defense and security, and to protect the environment. As such, any new requirements that the agency imposes on commercial nuclear plants must meet this standard, according to NRC officials.

[13]NRC issued subsequent license renewals to Turkey Point Units 3 and 4 in December 2019; Peach Bottom Units 2 and 3 in March 2020; and Surry Units 1 and 2 in May 2021.

[14]The United States does not have a consolidated storage facility or repository where plants can send their spent fuel during operations or after a plant shuts down. GAO, *Commercial Spent Nuclear Fuel: Congressional Action Needed to Break Impasse and Develop a Permanent Disposal Solution,* GAO-21-603 (Washington, D.C.: Sept. 23, 2021).

such as hurricanes and floods, without losing the ability to perform their safety functions.[15]

License applicants are responsible for ensuring their plants are protected against natural hazards by assessing the hazards that may affect their plants and designing the plants to withstand those hazards. NRC is responsible for reviewing plant and reactor designs and comparing the design limits for natural hazards with those found in applicants' hazard assessments, which consider the characteristics of the plant's geographic location. Once a nuclear power plant is licensed and operational, NRC conducts regular inspections of the plant's systems and ensures that the licensee is operating in accordance with its license. If a plant experiences external conditions that exceed the limiting conditions for operation, the licensee is required to either shut the reactor down, take remedial actions as permitted in its license, or request a license amendment or enforcement discretion from NRC to continue operations.[16]

NRC also regulates the decommissioning of nuclear power plants, which means safely removing nuclear power plants from service by reducing residual radioactivity to a level that permits the release of the property and termination of the license.[17]

## NRC's Regulatory Approach

NRC uses conservatism, safety margins, and defense-in-depth to implement regulatory requirements for the design, construction, maintenance, operation, and decommissioning of nuclear power plants to prevent and mitigate accidents that could release radiation or hazardous

[15]10 C.F.R. Part 50, Appendix A, General Design for Nuclear Power Plants, Criterion 2—*Design Bases for Protection Against Natural Phenomena*. According to an NRC document, all currently operating reactors were licensed to meet the intent of the General Design Criteria, which include General Design Criterion 2. See also 10 C.F.R. §§ 50.34, 52.79 (detailing safety analysis and design requirements for a license application).

[16]Limiting conditions for operation are the lowest functional capability or performance levels of equipment required for safe operation of the plant. 10 C.F.R. § 50.36(c)(2)(i). If the limiting conditions are exceeded by an extreme weather event, licensees can request the following from NRC: a temporary enforcement discretion for a brief period to allow them to continue operating despite the exceedance; a temporary license amendment to revise the limiting conditions for a specified period (e.g., 1–3 months); or a permanent license amendment to change the technical specifications.

[17]The NRC ensures that safety requirements are being met throughout the decommissioning process by reviewing decommissioning or license termination plans, conducting inspections, monitoring to ensure that radioactive contamination is reduced or stabilized, and issuing permits for spent nuclear fuel that will remain on site after license termination. See 10 C.F.R. pt. 20, subpt. E; 10 C.F.R. §§ 50.75, 50.82, 51.53, 51.95.

materials. According to agency documents and NRC officials we interviewed, the approach can be described as follows:

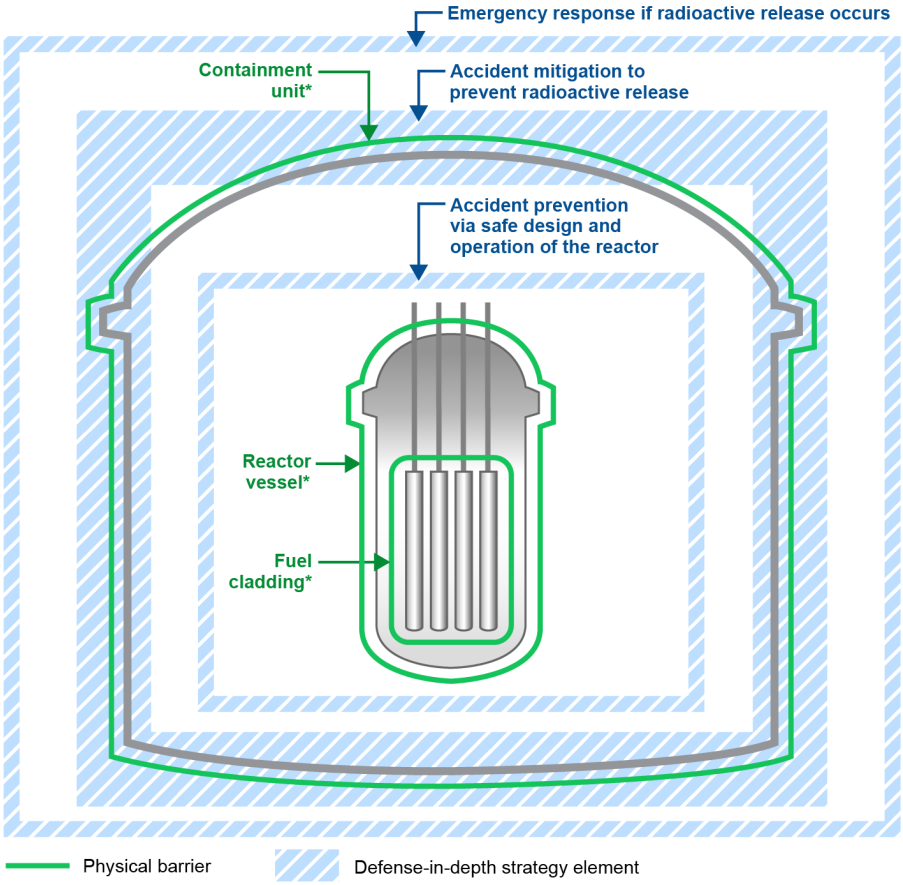
- Conservatism, for example, includes the consideration of the most severe natural phenomena that have been historically reported for a nuclear power plant site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.[18]
- Safety margins are the extra capacity factored into the design of a structure, system, or component so that it can cope with conditions beyond what is expected as a way to compensate for uncertainty.[19]
- Defense-in-depth includes multiple independent and redundant layers of defense to compensate for potential human and mechanical failures so that no single layer, no matter how robust, is exclusively relied upon. Defense-in-depth includes the use of access controls, physical barriers, redundant and diverse key safety functions, and emergency response measures (see fig. 3).[20]

[18]10 C.F.R. Part 50, Appendix A, General Design Criterion 2, *Design Bases for Protection Against Natural Phenomena*. See also, NRC, *Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decision-Making*, NUREG-1855 (Washington, D.C.: March 2017).

[19]NRC, *Glossary of Risk-Related Terms in Support of Risk-Informed Decision-Making,* NUREG-2122 (Washington, D.C.: Nov. 2013).

[20]For more information on defense-in-depth, see NRC, *Historical Review and Observations of Defense-in-Depth*, NUREG/KM-0009 (Washington, D.C.: April 2016).

**Figure 3: Measures Consistent with the Nuclear Regulatory Commission's (NRC) Defense-in-Depth Approach**




***Containment unit** – airtight enclosure around the nuclear reactor to confine radiation that otherwise might be released to the atmosphere in the event of an accident

***Reactor vessel** – forms a reactor coolant pressure boundary that provides a barrier against the release of radioactivity generated within the reactor

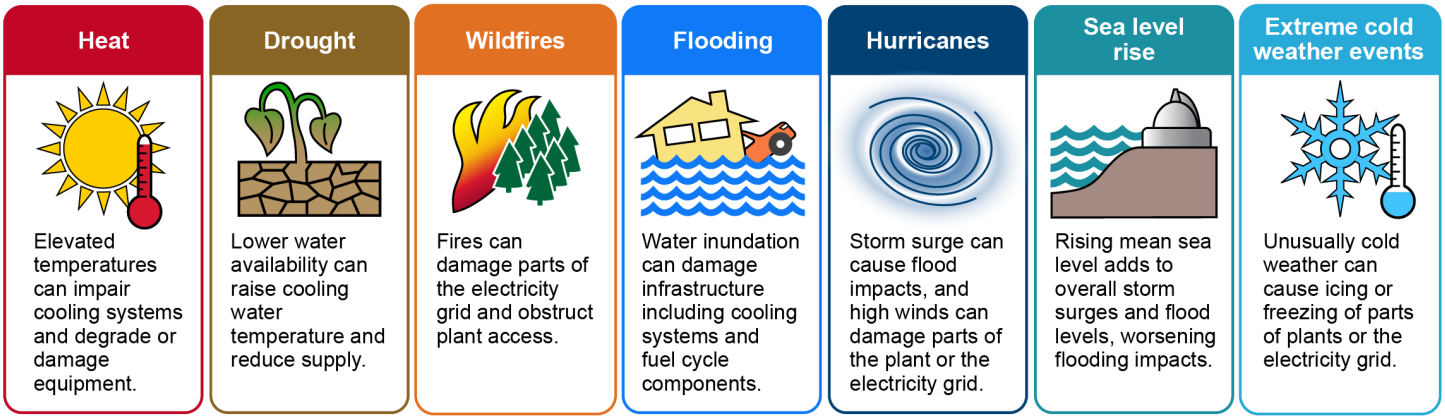
***Fuel cladding** – the thin-walled metal tube that forms the outer jacket of a nuclear fuel rod

Source: GAO and NRC documentation. | GAO-24-106326

## Climate Change Is Expected to Exacerbate Natural Hazards That Pose Risks to Nuclear Power Plants

Climate change is expected to exacerbate natural hazards—including heat, drought, wildfires, flooding, hurricanes, and sea level rise. In addition, climate change may affect extreme cold weather events.[21] These natural hazards pose risks to nuclear power plants (see fig. 4).

**Figure 4: Examples of Natural Hazards that May Pose Risks to Nuclear Power Plants**




Sources: Nuclear Regulatory Commission documents; summary of literature; GAO (icons). | GAO-24-106326

Note: The potential risks to nuclear power plants from these hazards include a loss of offsite power, diminished cooling capacity, flood damage, and reduced operations or temporary plant shutdowns. The loss of offsite power is a complete loss of electrical power from the grid to a nuclear power plant. The loss can decrease a plant's ability to maintain safe shutdown conditions. Diminished cooling capacity refers to any impact which reduces a plant's ability to cool reactor or fuel cycle components and can result in a temporary plant shutdown.

[21]According to the NCA, climate change has driven increases in the frequency and severity of some extreme weather events. For example, climate change caused Hurricane Harvey's rainfall to be an estimated 15 and 20 percent heavier than it would have been without human-caused warming. However, researchers disagree about some climate impacts. For example, whereas emerging research suggests that the frequency of cold-weather events and heavy snowfall may be increasing because of warming Arctic temperatures, there is some disagreement in the research community regarding this projection.

## Heat, Drought, and Wildfires Pose Risks to Nuclear Power Plants, and Climate Change Is Expected to Exacerbate These Hazards, Particularly in the South and Southwest

According to our analysis of NCA and U.S. Forest Service data, all 75 operating and shutdown U.S. nuclear power plants are located in areas where climate change is expected to exacerbate heat, drought, wildfires, or all three.

**Heat and drought.** Heat and drought pose risks to nuclear power plants because they can affect the water used for cooling. Specifically, higher-than-usual ambient air temperatures may increase the temperature of water used for cooling. Drought can also reduce the supply of cooling water. If a plant has an insufficient supply of cooling water or its cooling water approaches or exceeds the maximum allowable temperature for cooling certain reactor components, a licensee may need to temporarily limit or stop operations to ensure plant safety. Higher temperatures in the bodies of water into which nuclear power plants discharge cooling water may also require a plant to limit or temporarily stop operations to comply with laws designed to protect aquatic ecosystems and wildlife.[22] In addition, high temperatures can also degrade the performance or cause failure of pumps and other equipment, reduce the lifetime of plant components, and reduce the overall efficiency of power plants. Warmer temperatures may also increase levels of certain algae or other biological material which can block cooling water systems and lead to reduced production or a temporary plant shutdown.

[22]Some plants that discharge cooling water into rivers or lakes are subject to environmental requirements. These requirements could force a power plant to shut down or reduce power generation. For example, in 2007, 2010, and 2011, the Tennessee Valley Authority had to reduce power output from its Browns Ferry Nuclear Power Plant in Alabama because river temperatures were too high to receive discharge water from the plant without posing ecological risks.

**Heat and Drought at Turkey Point Nuclear Generating Station**

According to the Nuclear Regulatory Commission (NRC) and Turkey Point Nuclear Generating Station officials, in 2014, extended drought conditions and high algae content caused the cooling water for the Turkey Point Generating Station to exceed its maximum allowable temperature in its license. NRC approved the licensee's requests to not enforce the temperature requirement for the plant's cooling water for a limited period. Later, NRC granted the licensee a permanent license amendment that raised the maximum allowable cooling water temperature for the plant from 100 degrees to 104 degrees Fahrenheit.

High temperatures and drought conditions at Turkey Point Nuclear Generating Station potentially created risks to local drinking water sources when decreased water levels and increased evaporation rates led to higher salinity in the cooling canals. Higher salinity levels made the water denser, causing it to sink below the canals that contain it. This could have led to intrusion of higher salinity water into the areas of the Biscayne Aquifer, a source of drinking water for the Miami-Dade area.

To mitigate these risks, the licensee constructed a series of wells to decrease the water salinity in the cooling canals.

Well used to adjust salinity in the Turkey Point Nuclear Generating Station's cooling canals

Sources: Interviews with plant personnel at the Turkey Point Nuclear Generating Station, and review of NRC documents; GAO (photo). | GAO-24-106326

All operating and shutdown nuclear power plants are located in areas where climate change is projected to increase measures of heat, including daily and average maximum temperature, according to our analysis of NCA and NRC data. The effects of climate change on maximum temperatures are projected to be most severe in the South, where one-third of the plants are located.[23] The plants in the South are projected to experience an annual average of from 21 to 31 days with higher maximum temperatures than historical high temperatures. In addition, according to the NCA, climate change is expected to increase drought intensity in some regions, specifically in the Southwest, where two operating and four shutdown nuclear power plants are located.

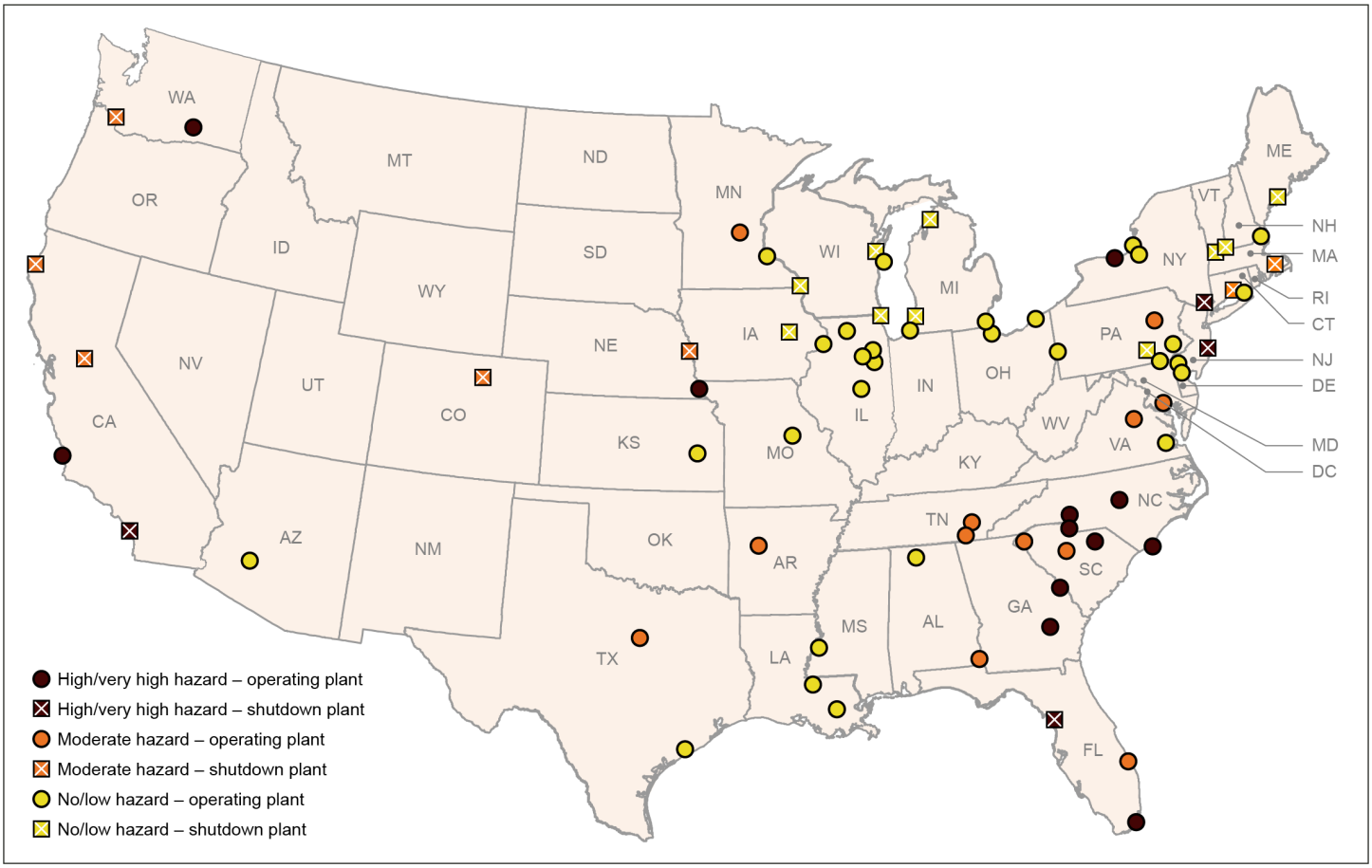
[23]Of the 25 plants in the South, 24 are operational and one is shutdown.

**Wildfire.** According to the NCA, increased heat and drought contribute to increases in wildfire frequency, and climate change has contributed to unprecedented wildfire events in the Southwest. The NCA projects increased heatwaves, drought risk, and more frequent and larger wildfires. Wildfires pose several risks to nuclear power plants, including increasing the potential for onsite fires that could damage plant infrastructure, damaging transmission lines that deliver electricity to plants, and causing a loss of power that could require plants to shut down. Wildfires and the smoke they produce could also hinder or prevent nuclear power plant personnel and supplies from getting to a plant.

According to our analysis of U.S. Forest Service and NRC data, about 20 percent of nuclear power plants (16 of 75) are located in areas with a high or very high potential for wildfire.[24] More specifically, more than one-third of nuclear power plants in the South (nine of 25) and West (three of eight) are located in areas with a high or very high potential for wildfire (see fig. 5).

[24]The U.S. Forest Service maps wildfire hazard potential based on landscape conditions and other observations. These maps include an index of wildfire hazard potential for the United States, based on, among other factors, annual burn probabilities and the potential intensity of large fires. The wildfire potential index is a relative ranking. The U.S. Forest Service categorizes the wildfire hazard potential index into five classes: very low, low, moderate, high, and very high. The U.S. Forest Service designates as “high” those areas with wildfire hazard potential index from the 85th to the 95th percentile, and as “very high” those areas above the 95th percentile. For this analysis, we combined the high and very high wildfire hazard potential categories; we did not identify the number of facilities in each of these categories separately. Of the 16 plants with high or very high potential for wildfire, 12 are operating and four are shutdown.

**Figure 5: Nuclear Power Plants Located in Areas with Exposure to No/Low, Moderate, and High/Very High Wildfire Hazard Potential**




Sources: U.S. Forest Service and Nuclear Regulatory Commission data; U.S. Census Bureau (map). | GAO-24-106326

Note: To determine if a plant is located in an area with wildfire hazard potential, we identified overlap between a 0.5-mile radius around nuclear power plant coordinates provided by the Nuclear Regulatory Commission and wildfire hazard potential data. Overlap indicates that a facility is located in an area that may be affected by the selected hazard. We used the U.S. Forest Service Wildfire Hazard Potential Map to show exposure to wildfire hazard potential. The U.S. Forest Service categorizes the wildfire hazard potential index into five classes of very low, low, moderate, high, and very high. We analyzed the moderate, high, and very high wildfire potential layers, and combined results for the high/very high layers. No/low refers to plants that are not located in an area with wildfire potential of moderate, high, or very high, based on the U.S. Forest Service Wildfire Hazard Potential Map. See appendix I for more details on our data analysis. We previously reported that the primary intended use of the wildfire hazard potential map is to identify priority areas for hazardous fuels treatments from a broad, national- to regional-scale perspective. This analysis does not account for any protective measures plants may have taken to mitigate the risk of selected natural hazards.

Appendix III provides additional details of exposure to heat and wildfire hazard potential in areas where nuclear power plants are located.

## Flooding, Hurricanes, and Sea Level Rise Pose Risks to Nuclear Plants, and Climate Change Is Expected to Exacerbate These Hazards, Particularly in Coastal Regions

According to our analysis of NOAA and NRC data, about 63 percent of nuclear power plants (47 of 75) are located in areas with exposure to either Category 4 or 5 hurricane storm surge or high flood hazard, and nine are located on a coastline, where NOAA projects a range of sea level increases.[25] In addition, 20 percent of nuclear power plants (15 of 75) are located in areas with exposure to both Category 4 or Category 5 hurricane storm surge and high flood hazard. The NCA predicts that climate change will exacerbate all three hazards.

[25]To identify coastal plant locations, we used nuclear power plant coordinates from NRC and added a 0.5-mile radius around NRC's plant coordinates as a proxy for an average size nuclear power plant. Coastal plants were those with a radius that intersected with or beyond the coastline.

**Flood Protection**

To mitigate the impacts of flooding, licensees have implemented various measures, including the elevation of spent fuel pools and use of flood barriers.

Flood barrier protecting part of the Turkey Point Nuclear Generating Station

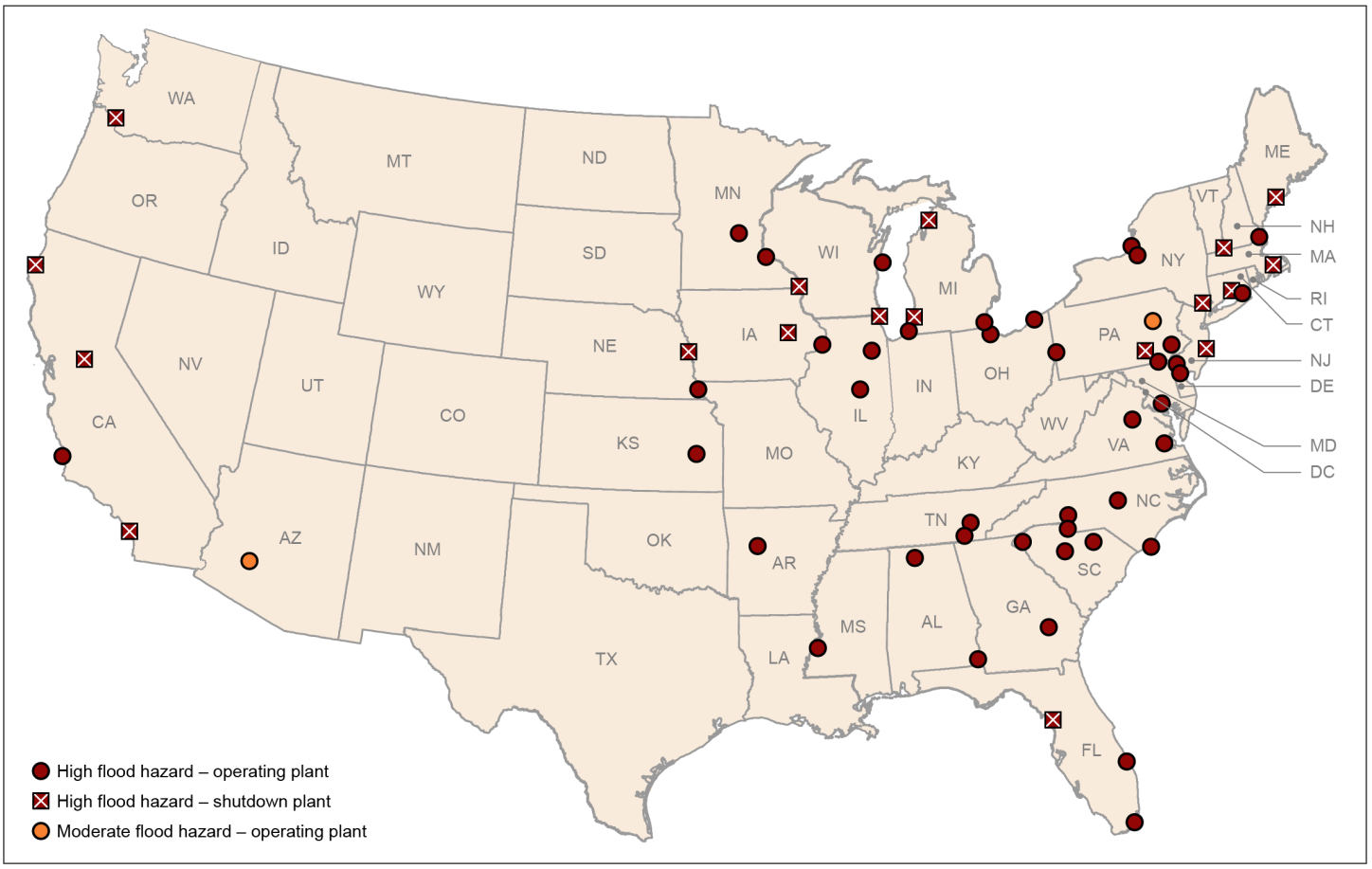
Sources: GAO site visit and interviews with plant personnel at the Turkey Point Nuclear Generating Station; GAO (photo). | GAO-24-106326

**Flooding.** Flooding could pose risks to nuclear power plants by, among other things, diminishing a plant's cooling capacity. Flooded roads could prevent personnel, equipment, and supplies from reaching a plant. Flooding could also cause damage to buildings, equipment, and electrical systems that could require a plant to curtail operations or shut down. In addition, flood waters could interfere with heat removal from spent fuel pools by blocking ventilation ports with water. Prolonged exposure to salt water from coastal flooding could also degrade or corrode a cask's exterior, potentially posing risks to the environment and human health.

Our analysis of Federal Emergency Management Agency data found that 60 of the 75 nuclear power plants in the United States are located in areas with high flood hazard and two are in areas with moderate flood hazard.[26] Just over one-third of the plants (21 of 60) located in areas with high flood hazard are in the South (see fig. 6). According to the NCA, heavy rainfall and flooding are expected to become more frequent and severe across the United States. The NCA predicts that climate change will continue to exacerbate hurricane storm surge, rainfall, and flood events in U.S. coastal areas.

[26]We analyzed Federal Emergency Management Agency data from 2023. For our analysis, high flood hazard corresponds to areas in 100-year floodplains (areas with a 1 percent or higher annual chance of flooding), moderate flood hazard corresponds to areas in 500-year floodplains (areas with a 0.2 percent or higher annual chance of flooding), and no/low corresponds to areas with minimal, unknown, or other flood hazards, including areas with reduced risk because of levees as well as areas with flood hazard based on future conditions, such as the future implementation of land-use plans. Of the 60 plants located in areas with high flood hazard, 42 are operating and 18 are shutdown. Both of the plants located in areas with moderate flood hazard are operating.

**Figure 6: Nuclear Power Plants Located in Areas with High and Moderate Flood Hazard**




Sources: Federal Emergency Management Agency and Nuclear Regulatory Commission data; U.S. Census Bureau (map). | GAO-24-106326

Note: To determine if a plant is located in an area with exposure to moderate or high flood hazard, we identified overlap between a 0.5-mile radius around nuclear power plant coordinates provided by the Nuclear Regulatory Commission and the flood hazard data. Overlap indicates that a facility is located in an area that may be affected by the selected hazard. See appendix I for more details on our data analysis. To show exposure to flooding, we use the Federal Emergency Management Agency's National Flood Hazard Layer, which estimates several levels of flood hazard, including high flood hazard (areas with a 1 percent or higher annual chance of flooding), and moderate flood hazard (areas with a 0.2 percent or higher annual chance of flooding). This analysis does not account for any protective measures plants may have taken to mitigate the risk of selected natural hazards.

**Hurricanes.** High winds from hurricanes can generate projectiles capable of damaging parts of nuclear power plants and electricity transmission lines that provide nuclear power plants with power. In addition, storm surge from hurricanes can cause flooding, which could diminish a plant's cooling capacity and damage buildings, equipment, and electrical

systems. About 23 percent of nuclear power plants (17 of 75) are located in areas that may be inundated by storm surge from Category 4 or Category 5 hurricanes,[27] according to our analysis of NOAA and NRC data.[28] All 17 of these plants are in the East and South, and the six plants with exposure to Category 5 hurricanes are located in the South (see fig. 7).[29] According to the NCA, climate change is expected to heighten hurricane storm surges, wind speeds, and rainfall rates.[30]

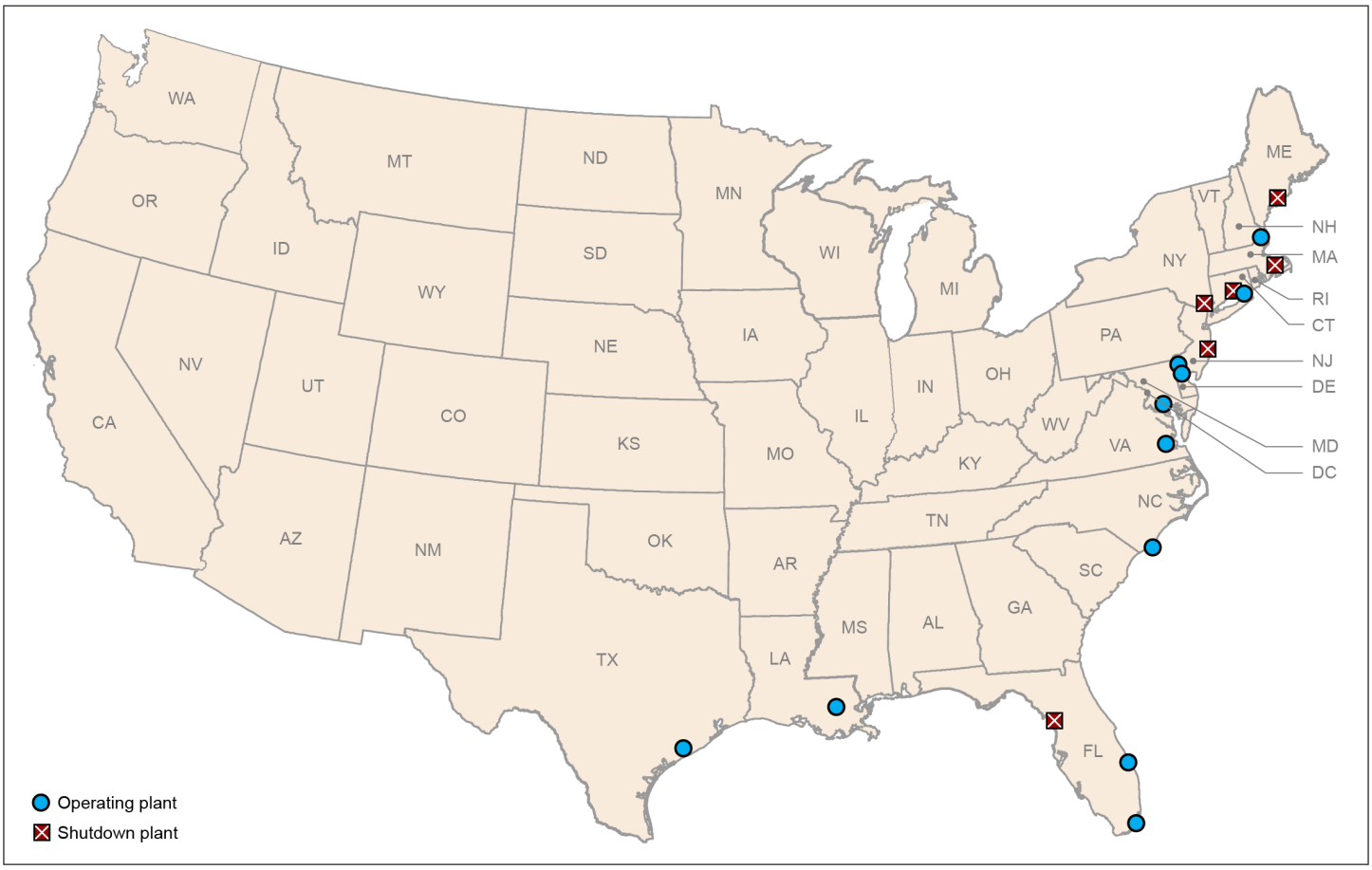
[27]Of the 17 plants located in areas that may be inundated by storm surge from Category 4 or 5 hurricanes, 11 are operating and six are shut down. For the West Coast of the United States, storm surge data were only available for Southern California.

[28]Our analysis of NOAA storm surge data is based on a model that estimates the maximum extent of storm surge at high tide. NOAA provides estimates of hurricane storm surge using a model called Sea, Lake, and Overland Surges from Hurricanes. This model includes hypothetical hurricanes under different storm conditions, such as landfall location, trajectory, and forward speed. Hurricanes reaching Category 3 and higher are considered major hurricanes because of the potential for significant loss of life and damage. In our analysis, we used the maximum extent of storm surge from Category 1 hurricanes (the lowest possible category) and Category 5 hurricanes (the highest possible category) to show a range of potential climate change effects. Category 4 hurricanes carry sustained winds of 130–156 miles per hour. Category 5 hurricanes have sustained winds exceeding 156 miles per hour.

[29]Storm surge impacts to nuclear power plants would depend on several factors, including a plant's elevation and protective measures.

[30]Climate change leads to warmer ocean surface temperatures. This, in turn, makes hurricanes more powerful because the temperature increase causes more water to evaporate from the ocean. Evaporation adds moisture to the air, and warmer air temperatures can hold more water vapor. The increased moisture in the air leads to more intense rainfall. In a hurricane, spiraling winds draw moist air toward the center, fueling the thunderstorms that surround it.

**Figure 7: Nuclear Power Plants Located in Areas with Exposure to Storm Surges from Category 4 and Category 5 Hurricanes**




Sources: National Oceanic and Atmospheric Administration and Nuclear Regulatory Commission data; U.S. Census Bureau (map). | GAO-24-106326

Notes: To determine if a plant exists in an area with exposure to hurricane storm surge, we identified overlap between a 0.5-mile radius around nuclear power plant coordinates provided by the Nuclear Regulatory Commission and storm surge data. Overlap indicates that a facility is located in an area that may be affected by the selected hazard. See appendix I for more details on our data analysis. To show exposure to hurricane storm surge, we use the National Oceanic and Atmospheric Administration's Sea, Lake, and Overland Surges from Hurricanes Model, which estimates storm surge heights resulting from the various categories of hurricanes. This analysis does not account for any protective measures plants may have taken to mitigate the risk of selected natural hazards.

**Sea level rise.** Sea level rise could affect nuclear power plants by contributing to greater storm surges and flooding. According to NOAA officials, a rise in sea level can increase corrosion from saltwater intrusion and lead to chronic long-term erosion of coastal cliffs, where some plants

are located.[31] According to a NOAA report, over the next 30 years sea levels will continue to rise as climate change warms glaciers and ice sheets, causing additional water mass to enter the ocean.[32] The rise in sea level is expected to increase coastal flooding by contributing to higher tides and storm surges that reach further inland, potentially affecting coastal nuclear power plants.

Our analysis of NOAA and NRC data indicates that about half of nuclear power plants (37 of 75) are located in a coastal region, and nine of these are located on the coastline.[33] Projected sea level rise in 2050 varies by coastal region, from 0.5 feet in the Northwest to 1.9 feet in the Western Gulf (see fig. 8). In addition, sea level rise may increase saltwater intrusion into the coastal rivers or groundwater aquifers that some nuclear power plants use for service or potable water.[34]

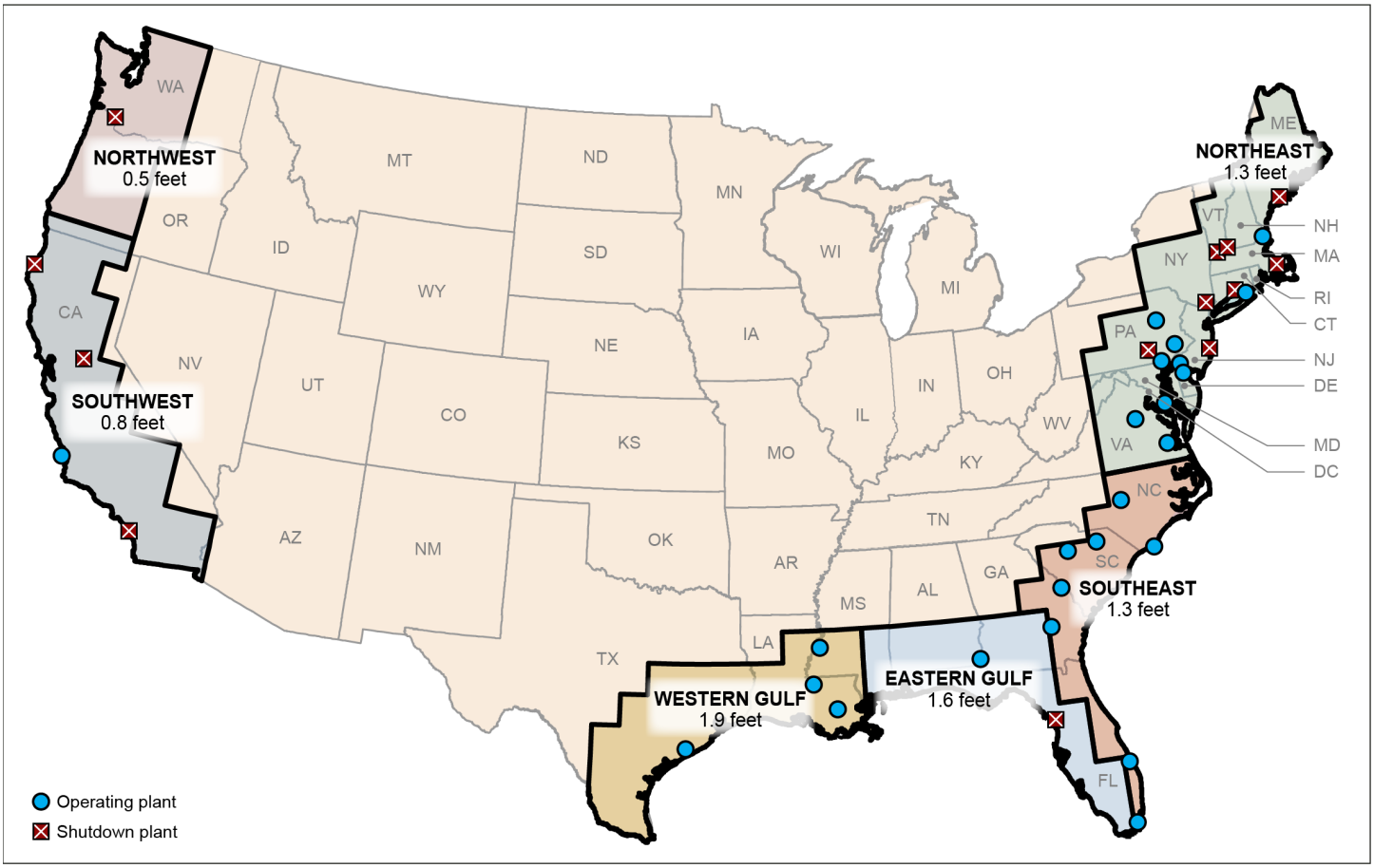
[31]NOAA officials said that Turkey Point Nuclear Generating Station is an example of a plant where, if unaddressed, sea level rise could lead to saltwater intrusion into the plant's cooling canals. Officials also said that Southern California is an example of an area where cliffs consist of unconsolidated rock, a type of loose rock composition that is particularly vulnerable to long-term erosion from sea level rise.

[32]W. V. Sweet, B. D. Hamlington, R. E. Kopp, C. P. Weaver, P. L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A. S. Genz, J. P. Krasting, E. Larour, D. Marcy, J. J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K. D. White, and C. Zuzak, *2022: Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines*, NOAA Technical Report NOS 01 (Silver Spring, MD: Feb. 2022).

[33]Of the 37 nuclear power plants located in a coastal region, 24 are operating and 13 are shut down. Of the nine nuclear power plants located on the coastline, seven are operating and two are shut down. To determine which nuclear power plants are located on the coastline, we identified plants whose coordinates intersect with a coastline. NRC provided coordinate data, and we used a 0.5-mile radius as a proxy for plant size in our analysis.

[34]According to one U.S. Environmental Protection Agency source, sea level rise may increase river levels and the risk of saltwater intrusion into rivers and coastal groundwater aquifers, especially during dry periods. According to NRC's Generic Environmental Impact Statement for License Renewal of Nuclear Plants, saltwater intrusion into groundwater aquifers can degrade the quality of groundwater used for potable and service water at nuclear power plants. See NUREG-1437, Vol. 1, Revision 1.

**Figure 8: Nuclear Power Plants in the National Oceanic and Atmospheric Administration (NOAA) Coastal Regions and Projected Sea Level Rise in 2050**




Sources: National Oceanic and Atmospheric Administration and Nuclear Regulatory Commission data; U.S. Census Bureau (map). | GAO-24-106326

Note: The regional sea level rise values for 2050 are regional observation-based extrapolations from an interagency report covering sea level rise scenarios. These extrapolations use observed changes in sea level rise and other factors to estimate the trajectory of sea level rise in the near term. Sea-level rise primarily affects coastlines but may also affect the salinity and level of coastal rivers and groundwater aquifers. This map includes all nuclear power plants that are located in NOAA coastal regions. The analysis does not account for site-specific plant elevation or protective measures plants may have taken to mitigate the risk of selected natural hazards.

Appendix III provides additional details of our analysis of exposure to flooding, hurricane storm surges, and sea level rise in areas where nuclear power plants are located.

## Extreme Cold Weather Events Pose Risks to Nuclear Power Plants, and Climate Change May Affect These Events in Certain Regions

Cold temperatures can diminish cooling capacity and lead to the loss of offsite power, posing risks to nuclear power plants. Specifically, extreme cold conditions may create ice that could block a plant's cooling water intake system, potentially reducing the supply of cooling water to safety-related systems and components. In addition, frozen precipitation can cause icing of power lines and lead to full or partial loss of off-site power, potentially forcing a plant to rely on backup diesel that may be vulnerable to extremely cold air temperatures.

**Extreme Cold at South Texas Project Nuclear Power Plant**

On February 15, 2021, the South Texas Project experienced an automatic reactor shutdown when a 5-foot section of uninsulated water line froze, causing the failure of a feed water pump. The Nuclear Regulatory Commission (NRC) found that the facility shut down safely, but the licensee failed to implement a required Freezing Weather Plan to insulate the line. According to one NRC official, a cold weather event nearly rendered another plant's diesel generators inoperable when the air intake temperature dipped to -50 degrees Fahrenheit.

South Texas Project, reactor units 1 and 2

Sources: GAO analysis of NRC documents; U.S. NRC Blog (photo). | GAO-24-106326

Climate change may affect extreme cold weather events.[35] While the NCA found that climate change is expected to cause an overall increase in average temperatures, a 2021 study funded in part by NOAA found that Arctic warming caused by climate change may cause extremely cold air from the Arctic to stretch into the United States.[36] The study links climate change to extreme cold events, such as the record cold temperatures in Texas in 2021. Our analysis of NCA climate projections data and NRC location data found that the average operating nuclear power plant will

[35]As noted previously, according to the NCA, there is disagreement among researchers about some climate impacts. For example, whereas emerging research suggests that the frequency of cold weather events and heavy snowfall may be increasing because of warming Arctic temperatures, there is some disagreement in the research community regarding this projection.

[36]J. Cohen, L. Agel, M. Barlow, C. I. Garfinkel, and I. White, *Linking Arctic Variability and Change with Extreme Winter Weather in the United States*, Science, Volume 373, Issue 6559 (Washington, D.C.: 2021) 1116-1121.

experience from 17 to 22 fewer frost days annually.[37] However, certain regions may also see an increase in extreme cold weather events.

**Cold Protection**

Licensees have insulated water lines and added cold-weather insulation for turbines to protect against freezing water in pipes and damage to other plant equipment.

Example of insulation at an industrial facility

Sources: Interviews with plant personnel at the Turkey Point Nuclear Generating Station; rootstocks/stock.adobe.com (photo). | GAO-24-106326

Following 2021's Winter Storm Uri, the Federal Energy Regulatory Commission approved a new standard, effective October 2024, that will require certain owners of certain electricity generating units, including nuclear power reactors, to implement freeze protection measures to operate for at least 12 continuous hours at the unit's recorded extreme cold weather temperature.[38]

Appendix III provides additional details of our analysis of exposure to cold weather events in areas where nuclear power plants are located.

[37]Climate projections are used to show a range of future outcomes, and are limited by uncertainties in emissions, natural variability, and scientific models. To show a range of possible outcomes, we used climate projections for a low-emission scenario (17 days) and a high-emission scenario (21 days). Climate projections rely on a variety of assumptions about the future. These limitations are further discussed in appendix II.

[38]In 2023, the Federal Energy Regulatory Commission (FERC) approved Emergency Operation Standard 012-01, also known as the Extreme Cold Weather Preparedness and Operations standard. Effective October 1, 2024, the standard addresses the effects of operating in extreme cold weather by ensuring owners and operators of generating units like nuclear power reactors develop and implement plan(s) to mitigate the reliability impacts of extreme cold. FERC defines extreme cold weather as the temperature equal to the lowest 0.2 percentile of the hourly temperatures measured in December, January, and February. The standard exempts certain generating units, including nuclear power reactors, which have an extreme cold weather temperature exceeding 32 degrees Fahrenheit or operate only in a backup or non-winter capacity.

## NRC's Actions to Address Risks to Nuclear Power Plants from Natural Hazards Do Not Fully Consider the Potential Effects of Climate Change

NRC's processes for licensing and overseeing nuclear power plants include actions to address risks from natural hazards. However, NRC's actions do not fully consider the potential effects of climate change.

### NRC's Oversight of Nuclear Power Plants Includes Actions to Address Risks from Natural Hazards

NRC's existing processes are designed to address risks to the safety of nuclear power plants, including risks from natural hazards. For example:

- **Defense-in-depth.** A nuclear power plant must be designed and built to withstand phenomena or events such as earthquakes, tornadoes, hurricanes, and floods without the loss of the structures, systems, or components necessary to ensure public health and safety. According to NRC, NRC's defense-in-depth approach focuses on protecting plants against risks such as those related to events that exceed a plant's design basis, including flooding from intense precipitation or hurricanes.[39] As such, NRC's defense-in-depth approach includes verifying that plants have multiple physical barriers and equipment backups to ensure plant safety if plant structures and equipment are damaged due to such severe weather events or if a power outage threatens a plant's ability to continue cooling the reactor.

[39]The design basis for a plant includes the specific functions to be performed by the structures, systems, or components that could be compromised by an adverse weather event that exceeds what the plant was designed to withstand, such as the maximum flood elevation or maximum temperature limit allowed for a plant to continue operating. 10 C.F.R. Part 50, Appendix A, General Design for Nuclear Power Plants, Criterion 2—Design Bases for Protection Against Natural Phenomena.

**Defense-in-Depth at Duane Arnold Energy Center**

In 2020, the Iowa "Derecho Windstorm" brought heavy rains and winds up to 130 miles per hour to the Duane Arnold Energy Center. The storm resulted in the loss of offsite power, which caused an emergency shutdown of the reactor. Winds from the storm also damaged two cooling towers and buildings housing the reactor, turbine, and equipment.

However, according to a Nuclear Regulatory Commission (NRC) document, the plant's safety margins and use of a defense-in-depth approach mitigated the effects of storm damage. Specifically, the plant had multiple backup generators and pumps as well as physical barriers to protect the plant.

During the storm, the plant lost offsite power, and the cooling pump for the spent fuel pool turned off. Before the outage, two emergency diesel generators started automatically due to grid-related storm impacts. Staff immediately started a second cooling pump. This action prevented the water in the spent fuel pool from boiling and potentially exposing the fuel rods. According to NRC, the winds also damaged the reactor's containment unit, but it remained functional and would have prevented a release of radiological material in the event of damage to the reactor core.

Duane Arnold Energy Center

Sources: Nuclear Regulatory Commission; AsNuke (photo), https://creativecommons.org/licenses/by-sa/4.0/deed.en. No changes were made to this photo. | GAO-24-106326

- **Licensing**. During the licensing process, NRC assesses a plant's risks from natural hazards as part of its safety evaluation. In doing so, NRC reviews reactor and plant designs and compares the design limits for natural hazards with the site's expected exposure to natural hazards on the basis of the licensee's hazard assessments. According to NRC officials, NRC also conducts a confirmatory analysis of the licensee's hazard assessments, which if deemed insufficient, must be revised by the licensee.
- **Inspections.** NRC resident inspectors use inspection manual procedures to inspect licensees' preparations for addressing adverse weather events and extreme temperatures.[40] As part of their inspections, NRC resident inspectors verify that selected systems and components will function when affected by adverse weather. NRC officials explained that an inspection includes observing licensees repair and run pieces of equipment, conducting emergency drills, and verifying that licensees are taking appropriate actions in response to severe weather conditions. Inspectors from NRC regional offices may also conduct plant inspections after adverse weather events, such as floods or hurricanes.
- **Probabilistic risk assessments.** NRC uses probabilistic risk assessments in its licensing and inspection processes to analyze various risks, including safety risks posed by natural hazards.[41] These assessments are a systematic method for assessing what can go wrong, its likelihood, and its potential consequences to provide insights into the strengths and weaknesses of the design and operation of a nuclear power reactor. Probabilistic risk assessments are used to estimate the risk of reactor core damage, radioactive material release, and related consequences to the public and environment based on the as-built, as-operated plant.
- **Operating experience program.** NRC's operating experience program collects and evaluates information from various regulatory oversight activities and inspection findings and shares information about plants' operating experiences with NRC staff. In addition, according to NRC officials, NRC has a research office that analyzes long-term trends, such as the loss of offsite power due to severe

[40]Inspections by resident inspectors at the plant level are called baseline inspections, and different types of baseline inspections occur either daily, quarterly or annually.

[41]Applicants for certain licenses for new reactors must submit a description of the plant-specific probabilistic risk assessment and its results to NRC as a part of their application.

**NRC Inspectors Address Heat Risks at the Palo Verde Nuclear Generating Station**

To prepare for extreme summer heat, Nuclear Regulatory Commission (NRC) resident inspectors at the Palo Verde Nuclear Generating Station in Arizona inspect systems likely to be affected by high temperatures, such as diesel generators and spray ponds, both of which are used to cool the reactor. The spray ponds contain a 26-day supply of water to ensure that plants have adequate cooling capacity to safely shut down.

Because high temperatures can cause water held in the spray ponds to evaporate, the plant relies on its reservoirs and deep wells as backup sources of water.

Palo Verde Nuclear Generating Station spray pond

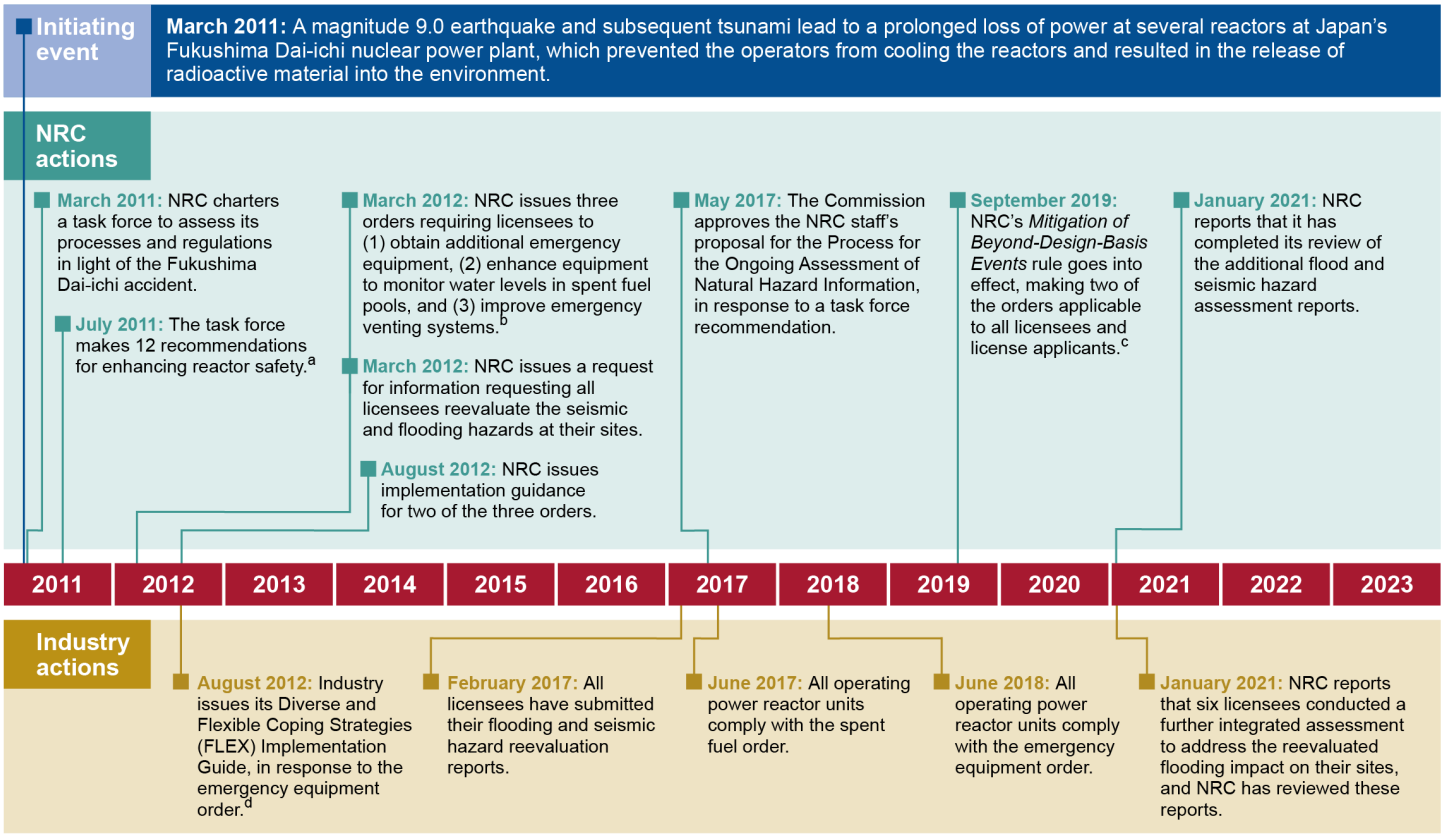
Sources: NRC; GAO (photo). | GAO-24-106326

weather, to identify lessons learned that could be applied to the oversight of other plants.

Following the 2011 accident at Japan's Fukushima Dai-ichi nuclear power plant, NRC and industry took several actions to further address risks to nuclear power plants from natural hazards.[42] Some of these actions were taken in response to recommendations from a task force NRC established to assess its regulatory approach (see fig. 9).

[42]On March 11, 2011, a 9.0-magnitude earthquake and subsequent tsunami devastated northeast Japan and led to the most extensive release of radioactive material at a nuclear power plant since the 1986 Chernobyl disaster. The Fukushima Dai-ichi nuclear power plant suffered extensive damage when a 45-foot-high tsunami wave exceeded the plant's seawall and flooded the site, causing a prolonged loss of electrical power at several of its reactors. As a result of the loss of power, plant operators were unable to keep three of the reactors cool, which led to fuel melting, hydrogen explosions, and the release of radioactive material into the environment. The disaster displaced tens of thousands of residents and contaminated the surrounding area. Nuclear-power-generating countries worldwide have since taken actions to prepare for an event like this, which far exceeded the Fukushima Dai-ichi plant's design basis.

**Figure 9: Timeline of Selected Nuclear Regulatory Commission (NRC) and Industry Actions after the Fukushima Dai-ichi Accident in 2011**




Source: GAO review of NRC and industry documents. | GAO-24-106326

[a]NRC prioritized the recommendations in three tiers: (1) recommendations NRC should implement without unnecessary delay; (2) recommendations that could not be initiated in the near term due, in part, to resource or critical skill set limitations; and (3) recommendations that required further study by NRC to determine if regulatory action was necessary, among other factors.

[b]NRC, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events, Order EA-12-049 (Washington, D.C.: Mar. 12, 2012); Issuance of Order to Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation, Order EA-12-051 (Washington, D.C.: Mar. 12, 2012); and Order Modifying Licenses with Regard to Reliable Hardened Containment Vents, Order EA-12-050 (Washington, D.C.: Mar. 12, 2012).

[c]NRC, Mitigation of Beyond-Design-Basis Events, 84 Fed. Reg. 39,684 (Aug. 9, 2019). Orders EA-12-049 and EA-12-051 are applicable to all licensees and construction permit holders. Order EA-12-050 applies to licensees with boiling water reactors that feature certain containments that require proper venting to ensure safety.

[d]Nuclear Energy Institute, Diverse and Flexible Coping Strategies (FLEX) Implementation Guide, NEI 12-06 (August 2012) and NRC, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events, Order EA-12-049 (Washington, D.C.: Mar. 12, 2012).

The actions NRC took in response to the task force recommendations include the following:

- **Required licensees to assess flooding risks.** NRC required all licensees to assess updated flood hazard risk information and reevaluate and upgrade, as necessary, their plants' flood protection of structures, systems, and components. On the basis of these assessments, NRC did not identify the need to require any plant modifications or revise plant safety procedures.[43]
- **Created a process for ongoing hazard assessments.** In May 2017, the Commission approved the Process for the Ongoing Assessment of Natural Hazard Information (POANHI) to determine the need for site-specific assessments, additional research, or regulatory action.[44] POANHI involves collecting and maintaining hazard information in the

[43]NRC required all nuclear power plant licensees to conduct on-site inspections of safety-related systems to verify that plant features that protect against flooding are available, functional, and properly maintained. All licensees conducted flood reevaluations for their plants, and licensees at six plants conducted further integrated assessments, which are requested by NRC if the plant's design for a potential flood is exceeded by the reevaluation's estimates of potential maximum elevation of flood waters. These assessments evaluate the plant response to flooding hazards and the effectiveness of existing systems and procedures to mitigate risks from flooding. In addition, NRC required licensees to identify and address plant-specific vulnerabilities related to flooding and verify the adequacy of monitoring and maintenance for protection features in the interim period until longer term actions were completed to reevaluate design-basis flooding hazards. Also, following the accident at the Fukushima Dai-ichi plant, NRC issued a temporary instruction directing its inspection staff to independently assess the adequacy of actions taken by licensees. NRC also required licensees to assess seismic hazard risks. Seismic hazard risks are not included in the scope of this report.

[44]Preceding the approval of POANHI, NRC conducted a 2013 Probabilistic Flood Hazard Assessment workshop following the accident at the Fukushima Dai-ichi nuclear power plant, in which participants from federal agencies and other organizations shared information about probabilistic assessment of extreme rainfall, flood-induced dam and levee failures, tsunami flooding, river flooding, extreme storm surge, and combined-events flooding. NRC continues to host Probabilistic Flood Hazard workshops nearly annually, and these workshops often share research results with the public. For example, NRC contracted with the Pacific Northwest National Laboratory to publish four national and regional reports on the potential impacts of climate change, which as of 2022 have not yet led to additional NRC guidance for probabilistic flood hazard assessment. These reports are publicly available at https://www.osti.gov/biblio/1259942, https://www.osti.gov/biblio/1593340, https://www.osti.gov/biblio/1524249, and https://www.osti.gov/biblio/1605280.

Natural Hazards Information Digest[45]—a database that supports POANHI—and reviewing and assessing the hazard information to determine whether a hazard has a potentially significant impact on plant safety.[46] To ensure that NRC is aware of new hazard information from a variety of sources for inclusion in this database, NRC regularly interacts with internal and external stakeholders, including other federal agencies, academia, industry, regulators from other countries, and other technical and scientific organizations, according to NRC officials. If a POANHI assessment of new hazard information identifies a potentially significant effect on plant safety, NRC refers the issue to the appropriate regulatory program, at which point the program office determines how to proceed. POANHI leverages and is integrated into other existing processes, such as the operating experience program, for the assessment of new information and the determination of whether a change is needed to a particular plant's licensing basis. According to NRC officials, NRC has not taken any regulatory actions as a result of POANHI.[47]

- **Required enhanced safety and emergency equipment**. In 2012, NRC ordered all licensees and nuclear power plant construction permit holders to ensure that a plant's key safety functions could be

[45]NRC incorporates new hazard information, such as records of site-specific or regional extreme weather events, into its Natural Hazards Information Digest, which NRC began using in 2019. This database is NRC's repository for information on natural hazard-related events at or near nuclear power plants. The database captures documentation provided by licensees in response to site hazard reevaluations and plant inspections as well as historical site-specific events and information about natural hazards that could affect plants. In addition to informing POANHI, the database also supports NRC efforts to (1) respond to emergent events associated with natural hazards by providing relevant information, (2) engage with stakeholders, (3) evaluate natural hazard-related inspection findings to determine their safety significance, (4) implement natural hazards research plans, and (5) update regulatory and staff guidance.

[46]According to NRC policy, the significance assessment determines whether the new information indicates that the hazard could adversely affect the capability of a plant's structures, systems, and components to perform their intended safety functions. To make this determination, NRC staff either conduct a quantitative assessment that compares the new information with risk insights from past hazard analyses to assess the impacts of plant response or conduct a qualitative assessment that considers the likelihood of the event, identifies vulnerabilities and actions to address them, and adheres to defense-in-depth principles, among other factors.

[47]NRC is reviewing new seismic information from a 2018 report to assess updated seismic hazards at the nuclear power plants located in the region addressed by the report. See Pacific Earthquake Engineering Research Center, *Central and Eastern North America Ground-Motion Characterization: NGA-East Final Report*, (Berkeley, CA: December 2018). After reviewing this report, NRC determined that 13 nuclear power plants located in the central and eastern United States needed further assessment. Based on assessments conducted as of March 2024, NRC determined that no regulatory action was needed.

maintained during a natural disaster that exceeds a plant's design basis. In response, the nuclear industry developed and implemented the *Diverse and Flexible Coping Strategies (FLEX) Implementation Guide,* which NRC has endorsed as one method to comply with the 2012 order.[48] FLEX is a strategy that uses controls, procedures, and backup equipment to ensure that the key safety functions related to cooling a reactor's core and spent fuel, as well as containment to prevent accidental releases of radiation, are maintained if a disaster occurs at a plant. According to NRC officials, as part of this strategy, all plants have backup equipment on site. In addition, the nuclear power industry operates two Strategic Alliance for FLEX Emergency Response (SAFER) centers that maintain emergency equipment that can be provided to plants as a backup to plants' primary backup equipment onsite.[49] See figure 10 for examples of FLEX and SAFER equipment.

[48]Nuclear Energy Institute, *Diverse and Flexible Coping Strategies (FLEX) Implementation Guide*, NEI 12-06, August 2012.

[49]The SAFER centers are located in Phoenix, Arizona, and Memphis, Tennessee. The SAFER centers' staff comprises staff from a private company that has contractual agreements to manage and deploy offsite equipment with every nuclear licensee in the United States as part of FLEX. The SAFER centers maintain generic equipment useful for multiple plants, including various types of generators and pumps, and site-specific equipment unique to certain plants. NRC determined there is reasonable assurance that equipment at the SAFER centers can be deployed to any plant in the United States within 24 hours, as specified by licensees' SAFER response plans. To date, no SAFER response plan has been activated. According to our analysis of federal hazard data, SAFER centers are in areas with no exposure to sea level rise or hurricane storm surge, and either low (Memphis) or high (Phoenix) flood hazard. The centers are located in areas projected to see an increase in daily temperature from 3.6 to 4.9 degrees, and the Phoenix SAFER center is in an area with high or very high wildfire risk.

**Figure 10: Examples of the Diverse and Flexible Coping Strategies (FLEX) and Strategic Alliance for FLEX Emergency Response (SAFER) Center Equipment**


Top: Water purification equipment, located at the National SAFER Response Center in Phoenix, Arizona, is designed to facilitate the use of higher quality water for the reactor coolant system's makeup. Bottom left: Arizona's Palo Verde Generating Station high-pressure reactor coolant system injection pump is used to support the FLEX strategy and receives borated water from an onsite storage tank to inject into the reactor coolant system to maintain reactor coolant system inventory and nuclear reactivity. Bottom right: Florida's Turkey Point Nuclear Generating Station steam generator FLEX well pump is a piece of backup equipment used to refill a storage tank from an artesian well for the purpose of adding water to the steam generator.

Sources: GAO analysis of Nuclear Regulatory Commission documents and interview with licensee staff; GAO (photos). | GAO-24-106326

## NRC's Actions Do Not Fully Consider the Potential Effects of Climate Change

NRC's actions to address risks to nuclear power plants from natural hazards in its licensing, license renewal, and inspection processes do not fully consider the potential increased risks from natural hazards that may be exacerbated by climate change.

- **Licensing.** NRC does not use climate projections data to identify and assess risk as part of the safety reviews or probabilistic risk

assessment reviews it conducts during the initial licensing process.[50] Rather, NRC uses historical data to extrapolate the future risks of natural hazards that may occur during the lifetime of a nuclear power plant.[51] Extrapolating historical data into the future assumes that existing climatological trends will continue.[52] According to NRC officials, NRC uses historical data in conjunction with other information to establish a conservative licensing basis, and many of the natural hazards considered during licensing target annual exceedance probabilities such that an event is unlikely to occur during the lifetime of the plant. In such a case, NRC expects the event to occur only once in 10,000 to 10 million years, depending on the hazard. NRC officials we interviewed told us that they review regional climate projections information for some hazards but do not incorporate site-specific climate projections data, which include hazard assessments, design bases, or determining the adequate safety margin for plants. For example, NRC officials said they review the projected average increase in temperature that applies to a multi-state region according to the NCA designation and compare that with the maximum temperature limits for a particular plant in that region. The officials said that they do not use data on the projected temperature increase to inform licensing decisions at the plant site itself.

- **License renewals.** Following an initial 40-year licensing period, NRC does not reevaluate natural hazard risks, including climate-related

[50]The NCA defines a "climate projection" as the simulated response of the climate system to a scenario of future emissions or concentrations of greenhouse gases and aerosols, generally derived using climate models. Projections data could be based on a range of possible future scenarios for particular time frames, such as the projected temperature of a specific location in the year 2050, as identified by models that consider climate systems' physical, chemical, and biological properties and their interactions. According to NRC officials we interviewed, probabilistic risk assessments use current estimates of the probability of external events, and neither licensees' nor NRC's assessments incorporate climate projections data, despite their role in assessing the likelihood of future events. NRC officials said that while it is both technical and feasible to update these models with the latest information reflecting their current state of knowledge, using climate projections data would increase uncertainty in the results of the probabilistic risk assessments, and no historical trends have emerged to suggest the need to adjust these.

[51]For example, NRC regulations for evaluating sites for initial licensing require NRC to consider the seismology, meteorology, geology, and hydrology of the site and to estimate the "maximum probable flood" using historical data, among other factors. 10 C.F.R. § 100.20(c). These regulations do not preclude NRC from using climate projections data.

[52]As noted previously, according to the NCA, climate change is altering the characteristics of many extreme weather events. Specifically, some of these events have already become more frequent, intense, widespread, or of longer duration, and many are expected to continue to worsen.

risks, to update the safety reviews required for the license renewal process. NRC's license renewal process focuses on evaluating and managing the effects of aging on the extended operations of nuclear power plants and considers the original licensing basis in that context.[53] As of January 2024, NRC had issued license renewals to 49 of the 54 operating nuclear power plants, meaning most plants are operating on the basis of assessments of natural hazard risk that are over 40 years old.

- **Inspections.** During regular inspections, NRC resident inspectors are responsible for focusing on the immediate day-to-day safety of plants rather than on the potential long-term safety risks. Inspections do not include an assessment of future climate projections data. In addition, while NRC sometimes conducts additional inspections using outside teams—including staff from NRC regional offices—to address recent events or emerging issues related to safety, these inspections also do not focus on long-term safety risks.

NRC officials we interviewed told us that while their regulatory processes—including licensing, license renewals, and inspections—do not use climate projections data to assess climate risks, they believe conservatism, safety margins, and defense-in-depth provide an adequate margin of safety to address climate risks to the safety of nuclear power plants.[54] However, NRC has not conducted an assessment to demonstrate that this is the case.

Moreover, NRC actions taken to address risks to nuclear power plants from natural hazards post-Fukushima did not fully consider the effects of climate change. Specifically, NRC required licensees to assess flooding risk and enhance safety and emergency equipment, but NRC did not require licensees to use climate projections data to assess future flooding

[53]Licensees are not required to reevaluate their plant's design basis pertaining to natural hazards as part of the license renewal process.

[54]According to NRC officials, NRC uses the NCA, which includes climate projections, in the environmental reviews it conducts during licensing and license renewals to assess the expected effects of nuclear power plants on the environment. For example, NRC addresses the greenhouse gas emissions associated with the life cycle of the plant as well as the potential effects of climate change on the environment in these reviews.

risks as part of these assessments or in the FLEX equipment needs assessments.[55]

NRC also created POANHI—its process for ongoing hazard assessments following Fukushima—which, according to NRC officials, NRC relies on to identify and assess changes in natural hazard risks, including those driven by climate change. However, POANHI has several limitations as a mechanism for comprehensively identifying and assessing climate risks. Specifically:

- While POANHI was designed to assess all natural hazards, NRC has not used POANHI to assess potential changes to all natural hazards, nor has NRC comprehensively reviewed natural hazards on a regular basis to determine whether available information indicates the need for a POANHI assessment. NRC officials told us that while POANHI requires continuous evaluation of new information on natural hazards, NRC conducts POANHI assessments for one hazard at a time, and the agency does not have a schedule for reviewing natural hazards beyond the assessment of seismic hazards currently underway. As such, POANHI is used to react to new hazard information or events when NRC staff become aware of them.
- NRC has not documented the new hazard information it reviews as part of POANHI or the way it incorporates climate projections data to determine whether to initiate a POANHI assessment, require additional plant-specific assessments, conduct an overall hazard reevaluation, or take regulatory action.
- NRC has not implemented POANHI and the Natural Hazards Information Digest at all levels of the agency. For example, several regional branch chiefs and resident inspectors we interviewed were unaware of POANHI and this information database. An official from one NRC regional office said that if the database were shared more broadly, it would benefit resident inspectors, who could access and use information on weather-related events and inspection findings to inform probabilistic risk assessments. According to NRC officials, the

[55]According to NRC officials, the plant-specific mitigation strategy relied on information each licensee had previously been required to provide as part of reevaluations of external events for comparison against the current licensing bases and FLEX equipment reflect the most severe external events that could occur based on known available meteorological, geological, and geographical data. According to NRC officials, the external hazards needing to be considered were both extreme and rare in nature which resulted in the regulatory approach of using flexible, diverse strategies to maintain or restore core cooling, containment, and spent fuel pool cooling.

agency is conducting internal outreach to increase NRC staff's knowledge of POANHI.

NRC's Fiscal Year 2022–2026 Strategic Plan calls for ensuring that licensees have measures to address the potential for increased risks from climate change. The strategic plan also promotes risk-informed decision-making to support NRC's strategic objective of providing quality licensing and oversight of nuclear facilities. Moreover, *GAO's Standards for Internal Control in the Federal Government* state that management should identify, analyze, and respond to risks related to achieving defined objectives.[56] These standards also call for agency management to use quality information to achieve their objectives.

Assessing its current processes would help NRC to determine whether they adequately address the potential for increased risks to nuclear power plants from climate change. Specifically, identifying gaps in its processes and developing a plan to address them, including by using climate projections data or augmenting POANHI, would help ensure that NRC adopts a comprehensive approach for assessing risks and fulfills its mission to protect public health and safety.

NRC officials told us that they use historical data in licensing and oversight processes rather than climate projections data, in part because regulations require NRC to use available historical data to assess the safety of the reactor site and design and they believe these data are reliable and sufficient for developing an adequate margin of safety for plants.[57] According to NRC officials, using site-specific climate projections

[56]GAO-14-704G. Risk assessment is the identification and analysis of risks related to achieving defined objectives to form a basis for developing responses to these risks. Our prior work has shown that assessing risks includes assessing both the likelihood of an event occurring and the effect the event would have. Agency leaders and subject matter experts should assess each risk by assigning the likelihood of the event's occurrence and the potential effect if the event occurs. GAO, *Enterprise Risk Management: Selected Agencies' Experiences Illustrate Good Practices in Managing Risk*, GAO-17-63 (Washington, D.C.: Dec. 1, 2016).

[57]See, e.g., 10 C.F.R. § 100.20(c) (requiring NRC to consider for initial licensing of new reactors the seismology, meteorology, geology, and hydrology of the site and to estimate the "maximum probable flood" using historical data). See also 10 C.F.R. § 60.2 (defining "design bases" to include using severe natural events estimates based on historical and physical data); and 10 C.F.R. Part 50, Appendix A, General Design for Nuclear Power Plants, Criterion 2—*Design Bases for Protection Against Natural Phenomena* (requiring the design bases for the reactor's safety structures, systems, and components to consider the "most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated," among other factors).

data for extreme hazard levels in nuclear power plant design and safety reviews is challenging because of the uncertainty associated with applying these data to specific sites. However, NRC regulations do not preclude NRC from using climate projections data, and new sources of reliable projected climate data are available to NRC. In 2023, the White House Office of Science and Technology Policy issued guidance to federal agencies on selecting and using climate data to assess risks and their potential impacts.[58] This guide provides information on climate models and projections to help federal agencies understand exposure to current and future climate-related hazards and their potential impacts. Without incorporating the best available information into its licensing and oversight processes, it is unclear whether the safety margins for nuclear power plants established during the licensing period—in most cases over 40 years ago—are adequate to address the risks that climate change poses to plants.

## Conclusions

Commercial nuclear power plants in the United States were licensed and built an average of 42 years ago, and weather patterns and climate-related risks to their safety and operations have changed since their construction. Climate change is expected to exacerbate natural hazards—such as heat, drought, wildfires, flooding, hurricanes, sea level rise, and extreme cold weather events—that can affect nuclear power plant safety and operations in various ways. Some of these effects are already occurring, and many are expected to continue to worsen.

However, NRC does not use climate projections data to identify and assess risk as part of the safety reviews it conducts or the probabilistic risk assessments it reviews during the initial licensing process. NRC has also not fully developed POANHI, which the agency relies on to identify and assess changes in natural hazard risks, including climate change.

NRC has the opportunity to consider climate risks more fully and, in doing so, to better fulfill its mission to protect public health and safety.

[58]Office of Science and Technology Policy, *Selecting Climate Information to Use in Climate Risk and Impact Assessments: Guide for Federal Agency Climate Adaptation Planners*, (Washington, D.C.: March 2023). Although climate projections data and guidance are available to federal agencies, we previously recommended that the federal government, through the Executive Office of the President, make authoritative climate data and information accessible and assist in translating that information for decision makers. GAO, *High-Risk Series: Efforts Made to Achieve Progress Need to Be Maintained and Expanded to Fully Address All Areas,* GAO-23-106203 (Washington, D.C.: April 20, 2023) and *Climate Information: A National System Could Help Federal, State, Local, and Private Sector Decision Makers Use Climate Information,* GAO-16-37 (Washington, D.C.: Nov. 23, 2015).

Specifically, assessing whether its licensing and oversight processes adequately consider climate risks to nuclear power plants and developing and implementing a plan to address any gaps identified would help the agency do so. As NRC makes licensing, license renewal, and oversight decisions, adopting an approach that incorporates the best available information on climate risks and ways that those risks may affect nuclear plants, would provide greater assurance that licensees have adequate measures to address risks from climate change.

## Recommendations for Executive Action

We are making the following three recommendations to NRC:

The Chair of the NRC should direct NRC staff to assess whether its licensing and oversight processes adequately address the potential for increased risks to nuclear power plants from climate change. (Recommendation 1)

The Chair of the NRC should direct NRC staff to develop, finalize, and implement a plan to address any gaps identified in its assessment of existing processes. (Recommendation 2)

The Chair of the NRC should direct NRC staff to develop and finalize guidance on incorporating climate projections data into relevant processes, including what sources of climate projections data to use and when and how to use climate projections data. (Recommendation 3)

## Agency Comments and Our Evaluation

We provided a draft of this report for review and comment to NRC.

In its written comments, reproduced in appendix IV, NRC stated that the three recommendations are consistent with actions that are either underway or under development. In addition, NRC stated that the layers of conservatism and defense-in-depth incorporated into NRC's processes provide reasonable assurance regarding any plausible natural hazard and combinations at a site for the licensed operational lifetime of the reactor, including those that could result from climate change. As we noted in our report, NRC has not conducted an assessment to demonstrate that the safety margins for nuclear power plants established during the licensing period are adequate to address the risks that climate change poses to plants. According to the NCA, many of the climate conditions and impacts experienced in the United States today are unprecedented for thousands of years. Across all regions of the United States, extremes, including heat, drought, flooding, wildfire, and hurricanes, are becoming more frequent and/or severe, with a cascade of effects in every part of the country. We continue to believe that NRC cannot fully consider potential

climate change effects on plants without using the best available information—including climate projections data—in its licensing and oversight processes.

NRC also provided technical comments, which we incorporated, as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Chair of the NRC, and other interested parties. In addition, the report is available at no charge on the GAO website at https://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or ruscof@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix V.

Frank Rusco
Director, Natural Resources and Environment

# Appendix I: Objectives, Scope, and Methodology

This report examines (1) how climate change is expected to affect nuclear power plants and (2) actions the Nuclear Regulatory Commission (NRC) has taken to address the risks to nuclear power plants from climate change.

To address both objectives, we interviewed officials from NRC headquarters, all four NRC regional offices, and two nuclear power plants. We also interviewed officials from the Department of Energy—including the Office of Nuclear Energy and the Idaho National Laboratory—the Department of Homeland Security, the Federal Energy Regulatory Commission, and the National Oceanic and Atmospheric Administration (NOAA). We also interviewed nine stakeholders knowledgeable about nuclear power plant safety and operations, climate change, and resilience measures. These included stakeholders from three industry groups, four nongovernmental organizations, and two academic institutions. We identified stakeholders using snowball sampling.[1] Views from selected stakeholders cannot be generalized to all stakeholders.

We conducted site visits to two nuclear power plants—Palo Verde Nuclear Generating Station in Buckeye, Arizona, and Turkey Point Nuclear Generating Station in Homestead, Florida. We toured the power plants and interviewed plant staff and NRC resident inspectors at each site. To answer both objectives, we chose these sites for in-person visits based on factors including exposure to distinct natural hazards, regional diversity, reactor type, licensee size, and agency resources. Findings from selected site visits are not generalizable to all sites.

To address how climate change is expected to affect nuclear power plants, we reviewed prior GAO reports and sources of climate change information (including the fourth and fifth National Climate Assessments (NCA)), completed a literature review, and conducted data analysis.[2] To conduct the literature review of articles and reports related to the effects of selected hazards and climate change on nuclear power plants, we searched a variety of scholarly, trade, and news databases, such as Ei

[1]In snowball sampling, the methodology begins with an initial list of contacts and asks each person interviewed to refer the interviewer to additional cognizant persons. The group of referred contacts (or "snowball") grows larger and then narrows as a group of individuals are identified frequently.

[2]Few supporting sources distinguish between the impact of selected natural hazards on operating versus shutdown nuclear power plants. As a result, we most often do not make this distinction.

Encompass LIT, Geobase, Inspec, the National Technical Information Service, ProQuest Environmental Science Professional, and Scopus using relevant keywords (e.g., “nuclear power,” “climate change,” “risk,” and “extreme weather”) for articles and other documents published since 2012. The results yielded 107 potentially relevant articles and other documents published from January 2012 through January 2023. To determine which articles were relevant to our scope, one analyst reviewed the articles’ abstracts and determined whether the articles were in scope using professional judgment based on their knowledge of the engagement’s scope. A second analyst reviewed the first analyst’s determinations, and the two came to a consensus on which articles were in scope. Using this method, we selected 56 articles and other documents for further review. Reviewing them for relevance, we ultimately identified and used 36 articles to support findings in our report.

To conduct our data analysis, we identified national-level data sets from relevant federal agencies for six of the seven natural hazards identified by the NCA, and our review of literature, as likely to be exacerbated by climate change in the United States. The six hazards are heat, cold, wildfires, flooding, storm surge from hurricanes, and sea level rise.[3] For heat and cold, we used climate projections data that incorporate emission scenarios to project future exposure to those hazards.[4] For wildfires, flooding, and hurricane storm surge, we used climate data that show current conditions based on past conditions (which do not incorporate climate projections).[5] For sea level rise, we used data for coastal regions and sea level rise projections from an interagency report covering sea level rise scenarios to identify coastal nuclear power plants and projected

[3]To identify the best available federal-level hazard data, we relied on interviews with agency officials and prior GAO reports. We did not analyze drought data because we were unable to identify national-level geospatial data that was both relevant to nuclear power plants and sufficiently reliable for our purposes.

[4]To analyze projected exposure to heat and cold hazards, we used NCA data on the projected exposure to maximum and minimum temperatures in the midcentury (i.e., 2036–2065), using both a low and high emission scenario for projected climate change.

[5]To analyze flood exposure, we used 2023 data from the Federal Emergency Management Agency that categorizes flood exposure into high, moderate, minimal or other, and unknown flood hazard categories. To analyze exposure to hurricane storm surge, we used NOAA data on storm surge exposure from Categories 1, 4, and 5 hurricanes. To analyze exposure to wildfires, we used 2023 data from the U.S. Forest Service on wildfire hazard potential.

sea level rise in their respective regions.[6] In this report, we refer to these hazards collectively as selected natural hazards that may be exacerbated by climate change.

For our national-level data from federal agencies, we used data we determined to be the most appropriate to represent selected natural hazards.[7] Data sources for each of the hazards we analyzed are, as follows:

- **Heat and cold.** To analyze projected exposure to heat and cold, we used data from the fourth NCA on the projected exposure to maximum temperatures in the midcentury (i.e., 2036–2065).[8]
- **Wildfire.** To analyze exposure to wildfire hazard potential, we used 2023 data from the U.S. Forest Service's Wildfire Hazard Potential Map. For reporting purposes, we grouped wildfire hazard potential into the following three categories: no/low, moderate, and high/very high.[9]
- **Flooding.** To analyze exposure to flood hazards, we used 2023 data from the Federal Emergency Management Agency's National Flood Hazard Layer. For reporting purposes, we grouped flood hazard

[6]W. V. Sweet, B. D. Hamlington, R. E. Kopp, C. P. Weaver, P. L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A. S. Genz, J. P. Krasting, E. Larour, D. Marcy, J. J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K. D. White, and C. Zuzak, *Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines*, NOAA Technical Report NOS 01 (Silver Spring, MD: February 2022).

[7]Data sources were chosen based on use in prior GAO reports, review of the NCA, and interviews with federal agencies responsible for collecting and reporting on data related to the selected natural hazards.

[8]The fifth NCA was released on November 14, 2023, after we had obtained and analyzed the hazard data sets from the fourth NCA. We reviewed relevant sections from the fifth NCA and did not identify major differences in the predicted or projected trends for the selected natural hazards.

[9]We combined layers of "high" and "very high" wildfire hazard potentials, which correspond to areas at the 85th percentile or greater for wildfire hazard potential. The no/low category includes plants that are in areas that are not covered by the "moderate," "high," or "very high" wildfire potential layers.

zones into the following three categories: no/low, moderate, and high.[10]

- **Hurricane storm surge.** To analyze exposure to various levels of hurricane storm surge, we used data from NOAA's Sea, Lake, and Overland Surges from Hurricanes model. We used a range of categories from the data, including no exposure to hurricanes, and Categories 1, 4, and 5 hurricanes.[11]
- **Sea level rise.** To analyze potential exposure to sea level rise in 2050, we used data from an interagency report covering sea level rise scenarios to illustrate regional climate projections for sea level rise in coastal regions. The data include two types of estimates–observation-based extrapolations and regionalized global mean sea level scenarios. NOAA officials recommended using these projections for our analysis of sea level rise data.

To identify nuclear power plant locations, we used nuclear power plant location data from NRC.[12] We used a 0.5-mile radius around the plant coordinates provided by NRC as a proxy for approximate plant size. We based the size of the radius on approximations we made for an average U.S. nuclear power plant.[13]

See appendix II for further discussion of these data sources.

[10]No/low corresponds to areas with minimal, unknown, or other flood hazards, including areas with reduced risk because of levees as well as areas with flood hazard based on future conditions, such as the future implementation of land-use plans. Moderate flood hazard zones correspond to a 500-year floodplain, which indicates between 0.2 percent and 1 percent annual chance of flooding. High flood hazard zones correspond to a 100-year floodplain, which indicates a 1 percent or higher annual chance of flooding.

[11]In our analysis, we used data on storm surge from Category 1 hurricanes (the lowest possible category) and for Categories 4 and 5 hurricanes (the highest possible categories) to show a range of climate change effects.

[12]In March of 2023, we obtained NRC nuclear power plant coordinates for all 54 operating nuclear power plants. In July 2023, we obtained NRC nuclear power plant coordinates for the 21 nuclear power plants that have shut down and have spent nuclear fuel stored onsite in spent fuel pools or in dry cask storage. NRC provided coordinates, including a latitude and longitude value for each plant. In addition, NRC's location data file contained other identifying plant information including operating status, license number, and reactor type.

[13]We requested average plant size from NRC, but NRC was unable to provide these data. Instead, we approximated the size of a typical nuclear power plant using DOE documentation on nuclear power plants.

Using hazard and nuclear power plant location data, we analyzed natural hazard exposure in the areas around nuclear power plants. In our analysis, we included operating plants and plants at various stages of decommissioning, including those in the process of decommissioning and those already shut down, with spent nuclear fuel stored onsite. We did not include experimental or test reactors in our analysis.

For certain hazards, we analyzed exposure to a range of intensities. For example, we analyzed nuclear power plant exposure to storm surge from the weakest (Category 1) and strongest (Category 5) hurricanes, as modeled by NOAA.

To analyze whether nuclear plants are located in areas that may be affected by heat, cold, wildfire, flooding, and hurricane storm surge, we used MapInfo mapping software to determine whether the nuclear power plant locations were located in areas with exposure to the selected hazards. Exposure indicates that a facility is located in an area that may be affected by a selected hazard. If the plant overlapped with multiple hazard layers, the layer representing the highest level of exposure was reported. For example, in our report, we coded a plant whose locations showed exposure to both layers for Category 1 and Category 5 storm surge data as having exposure to Category 5 storm surge.

We assessed the reliability of the fourth NCA climate projections data we used to analyze heat and cold exposure by (1) interviewing NOAA officials knowledgeable about the data and (2) reviewing existing information about the data and system that produced them.

To assess the reliability of the Federal Emergency Management Agency's National Flood Hazard Layer, NOAA's data on Sea, Lake, and Overland Surges from Hurricanes, and the U.S. Forest Service's Wildfire Hazard Potential data, we reviewed prior GAO data reliability assessments for reports using the same data.[14] Then, through interviews and email correspondence with NOAA, the Federal Emergency Management Agency, and U.S. Forest Service officials, we ensured that these data remained appropriate and reliable, considering any subsequent updates or changes made to the data.

[14]GAO, *Chemical Accident Prevention: EPA Should Ensure Regulated Facilities Consider Risks from Climate Change*, GAO-22-104494 (Washington, D.C.: Feb. 28, 2022) and GAO, *Superfund: EPA Should Take Additional Actions to Manage Risks from Climate Change,* GAO-20-73 (Washington, D.C.: Oct. 18, 2019).

To assess the reliability and appropriate use of sea level rise data for use in our analysis, we reviewed regional sea level rise data in an interagency report covering sea level rise scenarios and interviewed NOAA officials knowledgeable about sea level rise data.

To assess the reliability of NRC's data on nuclear power plant locations, we communicated with NRC staff about data accuracy and conducted limited data testing.[15] As a result of the steps described above, we found the data from the NCA, the Federal Emergency Management Agency, NOAA, the U.S. Forest Service, and NRC to be sufficiently reliable for the purpose of our reporting objectives.

To examine NRC's actions to address risks to nuclear power plants from climate change, we conducted interviews and reviewed relevant agency documents. We interviewed officials from NRC headquarters, all four NRC regional offices, and two nuclear power plants. During our two nuclear power plant site visits, we interviewed plant operator staff as well as NRC's resident inspectors to assess whether NRC processes to mitigate the risks of natural hazards and extreme weather at those plants adequately consider climate change risks. We also observed an NRC safety evaluation review to understand the extent to which NRC incorporates considerations of climate change risks when determining whether and under what conditions to license a nuclear power plant.[16] We reviewed relevant documents consisting of the following: relevant laws and regulations, agency documents (including guidance on probabilistic risk assessments and NRC's 2022–2026 Strategic Plan), two NRC office instructions, NRC's inspection manual on adverse weather protection, and other documents.[17] We compared NRC's actions against requirements to identify any relevant gaps. We also reviewed GAO's

[15]Specifically, we inputted a selection of NRC's location data into mapping software to ensure NRC's latitude and longitude location data for nuclear power plants correctly corresponded to plant names and identifying information provided by NRC. Also, we compared the plant operating status of selected plants in NRC's dataset with public information to ensure the operating status of plants matched.

[16]This safety evaluation review was for Turkey Point's Units 6 and 7, which were granted an operating license under 10 C.F.R. Part 52 but have not been built, according to NRC officials.

[17]NRC, *Strategic Plan Fiscal Years 2022–2026,* NUREG-1614, Vol. 8 (Washington, D.C.: April 2022). See also, NRC, *Inspection Manual: Adverse Weather Protection,* Inspection Procedure 71111, Attachment 01 (Washington, D.C.: Jan. 1, 2018).

*Standards for Internal Control in the Federal Government* and compared NRC's actions against those standards.[18]

We conducted this performance audit from November 2022 to April 2024 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[18]GAO, *Standards for Internal Control in the Federal Government*, GAO-14-704G (Washington, D.C.: Sept. 10, 2014).

# Appendix II: Available Federal Data on Heat, Cold, Wildfires, Flooding, Storm Surge, and Sea Level Rise

This appendix provides information on data sources we used to analyze potential exposure of nuclear power plants to selected natural hazards—including heat, cold, wildfires, flooding, storm surge from hurricanes, and sea level rise. We include information, when available, on the data source name, description, purpose, update frequency, and limitations.

## National Climate Assessment Heat and Cold Climate Projections Data

The U.S. Global Change Research Program posts climate projections data on its website so that authors and other users can access their data.[1] The variables we used for heat and cold are part of a suite of variables intended to provide users insights into the effects of climate change on different variables under multiple emission scenarios.[2]

We analyzed and reported on the following heat or cold variables from the fourth National Climate Assessment (NCA):[3]

- projected change in maximum daily temperature;

[1]NOAA's Technical Support Unit and the Scripps Institute of Oceanography were involved in creating these data. Together, these stakeholders contributed to creating 100 variables derived through statistical downscaling—a process used to take climate model data, which are typically at a low resolution, and produce more detailed data relevant to a specific location or region. Climate projections have limitations that include uncertainties in emissions, natural variability, and differences in scientific models. "Emission uncertainty" refers to a climate projection's reliance on emission scenarios reliant on assumptions about future emissions, changes in population, energy use, and technology. "Natural variability" refers to unpredictable climate events like volcanic eruptions. Scientific models refer to the way processes are understood and incorporated. For example, any change in the scientific understanding of cloud properties and ocean circulation can affect projections of future climate. In this report, we refer to these data as NCA data.

[2]Climate projections are based on emissions scenarios. These scenarios are produced using a range of future assumptions about underlying socioeconomic conditions, such as population and global gross domestic product projections. The climate projections data from the fourth NCA enable users to analyze projected exposure to temperature, precipitation, and other related variables by using a range of emission scenarios and time periods. Four scenarios are available, including historical climate (averages based on the 1976–2005 climate), lower (averages based on NCA assumptions for intermediate-low sea level rise, lower population, and lower development land use), higher (averages based on intermediate sea level rise, higher population, and higher development land use), and the upper bound (averages based on extreme sea level rise, higher population, and higher development land use). All four scenarios base their future projections on historical climate data for 1976–2005. These scenarios are available for three time periods, which include the early 21st Century (2016–2045), mid-21st Century (2036–2065), and late 21st Century (2070–2099).

[3]The fifth NCA became available in November 2023, after we had obtained and analyzed heat and cold data from the fourth NCA.

- projected change in the annual days with a maximum temperature greater than the 99th percentile;
- projected change in the annual number of days with a maximum temperature greater than 115 degrees Fahrenheit;
- projected change in annual highest maximum temperature averaged over a 5-day period; and
- projected change in the annual number of days with a maximum temperature lower than the 1st percentile.[4]

## U.S. Forest Service Wildfire Hazard Potential Data

The U.S. Forest Service maps wildfire hazard potential based on landscape conditions and other observations. We previously reported that the primary intended use of the wildfire hazard potential map is to identify priority areas for hazardous fuels treatments from a broad, national- to regional-scale perspective. The data do not explicitly show wildfire threat or risk.[5]

The U.S. Forest Service maps an index of wildfire hazard potential for the contiguous United States based on, among other factors, annual burn probabilities and potential intensity of large fires. The U.S. Forest Service categorizes the wildfire hazard potential index into five classes: very low, low, moderate, high, and very high. The U.S. Forest Service designates as “high” those areas with wildfire hazard potential index from the 85th to the 95th percentiles, and as “very high” those areas above the 95th percentile. The U.S. Forest Service also categorizes some areas as non-burnable (including agricultural lands, developed lands, and water).

As we previously reported, according to the U.S. Forest Service, areas with higher levels of wildfire hazard potential have fuels that are more likely to burn with high intensity under certain weather conditions. However, areas with moderate, low, and very low wildfire hazard potential

[4]We selected temperature data using the projected change by the midcentury time frame under both a low and high emission scenario to show the range of potential projected change to selected natural hazards. The midcentury time frame was selected because it captures potential hazard effects during the period in which nuclear power plants are likely to remain operational. Other available variables include the average daily temperature and maximum 1- or 5-day precipitation. In this report, we refer to these data as NCA data.

[5]The objective of the wildfire hazard potential map is to depict the relative potential for wildfire that would be difficult for suppression resources to contain. The U.S. Forest Service’s Wildfire Hazard Potential map is available at https://doi.org/10.2737/RDS-2015-0047-4.

may still experience wildfires, particularly near areas with higher wildfire hazard potential.

We used 2023 wildfire hazard potential data. These data incorporated methodological changes to the fire simulation modeling to better represent probabilistic components of wildfire hazard for the fuel and climate conditions as they exist today, according to U.S. Forest Service officials we interviewed. For our analysis, we combined the high and very high wildfire hazard potential categories; we did not identify the number of facilities in each of these categories separately.

## Federal Emergency Management Agency Flood Hazard Data

The Federal Emergency Management Agency's National Flood Hazard Layer provides data on the most current coastal and riverine flooding hazard data.[6] Among other uses, the flood hazard data are used for flood insurance ratings and floodplain management. The National Flood Hazard Layer identifies areas with the highest risk of flooding, with a 1 percent or higher annual chance of flooding.[7] In some locations, the National Flood Hazard Layer also identifies areas with a 0.2 percent or higher annual chance of flooding, which the Federal Emergency Management Agency considers moderate flood hazards, and other flood hazards.[8] The National Flood Hazard Layer also identifies areas with minimal flood hazards, including those with less than 0.2 percent annual chance of flooding, and unknown flood hazards, including areas the Federal Emergency Management Agency has not assessed for flood hazards.

[6]Riverine flooding is flooding related to or caused by a river, stream, or tributary overflowing its banks because of excessive rainfall, snowmelt, or ice. The Federal Emergency Management Agency provides a tool for viewing, downloading, and printing flood maps for specific locations. The Federal Emergency Management Agency's flood hazard maps are available at https://www.fema.gov/flood-maps/national-flood-hazard-layer. Federal law requires the Federal Emergency Management Agency to assess the need to revise and update the nation's flood maps once every 5 years or more often as the Administrator determines necessary. 42 U.S.C. § 4101(e).

[7]These areas are known as Special Flood Hazard Areas. Under federal law, in communities that participate in the National Flood Insurance Program, homeowners are required to purchase flood insurance for properties located in Special Flood Hazard Areas that are secured by mortgages from federally regulated lenders. 42 U.S.C. § 4012a(b)(1).

[8]Other flood hazards include areas with reduced risk because of levees, as well as areas with flood hazard based on future conditions, for example, if land use plans were implemented.

## National Oceanic and Atmospheric Administration Storm Surge Hazard Data

The National Oceanic and Atmospheric Administration (NOAA) provides estimates of hurricane storm surge using a model called Sea, Lake, and Overland Surges from Hurricanes.[9] Estimates for storm surge are available for coastal areas in the eastern United States from Texas to Maine as well as in Hawaii, Puerto Rico, and the U.S. Virgin Islands. As of November 2023, storm surge data for coastal areas in the western United States were only available for Southern California.

The model accounts for specific shorelines by incorporating bay and river configurations, water depths, bridges, roads, levees, and other physical features. It estimates the maximum extent of storm surge at high tide by modeling hypothetical hurricanes under different storm conditions, such as landfall location, storm trajectory, and forward speed.

NOAA models storm surge for Category 1 through Category 5 hurricanes for the Atlantic coast south of the North Carolina-Virginia border, the Gulf of Mexico, Puerto Rico, and the U.S. Virgin Islands; and Category 1 through Category 4 hurricanes for the Atlantic coast north of the North Carolina-Virginia border and Hawaii.[10] As we previously reported, the model is to be used for educational purposes and to increase awareness of storm surge hazards at a city or community level. According to NOAA's website, the agency updates the model for portions of the shoreline each year to account for, among other changes, new data and the addition of flood protection devices, such as levees. The model does not account for future conditions such as erosion, subsidence (i.e., the sinking of an area of land), construction, or sea level rise.

## 2022 Interagency Sea Level Rise Technical Report Sea Level Rise Data

The 2022 Interagency Sea Level Rise Technical Report provides observation-based extrapolations and model-based global mean sea level scenarios as two distinct estimates of future sea level rise. Observation-based extrapolations use observed changes in sea level rise to estimate

[9]According to NOAA, "storm surge" is an abnormal rise of water generated by a storm, over and above the predicted tides. Storm surge is produced by water being pushed toward the shore by the force of the storm's winds. NOAA's storm surge hazard maps are available at https://www.nhc.noaa.gov/nationalsurge/.

[10]We previously reported that NOAA does not estimate storm surge for Category 5 hurricanes in areas where such hurricanes have not historically made landfall, such as areas north of the North Carolina-Virginia border.

the trajectory of sea level rise.[11] Model-based-global mean sea level scenarios use emission scenarios to estimate future sea level rise. The 2022 Interagency Sea Level Rise Technical Report provides both types of estimates for sea level rise in 2050 (relative to a baseline of the year 2000) for eight coastal regions of the United States. Formed by analyzing aggregated tide gauge data, the regional boundary data that NOAA provided our team include the Northeast (Maine to Virginia), the Southeast (North Carolina to the east coast of Florida), the Eastern Gulf (west coast of Florida to Mississippi), the Western Gulf (Louisiana to Texas), the Southwest (California), the Northwest (Oregon to Washington), the Hawaiian Islands, and the Caribbean.

The 2022 Interagency Sea Level Rise Technical Report providing the sea level rise estimates and coastal regions is intended to help inform federal agencies, Tribes, state and local governments, and stakeholders in coastal communities about current and future sea level rise.[12] The two primary limitations that the report discusses for the sea level rise estimates we use include process uncertainty and emission uncertainty. Process uncertainty refers to uncertainty about the impact of emissions on ice sheet loss, ocean expansion, and local ocean dynamics. Emission uncertainty refers to the uncertain amount of greenhouse gas emissions that will enter the atmosphere, trap heat, and affect temperature and sea level rise.

[11]The observation-based extrapolations are intended to serve as a comparison with the model-based-global mean sea level scenarios.

[12]W. V. Sweet, B. D. Hamlington, R. E. Kopp, C. P. Weaver, P. L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A. S. Genz, J. P. Krasting, E. Larour, D. Marcy, J. J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K. D. White, and C. Zuzak, *2022: Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines*, NOAA Technical Report NOS 01 (Silver Spring, MD: February 2022).

# Appendix III: Nuclear Power Plant Exposure to Selected Natural Hazards

Table 1 shows the exposure of areas around operating nuclear power plant locations to six current or projected natural hazards: flooding, hurricane storm surge, wildfire, sea level rise, heat, and cold. Data for flooding, hurricane storm surge, and wildfire are current and based on historical observation data. Data for sea level rise and heat and cold temperature variables are climate projections data, which incorporate emission scenarios. For more information about the data sources used, see appendix II.

**Table 1: Potential Exposure to Current and Future Hazards at Operating Nuclear Power Plants**

| Plant[a] | State | Flood hazard level[b] | Hurricane storm surge level[c] | Wildfire potential level[d] | Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e] | Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f] | Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/year)[g] | Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h] | Projected change in 5-day max. temp., low and high emission scenarios, (°Fahrenheit)[i] | Projected change in max. temp. below historical lows, low and high emission scenarios (days/ year)[j] |
|---|---|---|---|---|---|---|---|---|---|---|
| **Browns Ferry** | AL | High | No exposure | None/ low | N/A | 3.74, 4.61°F | 21.07, 29.35 days | 0.01, 0.05 days | 5.05, 6.32°F | -1.86, -2.18 days |
| **Joseph M. Farley** | AL | High | No exposure | Moderate | 1.0, 1.7 ft. | 3.53, 4.33°F | 19.79, 28.87 days | 0.01, 0.02 days | 4.33, 5.44°F | -1.88, -2.27 days |
| **Arkansas Nuclear One** | AR | High | No exposure | Moderate | N/A | 3.90, 4.85°F | 14.15, 20.63 days | 0.09, 0.17 days | 4.94, 6.10°F | -2.01, -2.25 days |
| **Palo Verde** | AZ | Moderate | No exposure | None/ low | N/A | 3.64, 4.73°F | 16.66, 24.67 days | 15.09, 22.64 days | 3.82, 4.85°F | -2.34, -2.72 days |
| **SAFER Phoenix[k]** | AZ | High | No exposure | High/ very high | N/A | 3.59, 4.66°F | 19.21, 28.16 days | 12.86, 19.86 days | 4.31, 5.32°F | -2.09, -2.52 days |
| **Diablo Canyon** | CA | High | No exposure | High/ very high | 0.5, 1.2 ft. | 2.59, 3.27°F | 5.14, 7.10 days | 0, 0 days | 3.56, 4.35°F | -2.49, -2.82 days |
| **Millstone** | CT | High | Category 4 | None/ low | 1.2, 1.8 ft. | 3.38, 4.32°F | 8.28, 12.78 days | 0, 0 days | 3.52, 4.76°F | -2.37, -2.77 days |
| **St. Lucie** | FL | High | Category 5 | Moderate | 0.9, 1.6 ft. | 3.05, 3.99°F | 37.60, 60.07 days | 0, 0 days | 3.52, 4.60°F | -1.52, -2.05 days |
| **Turkey Point** | FL | High | Category 5 | High/ very high | 0.9, 1.6 ft. | 2.91, 3.75°F | 54.28, 79.80 days | 0, 0 days | 3.11, 3.94°F | -1.99, -2.40 days |
| **Edwin I. Hatch** | GA | High | No exposure | High/ very high | 0.9, 1.6 ft. | 3.39, 4.22°F | 20.62, 30.21 days | 0, 0.01 days | 4.38, 5.56°F | -1.78, -2.25 days |

| Plant[a] | State | Flood hazard level[b] | Hurricane storm surge level[c] | Wildfire potential level[d] | Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e] | Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f] | Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/year)[g] | Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h] | Projected change in 5-day max. temp., low and high emission scenarios, (°Fahrenheit)[i] | Projected change in max. temp. below historical lows, low and high emission scenarios (days/ year)[j] |
|---|---|---|---|---|---|---|---|---|---|---|
| **Vogtle** | GA | No/low | No exposure | High/ very high | 0.9, 1.6 ft. | 3.54, 4.38°F | 16.23, 22.88 days | 0.01, 0.01 days | 4.30, 5.41°F | -2.02, -2.41 days |
| **Braidwood** | IL | No/low | No exposure | None/ low | N/A | 4.26, 5.35°F | 16.66, 24.74 days | 0.01, 0.01 days | 5.06, 6.57°F | -2.48, -2.76 days |
| **Byron** | IL | No/low | No exposure | None/ low | N/A | 4.37, 5.46°F | 15.92, 24.51 days | 0, 0 days | 5.26, 6.88°F | -2.61, -2.84 days |
| **Clinton** | IL | High | No exposure | None/ low | N/A | 4.35, 5.35°F | 19.12, 26.98 days | 0.05, 0.03 days | 5.50, 6.87°F | -2.41, -2.74 days |
| **Dresden** | IL | High | No exposure | None/ low | N/A | 4.27, 5.38°F | 17.00, 25.26 days | 0.01, 0.01 days | 5.08, 6.61°F | -2.52, -2.80 days |
| **LaSalle** | IL | No/low | No exposure | None/ low | N/A | 4.28, 5.40°F | 16.67, 24.88 days | 0.02, 0.01 days | 5.21, 6.79°F | -2.47, -2.77 days |
| **Quad Cities** | IL | High | No exposure | None/ low | N/A | 4.20, 5.22°F | 17.12, 25.92 days | 0.01, 0 days | 5.20, 6.73°F | -2.45, -2.70 days |
| **Wolf Creek** | KS | High | No exposure | None/ low | N/A | 3.91, 4.91°F | 11.36, 16.85 days | 0.15, 0.22 days | 4.92, 6.16°F | -1.87, -2.26 days |
| **River Bend** | LA | No/low | No exposure | None/ low | 1.6, 2.3 ft. | 3.09, 3.91°F | 29.25, 41.28 days | 0, 0 days | 3.85, 4.88°F | -1.33, -1.70 days |
| **Waterford** | LA | No/low | Category 5 | None/ low | 1.6, 2.3 ft. | 2.88, 3.59°F | 22.43, 33.67 days | 0, 0 days | 3.14, 4.04°F | -1.70, -2.04 days |
| **Calvert Cliffs** | MD | High | Category 4 | Moderate | 1.2, 1.8 ft. | 3.62, 4.58°F | 16.21, 24.27 days | 0, 0 days | 4.75, 6.22°F | -2.32, -2.61 days |

| Plant[a] | State | Flood hazard level[b] | Hurricane storm surge level[c] | Wildfire potential level[d] | Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e] | Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f] | Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/year)[g] | Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h] | Projected change in 5-day max. temp., low and high emission scenarios, (°Fahrenheit)[i] | Projected change in max. temp. below historical lows, low and high emission scenarios (days/ year)[j] |
|---|---|---|---|---|---|---|---|---|---|---|
| **Donald C. Cook** | MI | High | No exposure | None/ low | N/A | 4.25, 5.43°F | 16.75, 25.52 days | 0, 0 days | 5.23, 6.85°F | -2.67, -2.97 days |
| **Fermi** | MI | High | No exposure | None/ low | N/A | 4.18, 5.29°F | 15.12, 23.04 days | 0, 0 days | 5.29, 7.01°F | -2.84, -3.09 days |
| **Monticello** | MN | High | No exposure | Moderate | N/A | 4.36, 5.41°F | 14.72, 22.40 days | 0, 0 days | 5.27, 6.87°F | -2.72, -2.96 days |
| **Prairie Island** | MN | High | No exposure | None/ low | N/A | 4.44, 5.51°F | 14.28, 22.42 days | 0, 0 days | 4.86, 6.45°F | -2.78, -3.00 days |
| **Callaway** | MO | No/low | No exposure | None/ low | N/A | 4.34, 5.33°F | 15.36, 23.26 days | 0.15, 0.22 days | 5.71, 7.11°F | -2.31, -2.54 days |
| **Grand Gulf** | MS | High | No exposure | None/ low | 1.6, 2.3 ft. | 3.72, 4.59°F | 24.81, 34.84 days | 0, 0.01 days | 4.30, 5.46°F | -1.93, -2.18 days |
| **Brunswick** | NC | High | Category 5 | High/ very high | 0.9, 1.6 ft. | 2.67, 3.39°F | 12.00, 18.35 days | 0, 0 days | 3.02, 3.91°F | -1.94, -2.28 days |
| **McGuire** | NC | High | No exposure | High/ very high | N/A | 3.89, 4.82°F | 17.41, 24.70 days | 0, 0.02 days | 4.64, 5.91°F | -2.07, -2.36 days |
| **Shearon Harris** | NC | High | No exposure | High/ very high | 0.9, 1.6 ft. | 3.79, 4.73°F | 17.66, 25.38 days | 0, 0.01 days | 4.47, 5.72°F | -2.05, -2.37 days |
| **Cooper** | NE | High | No exposure | High/ very high | N/A | 4.32, 5.32°F | 12.21, 18.53 days | 0.05, 0.09 days | 5.09, 6.55°F | -2.26, -2.46 days |
| **Seabrook** | NH | High | Category 4 | None/ low | 1.2, 1.8 ft. | 3.72, 4.77°F | 9.24, 13.56 days | 0, 0 days | 3.89, 5.18°F | -2.72, -3.07 days |

| Plant[a] | State | Flood hazard level[b] | Hurricane storm surge level[c] | Wildfire potential level[d] | Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e] | Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f] | Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/year)[g] | Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h] | Projected change in 5-day max. temp., low and high emission scenarios, (°Fahrenheit)[i] | Projected change in max. temp. below historical lows, low and high emission scenarios (days/ year)[j] |
|---|---|---|---|---|---|---|---|---|---|---|
| **Hope Creek** | NJ | High | Category 4 | None/ low | 1.2, 1.8 ft. | 3.74, 4.79°F | 12.70, 19.86 days | 0, 0 days | 4.24, 5.71°F | -2.63, -2.95 days |
| **Salem** | NJ | High | Category 4 | None/ low | 1.2, 1.8 ft. | 3.74, 4.79°F | 12.70, 19.86 days | 0, 0 days | 4.24, 5.71°F | -2.63, -2.95 days |
| **James A. FitzPatrick** | NY | High | No exposure | None/ low | N/A | 4.06, 5.16°F | 14.59, 21.08 days | 0, 0 days | 4.87, 6.44°F | -2.65, -3.06 days |
| **Nine Mile Point** | NY | High | No exposure | None/ low | N/A | 4.06, 5.16°F | 14.59, 21.08 days | 0, 0 days | 4.87, 6.44°F | -2.65, -3.06 days |
| **R. E. Ginna** | NY | No/low | No exposure | High/ very high | N/A | 4.39, 5.53°F | 14.43, 20.97 days | 0, 0.01 days | 4.98, 6.72°F | -2.84, -3.15 days |
| **Davis-Besse** | OH | High | No exposure | None/ low | N/A | 4.06, 5.08°F | 15.18, 22.48 days | 0, 0 days | 4.93, 6.46°F | -2.71, -2.98 days |
| **Perry** | OH | High | No exposure | None/ low | N/A | 4.27, 5.41°F | 15.04, 23.08 days | 0, 0 days | 4.82, 6.35°F | -2.82, -3.07 days |
| **Beaver Valley** | PA | High | No exposure | None/ low | N/A | 3.76, 4.79°F | 16.38, 24.97 days | 0, 0 days | 4.84, 6.54°F | -2.55, -2.87 days |
| **Limerick** | PA | High | No exposure | None/ low | 1.2, 1.8 ft. | 3.88, 4.91°F | 13.22, 20.69 days | 0, 0 days | 4.96, 6.66°F | -2.57, -2.87 days |
| **Peach Bottom** | PA | High | No exposure | None/ low | 1.2, 1.8 ft. | 4.06, 5.08°F | 16.27, 24.13 days | 0, 0 days | 5.20, 6.79°F | -2.56, -2.89 days |
| **Susquehanna** | PA | Moderate | No exposure | Moderate | 1.2, 1.8 ft. | 4.23, 5.27°F | 15.05, 21.82 days | 0, 0.02 days | 5.58, 7.13°F | -2.69, -3.00 days |

| Plant[a] | State | Flood hazard level[b] | Hurricane storm surge level[c] | Wildfire potential level[d] | Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e] | Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f] | Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/year)[g] | Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h] | Projected change in 5-day max. temp., low and high emission scenarios, (°Fahrenheit)[i] | Projected change in max. temp. below historical lows, low and high emission scenarios (days/ year)[j] |
|---|---|---|---|---|---|---|---|---|---|---|
| **Catawba** | SC | High | No exposure | High/ very high | N/A | 4.00, 4.96°F | 18.27, 25.53 days | 0, 0.03 days | 4.73, 6.02°F | -2.05, -2.30 days |
| **H. B. Robinson** | SC | High | No exposure | High/ very high | 0.9, 1.6 ft. | 3.57, 4.44°F | 15.03, 21.81 days | 0, 0.01 days | 4.39, 5.59°F | -1.94, -2.29 days |
| **Oconee** | SC | High | No exposure | Moderate | N/A | 3.66, 4.54°F | 19.32, 26.96 days | 0, 0.03 days | 4.86, 6.22°F | -1.56, -1.89 days |
| **Virgil C. Summer** | SC | High | No exposure | Moderate | 0.9, 1.6 ft. | 3.55, 4.50°F | 15.91, 22.53 days | 0.01, 0.05 days | 4.50, 5.72°F | -1.71, -2.12 days |
| **SAFER Memphis[k]** | TN | No/low | No exposure | None/ low | N/A | 3.99, 4.85°F | 21.63, 31.04 days | 0.01, 0.04 days | 5.09, 6.41°F | -1.98, -2.24 days |
| **Sequoyah** | TN | High | No exposure | Moderate | N/A | 3.70, 4.55°F | 19.20, 26.92 days | 0, 0.01 days | 4.99, 6.30°F | -1.68, -2.04 days |
| **Watts Bar** | TN | High | No exposure | Moderate | N/A | 3.70, 4.59°F | 18.75, 26.76 days | 0, 0.01 days | 4.78, 6.04°F | -1.90, -2.22 days |
| **Comanche Peak** | TX | High | No exposure | Moderate | N/A | 3.69, 4.67°F | 14.75, 21.52 days | 0.18, 0.62 days | 4.07, 5.42°F | -1.89, -2.15 days |
| **South Texas Project** | TX | No/low | Category 5 | None/ low | 1.6, 2.3 ft. | 2.93, 3.74°F | 22.77, 34.60 days | 0, 0 days | 3.16, 3.99°F | -1.62, -1.90 days |
| **North Anna** | VA | High | No exposure | Moderate | 1.2, 1.8 ft. | 3.82, 4.83°F | 18.28, 26.64 days | 0.01, 0.02 days | 4.95, 6.43°F | -2.20, -2.55 days |
| **Surry** | VA | High | Category 4 | None/ low | 1.2, 1.8 ft. | 3.47, 4.40°F | 13.85, 21.08 days | 0, 0 days | 3.96, 5.17°F | -2.36, -2.68 days |

| Plant[a] | State | Flood hazard level[b] | Hurricane storm surge level[c] | Wildfire potential level[d] | Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e] | Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f] | Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/year)[g] | Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h] | Projected change in 5-day max. temp., low and high emission scenarios, (°Fahrenheit)[i] | Projected change in max. temp. below historical lows, low and high emission scenarios (days/ year)[j] |
|---|---|---|---|---|---|---|---|---|---|---|
| **Columbia** | WA | No/low | No exposure | High/ very high | N/A | 3.90, 4.87°F | 9.56, 14.05 days | 0.01, 0.06 days | 4.15, 5.29°F | -1.64, -1.88 days |
| **Point Beach** | WI | High | No exposure | None/ low | N/A | 3.91, 4.93°F | 10.01, 15.74 days | 0, 0 days | 4.58, 6.13°F | -2.48, -2.78 days |

Source: GAO analysis of data from the fourth National Climate Assessment (NCA), U.S. Forest Service, National Oceanic and Atmospheric Administration (NOAA), the 2022 Interagency Sea Level Rise Technical Report, the Federal Emergency Management Agency, and the Nuclear Regulatory Commission (NRC). I GAO-24-106326

[a]To identify plant locations, we used nuclear power plant coordinates from NRC and added a one-half-mile radius around NRC's plant coordinates to approximate the size of a nuclear power plant. To analyze whether nuclear plants are located in areas that may be affected by heat, cold, wildfire, hurricane storm surge, and flooding, we used MapInfo mapping software to determine whether the nuclear power plant locations are located in areas with exposure to the natural hazards. Exposure indicates that a facility is located in an area that may be affected by the selected hazard. If the plant overlapped with multiple hazard layers, the layer representing the highest level of exposure was reported.

[b]To analyze exposure to flood hazards, we used 2023 data from Federal Emergency Management Agency's National Flood Hazard Layer. We grouped flood hazard zones into three categories: no/low, moderate, and high. "No/low" refers to areas with minimal, unknown, or other flood hazards, including areas with reduced risk because of levees as well as areas with flood hazard based on future conditions, such as the future implementation of land-use plans. "Moderate" corresponds to a 500-year floodplain, which indicates between 0.2 percent and 1 percent annual chance of flooding. "High" corresponds to a 100-year floodplain, which indicates a 1 percent or higher annual chance of flooding.

[c]To analyze exposure to various levels of hurricane storm surge, we used data from NOAA's Sea, Lake, and Overland Surges from Hurricanes model. We used a range of categories from the data, including no exposure to hurricanes, and Category 1, and 4, and 5 hurricanes.

[d]To analyze exposure to wildfire hazard potential, we used 2023 data from the U.S. Forest Service's Wildfire Hazard Potential Map. "None/low" refers to plants in areas that are not covered by the "moderate," "high," or "very high" wildfire potential layers. "Moderate" refers to plants in areas with moderate wildfire hazard potential. "High/very high" refers to plants in areas with high or very high wildfire hazard potential.

[e]To analyze potential exposure to sea level rise in 2050, we used data from an interagency report covering sea level rise scenarios to illustrate climate projections for sea level rise in coastal regions, under both a low and high scenario in the regions.

[f]"Projected change in daily max. temp." refers to the projected change in daily maximum temperature by the midcentury (i.e., 2036-2065) using both a low- and high emission scenario for projected climate change from the fourth NCA. Values are measured in degrees Fahrenheit.

[g]"Projected change in max. temp. exceeding historical highs" refers to the change in the annual number of days with a maximum temperature greater than the 99th percentile by the midcentury (i.e., 2036-2065), using both a low and high emission scenario for projected climate change from the fourth NCA. This

variable measures the annual number of days when the highest temperature of the day exceeds the hottest (99th percentile of) historical (1976-2005) high temperatures. Values are measured in number of days per year.

[h]"Projected change in max. temp. over 115°F" refers to the projected change in annual number of days with a maximum temperature over 115°F by the midcentury (i.e., 2036-2065) using both a low and high emission scenario for projected climate change from the fourth NCA. Values are measured in number of days per year.

[l]"Projected change in 5-day max. temp." refers to the projected change in highest maximum temperature averaged over a 5-day period by the midcentury (i.e., 2036-2065) using both a low and a high emission scenario for projected climate change from the fourth NCA. Values are measured in degrees Fahrenheit.

[j]"Projected change in min. temp. below historical lows" refers to projected change in the annual number of days with a maximum temperature lower than the 1st percentile by the midcentury (i.e., 2036-2065), using both a low and high emission scenario for projected climate change from the fourth NCA. This variable measures the annual number of days when the highest temperature of the day is lower than the coldest (1st percentile of) historical (1976-2005) high temperatures. A negative value indicates that there will be fewer days when the daily highest temperature falls below the 1st percentile. Values are measured in number of days per year.

[k]The nuclear power industry operates two Strategic Alliance for FLEX Emergency Response (SAFER) centers that maintain emergency equipment that can be provided to plants as a backup to a plant's onsite primary backup equipment.

Table 2 shows the exposure of areas around shutdown nuclear power plant locations to six current or projected natural hazards: flooding, hurricane storm surge, wildfire, sea level rise, heat, and cold.[1] Data for flooding, hurricane storm surge, and wildfire are current data and based on historical observation data. Data for sea level rise and heat and cold temperature variables are climate projections data, which incorporate emission scenarios. For more information about the data sources used, see appendix II.

[1]We included plants at various stages of decommissioning, including those in the process of decommissioning and those already decommissioned, with spent nuclear fuel stored onsite. We refer to these as shutdown plants because they are no longer operational.

**Table 2: Potential Exposure to Current and Future Hazards at Shutdown Nuclear Power Plants**

| Plant[a] | State | Flood hazard level[b] | Hurricane storm surge level[c] | Wildfire potential level[d] | Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e] | Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f] | Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/ year)[g] | Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h] | Projected change in 5-day max. temp., low and high emission scenarios (°Fahrenheit)[i] | Projected change in max. temp. below historical lows, low and high emission scenarios(days/ year)[j] |
|---|---|---|---|---|---|---|---|---|---|---|
| **Humboldt Bay** | CA | High | No exposure | Moderate | 0.5, 1.2 ft. | 2.65, 3.43°F | 8.70, 14.32 days | 0, 0 days | 3.22, 4.20°F | -2.36, -2.68 days |
| **Rancho Seco** | CA | High | No exposure | Moderate | 0.5, 1.2 ft. | 3.35, 4.26°F | 10.78, 15.07 days | 0.12, 0.26 days | 4.29, 5.35°F | -2.28, -2.65 days |
| **San Onofre** | CA | High | Category 1 | High/ very high | 0.5, 1.2 ft. | 2.52, 3.34°F | 6.59, 9.92 days | 0, 0 days | 3.10, 3.93°F | -2.66, -3.01 days |
| **Fort Saint Vrain** | CO | No/low | No exposure | Moderate | N/A | 4.43, 5.55°F | 20.00, 27.98 days | 0, 0 days | 5.07, 6.48°F | -1.43, -1.83 days |
| **Haddam Neck** | CT | High | Category 4 | Moderate | 1.2, 1.8 ft. | 3.64, 4.69°F | 9.65, 15.07 days | 0, 0 days | 3.86, 5.24°F | -2.42, -2.80 days |
| **Crystal River** | FL | High | Category 5 | High/ very high | 1.0, 1.7 ft. | 3.01, 3.87°F | 34.35, 52.84 days | 0, 0 days | 3.24, 4.22°F | -1.76, -2.22 days |
| **Duane Arnold** | IA | High | No exposure | None/ low | N/A | 4.50, 5.55°F | 17.40, 26.03 days | 0.01, 0.02 days | 5.47, 7.04°F | -2.60, -2.80 days |
| **Zion** | IL | High | No exposure | None/ low | N/A | 4.18, 5.25°F | 13.44, 20.26 days | 0.01, 0.01 days | 5.20, 6.80°F | -2.41, -2.65 days |
| **Pilgrim** | MA | High | Category 4 | Moderate | 1.2, 1.8 ft. | 3.23, 4.12°F | 7.35, 10.76 days | 0, 0 days | 3.53, 4.60°F | -2.06, -2.44 days |
| **Yankee Rowe** | MA | No/low | No exposure | None/ low | 1.2, 1.8 ft. | 4.24, 5.52°F | 11.92, 18.63 days | 0, 0 days | 4.82, 6.74°F | -2.73, -3.07 days |

| Plant[a] | State | Flood hazard level[b] | Hurricane storm surge level[c] | Wildfire potential level[d] | Projected regional sea level rise in 2050, low and high emission scenarios (feet)[e] | Projected change in max. daily temp., low and high emission scenarios (°Fahrenheit)[f] | Projected change in max. temp. exceeding historical highs, low and high emission scenarios (days/ year)[g] | Projected change in max. temp. over 115°F, low and high emission scenarios (days/ year)[h] | Projected change in 5-day max. temp., low and high emission scenarios (°Fahrenheit)[i] | Projected change in max. temp. below historical lows, low and high emission scenarios(days/ year)[j] |
|---|---|---|---|---|---|---|---|---|---|---|
| **Maine Yankee** | ME | High | Category 4 | None/ low | 1.2, 1.8 ft. | 3.74, 4.85°F | 9.87, 14.50 days | 0, 0 days | 4.09, 5.41°F | -2.58, -2.9 days |
| **Big Rock Point** | MI | High | No exposure | None/ low | N/A | 4.22, 5.39°F | 11.06, 17.29 days | 0, 0 days | 4.13, 5.71°F | -3.02, -3.28 days |
| **Palisades** | MI | High | No exposure | None/ low | N/A | 3.84, 4.92°F | 13.75, 21.03 days | 0, 0 days | 4.35, 5.78°F | -2.61, -2.99 days |
| **Fort Calhoun** | NE | High | No exposure | Moderate | N/A | 4.26, 5.32°F | 13.67, 20.69 days | 0.01, 0.01 days | 4.78, 6.15°F | -2.32, -2.58 days |
| **Oyster Creek** | NJ | High | Category 4 | High/ very high | 1.2, 1.8 ft. | 3.60, 4.54°F | 9.99, 14.93 days | 0, 0 days | 4.33, 5.65°F | -2.51, -2.81 days |
| **Indian Point** | NY | High | Category 4 | High/ very high | 1.2, 1.8 ft. | 3.78, 4.84°F | 12.33, 18.84 days | 0, 0 days | 4.78, 6.39°F | -2.63, -3.00 days |
| **Trojan** | OR | High | No exposure | Moderate | 0.3, 1 ft. | 3.44, 4.37°F | 6.64, 10.03 days | 0, 0 days | 4.19, 5.32°F | -1.96, -2.22 days |
| **Three Mile Island** | PA | High | No exposure | None/ low | 1.2, 1.8 ft. | 4.14, 5.21°F | 14.66, 21.37 days | 0.01, 0.05 days | 5.68, 7.31°F | -2.78, -3.05 days |
| **Vermont Yankee** | VT | High | No exposure | None/ low | 1.2, 1.8 ft. | 3.77, 4.89°F | 13.48, 21.03 days | 0, 0 days | 4.80, 6.64°F | -2.48, -2.84 days |
| **Kewaunee** | WI | No/low | No exposure | None/ low | N/A | 3.92, 4.96°F | 9.50, 14.96 days | 0, 0 days | 4.38, 5.92°F | -2.59, -2.88 days |
| **Lacrosse** | WI | High | No exposure | None/ low | N/A | 4.31, 5.38°F | 17.34, 26.24 days | 0, 0 days | 5.30, 6.96°F | -2.58, -2.79 days |

Source: GAO analysis of data from the fourth National Climate Assessment (NCA), U.S. Forest Service, National Oceanic and Atmospheric Administration (NOAA), the 2022 Interagency Sea Level Rise Technical Report, the Federal Emergency Management Agency, and the Nuclear Regulatory Commission (NRC). I GAO-24-106326

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# Appendix IV: Comments from the Nuclear Regulatory Commission

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 7, 2024

Frank Rusco, Director
Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION COMMENTS ON DRAFT GOVERNMENT ACCOUNTABILITY OFFICE REPORT GAO-24-106326, "NUCLEAR POWER PLANTS: NRC SHOULD TAKE ACTIONS TO FULLY CONSIDER THE POTENTIAL EFFECTS OF CLIMATE CHANGE"

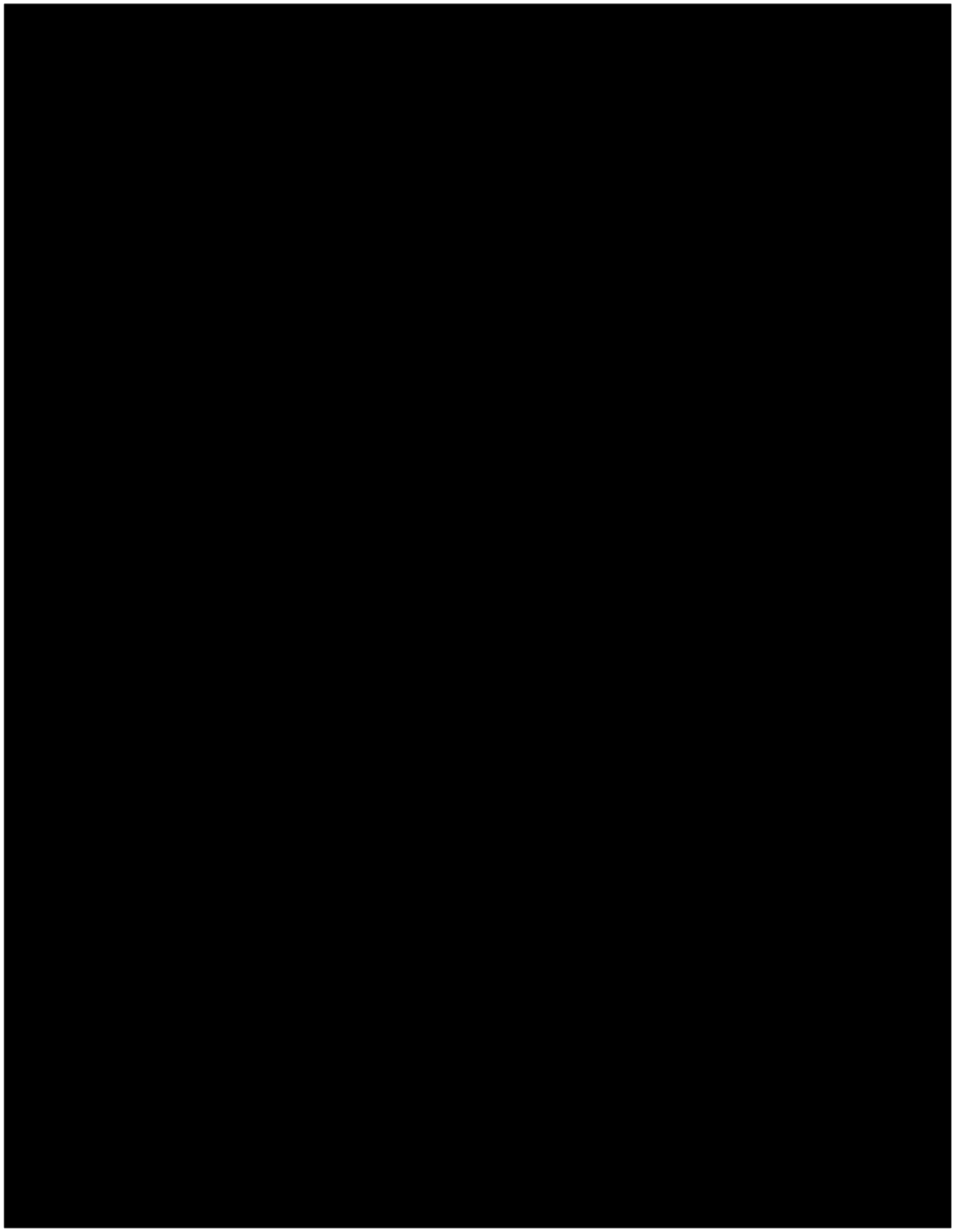
Dear Mr. Rusco:

Thank you for the opportunity to review and comment on the U.S. Government Accountability Office (GAO) draft report GAO-24-106326, "Nuclear Power Plants: NRC Should Take Actions to Fully Consider the Potential Effects of Climate Change," which the U.S. Nuclear Regulatory Commission (NRC) received on February 6, 2024.

The NRC appreciates the constructive engagement we have had with the GAO throughout the audit and the GAO's thoroughness in seeking to understand the NRC's regulatory framework related to external hazards, particularly given the complexity of the detailed processes and programs that the NRC uses to support its safety mission.

We are in general agreement with the findings. The three recommendations in the draft report are very broad but are consistent with actions that are either underway or under development. The NRC considers this report to be a fair characterization of its regulatory structure, processes, and strengths. However, considering the description of the conservatisms, safety margins, and defense-in-depth policies described in the report, the NRC does not agree with the conclusion that the agency does not address the impacts of climate change. In effect, the layers of conservatism and defense in depth incorporated into NRC's processes provide reasonable assurance regarding any plausible natural hazard and combinations at a site for the licensed operational lifetime of the reactor, including those that could result from climate change. Specifically, the processes, tools, methods, models, data, and additional margins provide reasonable assurance of the ability to withstand or mitigate projected changes in natural hazards.

It is also important to note that the NRC's mission is focused on nuclear safety; as such, we cannot impose requirements that would increase energy resilience or require consideration of potential future climate impacts without a sufficient nuclear safety justification. This is an important distinction since the predominant concerns expressed often in the draft report are that a licensee's operations may be disrupted more frequently by climate change and that the NRC should more fully consider future climate projections. The NRC is focused on nuclear safety and any potential increase in the risk of a radiological release, consistent with the NRC's mandate.



# Appendix V: GAO Contact and Staff Acknowledgments

## GAO Contact

Frank Rusco, at (202) 512-3841 or ruscof@gao.gov

## Staff Acknowledgments

In addition to the contact named above, Janice Ceperich (Assistant Director), Marissa Dondoe (Analyst-in-Charge), Bethany Benitez, Colleen Candrl, Breanne Cave, Lilia Chaidez, John Delicath, Cindy Gilbert, Claire McLellan, John Mingus, Katrina Pekar-Carpenter, Dan C. Royer, Wesley Sholtes, John Tanis, Joseph Dean Thompson, Linda Tsang, and Kristen Watts made significant contributions to this report.

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