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Indiana Michigan Power
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March 6, 2015

AEP-NRC-2015-14
10 CFR 50.54(f)
10 CFR 50.4

Docket Nos.: 50-315
50-316

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Subject: Donald C. Cook Nuclear Plant Unit 1 and Unit 2
Response to March 12, 2012, Request for Information, Enclosure 2, "Recommendation 2.1: Flooding," Required Response 2, Hazard Reevaluation Report

References:

1. Letter from E. J. Leeds, U. S. Nuclear Regulatory Commission (NRC), to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, "Request for Information Pursuant to Title 10 of the *Code of Federal Regulations* 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," dated March 12, 2012, Agencywide Documents Access and Management System (ADAMS) Accession No. ML12053A340.

2. Letter from E. J. Leeds, NRC, to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, "Prioritization of Response Due Dates for Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Flooding Hazard Reevaluations for Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident," dated May 11, 2012, ADAMS Accession No. ML12097A509.

3. Letter from E. J. Leeds, NRC, to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, "Supplemental Information Related to Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Flooding Hazard Reevaluations for Recommendation 2.1 of the Near-Term Task Force Review of Insights From the Fukushima Dai-ichi Accident," dated March 1, 2013, ADAMS Accession Number ML13044A561.

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4. Letter from J. P. Gebbie, Indiana Michigan Power Company, to the NRC, "Donald C. Cook Nuclear Plant Unit 1 and 2 - Response to March 12, 2012, Request for Information Enclosure 2, Recommendation 2.1, Flooding, Required Response 1, Integrated Assessment Approach," dated January 25, 2013, AEP NRC 2013-06, ADAMS Accession No. ML13037A305.

By Reference 1, Enclosure 2, the U. S. Nuclear Regulatory Commission (NRC) requested that licensees perform a reevaluation of all appropriate external flooding sources, and requested that the reevaluation apply present-day regulatory guidance and methodologies. The NRC requested that the flooding hazard reevaluation report be submitted on a schedule established by a subsequent NRC prioritization plan. The prioritization plan was transmitted by Reference 2. The prioritization plan designated the Donald C. Cook Nuclear Plant (CNP) as a Category 3 site. Category 3 sites are required to submit the Flood Hazard Reevaluation Report by March 12, 2015. This letter provides the Flood Hazard Reevaluation Report for CNP.

The enclosed CNP Flood Hazard Reevaluation Report documents that, for some locations, one of the potential flood causing mechanisms, local intense precipitation (LIP), could result in water levels that are not bounded by the current design basis flood elevation. The non-bounded hazard is the result of present-day regulatory guidance and methodologies which differ from the guidance and methodologies used to establish the design basis for CNP. As such, the non-bounded hazard does not represent an error in the CNP design basis. The CNP flood hazard reevaluation determined that, other than the LIP, no applicable flood causing mechanism would result in a water level above that established by the design basis. Therefore, consistent with the NRC guidance provided in Reference 3, the CNP flood hazard reevaluation results do not indicate the inoperability of a CNP structure, system, or component.

In accordance with Reference 1, Indiana Michigan Power Company (I&M) is also providing an interim action plan to address the reevaluated LIP hazard. As also required by Reference 1, I&M will submit an Integrated Assessment of the reevaluated flood hazard. I&M's commitment to perform an Integrated Assessment in accordance with the applicable NRC guidance is documented in Reference 4.

Enclosure 1 to this letter provides an affirmation regarding the information contained herein. Enclosure 2 provides the CNP Flood Hazard Reevaluation Report. Enclosure 3 provides a summary of the CNP Interim Action Plan. Enclosure 4 provides a tabulation of the new regulatory commitments made in this letter.

If there are any questions concerning this letter, please contact Mr. Michael K. Scarpello, Manager, Nuclear Regulatory Affairs, at (269) 466-2649.

Sincerely,

Joel P. Gebbie
Site Vice President

JRW/mhs

Enclosures:

1. Affirmation
2. Flood Hazard Reevaluation Report for the Donald C. Cook Nuclear Plant
3. Interim Action Plan for Donald C. Cook Nuclear Plant
4. Regulatory Commitments

c: J. P. Boska, NRC Washington, DC
M. L. Chawla, NRC Washington, DC
J. T. King, MPSC
MDEQ – RMD/RPS
NRC Resident Inspector
C. D. Pederson, NRC Region III
A. J. Williamson, AEP Ft. Wayne, w/o enclosures

Enclosure 1 to AEP-NRC-2015-14

AFFIRMATION

I, Joel P. Gebbie, being duly sworn, state that I am Site Vice President of Indiana Michigan Power Company (I&M), that I am authorized to sign and file this request with the U. S. Nuclear Regulatory Commission on behalf of I&M, and that the statements made and the matters set forth herein pertaining to I&M are true and correct to the best of my knowledge, information, and belief.

Indiana Michigan Power Company

Joel P. Gebbie
Site Vice President

SWORN TO AND SUBSCRIBED BEFORE ME

THIS 6th DAY OF March, 2015

Notary Public

My Commission Expires 01/21/2018

Enclosure 2 to AEP-NRC-2015-14

Flood Hazard Reevaluation Report for the Donald C. Cook Nuclear Plant

AMERICAN ELECTRIC POWER — AEP: America's Energy Partner	DONALD C. COOK NUCLEAR PLANT **CALCULATION/REPORT COVER SHEET**

Document No. MD-12-FLOOD-011-N AREVA Document: 51-9228777-000	Rev No. __0___	☒ Full Rev ☐ Addendum ☐ Status Change

Title: Flood Hazard Reevaluation Report for the Donald C. Cook Nuclear Plant

STATUS:	☒ Approved	☐ Superseded	☐ Voided	☐ Information Only

Document Type/Class:	☐ Calculation ☒ Report	☐ Class 1 ☐ Class 2 ☒ Class 3

QUALITY CLASSIFICATION:	SYSTEM CODE:	UNIT NO.:	COMPUTER MEDIA:	REVIEW METHOD:
☒ Safety-Related ☐ Non-Safety Related with Special Requirements ☐ Non-Safety Related	NAPL	12	☐ Yes ☒ No	☒ Detailed Review ☐ Alternate Calculation ☐ Other ☐ N/A – Status/Class Change **Only**

Do any assumptions require later verification? ☐ Yes ☒ No	If yes, Action No.

Description: This report describes the approach, methods, and results from the reevaluation of external flood hazards and provides information to support Phase I of the requested actions by the U.S. Nuclear Regulatory Commission (NRC) staff in its 10 CFR 50.54(f) letter of March 12, 2014. Original Issue.

If the Reviewer is the Preparer's supervisor, the supervisor review is needed and is approved: ☒ N/A

Supervisor's Manager's Name	Title	Signature	Date

Qualification Matrix Verification

* The responsible Engineering Supervisor/Manager approval signature also serves to signify that the qualifications of the individual(s) assigned as Preparer(s) and Reviewer(s) and Independent Design Verifier(s) were verified in the Plant Qualification Matrix.

Preparation & Review

	PREPARED BY:	REVIEWED BY:	*APPROVED BY:
Name:	Cynthia Fasano	Theodore Messier	Mark Rinckel
Title:	Engineering Supervisor	Principal Scientist	Technical Manager
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Signature:	See attached report	See attached report	See attached report
Date:			

☒ **Sign-offs for additional Preparer(s) and Reviewer(s) on next page**

This document includes the following pages:	See Table of Contents from the attached vendor report	

Non-AEP Preparation, Review & Approval		
If the Preparer, Reviewer and Approver are non-AEP individuals and the calculation was performed under the DONALD C. Cook QA program, the appropriate AEP Design Discipline Supervisor(s) approval is needed. ☒ N/A		
AEP Design Discipline Supv:	OAR was prepared for this document. Printed Name/Signature	2/6/15 Date

Additional Preparer(s) & Reviewer(s)

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Title:			Project Manager
Organization:			AREVA
Signature:			
Date:			
Name:			
Title:			
Organization:			
Signature:			
Date:			

AREVA

AREVA Inc.

Engineering Information Record

Document No.: 51 - 9228777 - 000

CNP Document No.: MD-12-FLOOD-011-N Revision 0

Flood Hazard Reevaluation Report for the Donald C. Cook Nuclear Plant

Flood Hazard Reevaluation Report for the Donald C. Cook Nuclear Plant

Safety Related? ☒ YES ☐ NO

Does this document establish design or technical requirements? ☐ YES ☒ NO

Does this document contain assumptions requiring verification? ☐ YES ☒ NO

Does this document contain Customer Required Format? ☒ YES ☐ NO

Signature Block

Name and Title/Discipline	Signature	P/LP, R/LR, A-CRF, A	Date	Pages/Sections Prepared/Reviewed/ Approved or Comments
Cynthia A. Fasano Engineering Supervisor	Cynthia Fasano	LP	2-2-15	All
Theodore Messier Principal Scientist	Theodore Messier	LR	2-2-15	All
Mark Rinckel Technical Manager	M. J. Rinckel	A	2-3-15	All
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R/LR designates Reviewer (R), Lead Reviewer (LR)
A-CRF designates Project Manager Approver of Customer Required Format (A-CRF)
A designates Approver/RTM – Verification of Reviewer Independence

Project Manager Approval of Customer References (N/A if not applicable)

Name (printed or typed)	Title (printed or typed)	Signature	Date
Karen Rudd	Project Manager	Karen Rudd	2/3/15

Record of Revision

Revision No.	Pages/Sections/ Paragraphs Changed	Brief Description / Change Authorization
000	All	Initial Issuance

Overview

This report describes the approach, methods, and results from the reevaluation of flood hazards at the Donald C. Cook Nuclear Plant (CNP). It provides information to support Phase I of the requested actions by the U.S. Nuclear Regulatory Commission (NRC) staff in its 10 CFR 50.54(f) letter of March 12, 2014 ("10 CFR 50.54(f) letter"), to reevaluate all appropriate external flooding sources for D.C. Cook. The flood hazards reevaluation in this report include the effects from local intense precipitation on the site, probable maximum flood (PMF) on stream and rivers, storm surges, seiches, tsunami, and dam failures. The report also contains groundwater intrusion and combined effect flood, including one additional, unique, potential flood causing mechanism identified for CNP: flooding due to overflow or slope failure of the Infiltration Pond. The reevaluation applied present-day regulatory guidance and methodologies being used for early site permits and combined operating license reviews, including current techniques, software, and methods used in present-day standard engineering practice to reassess the flood hazards applicable to the plant site. If reevaluated flood hazards exceed the current design basis or result in potential vulnerabilities for the plant site, the reevaluated hazards information will be used in Phase II to complete an integrated assessment of the protection and mitigation capabilities of the plant. Section 1 provides introductory information related to the flood hazard. The section includes background regulatory information, scope, general method used for the reevaluation, assumptions, the elevation datum used throughout the report, and a conversion table to determine elevations in other common datum.

Section 2 describes detailed CNP site information, including present-day site layout, topography, and current licensing basis flood (CLB) protection and mitigation features. The section also identifies relevant changes since license issuance to the local area and watershed as well as flood protections.

Section 3 presents the results of the flood hazard reevaluation. It addresses each of the eight flood-causing mechanisms and a combined effect flood required by the NRC in the 10 CFR 50.54(f) letter. Groundwater intrusion and one additional, unique, potential flood causing mechanism identified for CNP: flooding due to overflow or slope failure of the Infiltration Pond (a natural pond) are also included. In cases where a mechanism does not apply to the CNP site, a justification is included. The section also provides a basis for inputs and assumptions, methods, and models used.

Section 4 compares the current and reevaluated flood-causing mechanisms. It provides an assessment of the current licensing and design basis flood elevation to the reevaluated flood elevation for each applicable flood-causing mechanism evaluated in Section 3.

Section 5 presents an interim evaluation and actions taken, or planned, to address those higher flooding hazards identified in Section 4 relative to the current licensing and design basis.

The report also contains two appendices. Appendix A describes the software model FLO-2D used in the reevaluation, including the quality assurance criteria and a discussion of validation of model-derived results. Appendix B provides time series plots for flood elevations at each potential flood-water-entry location.

Each report section is provided with independent reference section to facilitate review.

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Acronyms and Abbreviations

Acronym/Abbreviation	Description
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
CFR	Code of Federal Regulations
cfs	cubic feet per second
CLB	Current License Basis
CN	Curve Number
CNP	Donald C. Cook Nuclear Plant
DEM	Digital Elevation Model
DTM	Digital Terrain Model
HHA	Hierarchical Hazard Assessment
HMR	Hydrometeorological Report
ISG	Interim Staff Guidance (NRC)
LiDAR	Light Detection and Ranging
LIP	Local Intense Precipitation
MSL	Mean Sea Level
NGVD29	National Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NRC	U.S. Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service
NTTF	Near-Term Task Force
PDF	Project Design Flood
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SSPMP	Site-Specific Probable Maximum Precipitation
SCS	Soil Conservation Service
SSCs	Structures, Systems and Components
UFSAR	Updated Final Safety Analysis Report
USACE	U.S. Army Corps of Engineers

1.0 INTRODUCTION

Following the Fukushima Daiichi accident on March 11, 2011, which resulted from an earthquake and subsequent tsunami, the U.S. Nuclear Regulatory Commission (NRC) established the Near-Term Task Force (NTTF) to review the accident. The NTTF subsequently prepared a report with a comprehensive set of recommendations.

In response to the NTTF recommendations, and pursuant to Title 10 of the Code of Federal Regulations, Section 50.54(f), the NRC has requested information from all operating power licensees (NRC, 2012). The purpose of the request is to gather information, in part, to re-evaluate flooding hazards at U.S. operating reactor sites.

The Donald C. Cook Nuclear plant (CNP), located on the eastern shore of Lake Michigan in Bridgman, MI, is one of the plants required to submit beyond-design-basis information.

The NRC information request relating to flooding hazards requires licensees to re-evaluate their sites using updated flooding hazard information and present-day regulatory guidance and methodologies and then compare the results against the site's current licensing basis (CLB) for protection and mitigation from external flood events.

1.1 Purpose

This report satisfies Phase I of the 10 CFR 50.54(f) letter to reassess all flooding mechanism and submit a "Hazard Reevaluation Report".

1.2 Scope

This report satisfies Phase I of the 10 CFR 50.54(f) letter to reassess all flooding mechanisms and submit a "Hazard Reevaluation Report," a reevaluation of the flooding hazards at the plant site using updated flooding hazard information and present-day regulatory guidance and methodologies. The evaluations associated with the requested information in this letter do not revise the design basis of the plant.

It addresses the eight flood-causing mechanisms and a combined effect flood, identified in Attachment 1 to Enclosure 2 of the 10 CFR 50.54(f) letter (NRC, 2012). Groundwater intrusion and one additional, unique, potential flood causing mechanism were identified for CNP: flooding due to overflow or slope failure of the Infiltration Pond (a natural pond).

Each of the reevaluated flood causing mechanisms and the potential effects on the CNP plant is described in Sections 3 and 4 of this report.

1.3 General Approach

This report follows the Hierarchical Hazard Assessment (HHA) approach, as described in NUREG/CR-7046:"Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America" (referred to in this report as "NUREG/CR-7046"(NRC, 2011), NRC Interim Staff Guidance (ISG) (NRC, 2012a and NRC, 2013), as appropriate, and their supporting reference documents.

A HHA consists of a series of stepwise, progressively more refined analyses to evaluate the hazard resulting from phenomena at a given nuclear power plant site to structures, systems, and components (SSCs) important to safety with the most conservative plausible assumptions consistent with the available data. The HHA starts with the most conservative, simplifying assumptions that maximize the hazards from the maximum probable event. If the assessed hazards result in an adverse effect or exposure to any SSCs important to safety, a more site-specific hazard assessment is performed for the probable maximum event.

The HHA approach was carried out for each flood-causing mechanism, with the controlling flood being the event that resulted in the most severe hazard to the SSCs important to safety at CNP. The steps involved to estimate the design-basis flood typically included the following:

1. Identify flood-causing phenomena or mechanisms by reviewing historical data and assessing the geohydrological, geoseismic, and structural failure phenomena in the vicinity of the site and region.
2. For each flood-causing phenomenon, develop a conservative estimate of the flood from the corresponding probable maximum event using conservative simplifying assumptions.
3. If any SSCs important to safety are adversely affected by flood hazards, use site-specific data and/or more refined analyses to provide more realistic conditions and flood analysis, while ensuring that these conditions are consistent with those used by Federal agencies in similar design considerations.
4. Repeat Step 2 until all SSCs important to safety are unaffected by the estimated flood, or if all site-specific data and model refinement options have been used.

Section 3 of this report provides additional HHA detail for each of the flood-causing mechanisms evaluated.

Due to use of the HHA approach, the results (water elevation) for any given flood hazard mechanism may be significantly higher than results that could be obtained using more refined approaches. Where initial, overly conservative assumptions and inputs result in water elevations bounded by the CLB, no subsequent refined analyses are required to develop flood elevations that are more realistic or reflect a certain level of probability.

1.4 Assumptions

Assumptions used to support the flood reevaluation are described in Section 3 and its subsections, and depend on the mechanism being evaluated. Details relating to assumption justifications are discussed further in referenced supporting documentation.

1.5 Elevation Values

Elevation values cited in this report are based on National Geodetic Vertical Datum of 1929, referred to as NGVD29 or mean sea Level (MSL). To determine elevations in another datum in references, use the conversion table below (NOAA 2013a. and b.).

		To:		
	Datum (ft)	IGLG 85	NGVD 29	NAVD 88
From:	IGLD85	0	+0.936	+0.504
	NGVD29	-0.936	0	-0.432
	NAVD88	-0.504	+0.432	0

Where:

IGLD 85 = International Great Lakes Datum of 1985
NGVD 29 = National Geodetic Vertical Datum of 1929
NAVD 88 = North American Vertical Datum of 1988

1.6 References

NOAA, 2013a. National Oceanic Atmospheric Administration, National Geodetic Survey, VERTCON, North American Vertical Datum Conversion. Website: http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html; accessed June 24, 2013.

NOAA, 2013b. National Oceanic Atmospheric Administration, National Geodetic Survey, IGLD 85 Height Conversion. Website http://www.ngs.noaa.gov/cgi-bin/IGLD85/IGLD85.prl; Accessed June 24, 2013.

NRC, 2011. U.S. Nuclear Regulatory Commission "NUREG/CR-7046: Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America", Springfield, VA, National Technical Information Service, 2011 (ADAMS Accession No. ML 11321A195).

NRC, 2012. U.S. Nuclear Regulatory Commission, "Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident," March 2012 (ADAMS Accession No. ML12053A340).

NRC, 2012a. U.S. Nuclear Regulatory Commission, Japan Lessons-Learned Project Directorate, "JLD-ISG-2012-05, Guidance for Performing the Integrated Assessment for External Flooding, Interim Staff Guidance," Revision 0, 2012. (ADAMS Accession No. ML12311A214)

NRC, 2013. U.S. Nuclear Regulatory Commission, Japan Lessons-Learned Project Directorate, JLD-ISG-2012-06. Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment. Interim Staff Guidance, Revision 0. January 2013 (ADAMS Accession No. ML12271A036).

2.0 CURRENT FLOOD HAZARDS LICENSING BASIS

2.1 Detailed Site Information

The CNP site is located near the town of Bridgman, Michigan. The site is situated among lake-shore sand dunes. The site consists of about 650 acres along the eastern shore of Lake Michigan, with approximately 4,350 ft of lake frontage, and extends an average of about one and one quarter miles eastward from the lake (CNP, 2013).

2.1.1 Site Location and Layout

Figure 2-1 "Site Location Map" shows the general location of the site on the southeastern shore of Lake Michigan. Figure 2-2 "Site and Vicinity Aerial, Looking North" shows the local drainage basin and the site location along the lake shore bounded by forested sand dunes. Figure 2-3 "Site Topography" shows local topography in relation to the plant. Figure 2-4 "Site Layout with Major Features Significant to Flooding" shows the layout of site structures, including those important features related to flood modeling.

In general, the site is on a flat area above the Lake Michigan shoreline at about elevation 609 ft for most of the Protected Area. Near the lake, site grade in the Protected Area falls to about 594 ft for the area west of the Screenhouse and Turbine Building. A sheetpile wall at the head of the lake beach retains the site grade at the west edge of the Protected Area. The lake beach level west of the sheetpile wall is between about elevations 584 to 577 ft. To the north and south of the Protected Area are sand dunes with elevations up to about 650 ft.

2.2 Current Design Basis Flood Elevations

The plant grade and the design bases of features related to plant safety were established to consider the coincidence of maximum seiches postulated for the site with the highest recorded lake level. According to the Updated Final Safety Analysis Report (CNP, 2013), to determine the plant elevation necessary to protect the plant from flooding due to seiches, the characteristics of the lake shore at the plant, historical meteorological conditions, and mathematical modeling were used to determine a maximum seiche of 11 ft. This equates to a plant elevation of 594.6 ft above mean sea level.

The plant is flood protected from the maximum (monthly mean) high lake water level; however, a design basis seiche occurring when the lake is at its maximum recorded level will cause flooding in the Turbine Building Screen-house. Safety-related components located in the Turbine Building Screen-house have been evaluated for the condition and flood sensitive components have been protected. Thus, protection has been provided for safety-related equipment from flooding, waves, ice storms and other lake related hazards.

2.3 Current Licensing Basis Flood Protection and Mitigation Features (CLB)

The CLB for flooding protection at CNP is described in CNP, 2013. Flooding results from a weather-driven seiche on Lake Michigan with a maximum height of 11 ft above record high lake level: a flood elevation of 594.6 ft. Flood mitigation features include:

- Inherent protection of the Auxiliary and Containment Buildings is provided by the structural integrity of those structures themselves.
- A PVC 40 mil thick membrane on the outside of the Containment Building and Auxiliary Building foundations extending up at least 5 ft above the maximum known groundwater level.
- In addition, the elevation of the Protected Area, including the area around the Containment and Auxiliary Buildings is at an approximate elevation of about 609 ft, over 14 ft above the seiche flood elevation.

- Flooding of the Turbine Building is prevented by elevated access from the Screenhouse; a check-valve in the Turbine Building discharge sump and the sump access cover; embedment in concrete of pipe penetrations from the Screenhouse to the Turbine Building, and asphalt berms at rollup doors and entrances on the west side of that building.
- The structural integrity of the foundation concrete grade beam of the west side of the Turbine Building (CLB supporting element).
- All vital safety-related equipment housed at lower elevations within the Turbine Building and Auxiliary Buildings are suitably protected against a flood elevation of 594.6 ft by building walls, and/or permanent flood protection barriers.
- Essential Service Water Pumps and their motor controls are vital safety systems components located inside the Screenhouse. Pump motors and all vital controls are installed above elevation 594.6 ft, the maximum flood elevation.

The CNP UFSAR (CNP, 2013) in Section 2.4.3 states, “Infiltration of rainfall into the sandy surficial soils at the site is very rapid and flooding conditions are non-existent.”

All flood protection features at CNP were evaluated in the November 2012 submittal to NRC (CNP, 2012).

2.3.1 Flood Causing Mechanisms

A seiche is the only mechanism accounted for in the CNP plant CLB. The requirement to evaluate the worse-case phenomena is given in the UFSAR, Section 1.4.1, Criterion 2 (CNP, 2013).

2.3.2 Flood Protection and Mitigation

Flood protection features are fully described in CNP, 2012. For the CLB, protection is provided against flooding of the Screenhouse and Turbine Building as a result of seiche flooding from Lake Michigan and against groundwater intrusion.

2.4 Licensing Basis Flood-Related and Flood Protection Changes

No new flood protection enhancements or mitigation measures have been installed or enacted at CNP since its initial licensing (CNP, 2012).

2.5 Watershed and Local Area Changes

CNP is contained in a small watershed depicted by the dotted line in Figure 2-5 “CNP Drainage Basin”. No major changes that would affect plant flooding have occurred in the watershed since plant construction. Local changes are detailed below.

2.5.1 Watershed Changes

The site is located within the Grand Marais Embayment drainage basin which is separated from the St. Joseph River drainage basin to the east by a glacial moraine known as Covert Ridge (CNP, 2013). Changes to the watershed that might affect the plant site have been limited to those within the local area of at the plant itself as described in the following section.

2.5.2 Local Area Changes

Changes to the local area surrounding the plant site have been minimal since plant operation began. Changes to the plant site since initial plant operation have included a number of new structures, security barriers and area paving. Table 2-1 "Applicable Site Changes That May Impact Site Flooding" summarizes the specific site areas and plant structures involved.

2.6 Additional Site Details

Per Item 1.a.vi of requested information in Enclosure 2 of the 10 CFR 50.54(f) letter, the results from the 2012 Flood Walkdown are included here. A total of 19 walkdown flood protection features that included 30 attributes were reviewed during the walkdown completed at CNP in 2012 (CNP, 2012). Of the total flood protection features 13 were defined as passive-incorporated; 0 as passive-temporary; 1 as active-incorporated; 0 as active-temporary; and 5 as external passive.

CNP flood protection features included incorporated active and passive features as defined in the NEI Report 12-07 [Rev 0-A],"Guidelines for Performing Verification Walkdowns of Plant Protection Features" (NEI, 2012); there are no temporary flood protection features, either active or passive, for the plant and there are no CLB credited operator actions. Incorporated Barrier/Features are engineered passive or active flood protection features that are permanently installed in the plant that protect safety related systems, structures and components from inundation and static/dynamic effects of external flooding.

Engineered passive or active flood protection features external to the immediate plant area and credited as part of the CLB that protect SSCs important to safety from inundation and static/dynamic effects of external floods. Examples Include levees, dikes, flap gates, and pump stations (NEI, 2012).

The walkdown scope included evaluation of flood protection features with respect to design specifications and capacity to withstand CLB flood elevations. None of the flood protection features reviewed was determined to be non-functional (CNP, 2012). However, several of the features were inaccessible or had restricted access (CNP, 2012). All observations that did not meet the walkdown acceptance criteria were entered into the plant's corrective action program (CAP) and an operability determination associated with the observation was made. All observations entered into the CAP have subsequently been dispositioned (CNP, 2012). As a result, there are no planned corrective actions (CNP, 2012).

2.7 References

CNP, 2012. Flooding Walkdown Report In Response To The 50.54(f) Information Request Regarding Near-Term Task Force Recommendation 2.3: Flooding for the D.C. Cook Nuclear Power Plant, November 13, 2012, MD-12-FLOOD-002-S (ADAMS Accession No. ML12340A444).

CNP, 2013. "D.C. Cook Nuclear Plant Updated Final Safety Analysis Report (UFSAR)," Docket Nos. 50-315 and 50-316, Revision 25, September 9, 2013. (AREVA Doc. No. 38-9210897-000).

NRC, 2012. U.S. Nuclear Regulatory Commission, "Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident," March 2012 (ADAMS Accession No. ML12053A340).

NEI, 2012. NEI Report 12-07 [Rev 0-A], Guidelines for Performing Verification Walkdowns of Plant Protection Features, May 2012 [NRC endorsed May 31, 2012; updated and re-issued June 18, 2012].

Table 2-1: Applicable Site Changes That May Impact Site Flooding

Construction of Fire Protection Water Storage Tanks
Construction of Fire Pumphouse
Construction of Fish Deterrent House
Construction of Auxiliary Boiler House
Construction of a Drain Trough Added at the Auxiliary Building Roll-up Doors
Construction of Fabrication Warehouse
Construction of Maintenance Outage Facility
Construction of Supplemental Diesel Generators and adjacent 4KV switchgear
Construction of Office Building Addition and Service Building Extension and related fencing
Construction of a trough drain added at the Screenhouse rollup door
Construction of Auxiliary Boiler Fuel Oil storage area
Construction of Training Center
Construction of Radiological Materials Building
Construction of Neutralization Tank and Chemical Truck unloading pad
Construction of Independent Spent Fuel Storage Installation (ISFSI)
Construction of double security fencing along the lake front
Construction of guard towers (BREs)
Construction of Technical Support Office Center (TSOC)
Construction of Security Post
Construction of Sewage Treatment Plant
Placement of Jersey security barriers
Construction of Delay Barrier encircling the Protected Area
Construction of FLEX Storage Building
Paving of the northeast parking area (Ontario lot)
Paving of the east parking expansion lot areas (Michigan, Huron, Erie lots)
Paving of Training Center parking lot
Paving of Radiological Materials Building parking area
Paving of a new parking area south of the plant entrance road (Superior lot)
Paving of Units 1 and 2 Refueling Water Storage Tank yard

Figure 2-1: Site Location Map

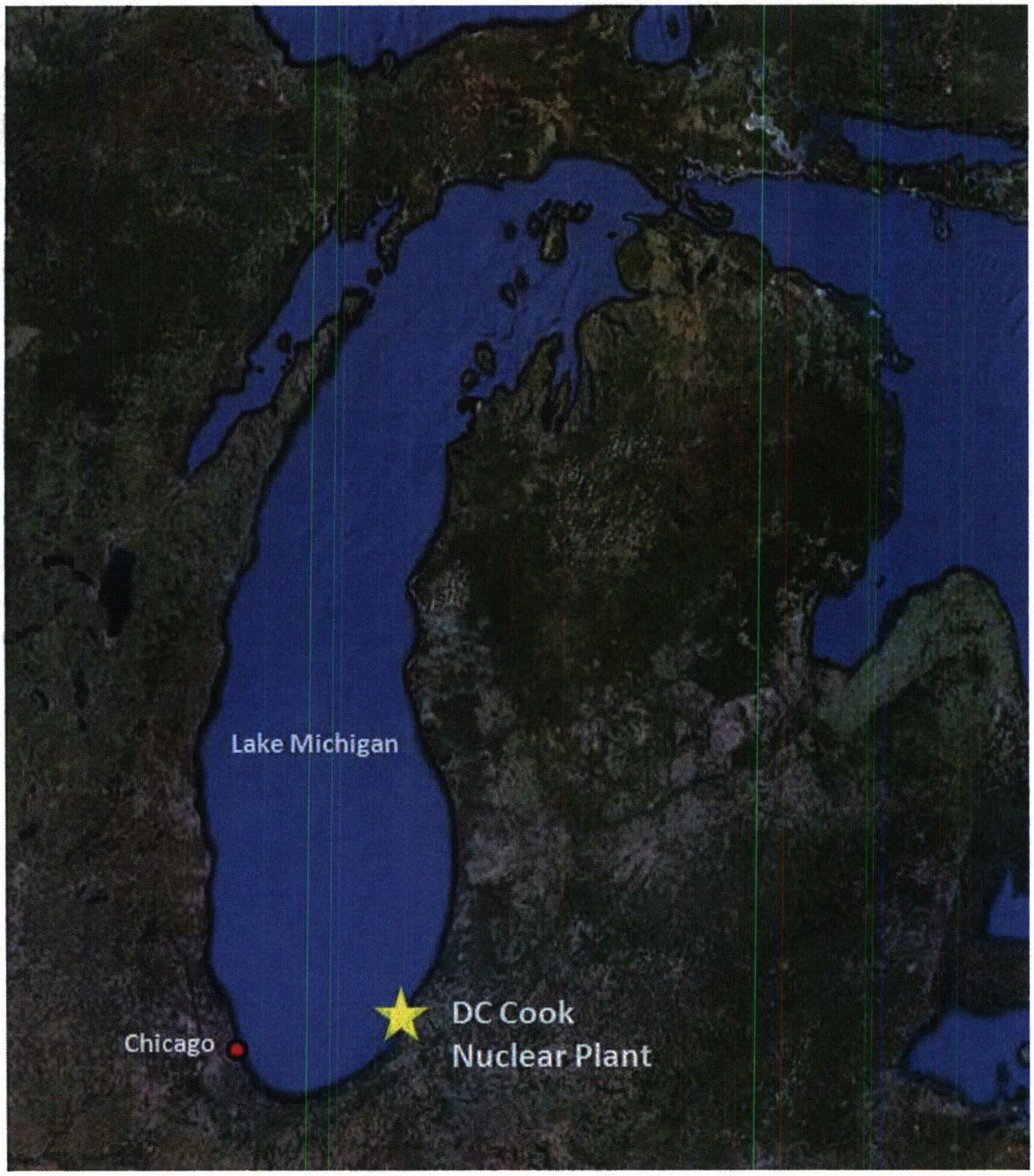


Figure 2-2: Site and Vicinity Aerial, Looking North

Figure 2-3: Site Topography

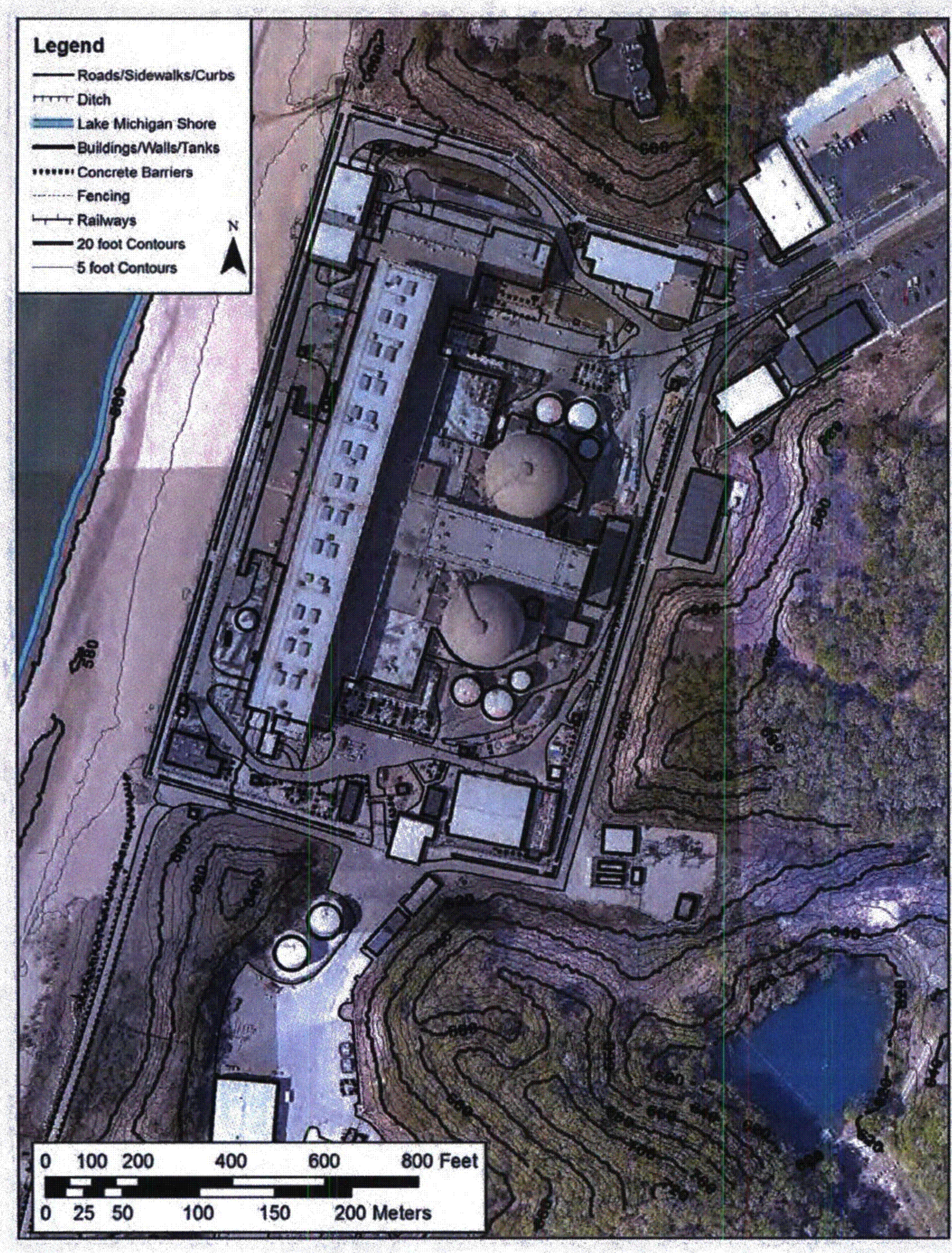
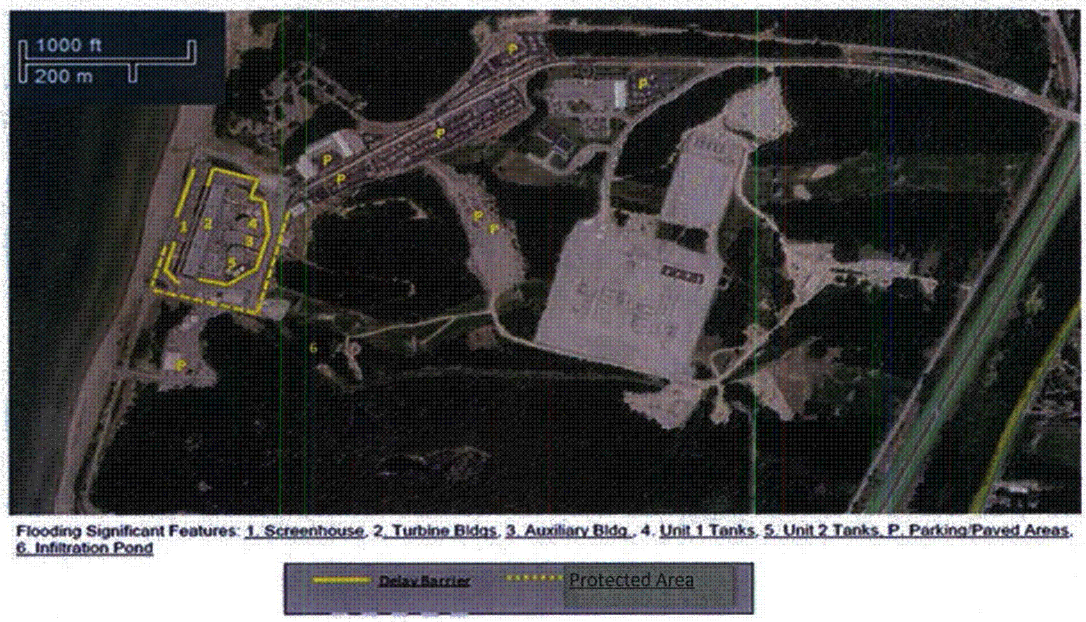
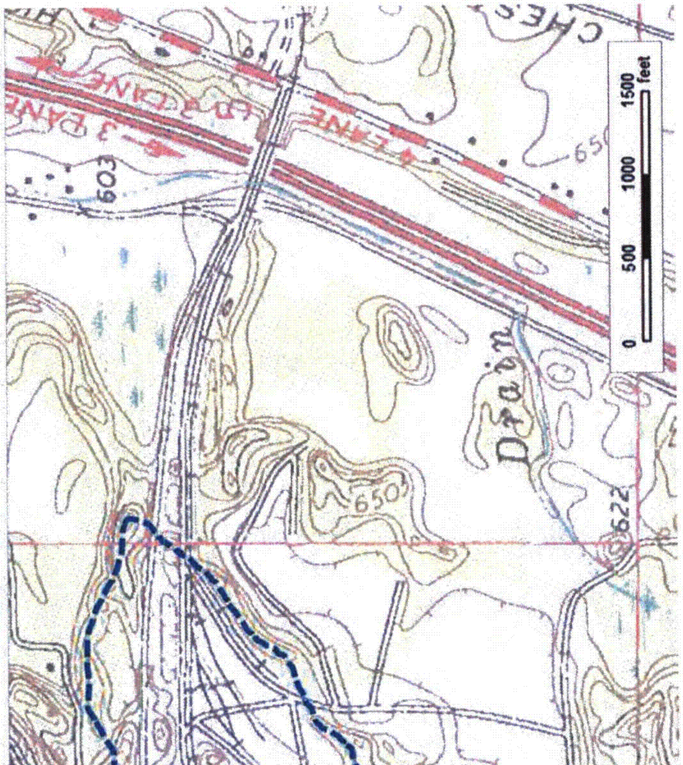


Figure 2-4: Site Layout with Major Features Significant to Flooding



Flooding Significant Features: 1. Screenhouse, 2. Turbine Bldgs, 3. Auxiliary Bldg., 4. Unit 1 Tanks, 5. Unit 2 Tanks, P. Parking/Paved Areas, 6. Infiltration Pond

Figure 2-5: CNP Plant Drainage Basin



3.0 FLOOD HAZARD REEVALUATION

This section details the evaluation of the eight flood causing mechanisms and a combined effect flood for CNP as detailed in Attachment 1 to Enclosure 2 of the 10 CFR 50.54(f) letter (NRC, 2012) as well as the flooding mechanism due to groundwater intrusion as described in the CNP USFAR, and one additional, unique, potential flood causing mechanism due to overflow or slope failure of the Infiltration Pond (a natural pond). Flooding from that pond was evaluated as part of the combined effect flood evaluation.

3.1 Probable Maximum Precipitation

This section summarizes the evaluation for the potential impact of a Probable Maximum Precipitation (PMP). Validation of all design inputs, assumptions, software, etc. is in the full evaluation (AREVA, 2014). Analysis for PMP evaluates a maximum potential for regional rainfall flooding and provides an input for a Local Intense Precipitation (LIP) analysis.

3.1.1 Site-Specific Probable Maximum Precipitation Methodology

The PMP was first developed based on Step 1 of the HHA process described in Section 2 of NUREG/CR 7046, (NRC, 2011) using NOAA HMR 51 and HMR 52 (NOAA, 1980 and NOAA, 1982) data. A conservative estimate of the LIP generated flood was developed based on Step 2 of the HHA process. Based on Step 3 of the HHA process, and because SSCs important to safety were found to be adversely affected by the conservative LIP generated flood from Step 2, use of site-specific data to provide more realistic conditions was warranted.

Thus, a Site-Specific Probable Maximum Precipitation (SSPMP) was performed to avoid inappropriate conservatism provided for the site by use of NOAA HMR 51 and HMR 52 (NOAA, 1980 and NOAA, 1982) and to determine appropriate, data-based, and physically possible LIP/PMP values for the site. HMR 51 is a generalized study that provides PMP estimates for all of the United States east of the 105th meridian, a large and climatologically diverse area. The developers of HMR 51 recognized that it is possible to analyze smaller, more site-specific regions within the large area covered by HMR 51. Improved analysis procedures, and technology advances such as new computer models, weather radar, and geographic information system (GIS) software now exist to analyze depth-area-duration data. PMP reductions from site specific studies have been provided for long duration storms (Tomlinson & Kappel, 2009; Tomlinson et al., 2008). This approach produced site-specific all-season LIP/PMP values for CNP that were less than those provided by using HMR 52 (NOAA, 1982).

Major steps in the SSPMP included development of an updated storm database (i.e. to those used in HMR 51 and HMR 52, NOAA, 1980 and NOAA, 1982) and explicit evaluation of storms that are directly transpositionable to the CNP site. Transpositioning is the transfer of a storm from where it occurred to a location that is meteorologically and topographically similar (NOAA, 1980,). In addition, understanding of the meteorology of these events has advanced significantly since HMR 51 (NOAA, 1980) was published. The storm-based approach utilized actual data from rainfall events which have occurred over the site and in regions transpositionable to the CNP site location.

The basic methods used to develop the SSPMP were those used in the development of rainfall in HMR 51 (NOAA, 1980) and HMR 52 (NOAA, 1982). The methods are consistent with guidelines provided in NUREG/CR-7046 (NRC, 2011) as well as the World Meteorological Organization (WMO) manual for PMP determination (WMO, 2009). The approach includes a process of Storm Maximization, increasing rainfall associated with a historical observed extreme storm under the potential condition that additional moisture could have been available to the storm for rainfall production. That process used the HYSPLIT trajectory model (Draxler, R.R. and G.D. Rolph, 2010). HYSPLIT is an interactive online interface provided by the Air Resource Laboratory division of NOAA.

Once each storm is maximized in-place, it is transpositioned from its original location to the CNP site. The transpositioning process provides a way to quantify how much rainfall the storm would have produced over the CNP site had it occurred there instead of its original location. In this transposition process, differences in moisture and elevation between the original location and the site are accounted for and quantified. Figure 3-1 "Extent of Storm Search Domain for CNP" provides the domain for the storm search locations for CNP and Figure 3-2 "Storm Locations Used for LIP/PMP Development in Relation to CNP" provides the boundaries for the geographic extent storms considered in the assessment of PMP for CNP. The domain is defined by evaluating existing documentation on the storm as well as plotting and evaluating initial precipitation gauge data on a map. The analysis domain is defined to include as many hourly recording gauges as possible given their importance in timing. The domain must include enough of a buffer to accurately model the nested domain of interest. Given radar data an area with a minimum of about 30 stations can adequately provide reliable radar-precipitation intensity relationships.

Excel spreadsheets were developed for each storm used in the SSPMP assessment. Spreadsheets incorporate relevant storm information, calculate appropriate adjustment factors, and compute the adjusted site-specific values for each storm. These adjusted values then become the basis for determining the PMP and LIP input values. The storm spreadsheet calculates an in-place maximization factor (IPMF), a moisture transposition factor (MTF), and finally the total adjustment factor (TAF). The TAF is a product of the IPMF and MTF and produces a value that represents what the amount of rainfall would have been for a given storm had it occurred over the site instead of its original location. This TAF was applied to the observed storm rainfall values to provide the final adjusted values for the maximized and transpositioned storm rainfall for a given storm. The largest of these total adjusted values then becomes the site-specific LIP.

Basic to the analysis are results from the program Storm Precipitation Analysis System (SPAS). SPAS is a state-of-the-science hydrometeorological tool used to characterize the magnitude, temporal, and spatial details of precipitation events. SPAS processes and analyzes data following the same procedures used by the USACE and NWS in the development of rainfall data used to derive PMP information in the HMRs. This process is outlined in USWB, 1946. SPAS followed these guidelines so the analyzed events would be consistent with the data used in HMR 51 and HMR 52 (NOAA, 1980 and NOAA, 1982). SPAS data has been extensively peer reviewed and explicitly accepted for use in determining PMP values by the FERC, several state dam safety offices, the NRCS, the USACE, the Bureau of Reclamation, and is under review by the NRC. The SPAS program has gone through and been accepted under the NRC Appendix B certification and validation process.

SPAS utilizes precipitation gauge data, base maps and radar data (where available) to produce gridded precipitation at time intervals as short as 5-minutes, at spatial scales as fine as 1 km^2. Hourly precipitation data is generated from direct readings and using Next Generation Radar (NEXRAD) data, improving data reliability over historical precipitation rates. Detailed SPAS-computed precipitation data allow for production of accurate model runoff from basins, particularly when the precipitation is unevenly distributed over the drainage basin or when rain gauge data is limited or not available. The increased spatial and temporal accuracy of precipitation estimates has eliminated the need for commonly made assumptions about precipitation characteristics (such as uniform precipitation over a watershed), thereby greatly improving the precision and reliability of hydrologic analyses compared to prior methods.

Quality control measures are taken throughout the SPAS analysis. These include:

- A QC-methodology is used to ensure the timing of precipitation at all gauges is consistent with nearby gauges.
- Gauge elevations are checks to eliminate erroneous longitude and/or latitude values.
- Accuracy for all co-located gauges is assured by use of the highest precipitation values and any large discrepancies between any co-located gauges are investigated and conservatively resolved.

- SPAS results produced for projects referenced for this PMP analysis (AWA, 2013 and Tomlinson et al, 2008) were validated within each analysis using either another code or a hand check.

SPAS has been used to analyze over 300 US extreme precipitation events for PMP derivation, runoff model calibration/validation, and storm reconstructions. SPAS incorporates quality control algorithms, utilizes real-time rain gauge observations and the highest resolution NEXRAD radar data. Using a climatological "basemap" approach, SPAS produces gridded rainfall at a spatial resolution of 1/3rd-square mile and a temporal resolution of 5-minutes (with radar).

Assumptions made for this work were all verified. They are:

- An appropriate set of storm events has been identified, analyzed, and maximized specific to the site, to represent the meteorological environment associated with the 1- and 6-hour, 1-square mile PMP accumulations for the site. This assumption is validated by including a large enough set of PMP-type storms to ensure no storms which could have potentially affected PMP values after all adjustments were applied were left out of the analysis. In the analysis for the CNP location, only one storm controlled the value for 1-hour and only one storm controlled the value for 6-hours. However, 21 PMP-type storm events were considered. Several of the other storm events were of similar magnitude, providing support to the calculated values.
- Storms transposed to the CNP location could have occurred over the area under similar meteorological conditions. This decision is made using scientific judgment related to the storm type, season of occurrence, similarity of topography between the two locations, and experience analyzing past storms.
- For storms where no 1-hour, 1-square mile data exist, HMR 52 (NOAA, 1982) ratios were assumed to be appropriate to convert the 6-hour, 10-square mile values to 1-hour, 1-square mile values for several storms during the LIP/PMP development. HMR 52 (NOAA, 1982) provides PMP ratios for 5-, 15-, and 30 – 60 minute rainfall depths for watersheds under 200-square miles.
- HMR, USACE, and SPAS data are valid and HYSPLIT functions as required.
- The atmospheric air masses that provide moisture to both historic storms and the PMP storm are assumed to be saturated through the entire depth of the atmosphere and to contain the maximum moisture possible based on the surface dew point. This assumes moist pseudo-adiabatic temperature profiles for both the historic storms and the PMP storm. This is a conservative assumption because it is unlikely that the atmosphere is completely saturated through the entire atmospheric column. Therefore, assuming that the air is saturated in such a manner serves to maximize the precipitation capacity of the storm.
- If additional atmospheric moisture had been available, the storm would have maintained the same efficiency for converting atmospheric moisture to rainfall. The ratio of the maximized rainfall amounts to the actual rainfall amounts would be the same as the ratio of the precipitable water (the total atmospheric water vapor contained in a vertical column of unit cross-sectional area extending between any two specified levels in the atmosphere) in the atmosphere associated with each storm. This assumption is conservative, yielding the highest amount of rainfall possible.
- The climatological maximum dew point is assumed for a date 15 days towards the warm season from the date that the storm actually occurred is applied in the storm maximization process. This procedure assumes that the storm could have occurred 15 days earlier or later in the year when maximum dew points (and moisture levels) are higher. This assumption follows HMR guidance and is consistent with procedures used to develop PMP values in all the current HMR documents (e.g., NOAA, 1980 and NOAA, 1999), as well as all AWA PMP studies (AWA, 2013).

- Storm efficiency is assumed not to change if additional atmospheric moisture is available. For this analysis, the assumption of no change in storm efficiency is accepted, mirroring the HMR 52 (NOAA, 1982) and World Meteorological Organization assumptions (WMO, 2009).
- Changes in climate that will occur in the region are assumed to be adequately accounted for by the rarity of the resulting PMP and LIP values. Further, changes in climate which have occurred during the past 100 years are captured in the storm record and rainfall data used in this analysis therefore represent any changes that would be expected during the useful lifetime of the values (i.e., 30 to 50 years). Therefore, no adjustment is made to account for potential changes in climate during the useful lifetime of the values (i.e., 30 to 50 years).
- Cool-season rain-on-snow flooding is assumed to not control the PMP/LIP flood. Storms from all 12 months of the year were considered for this PMP analysis based on prior studies (NRC, 2011, AREVA, 2014). Also considered pertinent was that substantial snow melt will not occur during the relatively brief period (6-hour) of the LIP event.

Key inputs for the SSPMP analysis are:

- Cooperative Summary of the Day TD-3200/TD-3206 through 2014. These data are published by the National Climatic Data Center (NCDC) (AREVA, 2014).
- Hourly weather observations published by NCDC (NCDC, 2012), U.S. Environmental Protection Agency, and Forecast Systems Laboratory (now National Severe Storms Laboratory) (AREVA, 2014).
- Hydrometeorological Reports (NOAA, 1980 and NOAA, 1982). From these sources, the "6-hour 10-square mile" and "1-hour 1-square mile" values are used for the storms listed in AREVA, 2014.
- U.S. Army Corps of Engineers (USACE) storm studies (AREVA, 2014).
- Applied Weather Associates (AWA) storm analyses (AREVA, 2014).

The initial step in the development of the PMP values was to identify a set of storms which represents rainfall events that are PMP-type storms which would produce an LIP local storm event. This included storms where extreme rainfall accumulated over short durations and small area sizes with extreme intensities. Storm types included thunderstorms and intense rainfall associated with Mesoscale Convective Complexes (MCC). This procedure is similar to what is described in HMR 52, Section 6 (NOAA, 1982). The differences are that several more storms have been added to the storm database from which to develop PMP values. And, only storms explicitly transpositionable to the CNP site were used in this analysis. Influence of storms not transpositionable to the site was not allowed. Transpositioning is the hypothetical relocation of a storm, from the location where they occurred to another area where it could occur. The transposition process requires a binary answer: a storm is either transpositionable to a location or not. For a given storm to be considered transpositionable there must be similar meteorological/climatological and topographical characteristics at its original and new locations. This is a qualitative determination based on the meteorological judgment using conservative limits. The determination regarding transposition for storms was consistent with that used in HMR 52 (NOAA, 1982).

An evaluation was done for all storms used in previous LIP and PMP studies in the region considered transpositionable to the CNP site to develop a list of storms needed for proper evaluation and determination of the LIP/PMP values. All LIP/PMP-type rainfall events in the region were evaluated to ensure storms with the highest accumulation of rainfalls over short durations and small area sizes were analyzed. Emphasis was placed on storm events which produced high intensity rainfall over short durations (6 hours or less). The storm search domain included a region from southern Canada through the Central and Southern Plains and from the western boundary of the Central Plains to the west side of the Appalachian Mountains, east/west for locations within ±1,000 ft of the site elevation (Figure 3-1"Extent of Storm Search Domain for CNP").

Each storm chosen for final evaluation was included because its 1- and/or 6-hour rainfall values were of a magnitude where after all adjustments were applied could potentially influence the LIP values. In addition, storms used in HMR 51 (NOAA, 1980) and/or HMR 52 (NOAA, 1982) which were of this magnitude were included. The storms which are important for LIP development at the CNP site are known from previous storm analyses and storm maximization completed in the region (AREVA, 2014). This resulted in 21 events being evaluated for use in PMP calculations at the site (Figure 3-1 "Extent of Storm Search Domain for CNP" and Table 3-1 "List of Storms Used in the PMP/LIP Calculation"). Thirteen of these storms were previously analyzed in HMR 33 (NOAA, 1956) and HMR 51 by the NWS and USACE. The remaining eight storms were analyzed using AWA's SPAS (AREVA, 2014) during previous PMP/LIP work. Each of the previous PMP/LIP calculations have been submitted through standard NRC review processes.

3.1.2 Results

Extreme rainfall events that can produce 1-and 6-hour, 1-square mile LIP/PMP values were evaluated for the SSPMP. Those storms were maximized in place, then transpositioned to the CNP site. The largest of these events defined the LIP/PMP values.

3.1.3 Conclusions

Conclusions of the SSPMP analysis are as follows:

- The all-season PMP is the controlling PMP for evaluating Local Intense Precipitation flooding at CNP site.
- The 1-hr PMP depth for application to the Local Intense Precipitation is 12.8 inches (AREVA, 2014).
- The 30-min PMP depth for application to the Local Intense Precipitation is 9.8 inches (AREVA, 2014).
- The 15-min PMP depth for application to the Local Intense Precipitation is 6.8 inches (AREVA, 2014).
- The 5-min PMP depth for application to the Local Intense Precipitation is 4.3 inches (AREVA, 2014).
- The 6-hr PMP depth for application to the Local Intense Precipitation is 20.2 inches (AREVA, 2014).

3.1.4 References

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NCDC, 2012. National Climatic Data Center (NCDC), TD-3200 and TD-3206 Datasets - Cooperative Summary of the Day.

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Tomlinson & Kappel, 2009. "Revisiting PMPs," Tomlinson, E. M., and W.D. Kappel, October 2009, Hydro Review, Vol. 28, No. 7, 10-17.

USWB, 1946. Manual for Depth-Area-Duration analysis of storm precipitation. Cooperative Studies Technical Paper No. 1, U.S. Department of Commerce, Weather Bureau, Washington, D.C., 82pp.

WMO, 2009. World Meteorological Organization (WMO), Manual for Estimation of Probable Maximum Precipitation, Operational Hydrology Report No. 1045, Geneva 2009.

Table 3-1: List of Storms Used in the PMP/LIP Calculation

Storm Name	State	Lat	Lon	Year	Month	Day	Cook Total Adjustment Factor	Cook 1-hour 1mi^2 PMP	Cook Max 6hr 1mi^2 PMP	Precipitation Source
AURORA COLLEGE	IL	41.7500	-88.3333	1996	7	16	1.36	8.24	19.56	SPAS 1286
BEAULIEU	MN	47.3000	-95.9000	1909	7	18	1.17	8.46	11.55	UMV 1-11A
BOYDEN	IA	43.1900	-96.0100	1926	9	17	1.05	10.92	14.90	MR 4-24
COOPER	MI	42.3764	-85.6103	1914	8	31	1.36	11.81	16.11	GL 2-16
DUBUQUE	IA	42.4400	-90.7500	2011	7	27	1.05	4.31	11.13	SPAS 1220
DUMONT	IA	42.7519	-92.9755	1951	6	25	1.26	7.99	8.57	UMV 3-29
EDGERTON	MO	40.4125	-95.5125	1965	7	18	1.22	4.49	14.36	SPAS 1183
FALL RIVER	KS	37.6300	-96.0500	2007	6	30	1.17	5.34	10.37	SPAS 1228
FOREST CITY	MN	45.2394	-94.5404	1983	6	20	1.41	5.16	11.77	SPAS 1035
GRANT TOWNSHIP	NE	42.2400	-96.5900	1940	6	3	1.27	11.38	15.52	MR 4-5
HOKAH	MN	43.8125	-91.3625	2007	8	18	1.37	5.10	10.58	SPAS 1048
HOLT	MO	39.4528	-94.3422	1947	6	18	1.06	12.72	12.72	MR 8-20
KELSO	MO	37.1906	-89.5495	1952	8	11	1.14	10.21	13.93	UMV 3-30
LARRABEE	IA	42.8608	-95.5453	1891	9	10	1.10	7.88	10.75	MR 4-2
MINNEAPOLIS	MN	44.8890	-93.4021	1987	7	23	1.13	5.62	12.57	SPAS 1210
MOUNDS	OK	35.8770	-96.0610	1943	5	16	1.17	12.82	18.95	SW 2-21
NEOSHO FALLS	KS	38.0820	-95.7010	1926	9	12	1.26	11.63	17.14	SW 2-1
NEWCOMERSTOWN	OH	40.2723	-81.6060	1935	8	6	1.19	7.87	13.45	OR 9-11
STANTON	NE	41.8670	-97.0500	1944	6	10	1.30	12.00	20.15	MR 6-15
WOODBURN	IA	41.0120	-93.5991	1903	8	24	1.19	5.66	7.72	MR 1-10
WOOSTER	OH	40.9146	-81.9729	1969	7	4	1.27	5.87	11.19	SPAS 1209

Figure 3-1: Extent of Storm Search Domain for CNP

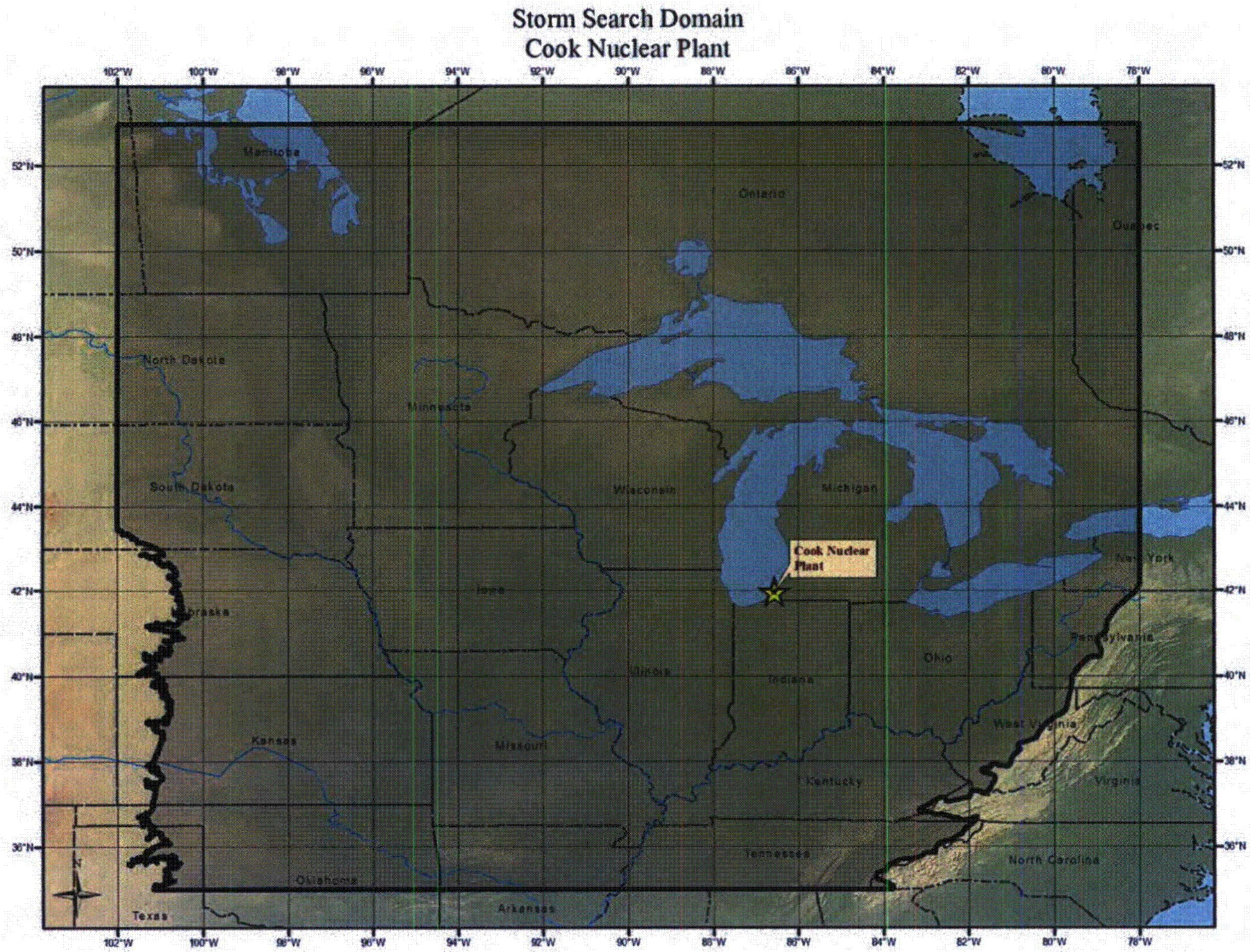
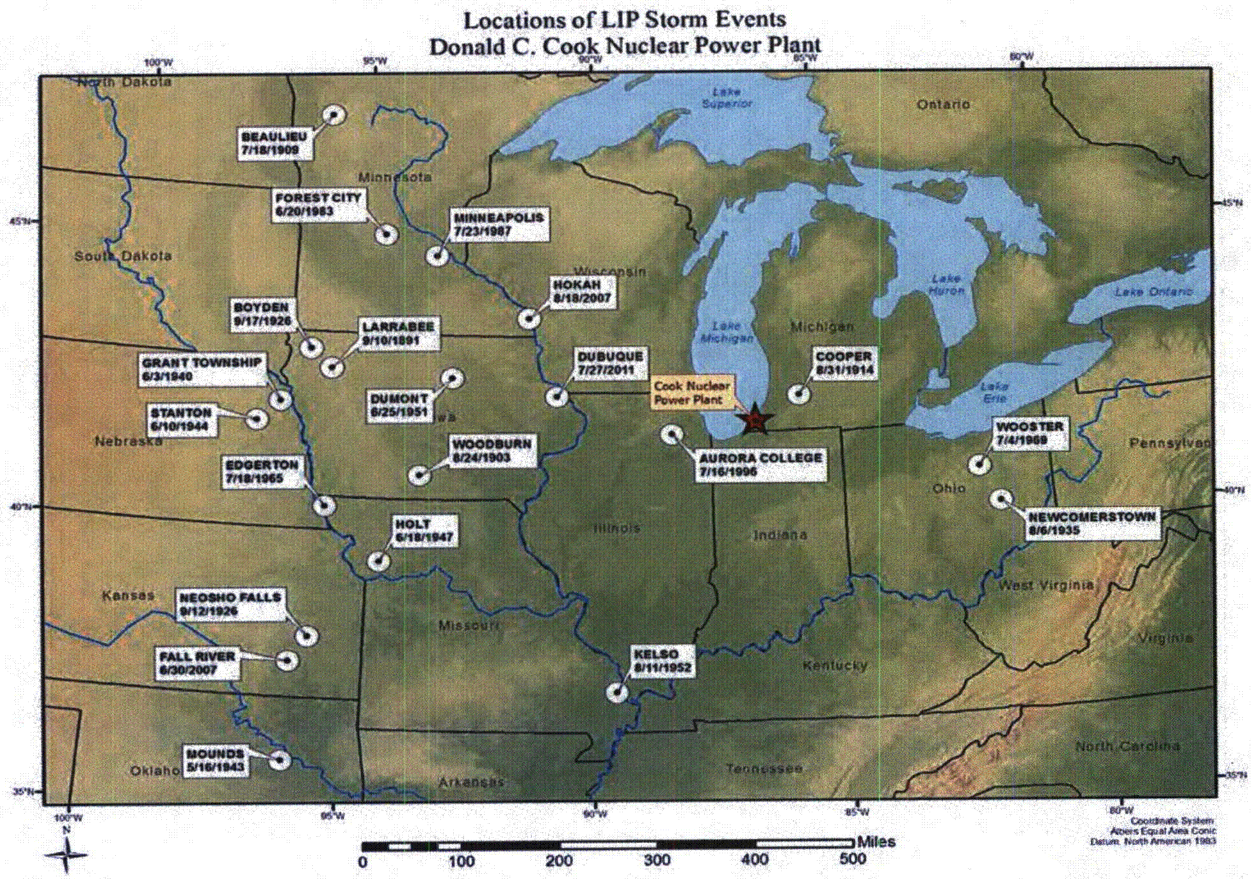


Figure 3-2: Storm Locations Used for LIP/PMP Development in Relation to CNP



3.2 Local Intense Precipitation

This section summarizes the evaluation for the potential flooding impact of a local intense precipitation (LIP) event (AREVA, 2015). The LIP event is a distinct flooding mechanism that consists of a short-duration, locally heavy rainfall centered upon the plant site itself. Validation of all design inputs, assumptions, software, etc. is in the full evaluation (AREVA, 2015). Local intense precipitation analysis addresses the potential for an extreme amount of water fall2014ing in the immediate vicinity of the site. Analysis for PMP evaluates a maximum potential for regional rainfall flooding and provides an input for an LIP analysis. LIP analysis addresses the potential for an extreme amount of water falling in the immediate vicinity of the site, usually taken as the one-square-mile PMP.

3.2.1 Method

A FLO-2D (FLO-2D, 2013) two dimensional rainfall to runoff model is the basis of the LIP Calculation (AREVA, 2015). The FLO-2D model applies the Site-Specific Probable Maximum Precipitation (SSPMP) (AREVA, 2014b) to grid-based site topography and provides time dependent output in terms of the resulting water surface elevation and flow velocity at locations throughout the CNP site.

A LIP flood is evaluated for CNP consistent with the Hierarchical Hazard Assessment (HHA) approach of NUREG/CR-7046 (NRC, 2011).

With respect to LIP, the analysis, following the HHA used the following steps:

1. Define FLO-2D model limits for LIP analysis,
2. Develop the FLO-2D computer model with site features,
3. Develop LIP/PMP inputs,
4. Perform flood simulations in FLO-2D and estimate maximum water surface elevations at CNP,
5. Analyze results for a "Case 3" and evaluate need for "Case 2" as defined in NUREG/CR-7046, Appendix B,
6. Analyze a "Case 2" as a final result.

Local Intense Precipitation was evaluated for the CNP site using the program FLO-2D (AREVA, 2015). FLO-2D is a physical process model that routes flood hydrographs and rainfall-runoff over unconfined flow surfaces or in channels using the dynamic wave approximation to the momentum equation. The watershed applicable for the LIP Analysis was computed internally within FLO-2D based on a digital terrain model (DTM).

As prescribed in NUREG/CR-7046 (NRC, 2011) the HHA process was followed to provide representations for both a Case 3 and a Case 2 in order to provide more realistic results while still using conservative site-specific inputs.

The LIP parameters for Case 3 were defined using HMR 51 and HMR 52; (NOAA, 1980 and NOAA, 1982) as prescribed in NUREG/CR-7046, Section 3.2 (NRC, 2011). The LIP parameters for Case 2 were defined using input from site-specific calculation (AREVA, 2014b) as prescribed for in NUREG/CR-7046 (NRC, 2011). LIP results for this report are those from Case 2.

The FLO-2D model for LIP flooding analysis at CNP utilizes 2013 topographic mapping results done using LiDAR to generate ground elevations and associated flood water surface elevations. The model ground elevations for each grid cell were derived from the site survey LiDAR points within the FLO-2D software. Model was obtained from the ground elevations in the 2013 aerial LiDAR site survey (AREVA, 2013).

Rainwater infiltration into natural sands in the area (dune sand) was derived from US Soil Conservation Service information (USDA, 1986). No evaporation losses were considered.

The CNP Storm Drain System (yard drainage) is considered to be operational at 25% capacity – consistent with NUREG/CR-7046 Appendix B.2 Case 2: Fully Functional Site Grading and Partially Blocked Drainage Channels (NRC, 2011).

Buildings within the watershed are considered to be solid and impervious (as in HHA Case 3). Security barriers, consisting of both concrete Jersey barriers and heavy steel fencing are considered pervious where they might block water from access to the site (upstream) and impervious where they might allow flow off site (downstream).

Rooftop drains are considered to be plugged with debris or otherwise overwhelmed and ineffective for Case 3. Runoff from the building roofs is generally directed to adjacent ground surface cells within the FLO-2D model.

Locations of critical areas (where LIP runoff could negatively impact SSCs important to safety) were identified based on general site and plant configuration and plant walkdowns. The 10 "Critical Locations" identified in the 2012 walkdown (CNP, 2012) are identified to be locations of potential SSC vulnerability, that is, where predicted flood elevations exceed surveyed threshold elevations (allowing water to potentially enter critical areas) are considered to be an adverse condition.

The model computational area (Figure 3-3 "FLO-2D Modeled Site Area") is defined by a 10 foot by 10 foot model grid over the 0.22 square mile contributing watershed (Figure 2-5 "CNP Plant Drainage Basin") to define the computational area for the FLO-2D model.

Assumptions made for this work were all verified:

- Watershed surfaces are assigned a realistic site-specific Soil Conservation Service (SCS) Curve Number (CN) based on soils type, vegetation, and land use.
- Runoff from the rooftop of parapet style building roofs is allowed to flow to an internal storm drain within the building, then offsite – not to adjacent ground surface cells (AREVA, 2015).
- Security barriers on the upstream edges of the model are not considered to block incoming stormwater and are omitted from the model (as in HHA Case 3).
- Jersey Barriers on the downstream edges of the site are considered impervious (as in Case 3).
- Delay Barriers on the downstream edges of the Protected Area are assumed to be 50% porous (AREVA, 2015).
- The CNP Protected Storm Drain is considered to be operational at 25% capacity – consistent with NUREG/CR-7046 Appendix B.2 Case 2: Fully Functional Site Grading and Partially Blocked Drainage Channels (NRC, 2011). The combined outfall section is adequate to convey inflow from all trench drains.
- Use of Site-Specific PMP (AREVA, 2014b) as described in Section 3.1. This assumption is appropriate because NUREG/CR-7046 (NRC, 2011) indicates that an HHA Case 2 analysis is supported by site-specific hydrometeorological data (NRC, 2011).
- No evaporation losses were considered. Buildings within the watershed are considered to be solid and impervious.

3.2.2 Results

Overland flow in the Protected Area initiates both in situ and into the Protected Area from 1) the east, traveling particularly from paved areas along the plant access road and 2) off of sand dunes that rise from near Protected Area grade (about 594 to 609 ft) to as high as elevation 650 ft north and south of the Protected Area. Security barriers, consisting of both concrete Jersey barriers and heavy steel fencing, significantly influence overland flow of rainwater.

Maximum ponding of rainwater at critical locations (shown in Figure 3-4 "CNP Critical Opening Locations") for Case 2 is shown in Table 3-2 "LIP Model Results: HHA Case 2". Additional figures are provided in AREVA, 2015. Appendix B provides water surface elevation over time for critical locations. These drawings include: Figure B-1 "Water Surface Elevation Over Time CL1 (HHA Case 2)", Figure B-2 "Water Surface Elevation Over Time CL2 (HHA Case 2)", Figure B-3 "Water Surface Elevation Over Time CL3 (HHA Case 2)", Figure B-8 "Water Surface Elevation Over Time CL4 (HHA Case 2)", Figure B-4 "Water Surface Elevation Over Time CL5 (HHA Case 2)", Figure B-5 "Water Surface Elevation Over Time CL6 (HHA Case 2)", Figure B-6 "Water Surface Elevation Over Time CL7 (HHA Case 2), Figure B-7 "Water Surface Elevation Over Time CL8 (HHA Case 2)", Figure B-8 "Water Surface Elevation Over Time CL9 (HHA Case 2)" and Figure B-9 "Water Surface Elevation Over Time CL10 (HHA Case 2)".

Debris loading and transportation during the LIP scenario is not considered a hazard for SSCs important to safety at CNP.

3.2.3 Conclusions

The flood height above critical threshold elevation from the FLO-2D model runs at the 10 Critical Locations is summarized in Table 3-2 "LIP Model Results: HHA Case 2". The following is a summary of the results of the LIP Calculation:

1. Turbine Building. HHA Case 2 LIP flood height above the critical threshold elevation at the northwest entrance roll up door is 0.0 ft, the southwest roll up door is 0.8 ft, the northeast roll up door is 0.8 ft, and the southeast roll up door is 0.2 ft.
2. Valve Sheds. The Unit 1 tanks (north) valve sheds show 1.5 ft of water above critical threshold elevation, and the south sheds have 0.6 to 1.2 ft of water above their critical threshold elevations for the HHA Case 2 LIP.
3. Auxiliary Building. The north roll up door for the Auxiliary Building has a maximum 1.0 ft of flood height above threshold elevation in the HHA Case 2 LIP.

3.2.4 References

AREVA, 2013. "Donald C Cook FHE Aerial Mapping Validation Report", AREVA Document No. 38-9207275-001, September 2013.

AREVA, 2014b. "Site-Specific Probable Maximum Precipitation (PMP) for Cook Nuclear Plant Flood Hazard Re-evaluation," AREVA Document No.: 32- 9226859-000, CNP Document No.: MD-14-FLOOD-012-N, Revision 0.

AREVA, 2015. "Site-Specific Local Intense Precipitation (SS LIP) for D.C. Cook Nuclear Plant," AREVA Document No.: 32- 9221898-001, CNP Document No.: MD-14-FLOOD-014-N, Revision 1.

CNP, 2012. Flooding Walkdown Report In Response The 50.54(f) Information Request Regarding Near-Term Task Force Recommendation 2.3: Flooding for the D.C. Cook Nuclear Power Plant, November 13, 2012, MD-12-FLOOD-002-S (ADAMS Accession No. ML12340A444).

FLO-2D, 2013. "FLO-2D® Pro Reference Manual", FLO-2D Software, Inc., Nutrioso, Arizona (www.flo-2d.com), 2013.

NOAA, 1980. Probable Maximum Precipitation Estimates - United States East of the 105th Meridian", Hydrometeorological Report No. 51 (HMR 51) by US Department of Commerce & USACE, August, 1977, Reprinted August, 1980.

NOAA, 1982. "Application of Probable Maximum Precipitation Estimates – United States East of the 105th Meridian", NOAA Hydrometeorological Report No.52 (HMR 52) by US Department of Commerce & USACE, August 1982.

NRC, 2011. U.S. Nuclear Regulatory Commission "NUREG/CR-7046: Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America", Springfield, VA, National Technical Information Service, 2011 (ADAMS Accession No. ML 11321A195).

USDA, 1986. "Urban Hydrology for Small Watersheds", United States Department of Agriculture, National Resources Conservation Service, Conservation Engineering Division, TR-55, June 1986.

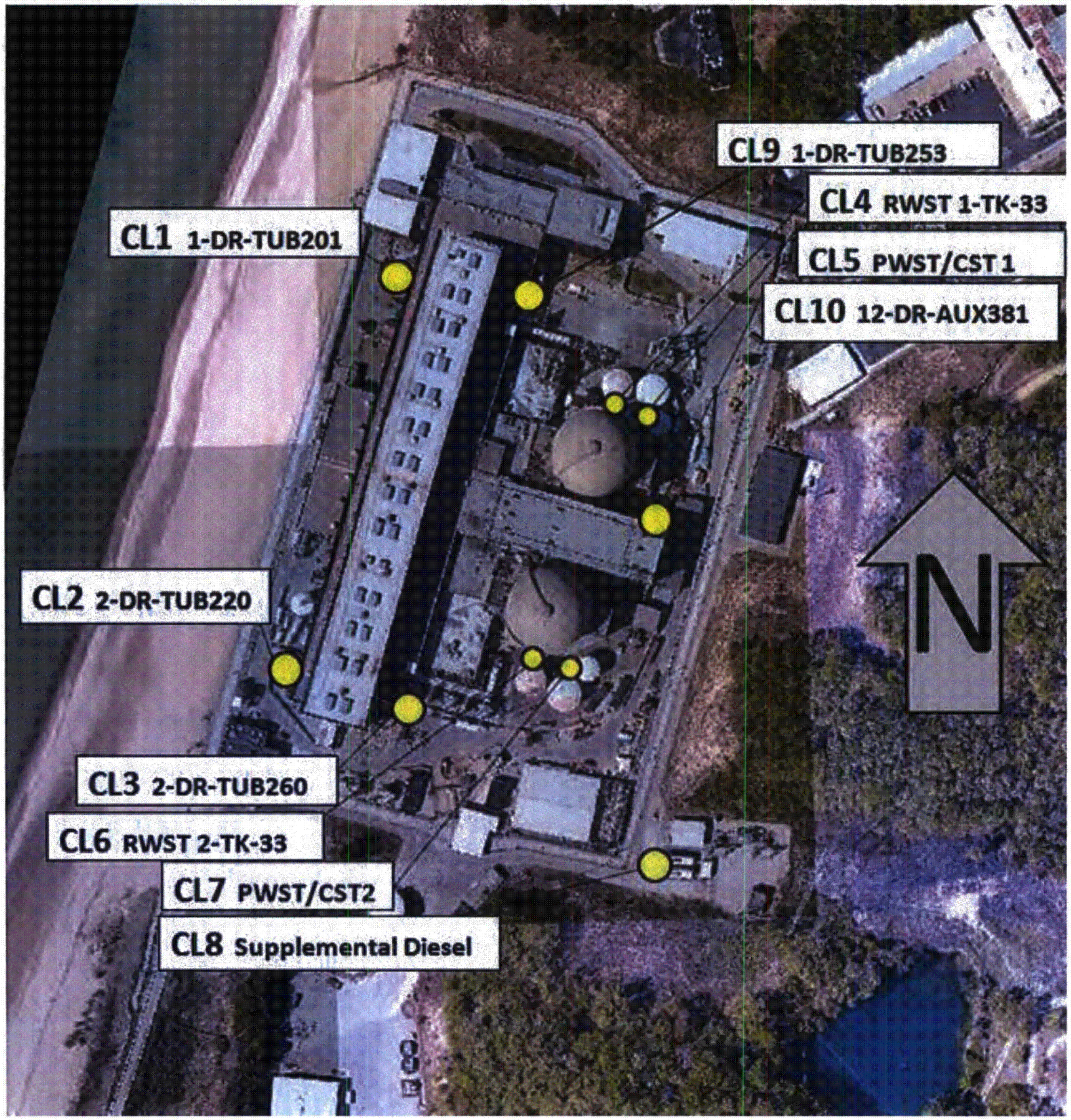
Table 3-2: LIP Model Results: HHA Case 2

Critical Location		FLO-2D Cell	Critical Elevation (Feet)	Computed Water Surface (feet) HHA Case 2	Inundation Depth (feet)
CL1	1-DR-TUB201	8478	594.8	594.8	0.0
CL2	2-DR-TUB220	4710	595.2	596.0	0.8
CL3	2-DR-TUB260	7718	609.0	609.2	0.2
CL4	Valve-shed RWST 1-TK-33	16301	608.4	609.9	1.5
CL5	Valve-shed PWST/CST 1	16964	608.4	609.9	1.5
CL6	Valve-shed RWST 2-TK-33	13002	608.9	609.5	0.6
CL7	Valve-shed PWST/CST 2	13962	608.4	609.6	1.2
CL8	Supplemental Diesel Generators	17333	609.0	609.6	0.6
CL9	1-DR-TUB253	13300	609.0	609.8	0.8
CL10	12-DR-AUX381	17167	608.9	609.9	1.0

NOTE: The Supplemental Diesel Generators at CL8 are not important to safety; that location is included for commercial information only.

Figure 3-3: FLO-2D Modeled Site Area

Figure 3-4: CNP Critical Opening Locations



3.3 Probable Maximum Flood: Flooding in Rivers and Streams

This section summarizes the potential flooding impact of a Probable Maximum Flood (PMF) evaluation (AREVA, 2014). PMF analysis addresses the applicable drainage area for potential flooding in streams and rivers adjacent to a site that may result in flooding at the site.

3.3.1 Method

A PMF is evaluated for CNP consistent with the Hierarchical Hazard Assessment (HHA) approach of NUREG/CR-7046 (NRC, 2011).

3.3.1.1 Site Hydrology

CNP is located within a series of heavily wooded sand dunes on the eastern shore of Lake Michigan. Ground elevation throughout the site (and surrounding dunes) ranges from about elevation 580 to 650 ft (CNP, 2013). Drainage in the area is generally westward toward Lake Michigan, and portions of the sand dunes in this area are characterized by poorly developed drainage systems with small lakes and swampy areas. The only nearby surface water channel, river, or stream to the site is the Thornton Valley Drain (AREVA, 2014). Keelo Creek, which is on the east side of I-94 is the next closest surface water channel, river or stream to the CNP site. At its closest point, Keelo Creek is 2 miles east from the CNP SSCs.

The basin draining to the CNP protected area was generated by tracing high points on the surrounding dunes to delineate the divide between the site watershed and areas flowing to the Thornton Drain to the east (AREVA, 2014). Figure 3-5 "Watershed Draining to CNP Critical Locations" shows the CNP protected area drainage basin. No intermittent streams were found on the western draining portion of the CNP property.

The watershed for CNP is depicted in Figure 3-5 "Watershed Draining to CNP Critical Locations" and drains directly to Lake Michigan (AREVA, 2014). The watershed contains all of the CNP safety related Structures, Systems, and Components (SSCs) which are relevant to the flooding hazard reevaluation due to the potential for floods to enter plant structures.

No assumptions were made for this analysis (AREVA, 2014).

3.3.2 PMF Results

3.3.2.1 Thornton Valley Drain Topography and Hydrology

An investigation of the United States Geologic Survey's National Hydrography Dataset (USGS NHD, 2013), shows no perennial or intermittent streams that would have the potential to impact the critical locations of the CNP site. Figure 3-6 "USGS Hydrography Dataset" shows the rivers and streams near the CNP site from the USGS NHD. The eastern portion of the CNP property is characterized by large coalescing sand dunes, some up to 150 ft tall. Precipitation falling on this portion of the property runs off to the Thornton Valley Drain (Figure 3-5 "Watershed Draining to CNP Critical Locations") which is, at its closest point, approximately ¼ mile east of the CNP Protected Area watershed boundary (area which drains to the Protected Area and the CNP SSCs). The drainage area of the Thornton Valley Drain watershed, as it passes along the eastern part of the CNP property is approximately 1.9 square miles. The Thornton Valley Drain flows northward to the Grand Mere Lakes and ultimately discharges surface water runoff to Lake Michigan approximately three miles north of the CNP Protected Area. Figure 3-7 "Thornton Valley Drain Flowpath" shows the flow path of the Thornton Valley Drain along I-94 and through the Grand Mere Lakes to Lake Michigan.

The Thornton Valley Drain is not adjoining the portion of CNP containing SSCs important to safety which are addressed in the flooding hazard reevaluation. These locations are in the western drainage basin, not in the

Thornton Valley Drain watershed (the SSCs are at least 1,700 ft west from the Thornton Valley Drain watershed boundary).

3.3.2.2 Watershed Division

The formation of the dunes and topography of the CNP site results in two distinct drainage basins within the CNP property. Two figures (Figure 3-8 "Watershed Division Map (elevations less than 626 ft)" and Figure 3-9 "Watershed Division Map (elevations greater than 626 ft)") are presented to render ground elevation from the detailed site topography (AREVA, 2013). Figure 3-8 and Figure 3-9 show a clear division between the eastern (draining to the Thornton Valley Drain) and western (draining directly to Lake Michigan) watersheds. Figure 3-8 shows the topographically lower portions of the CNP property (below the 626 foot level) which receive water from the higher portions of the property and discharge either to Lake Michigan on the west or the Thornton Valley Drain to the east. The CNP Protected Area and all safety related SSCs are located in the lowest part of the western watershed. Figure 3-9 shows the higher portions of the property (above 626 ft) and the north-south watershed divide.

The separation of colored areas in the lower elevation map (Figure 3-8) provides a visual demarcation of the two watersheds. Colored areas which are separated in Figure 3-8 (lower than 626 ft) but connected in Figure 3-9 (above 626 ft) indicate that the minimum basin division elevation (at the entrance road) is 626 ft. The watershed basin delineation is achieved by tracing the highest elevations in Figure 3-9 through the separated areas in Figure 3-8.

3.3.3 Conclusions

No surface water channels, rivers, or streams are present within or adjacent to drainage paths which contribute surface water runoff to the CNP Protected Area or the critical locations.

There are no surface hydrologic features identified by the USGS NHD as a perennial or intermittent stream in the vicinity of the CNP. The Thornton Valley Drain is the only nearby channel, and a preliminary screening dismisses the need for a PMF of this drainage feature since it is not adjoining, adjacent to, nor does it reside in the same drainage basin or watershed as the CNP SSCs important to safety.

Local topography defines a watershed basin division between the Thornton Valley Drain and the CNP critical location watersheds. There is no indication that a PMF event on the Thornton Valley Drain watershed would present a flooding hazard to CNP critical locations. As a result, Probable Maximum Flooding on Rivers and Streams is not a flood mechanism with potential to impact CNP SSCs important to safety.

3.3.4 References

AREVA, 2013. "Donald C Cook FHE Aerial Mapping Validation Report", AREVA Document No. 38-9207275-001, September 2013.

AREVA, 2014. "Probable Maximum Flood (PMF) for Cook Nuclear Plant Flood Hazard Re-evaluation," AREVA Document No.: 51-9214479-000, CNP Document No.: MD-14-FLOOD-009-N, Revision 0, April, 2014

CNP, 2013. "D.C. Cook Nuclear Plant Updated Final Safety Analysis Report (UFSAR)," Docket Nos. 50-315 and 50-316, Revision 25, September 9, 2013. (AREVA Doc. No. 38-9210897-000).

NRC, 2011. U.S. Nuclear Regulatory Commission "NUREG/CR-7046: Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America", Springfield, VA, National Technical Information Service, 2011 (ADAMS Accession No. ML 11321A195).

USGS NHD, 2013. "United States Geologic Survey National Hydrography Dataset. Michigan high definition NHD basemap data Sept, 2013. http://viewer.nationalmap.gov/viewer/nhd.html?p=nhd&b=base2&x=-

9632765.844079624&y=5157692.226378171&l=13&v=NHD%3A1%3B2%3B3%3B4%3B5%3B6%3B8%3B9%3B10%3B11%3B12%3B13%3B14, accessed November 6, 2013

Figure 3-5: Watershed Draining to CNP Critical Locations

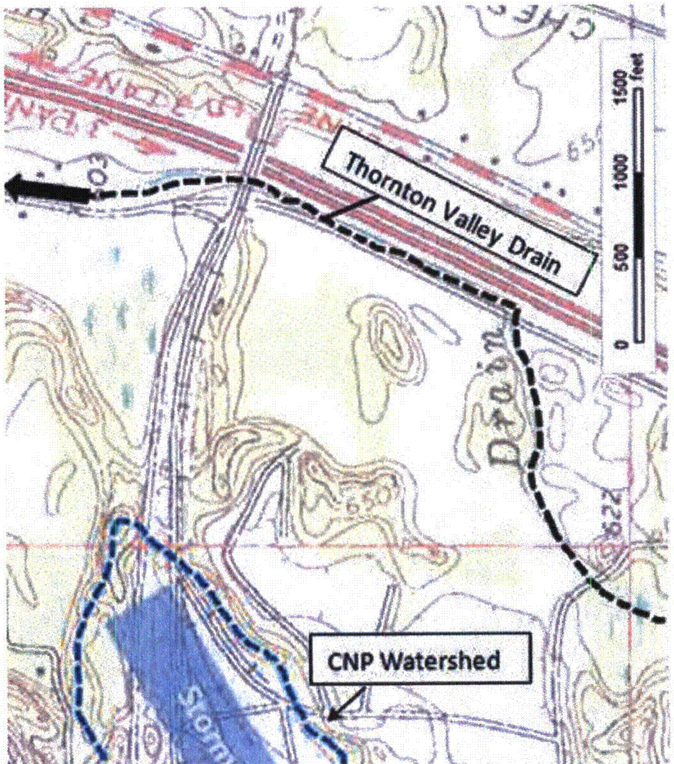


Figure 3-6: USGS Hydrography Dataset

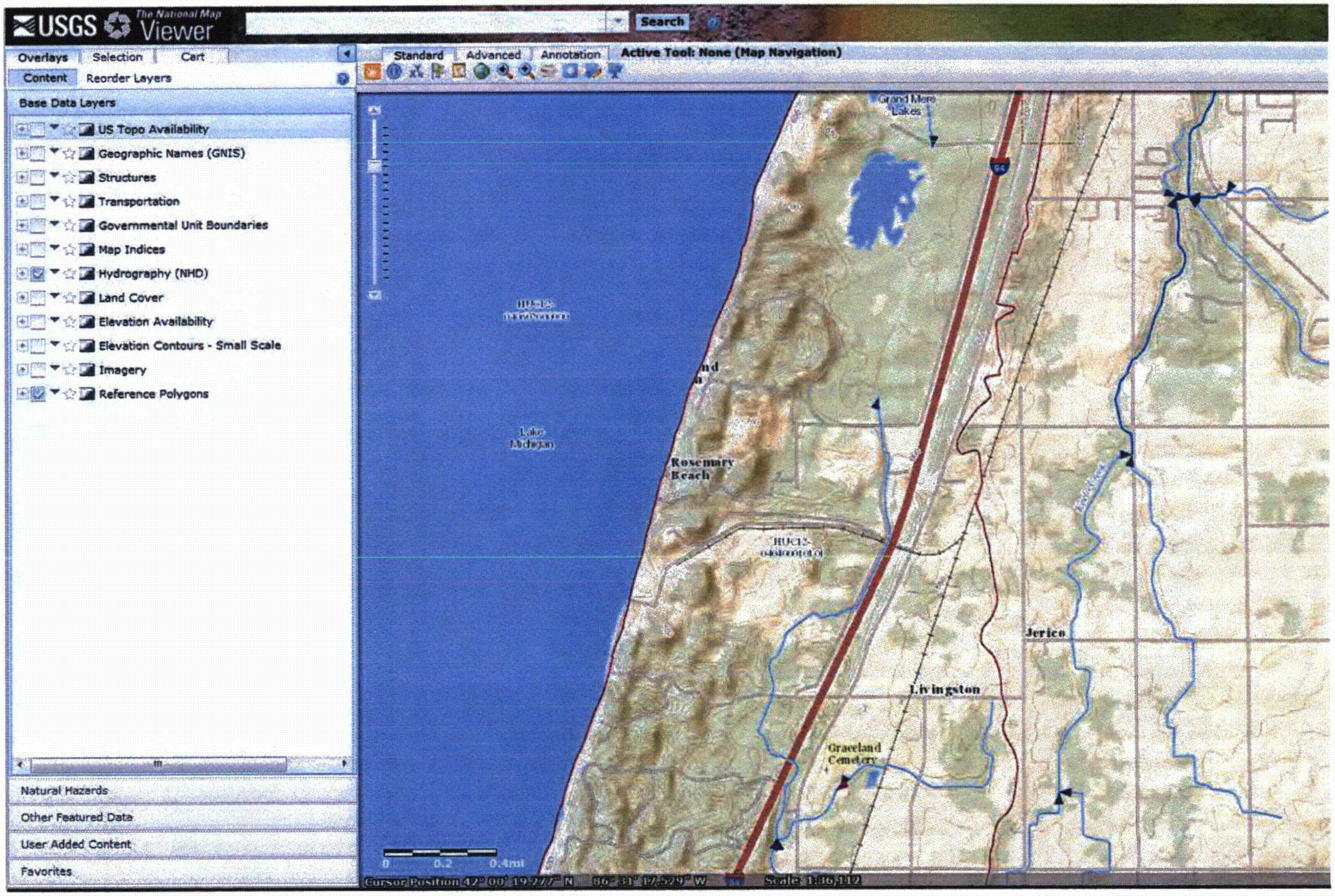
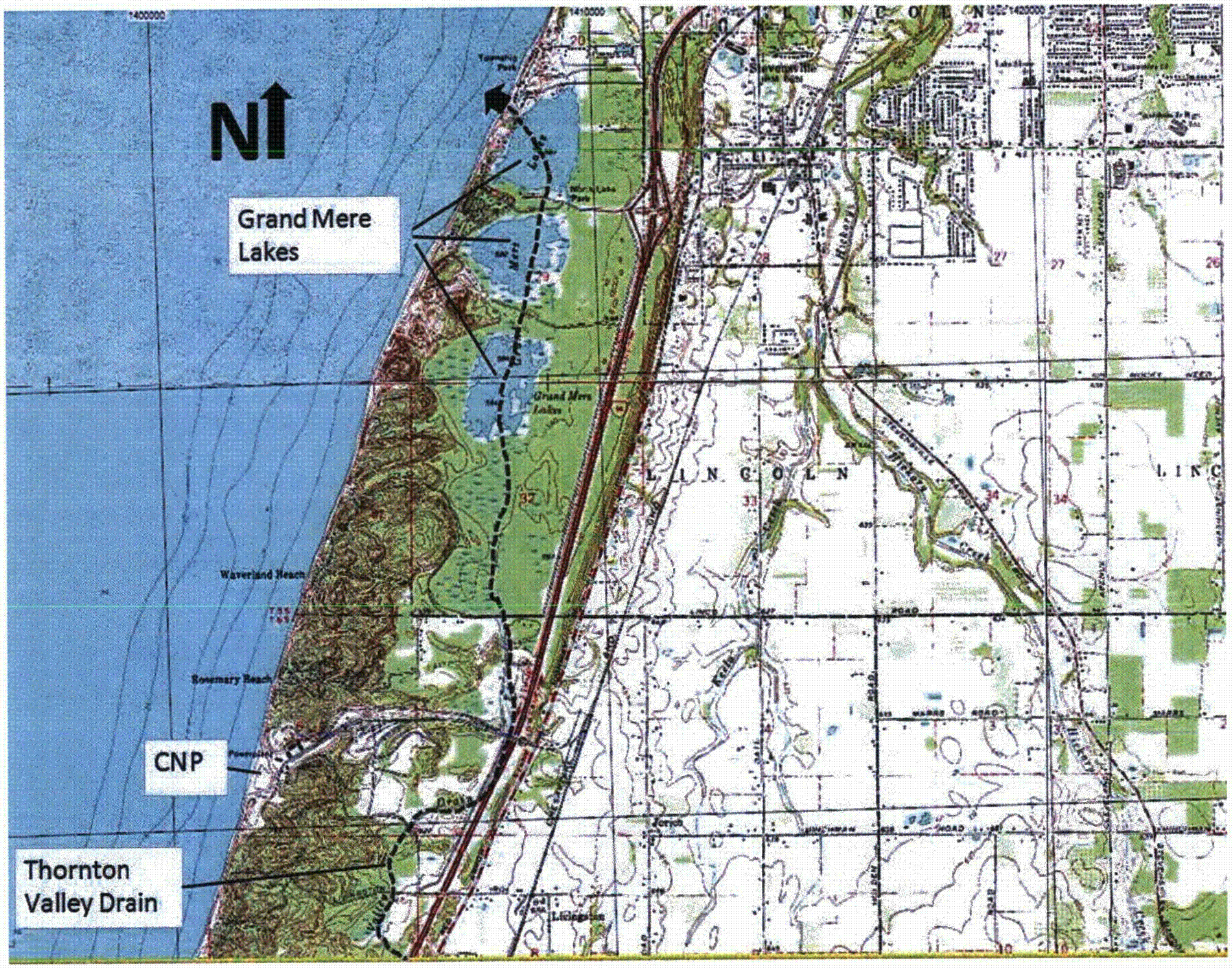
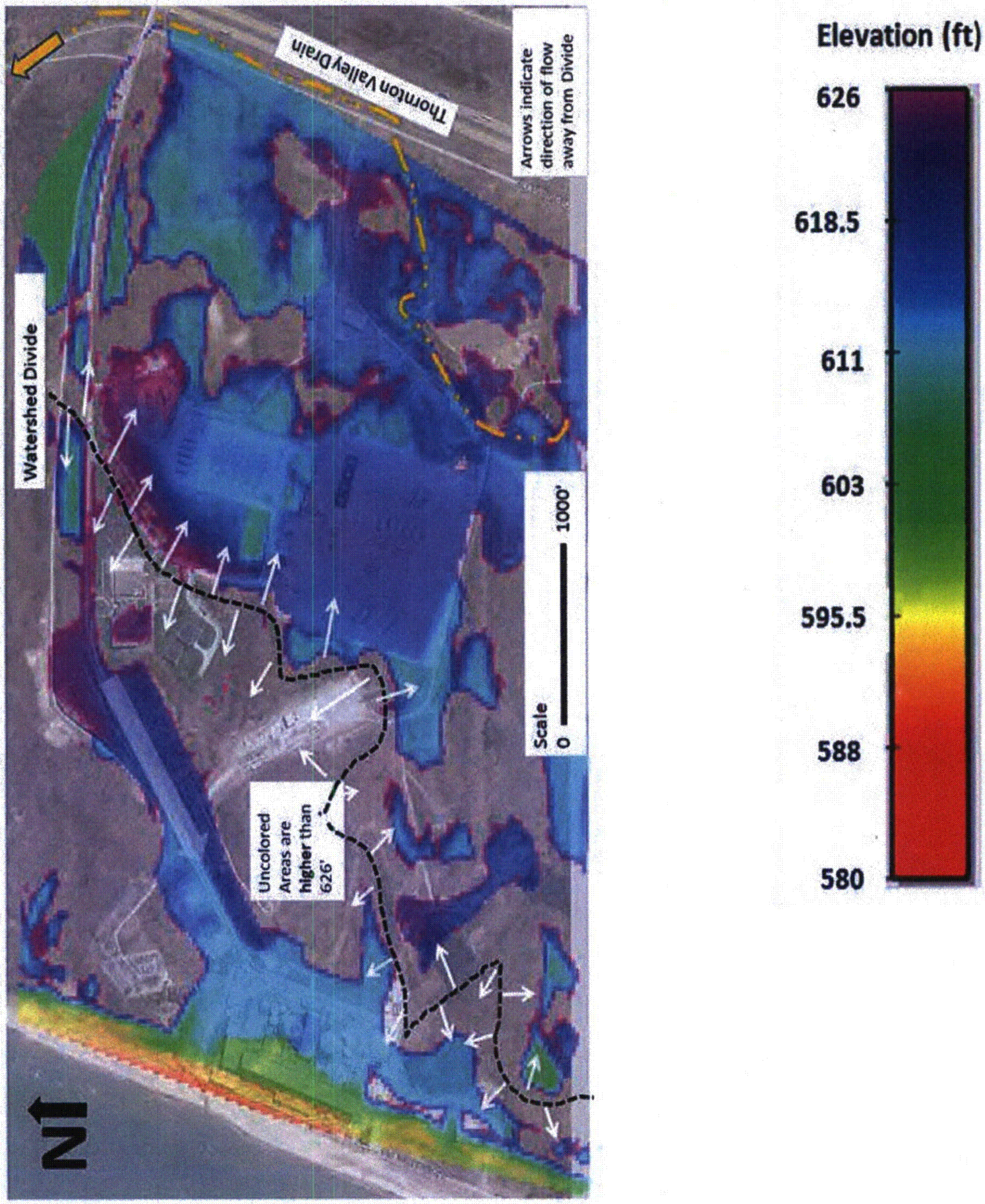


Figure 3-7: Thornton Valley Drain Flowpath



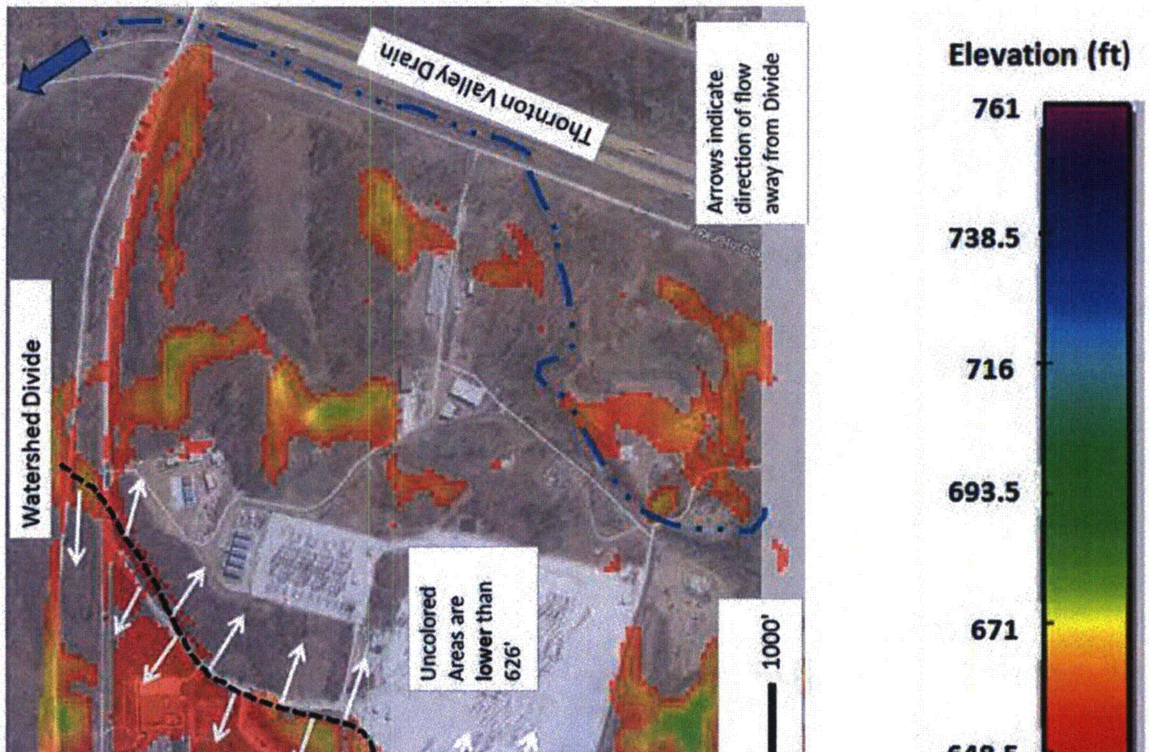
Any illegible text is not pertinent to the figure.

Figure 3-8: Watershed Division Map
(elevations less than 626 ft)



Any illegible text is not pertinent to the figure.

Figure 3-9: Watershed Division Map (elevations greater than 626 ft)



Any illegible text is not pertinent to the figure.

3.4 Dam Breaches and Failures

Analysis for dam breaches and failures addresses the potential for flooding at a site due to all manner of relevant dam or lock failures including multiple failures.

3.4.1 Method

The flood mechanism of dam breaches and failures on rivers or streams is not applicable to CNP. No dams exist on rivers or streams that might cause flooding of the CNP site. Potential failure of the Great Lakes lock system is described below.

Various channel ways connect the five Great Lakes, forming one system. Water is continually flowing from the headwaters of Lake Superior via the St. Mary's River, to Lake Huron and the remainder of the lake system. Lake Huron and Lake Michigan are connected by the deep Straits of Mackinac and are considered to be one lake hydraulically, having a common water level (USACE 1999).

Outflow from Lake Superior is controlled near the twin cities of Sault Ste. Marie, Ontario and Sault Ste. Marie, Michigan, by three hydropower plants, five navigation locks and a 16-gated controlled structure, called the Compensating Works. Outflows on Lake Superior have been regulated since completion of the Compensating Works in 1921. The locks at Sault Ste. Marie allow ships to travel between Lake Superior and the lower Great Lakes. Hence, the locks are essentially navigation structures and not water barriers. Outflow from Lake Superior is adjusted monthly in order to maintain the lake levels on Lake Superior and Lakes Michigan and Huron. Prior to man-made controls, a rock ledge at the head of the St. Mary's Rapids provided natural control for Lake Superior outflows. Evidence suggests that water levels on Lake Michigan and Lake Huron were 5 ft higher within the last 1,000 years, than they have been since the recording of lake levels in 1865 (USACE, 1999).

There are five locations on the Great Lakes where water is diverted into, out of, or between lake basins. The Long Lac and Ogoki diversions divert water into Lake Superior. These diversions take water from the Hudson Bay watershed and augment natural flows for hydropower plants in the northern part of Lake Superior. The nearest man-made water diversion to CNP is the Lake Michigan diversion at Chicago, known as the Chicago Sanitary and Ship Canal. The Chicago Sanitary and Ship Canal links Lake Michigan to the Mississippi River. Lake water has been diverted at Chicago since 1848 for various reasons, including water supply, sewage disposal and navigation. The Welland Canal is a navigational waterway between Lakes Erie and Ontario that allows ships to bypass the Niagara River's falls and rapids. This diversion also provides water for hydropower generation. The smallest of the five diversions is the New York State Barge Canal which draws water from the Niagara River and returns diverted water to Lake Ontario. The impact on the Great Lakes from the five man-made diversions has been determined to be insignificant compared to natural forces. For example, it has been determined that there is no measurable effect on the water level of Lakes Michigan and Huron from the cumulative impacts of all five diversions (USACE 1999).

Assumptions for this analysis were conservatively based on existing physical conditions. Although there are no dams, per se, on the Great Lakes (Superior, Michigan, Huron, Erie and Ontario), since the water level in Lake Michigan depends in part on discharge from Lake Superior through a lock system, the analysis conservatively assumed that the entire lock system between Lake Superior and Lakes Michigan and Huron fails along with man-made water diversion structures, simultaneously contributing to a rise in the level of Lake Michigan at the CNP site.

3.4.2 Results

3.4.2.1 Failure of Locks and Diversions

The CNP plant, specifically safety-related structures, systems and components (SSCs), is protected from lake flooding to elevation 594.6 ft. The CNP CLB uses a maximum lake elevation of 583.6 ft as a component of a maximum flood height. A conservatively assumed 5 ft increase due to dam failure on Lake Michigan would result in a flood elevation of 588.6 ft, 6 ft below the CLB elevation.

3.4.3 Conclusions

Based on conservative assumptions, potential breaches of the up-gradient locks and water diversion structures on the Great Lakes would not impact SSCs important to safety at CNP considering the following:

- The failure of the five, man-made water diversion structures on the Great Lakes have an insignificant impact on the water level of Lake Michigan.
- If the entire Sault Ste. Marie lock system fails and the water level of Lake Michigan instantly increases by 5 ft to its presumed natural level within the last 1,000 years (i.e., pre man-made alterations on the Great Lakes and lake tributaries), and the 5 ft is added to the high lake level used for the CLB, a margin of 6 ft would exist between the lake's water level and the CLB elevation.

3.4.4 References

USACE, 1999. Living with the Lakes: Understanding and Adapting to Great Lakes Water Level Changes, U.S. Army Corps of Engineers Detroit District and Great Lakes Commission, 1999.

3.5 Storm Surge and Seiche

This section summarizes the evaluation of the potential flooding impact of a storm surge and meteorologically-induced seiche (AREVA, 2014). Validation of all design inputs, assumptions, software, etc. is in the full evaluation (AREVA, 2014). The Surge and Seiche analysis addresses flooding from an adjacent water body due to a meteorological event including an increase in water elevation and wave runup.

3.5.1 Method

A storm surge and seiche flood is evaluated for CNP consistent with the Hierarchical Hazard Assessment (HHA) approach of NUREG/CR-7046 (NRC, 2011).

The evaluation of the Probable Maximum level of Lake Michigan caused by flooding due to storm surge or seiche (Probable Maximum Surge and Seiche event (PMS&S)) was determined for the CNP site. The evaluation uses recent work by the US Army Corps of Engineers (Melby, 2012; Scheffner, 2008; Scheffner, 1999a) and is based on a statistical analysis of the high water levels resulting from 150 historic storm events on Lake Michigan. The Empirical Simulation Technique (EST) is recommended to determine storm surge return periods for extra-tropical storms (NRC, 2013).

The U.S. Army Corps of Engineers (USACE) Coastal and Hydraulics Laboratory (CHL) of the Engineer Research and Development Center (ERDC) in Vicksburg, MS has recently completed a major study of the impact of historic storm events on Lake Michigan (Jensen, 2012; Melby, 2012; Nadal-Caraballo, 2012). This study was performed for the Federal Emergency Management Agency (FEMA) using the ADvanced CIRCulation (ADCIRC) long wave hydrodynamic model for the simulation of historic events impacting Lake Michigan. The 2012 USACE ADCIRC model (Melby, 2012; Scheffner, 2008; Scheffner, 1999a) is the most current and extensive resource available for studying surge and seiche on Lake Michigan and was selected as the basis for the CNP evaluation.

The storm and surge combination with an exceedance of $1x10^{-6}$ is considered as an acceptable risk level goal and is considered to envelope the Probable Maximum Surge and Seiche (PMS&S) (AREVA, 2014). Surge and seiche results at more frequent (higher) recurrence levels (1,000-yr and 10,000-yr) have higher confidence (lower uncertainty) are considered along with the $1x10^{-6}$ extrapolated surge and seiche magnitude.

Assumptions for this analysis were all verified:

- The storm and surge combination with an exceedance of $1x10^{-6}$ is considered to be an acceptable risk level goal and is considered to envelope the PMS&S (NRC, 2011). Surge and seiche results at more frequent (higher) recurrence levels (1,000-yr and 10,000-yr) have higher confidence (lower uncertainty) and are considered and presented along with the $1x10^{-6}$ extrapolated surge and seiche magnitude.
- Future storm events will be statistically similar in magnitude and frequency to past events (Scheffner, 1999a).
- Maximum drawdown caused by surge and seiche is equal to maximum peak of PMS&S.
- For HHA Step 1, the surge and seiche combine with a peak base Lake Michigan water surface level and wave runup and setup.
- Each storm event has an equal probability within the EST (storm consistency with past events) (Scheffner, 1999a).
- Considering the similarity of the beach profiles and the proximity of Holland MI to CNP, the wave runup and setup results from the ERDC/CHL study at the Holland gage was assumed to represent wave runup and setup for CNP (AREVA, 2014).

3.5.1.1 Computer Models

The USACE ADCIRC model application, (Jensen, 2012) represents a comprehensive study of Lake Michigan wave and water level modeling. The ADCIRC model utilizes a computational grid with 385,000 elements and 197,000 nodes to define the Lake Michigan study domain. The Lake Michigan model is part of a larger ADCIRC model (including Lake Huron) which has 778,000 elements and 409,000 nodes (Jensen, 2012). Figure 3-10 "ADCIRC Mesh Node Density" shows the ADCIRC node density near the CNP site; node spacing is about 1,000 to 1,500 ft on the shoreline by CNP. Results of the Jensen, 2012 wave and water level study are available at the output nodes shown in Figure 3-11 "ADCIRC Output Locations along the Banks of Lake Michigan." Figure 3-12 "ADCIRC Save Point 615 proximity to CNP" shows the location of ADCIRC model output node ("Save Point" 615) which was used for the statistical analysis described in this calculation.

Acceptable methods for computation of storm surge water levels are introduced in Section 3.3.3 of JLD-ISG-2012-06 "Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment Interim Staff Guidance" (referred to as "JLD-ISG-2012-06") (NRC, 2013) which states: "Storm surge models developed by Federal agencies, such as USACE or academic and research institutions, that are currently being used in standard engineering practice are adequate for storm surge hazard analysis." ADCIRC is the first model described in the JLD-ISG-2012-06 (NRC, 2013). ADCIRC's ability to simulate tidal circulation and storm-surge propagation over large computational domains (NRC, 2013) is an important feature for use in computing surge related water levels.

The EST computer program was used to extrapolate historic data to low probabilities to provide an extended simulation of storm surge and seiche response. The EST approach was developed by the USACE as a procedure for simulating multiple life-cycle sequences of nondeterministic multi-parameter systems such as storm events

(Scheffner, 1999a). The EST was utilized in this calculation at CNP. Use of the EST technique enhanced the USACE, 2012 ADCIRC dataset with a diverse set of storms based on historic observations.

3.5.1.2 Approach

Two approaches for evaluating the potential for and degree of extreme flood inundation at a specific location are described in NUREG/CR-7046 (Section 4 of NRC, 2011), a deterministic approach and a stochastic or probability approach involving the analysis of past events at a specific location. Due to the complicated nature and multiple driving functions of surge and seiche phenomena (wind direction and speed, storm intensity and storm track, pressure deficit, etc.) a singular, specific, and formulaic deterministic approach has not been developed for predicting Probable Maximum Surge and Seiche. The JLD-ISG-2012-06 guidance (NRC, 2013) considers the Empirical Simulation Technique (EST) "an option for a combined deterministic-probabilistic methodology" (NRC, 2013).

The USACE has developed and utilized stochastic procedures to understand storm events and their corresponding environmental impacts for complicated nondeterministic multi-parametric hazards such as storm events and their associated environmental impacts (Scheffner, 1999a). More than 14 US Army Corps of Engineer sponsored studies including the Brunswick Nuclear Generating Station (Scheffner, 1999b) have used the proposed EST methodology of applying combined or probabilistic methods to numeric models (i.e. ADCIRC) to quantify risk due to water surface elevation hazards. The JLD-ISG-2012-06 recommends using the Empirical Simulation Technique to determine return periods for extra-tropical storms (NRC, 2013).

The USACE's EST was utilized in this calculation to determine PMS&S for the CNP site. The EST is typically used for determining frequency of occurrence relationships by statistical resampling of historic data to develop joint probability relationships using various measured storm parameters. The EST resampling scheme generates large populations of data from limited historic datasets. With the expanded dataset the EST can simulate multiple time series of storm activity many times (Scheffner, 1999b). Very low probability (i.e. 1×10^{-6}) surge and seiche elevations (which are assumed to envelope the PMS&S) can be quantified by extrapolating final EST results and confidence intervals.

3.5.1.3 Storm Surge

Determination of a maximum storm surge and seiche water surface elevation for the CNP site requires a three part computation; peak base water level, storm surge and seiche, and wave runup/setup. Consistent with Step 1 of the NRC's HHA Process, the severe design storm event is assumed to occur at a time when the lake is at a historically high elevation or peak base water surface elevation. Over 150 years of data of water surface elevation data are available for Lake Michigan (USACE, 2012). Computation of a peak base water surface elevation for the lake is achieved using a rank ordering frequency computation technique. This procedure produces a long term design lake elevation on the order of hundreds of years. A stochastic frequency analysis based on the 150 historic severe storm events of the USACE, 2012 study was superimposed on the peak base lake water surface elevation to determine the peak base water surface elevation plus storm surge and seiche. Finally, a wave runup/setup component is added to the total. Required computations include those for 1) the peak base water surface elevation, 2) the stochastic storm surge, and 3) the wave runup and setup.

<u>Peak Base Water Surface Elevation</u>

Estimates of frequency-of-occurrence for the peak base water surface level begin with the calculation of a probability distribution function (PDF), using a procedure that makes use of the probability defined by the data and does not incorporate any prior assumptions concerning the probability relationship. Frequency-of-occurrence relationships are obtained by linear interpolation of stage from the PDF associated with the calculated return period (AREVA, 2014).

For the Lake Michigan data used in the ERDC/CHL study (USACE, 2012), over 150 years of monthly average water level (1860-2010), are available from the National Oceanic and Atmospheric Administration – NOAA, (Melby, 2012). The average long-term Lake Michigan lake levels are presented for nine locations (Melby, 2012, Figures 5 through 13). The record lengths of the nine gages vary so the results are difficult to compare or quantify. However, all values are in very close agreement leading to the statement that: "The record length does not have much of an impact on the average or the standard deviation of the average lake levels" (Melby, 2012). The calculated average of the mean monthly lake levels is 580.02 ft, with a maximum mean of monthly averages value of 580.1 ft at Milwaukee, Kewaunee, and Port Inland and a minimum mean of monthly averages of 579.8 ft at Calumet Harbor. Although the time periods of the data vary, the mean of monthly averages are in excellent agreement (within 0.3 ft).

3.5.1.4 Storm-induced Water Elevations – Storm Surge and Seiche

The EST storm surge magnitude was developed for addition to the peak long term average annual water level of Lake Michigan (defined above and shown in Figure 3-13 "Lake Michigan Water Surface Elevation").

150 severe extra-tropical events impacting Lake Michigan water surface elevations have identified (Melby, 2012). "The storm events were selected based on analysis of water level, wave and wind at ten long-term water level stations around Lake Michigan" (Melby, 2012). Each of these events was used to generate input data to the ADCIRC model (Jensen, 2012) over the domain shown in Figure 3-11 "ADCIRC Output Locations along the Banks of Lake Michigan". For a given storm, input parameters consisted of a spatial distribution of wind speed, direction, and pressure deficit at each of the 385,000 elements of the model grid for the temporal duration of the storm event.

3.5.1.5 Empirical Simulation Technique (EST) Approach to Frequency Estimates

The EST is a technique that simulates life-cycle sequences of cyclic multi-parameter systems such as storm events and their corresponding environmental impacts. The generalized approach is applicable to any cyclic or frequency-related phenomena (Scheffner, 1999a). The EST is based on a bootstrap resampling-with-replacement, interpolation, and subsequent smoothing technique in which random samplings of a finite length data base are used to generate a larger database. The EST's internal bootstrap resampling methodology builds on limited sets of observations (150 observed storm surge/seiche levels on Lake Michigan in this case) by varying input or driving parameters (wind speed, pressure deficit, and storm direction) to determine new responses (storm surge/seiche level). This approach is used to increase the number of surge events which can be used to extrapolate magnitudes of very low recurrence surge and seiche.

The EST begins with an analysis of historical storm events that have impacted a specific region. The ERDC/CHL study (Jensen, 2012; Melby, 2012; Nadal-Caraballo, 2012) is based on a selection of 150 historical extra-tropical events that have impacted the CNP site during the fifty year (1960-2009) wave magnitude period of record. The fifty year wave magnitude period of record began in 1960 when wave measurements were initially recorded for Lake Michigan. Each event was simulated with ADCIRC and the results were archived as previously described. The selected database of events was then parameterized to define:

- Descriptive characteristics of the event, and
- Response impacts of the event

For the CNP study, the response vector of interest is storm induced water surface elevation forced by the wind and pressure distribution of each of the 150 events. These data were then used as a basis for generating life cycle simulations of storm event activity with the EST. Details of the approach follow.

Once a set of historical events has been defined with each event represented by an appropriate input and response vector set, the EST can generate life cycle simulations. The EST process can be summarized as:

***Given** the historical data with input and response vectors for each storm*

***Produce** N simulations of a T-year sequence of events, each with their associated input vectors and response vectors.*

Two criteria are required of the T-year (T is the number of years) sequence of events. The first criterion is that the individual events must be similar in behavior and magnitude to historical events, i.e., the inter-relationships among the input and response vectors must be realistic. The second criterion is an assumption that the frequency of storm events in the future will remain the same as the past. The following sections describe how these two criteria are preserved.

The criterion for the first major assumption in the EST (that future events will be similar to past events) is maintained by insuring that the input vectors for simulated events are similar to those of past events and have similar joint probabilities to those historical or historically-based events of the training set. The simulation of realistic events is accounted for in the nearest-neighbor interpolation bootstrap re-sampling technique developed by Scheffner, 1999a.

The basic technique can be described in two dimensions as follows. Let $X_1, X_2, X_3, ..., X_n$ be n independent, identically distributed random vectors (storm events), each having two components $[Xi = \{x_i(1), x_i(2)\}; i=1,n]$. Each event X_i has a probability P_i as $1/n$; therefore, a cumulative probability relationship can be developed in which each storm event is assigned a segment of the total probability of 0.0 to 1.0. If each event has an equal probability (a basic assumption to the EST), then each event is assigned a segment s_j such that $s_j < X_j$. Therefore, each event occupies a fixed portion of the 0.0 to 1.0 probability space according to the total number of events in the training set. If each event has an equal probability, then each event is assigned a segment sj such that $s_j \rightarrow X_j$ and has probabilities defined by the following conditions:

$$\left[0 < s_1 \le \frac{1}{n}\right]$$

$$\left[\frac{1}{n} < s_2 \le \frac{2}{n}\right]$$

$$\left[\frac{2}{n} < s_3 \le \frac{3}{n}\right]$$

$$\vdots$$

$$\left[\frac{n-1}{n} < s_n \le 1\right]$$

A random number from 0 to 1 is selected to identify a storm event from the total storm population. The procedure is equivalent to drawing and replacing random samples from the full storm event population.

The EST is not simply a re-sampling of historical events technique, but rather an approach intended to simulate the input and response vector distribution contained in the training set database population. The EST approach is to select a sample storm based on a random number selection from 0 to 1 and then perform a random walk from the event Xi with x1 and x2 response vectors to the nearest neighbor vectors. The walk is based on independent uniform random numbers (-1,1) and has the effect of simulating responses that are not identical to the historical events but have reasonable combinations of driving factors and will enhance the historic dataset of similar to events which have occurred (Scheffner, 1999a).

The second criteria to be satisfied is that the total number of storm events selected per year must be statistically similar to the number of historical events that have occurred per year at the focus location. Given the mean frequency of storm events for a particular region, a Poisson distribution is used to determine the average number of expected events in a given year (Scheffner, 1999a). For example, the Poisson distribution ($\Pr(s;\lambda)$) can be written in the following form:

$$\Pr(s;\lambda) = \frac{\lambda^s e^{-\lambda}}{s!}$$

where for "s" events per year, λ is the historically based number of events per year.

3.5.1.6 Wave Runup/Setup

A required additional component of a total water elevation level analysis for CNP is the addition of wave induced runup and setup. The computed wave runup and setup is added to the Lake Michigan peak long term average annual water level and the computed storm surge.

The ERDC/CHL study computed estimates of combined wave runup and setup using data from nine NOAA water level gages on Lake Michigan. Figure 3-15 "ERDC/CHL Study Wave Gage Locations" shows the location of the wave and water level gages used in the ERDC/CHL study.

The Holland, MI water level gage is located 57 miles north from CNP (at 42.767 N Latitude and 86.200 W Longitude). This gage (NOAA wave gage #9087031) is the closest water level recording gage to the CNP site along an extent of comparable shoreline. Considering the similarity of the beach profiles and the proximity of Holland MI to CNP, the wave runup and setup results from the ERDC/CHL study at the Holland gage was assumed to represent wave runup and setup at CNP (AREVA, 2014).

3.5.2 Results

3.5.2.1 Peak Base Lake Level

Historic data for average annual Lake Michigan water levels is available online from the National Oceanic and Atmospheric Administration Great Lakes Environmental Research Laboratory (AREVA, 2014) for the period 1860-2012. An average of the average annual lake levels of the NOAA record of 1860-2012 data set yields an average Lake Michigan water surface elevation of 580.3 ft. The NOAA 1860-2012 lake level data are in good agreement with the long-term average of mean monthly average values for Lake Michigan reported by ERDC/CHL of 579.08 ft (AREVA, 2014). The NOAA average annual lake level data is slightly higher than the ERDC/CHL level (580.27 ft – 580.02 ft = 0.25 ft higher). Since the available NOAA average annual lake level data is in good agreement with the ERDC/CHL long term lake level study (Melby, 2012), the NOAA average annual lake level dataset was selected for the frequency analysis to determine a representative high lake level for the basis of the PMS&S calculation (AREVA, 2014).

Following the frequency calculation procedures described above with the NOAA 1860-2012 data, an average annual water surface elevation versus return period curve for Lake Michigan was calculated and is presented as Figure 3-13 "Lake Michigan Water Surface Elevation". The trend of lake level data versus return period was manually extended using a line to visually fit the observations and extrapolate average annual lake levels to peak base lake levels at very low recurrence levels. A Lake Michigan peak base lake level of 582.3 ft was determined to have a return period on the order of 1,000,000 years.

3.5.2.2 Storm Surge

The USACE's ADCIRC model generated water surface fluctuation results at each model node. Model surface elevation, atmospheric pressure, and directional wind velocity (U and V) results were then stored at each of the 916 save points for the 150 storm events. The nearest ADCIRC model output location to CNP is "Save Point" 615 which is located at 41.98024 N latitude, 86.56919 W longitude.

ADCIRC output at "Save Point" 615 for the 150 events in the ERDC/CHL study was used to compute long term storm surge estimates for the PMS&S calculation using the EST approach described above. The EST computes a mean value of surge and seiche magnitude versus recurrence for the 100 stage-frequency results of the EST analysis and a standard deviation. The mean and plus or minus one standard deviation EST output at CNP were plotted to define the storm surge and seiche frequency of occurrence relationship shown in Figure 3-14 "Surge and Seiche Magnitude Recurrence". The standard deviation is computed as a measure of variability and not for any specific quantitative purpose within the calculation. Use of one standard deviation to represent the variability of EST results is consistent with applications for standard use of the EST technique (Scheffner, 1999a). The surge and seiche magnitude trend was extrapolated fitting a power function trend through the last 10 points of the curve to determine a 6.9 foot PMS&S at a $1x10^{-6}$ recurrence level (a 7.1 foot surge and seiche would include 1 standard deviation in the PMS&S recurrence analysis).

3.5.2.3 Wave Runup

The ERDC/CHL study utilized the Stockdon equation to estimate wave runup and setup elevations on beach profiles based on deepwater wave parameters (Nadal-Caraballo, 2012).

Frequency estimates for both still water (surge only) and total water level (still water plus wave runup and setup) were obtained from the USACE (Scheffner, 2013) for beach profiles influenced by deep water wave conditions at the Holland gage. Figure 3-16 "Water Level and Water Level with Runup and Setup at Holland, MI Gage 9087031" shows the still water level and water level with runup and setup recurrence plots for the Holland, MI water level gage. At a 1-year recurrence level, the runup and setup curve is 2.5 ft higher than the still water curve (583.1 – 580.6 = 2.5 ft), and at a 1,000-year level the difference is 2.7 ft (586.2 - 583.5 = 2.7 ft). Considering this trend for water elevation data plotted against time on a logarithmic scale, (Figure 8 in AREVA, 2014), a conservative 3.0 foot difference at the 1,000,000-year level represents the difference between surge water level and surge water level plus wave runup and setup. Since the beach profiles are similar and due to the proximity of the Holland Gage to CNP, wave runup and setup in the vicinity of CNP is considered to be similar to the Holland Gage or 3.0 ft.

3.5.2.4 Uncertainty

The magnitude of a surge and seiche event is dependent on many driving factors including ambient lake level, wind speed and direction, pressure deficit, etc. The USACE has developed and utilized stochastic methods including the EST to evaluate environmental impacts for complicated nondeterministic events, such as surge and seiche.

From NUREG/CR-7046 (NRC, 2011), probabilistic techniques may be subject to uncertainty in estimated hazard magnitudes since historical data for extreme events are limited by the extent of the observed record. To bracket this uncertainty, the EST output plus one standard deviation value was plotted in Figure 3-14 "Surge and Seiche Magnitude Recurrence". The extension of plus and minus one standard deviation were fixed at the 200-year standard deviation based on a non-expanding trend in the standard deviation results from the EST.

3.5.3 Conclusions

The goal of the storm surge and seiche component of the CNP evaluation was to determine the potential for and severity of extratropical storm surge and seiche flooding at the CNP site. This goal was accomplished by evaluating three components: peak base Lake Michigan water level, surge and seiche magnitude, and wave runup and setup. The peak base Lake Michigan water surface elevation was calculated using historic data from NOAA (NOAA, 2012). The surge and seiche and wave runup and setup were derived from data developed by the USACE in their comprehensive ADCIRC study of water levels in Lake Michigan (Jensen, 2012; Melby, 2012; Nadal-Caraballo, 2012). Combining a 1×10^{-6} exceedance peak base lake elevation of 583.24 ft with a 6.9 ft to 7.1 ft surge and seiche (including 1 standard deviation), and a 3.0 ft wave runup and setup, results in a peak PMS&S water surface elevation of 593.3 ft.

This study indicates a PMS&S water elevation of 593.3 ft considering a peak base lake level of elevation 583.2 ft. If the calculated surge and seiche is added to the design-basis maximum monthly mean water elevation of 583.6 ft (AREVA, 2014), the PMS&S water elevation would be 593.7 ft. This elevation is lower than the seawall protecting CNP from Lake Michigan, which has a minimum elevation of 594.0 ft (CNP, 2013). Since the calculated PMS&S level is lower than the seawall protection elevation, the calculation ends with the first step of the HHA (if the site is not inundated by floods from the calculated storm surge and seiche to an elevation critical for safe operation of the SSCs, no further flood hazard assessment is required - Section 2 of NRC, 2011).

The potential for Surge and Seiche related drawdown of lake levels is assumed to be the same as the peak PMS&S (10.1 ft). Section 3.6 Tsunamis indicates 15.96 ft of margin between the historic minimum Lake Michigan water level and the required submergence water level for the Essential Service Water pumps. The margin is 5.9 ft greater than the 10.1 ft maximum potential PMS&S drawdown.

The JLD-ISG-2012-06, Sections 5.5 – 5,7 (NRC, 2013), indicates that hydrostatic and hydrodynamic forces and the effects of debris, water-borne projectiles, and sediment erosion and deposition should be determined when storm surge or seiche flood levels impinge on flood protection or safety-related SSCs. The computed PMS&S elevation of 593.3 ft NGVD29 is below the current lakeside seawall elevation of 594.0 ft (CNP, 2013). No flood protection, safety related SSCs, or foundation materials will be impinged upon by the PMS&S.

The results of this evaluation, a PMSS&S flood level elevation of 593.3 ft including 1 standard deviation in the PMS&S recurrence, indicate a Probable Maximum Surge and Seiche lower than the lowest plant grade elevation and the plant seawall (594.0 ft).

Combining a $1x10^{-6}$ exceedance peak base lake level of 583.2 ft with a 6.9 to 7.1 foot surge and seiche (including 1 standard deviation) yields a storm surge elevation of 590.3 ft. Adding the 3.0 foot wave runup and setup, results in a peak PMS&S water surface elevation of 593.3 ft. Results are summarized in Table 3-3 "Summary of total wave components used versus return period".

3.5.4 References

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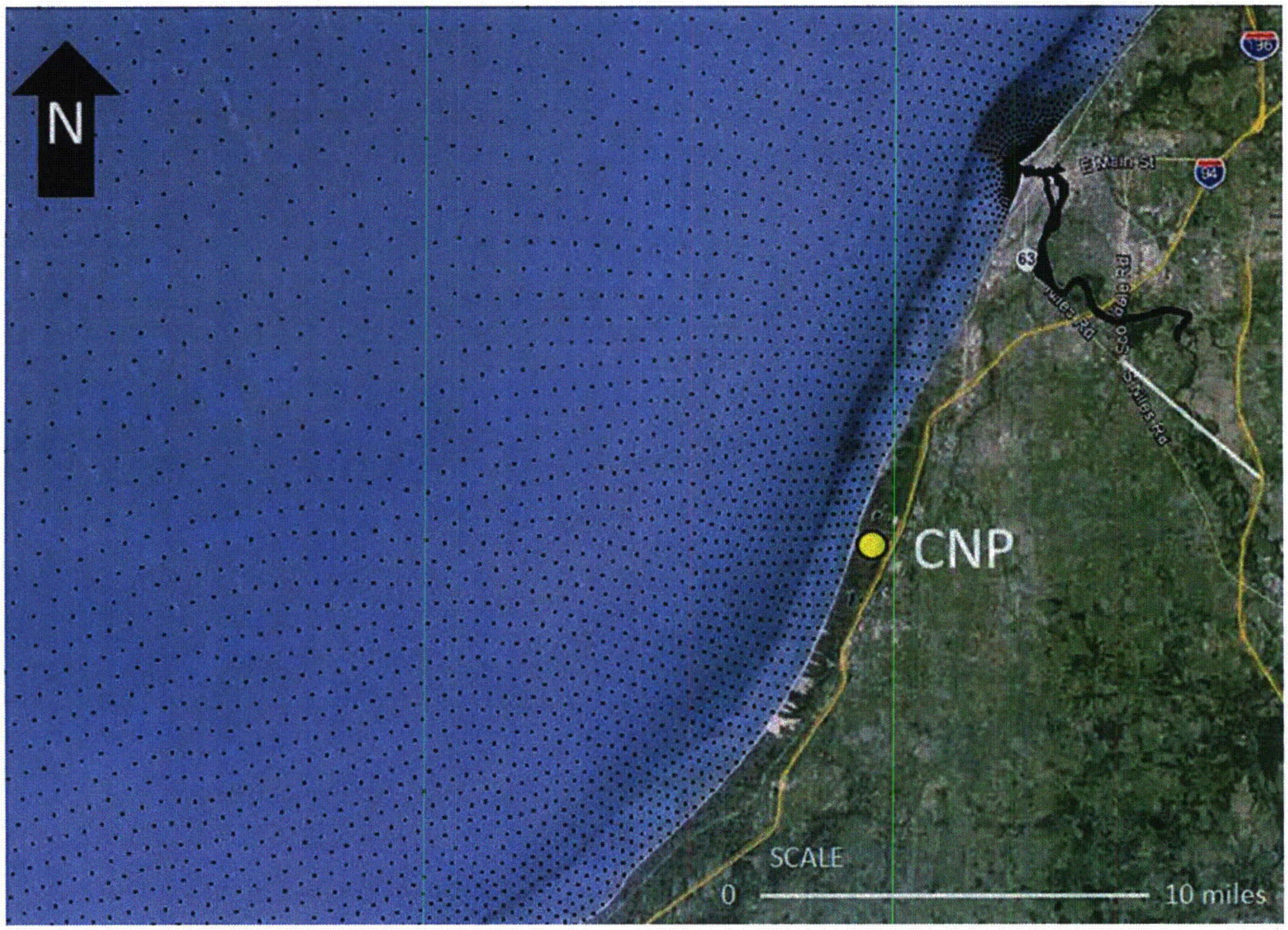
Table 3-3: Summary of Total Wave Components Used Versus Return Period

Return period	10	100	1,000	10,000	1,000,000
Long term lake level ft, IGLD85	581.11	581.89	582.07	582.13	582.30
Storm Surge and Seiche -ft	4.80	6.25	6.46	6.62	6.90
Wave setup/runup ft	2.60	2.60	2.70	2.80	3.00
TOTAL ft, IGLD85	588.51	590.74	591.23	591.55	592.20
Total NGVD 29	**589.45**	**591.68**	**592.17**	**592.49**	**593.14**

	Plus 1 STDev	Design Basis Lake Level Plus 1 STDev S&S
Return period	1,000,000	1,000,000
Long term lake level ft, IGLD85	582.30	582.66
Storm Surge and Seiche -ft	7.10	7.10
Wave setup/runup ft	3.00	3.00
TOTAL ft, IGLD85	592.40	592.76
Total NGVD 29	593.34	593.70

Figure 3-10: ADCIRC Mesh Node Density



Any illegible text is not pertinent to the figure.

Figure 3-11: ADCIRC Output Locations along the Banks of Lake Michigan

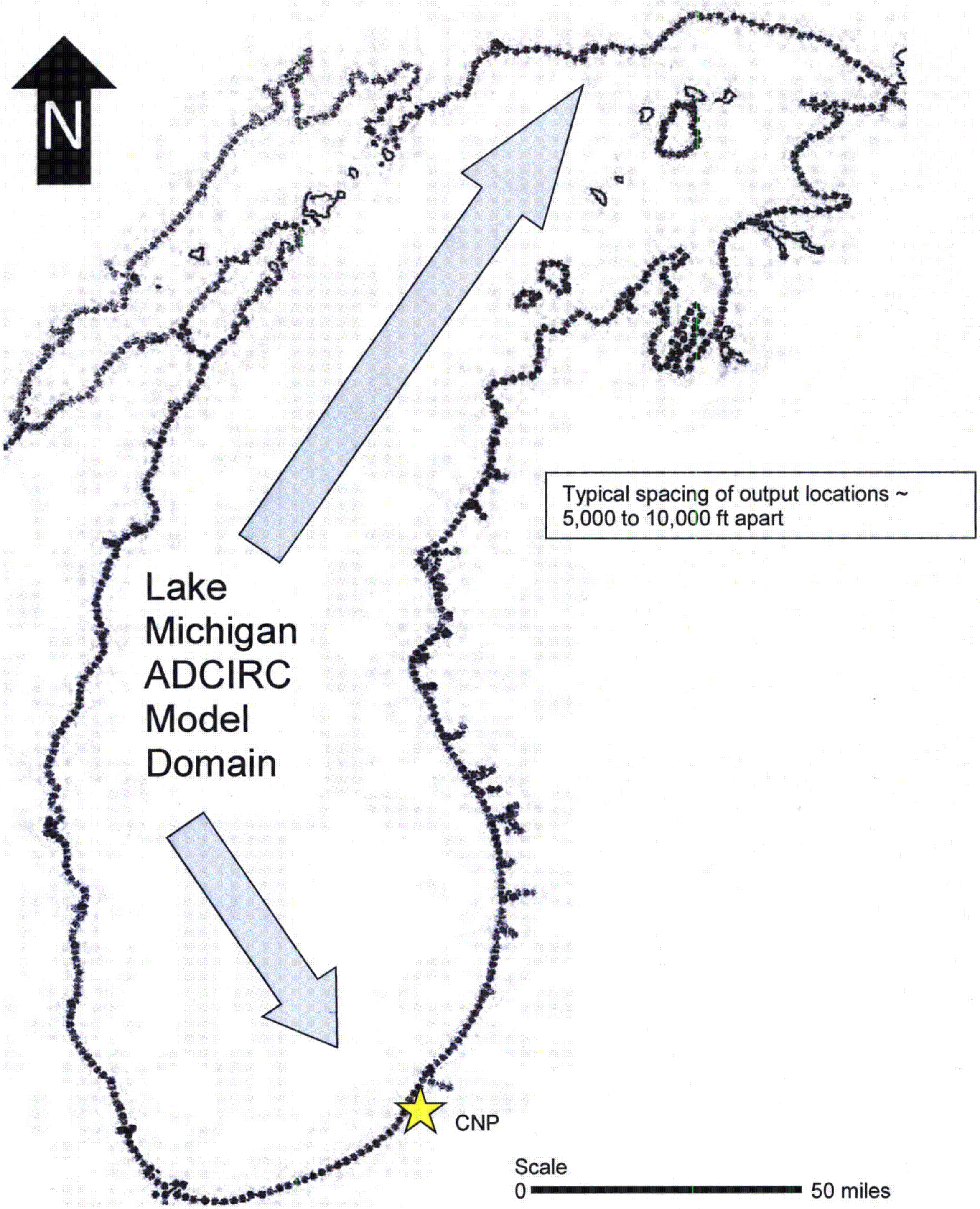


Figure 3-12: ADCIRC Save Point 615 proximity to CNP

Any illegible text is not pertinent to the figure.

Figure 3-13: Lake Michigan Water Surface Elevation

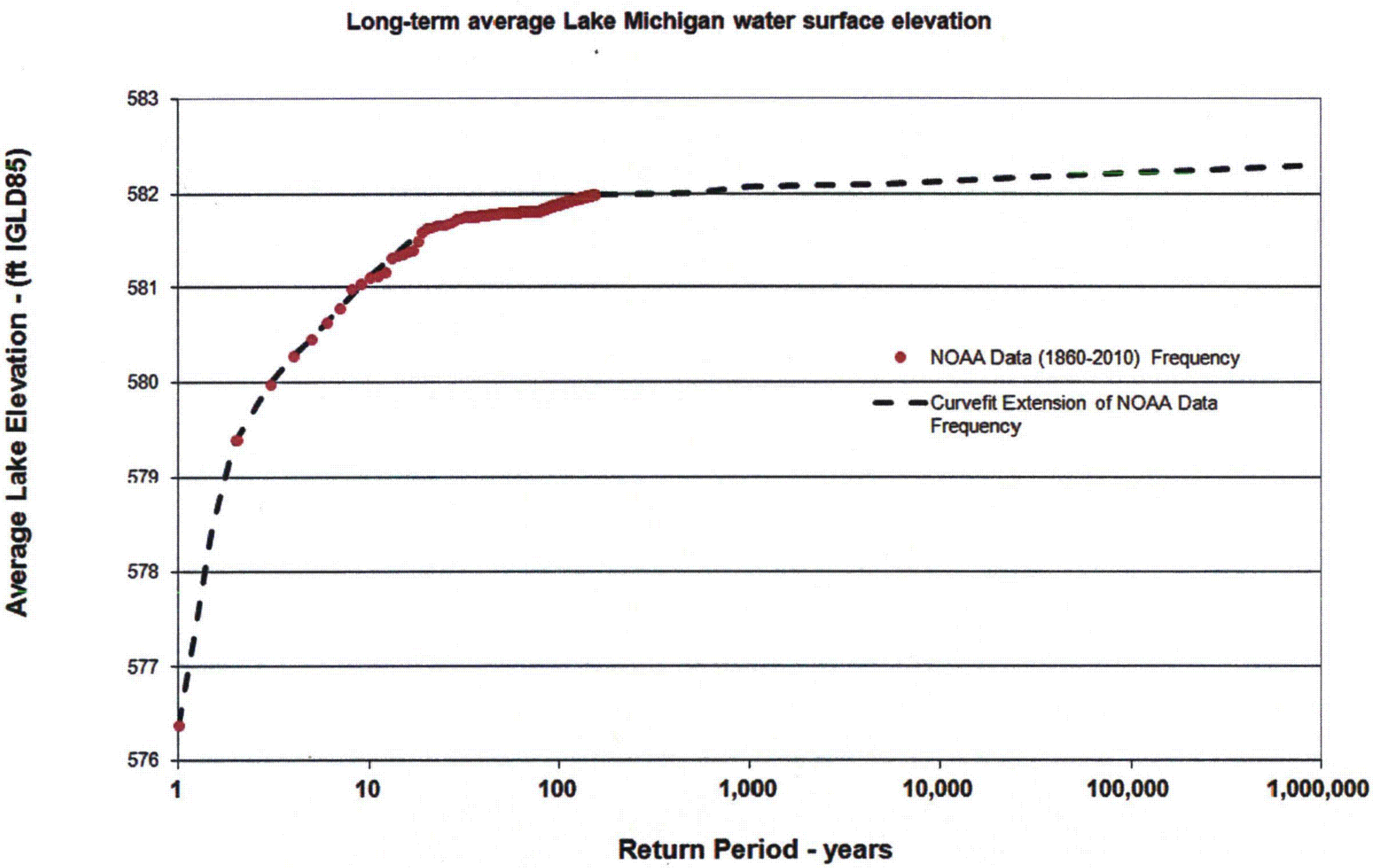


Figure 3-14: Surge and Seiche Magnitude Recurrence

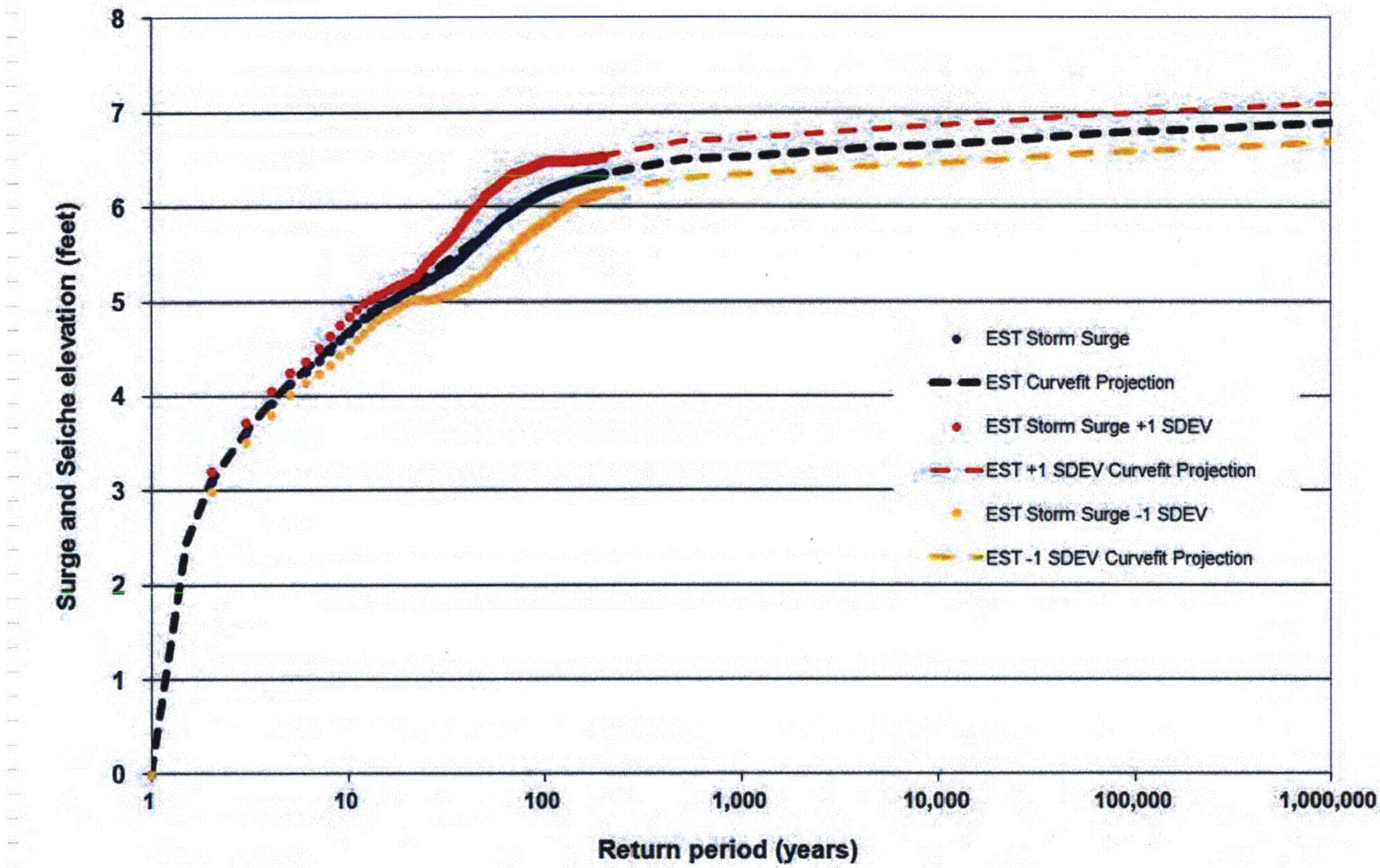


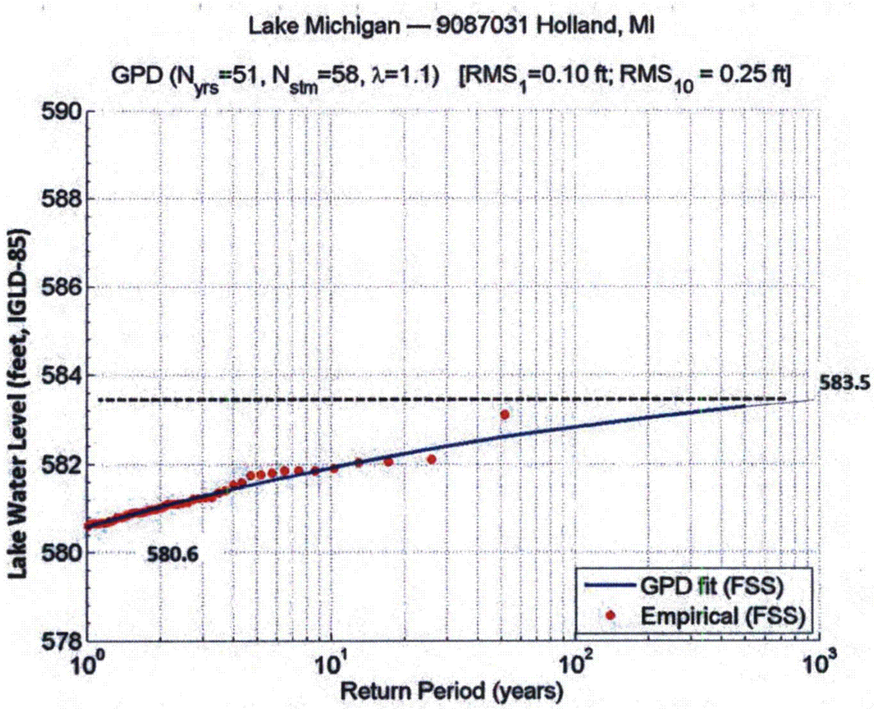
Figure 3-15: ERDC/CHL Study Wave Gage Locations

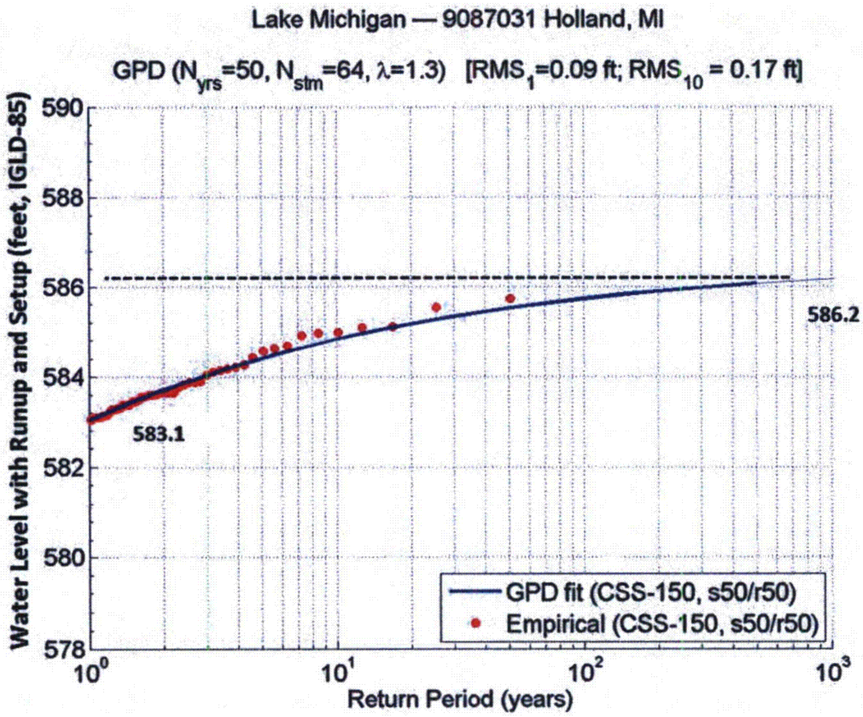
Figure 1. Locations of NOAA water level gages (three wavy lines), wave rider buoys (inverted teardrop) and meteorological (met) stations (flag) on Lake Michigan.

Station	Station ID	Latitude	Longitude	Hourly Records
Mackinaw City	9075080	45.777 N	84.725 W	1970 - 2010
Ludington, MI	9087023	43.947 N	86.442 W	1970 - 2010
Holland, MI	9087031	42.767 N	86.200 W	1970 - 2010
Calumet Harbor, IL	9087044	41.728 N	87.538 W	1970 - 2010
Milwaukee, WI	9087057	43.002 N	87.887 W	1970 - 2010
Kewaunee, WI	9087068	44.463 N	87.500 W	1973 - 2010
Sturgeon Bay, WI	9087072	44.795 N	87.313 W	1970 - 2010
Green Bay, WI	9087079	44.540 N	88.007 W	1970 - 2010
Port Inland, MI	9087096	45.968 N	85.870 W	1970 - 2010

Any illegible text is not pertinent to the figure.

Figure 3-16: Water Level and Water Level with Runup and Setup at Holland, MI Gage 9087031 (Reference 3.5.4.13)





3.6 Tsunamis

This section summarizes the evaluation for the potential flooding impact of a tsunami (AREVA, 2013). Tsunami analysis assesses the potential for site flooding due to seismic activity affecting an adjacent water body.

3.6.1 Method

A potential tsunami flood is evaluated for CNP consistent with the Hierarchical Hazard Assessment (HHA) approach of NUREG/CR-7046 (NRC, 2011). Analysis for tsunami hazard was performed based on NUREG/CR-6966 "Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America" (NRC, 2009) and JLD-ISG-2012-06 (NRC, 2013) related guidance.

A single assumption made for this analysis is that the amplitude of the drawdown from a tsunami-like wave is no larger than that of the runup (9 ft) for CNP.

3.6.2 Tsunami Results

A study was done to provide a basis for screening of a tsunami for the CNP site, following the hierarchical-hazard assessment (HHA) approach described in NRC, 2009 and related guidance, NRC, 2013.

With respect to tsunamis, the HHA is considered as a series of three tests or steps:

1. Is the site region subject to tsunamis?
2. Is the plant site affected by tsunamis?
3. What are the hazards posed to safety of the plant by tsunamis?

The first step is a regional screening test. If the site region is not subject to tsunamis, no further analysis for tsunami hazards is required. If the answer is yes, or undetermined based on available information, an analysis of the tsunami hazard is required in the second step.

The second step is a site screening test. The step determines whether structures, systems and components (SSCs) important to safety of the plant are exposed to hazards from tsunamis. If the answer is no, then no further action is required. If the answer is yes, however, then an additional analysis of the tsunami hazard is required in the third step.

The third step is a refined assessment, in which site-specific analyses are carried out to determine hazards posed by the Probable Maximum Tsunami (PMT) to the SSCs important to safety of the plant and to determine whether any protection is required. The step involves postulation of PMT source mechanisms, estimation of PMT source characteristics, initiation of the PMT wave, propagation of the PMT wave from the source toward the site, and estimation of tsunami hazards at the site.

3.6.2.1 Regional Survey

The Lake Michigan region was evaluated for the potential for tsunami occurrence. A regional survey and assessment of tsunamigenic sources was performed to determine the potential that a tsunami may pose a hazard to the CNP site. The regional survey was performed in four parts: 1) Review the Global Historical Tsunami Database, maintained by the National Oceanic Atmospheric Administration's National Geophysical Data Center (NGDC); and assessment of the mechanisms likely to cause a tsunami: 2) earthquake, 3) landslide, and 4) volcano.

3.6.2.2 NGDC Database Review

As an inland site, CNP need only consider the possibility of a tsunami-like wave in water bodies in the region (NRC, 2009). As a result, the regional survey based on a tsunami database (NOAA, 2013a) considered tsunami-like waves in the area around the Great Lakes.

Seven events in or near the Great Lakes are listed in the results of the regional survey (NOAA, 2013a). Two of the events on or near the Great Lakes (1823 and 1929) were confirmed as caused by earthquakes, two by meteorological conditions (1952 and 1954), one by a landslide (1912), and the two remaining unknown (1755 and 1884). The maximum event water height increase (1954) was nearly 10 ft. (3.00 m) in Lake Michigan and was related to a meteorological event. The maximum event water height related to an earthquake was 9 ft. (2.74 m) in Lake Erie (1823).

The seven events in the survey region produced 15 runup events, i.e., locations where tsunami-like effects occurred due to the tsunami source event (NOAA, 2013a). The 1811 runup was caused by an earthquake that occurred well outside the region (AREVA, 2013). As a result, the 1811 event was not part of the regional survey results. The most common landslide mechanism is an earthquake (NRC 2009).

3.6.2.3 Earthquakes

To generate a major tsunami, a substantial amount of slip and a large rupture area is required. Consequently, only large earthquakes with magnitudes greater than 6.5 generate observable tsunamis (NRC 2009).

The CNP Updated Final Safety Analysis Report indicates that seismicity of the CNP region is low (CNP, 2013). Only three recorded earthquakes with epicentral Modified Mercalli Intensities (MMI) of V or greater have occurred within approximately a 100-mile radius of the CNP site (CNP, 2013). The largest earthquake within 200 miles of the site had a maximum MMI of VII-VIII, and occurred 165 miles from the CNP site, equivalent to a magnitude of 6.0 to 7.0 (USGS, 2013b).

Updated seismological information for neighboring states south of and relevant to CNP is presented in the Safety Evaluation Report (SER) for the Exelon Generation Company Early Site Permit (ESP) application (NRC, 2006). The ESP site is located at the existing Clinton Power Station in east-central Illinois, about 170 miles southwest from CNP. The SER describes that region as one of moderate to large seismicity. Historical and estimated centers of large prehistoric earthquakes have occurred but well south and southeast of the ESP site (NRC, 2006, Figure 2.5.1-4). That study indicates that the largest regional seismic event was a magnitude 6.5, nearly 200 miles south of the CNP site (NRC, 2006).

Seismic activity outside the region was also considered because it could also produce tsunami like waves within the region (USGS, 2013a); for example, seismic waves from the Alaska earthquake of 1964 caused water bodies to oscillate at many places in North America. Favorable conditions for seismic seiche generation include thrust faults and locations controlled by structural uplifts and basins (USGS 2013a). The Lake Michigan region, however, lacks such features.

3.6.2.4 Landslides

Two broad categories of landslides exist: (1) subaqueous that are initiated and progress beneath the surface of the water body, and (2) subaerial that are initiated above the water and impact the water body during their progression or fall into the water body. In addition, landslide-generated tsunami-like waves have a very strong directivity in the direction of mass movement. Therefore, the outgoing wave from the landslide source propagates in the direction of the slide (NRC, 2009).

Also, the amplitude of the outgoing wave from a landslide is affected by the terminal velocity of the movement, which in turn is a function of the repose angle, i.e., the slope angle (NRC 2009). The steeper the slope angle, the greater the terminal velocity, and vice versa.

For Lake Michigan, the range of glacial soils present is enveloped by those described by (Evans, 1995) (very fine to very coarse: clays to sand and gravel). His conclusions are summarized as follows:

> "The limiting slope angle in the clays is estimated to be 15.7 degrees (1 in 3.6) above 6.5 m below the natural seabed and 36.9 degrees (1 in 1.3) below this depth. For a cohesive submarine slope the limiting slope angle is between 27 degrees (1 in 2) and 29 degrees (1 in 1.8).
>
> In the absence of external forces the limiting angle for the sands and gravels will be the friction angle, φ, i.e., 32.5 degrees (1 in 1.6) to 36 degrees (1 in 1.4)."

These cited slope angles provide a benchmark for slopes with failure potential in a seismic event. Based on Evans 1995, it is conservatively concluded that the angles of relevant subaqueous slopes present in Lake Michigan of less than 10 degrees do not approach sufficient steepness to provide an unstable slope condition that would result in a slope failure having a terminal velocity sufficient to produce a tsunami-like wave.

Additionally, the potential mass of a landslide is considered. The mass is a function of the bathymetric or topographic relief and the scale of the relief correlates directly with the mass. The larger the relief the more mass available and the smaller the relief the less mass available. Relevant conditions are described in subsections below.

3.6.2.5 Subaqueous Landslide - Lake Michigan Bathymetry

Studies considered the bathymetry of three areas of Lake Michigan: 1) the Chippewa Basin and the region to the north, 2) the Mid Lake Plateau, and 3) the South Chippewa Basin (NOAA 2013b & c).

The Chippewa Basin extends northward from the Two Rivers Ridge almost to the outflow point of the now-submerged Mackinac Channel (AREVA, 2013). Depths in excess of 275m (900 ft) are reached near the southern end of the basin. There are numerous ridges throughout the basin with the potential to produce a subaqueous landslide. However, the ridge locations, directional trending, and slopes make it unlikely that observable tsunami-like waves would be generated. The trending of ridges in the southern end of the basin is similar, with orientations that direct given a subaqueous landslide away from CNP. The only E-W trending ridge, the Door-Leelanau Ridge, has a slope of less than 2 degrees, a configuration judged unlikely to generate an observable tsunami-like wave.

The Mid Lake Plateau (AREVA, 2013) is a broad, relatively flat-topped ridge, which has lake depths of less than 90m (295 ft) and extends upward to minimum depths of 40-60m (131 to 197 ft). The steepest gradients occur on the northwest portion of the plateau abutting the Milwaukee Basin. The maximum slope in these gradient areas is about 2 degrees (AREVA, 2013). A subaqueous landslide in the area would be directed westward or eastward away from CNP.

The South Chippewa Basin, unlike the Chippewa Basin and Mid Lake Plateau, is characterized by linear bathymetry with uniform gradients. The maximum slope of gradients is in the SW portion of the basin, where the gradients trend NNE-SSW. Thus, a potential landside would be directed ESE toward CNP. However, the steepest slope in the area is less than 2 degrees and has a relief of only 10m (33 ft). Thus any landslide would be unlikely to generate an observable tsunami-like wave.

3.6.2.6 Volcanoes

The Global Historical Volcano Database, also maintained by the NGDC, was used to conduct a regional survey to determine if volcanic activity could be a mechanism to produce a tsunami or tsunami-like wave (NOAA 2013a).

The database survey area reviewed was the same as for the tsunami regional survey. No data were found (NOAA 2013a).

3.6.3 Conclusions

Based on historical records and the information above, the following conclusions are made:

- As an inland site, the CNP site is not subject to oceanic tsunamis; however, tsunami-like waves (seiches) have occurred in the Great Lakes region. Most of the reported waves were caused by meteorological conditions, but two were related to earthquakes and one to a landslide.
- Tsunami-like waves generated from:
  - an earthquake are limited because the required level of seismic activity for development of a tsunami, i.e., an earthquake with a magnitude greater than 6.5, is essentially absent within a 100-mile radius of the CNP site;
  - a subaqueous landslide is unlikely to generate an observable tsunami-like wave due to the limited bathymetric relief of ridges and their respective slopes and orientation; and
  - a subaerial landslide around the west, north, and east perimeter of the Lake Michigan is unlikely to affect CNP because topographic trends would direct any resultant tsunami-like wave away from the site. The exception is the southwest lake perimeter, where the topography is oriented such that a landslide and resultant tsunami-like wave, if it occurred, would be directed toward CNP. However, given a landside, it would cause little, if any, effect to the CNP site because of the limited topographic relief and slope angles.

Notwithstanding the occurrence of tsunami-like waves, the potential effects on the CNP site (wave runup, drawdown, and other effects assessed) are negligible because there is sufficient physical margin to protect SSCs important to safety. The margin is based on the maximum recorded tsunami-like wave resulting from an earthquake in the Great Lakes region occurring coincident with the maximum and minimum lake levels as it applies to the tsunami-like wave runup and drawdown, respectively. The study indicates a tsunami water elevation of 592.3 ft considering a peak base lake level of elevation 583.3 ft. If the derived tsunami elevation is added to the design-basis maximum monthly mean water elevation of 583.6 ft (AREVA, 2014), the tsunami water elevation would be 593.7 ft. This elevation is lower than the top elevation of the seawall protecting CNP from Lake Michigan, of 594 ft.

3.6.4 References

AREVA, 2013. Tsunami Hazard Assessment at Cook Nuclear Plant Site, AREVA Document No.: 51-9210054-000, CNP Document No.: MD- 12 -FLOOD-003-N, Revision 0.

AREVA, 2014. Surge and Seiche, Cook Nuclear Plant Flood Hazard Re-evaluation, AREVA Document 32-9208453-000, CNP Doc. No. MD-12-FLOOD-006-N

CNP, 2013. D.C. Cook Nuclear Plant Updated Final Safety Analysis Report (UFSAR), Docket Nos. 50-315 and 50-316, Revision 25, September 9, 2013. (AREVA Doc. No. 38-9210897-001)

Evans, 1995. Stability of Submarine Slopes, Geotechnical Engineering Office, Civil Engineering Department GEO REPORT No. 47, extracted from GEO Special Project Report No. SPR 4/94, Evans, N. C., June 1995.

NOAA, 2013a. National Oceanic Atmospheric Administration, National Geophysical Data Center, Tsunami Database; Available at: http://www.ngdc.noaa.gov/hazard/tsu_db.shtml; Accessed June 19, 2013.

NOAA, 2013b. National Oceanic Atmospheric Administration, National Geophysical Data Center, Bathymetry Website: http://www.ngdc.noaa.gov/mgg/greatlakes/greatlakes.html; Accessed June 18, 2013.

NOAA, 2013c. National Oceanic Atmospheric Administration, National Geophysical Data Center, Lake Michigan Bathymetry Website: http://www.ngdc.noaa.gov/mgg/greatlakes/lakemich_cdrom/html/geomorph.htm; Accessed June 18, 2013. (See AREVA, 2013TS, Figures 3 - 5).

NRC, 2006. U.S. Nuclear Regulatory Commission, NUREG-1844, Safety Evaluation Report for an Early Site Permit (ESP) at the Exelon Generation Company, LLC (EGC) ESP Site, Section 2.5, Geology, Seismology, and Geotechnical Engineering, May 2006 (ADAMS Accession No. ML061210203).

NRC, 2009. U.S. Nuclear Regulatory Commission, NUREG/CR-6966, Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America, March 2009. (ADAMS Accession No. ML091590193).

NRC, 2011. U.S. Nuclear Regulatory Commission, "NUREG/CR-7046: Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America", Springfield, VA, National Technical Information Service, 2011 (ADAMS Accession No. ML 11321A195).

NRC, 2013. U.S. Nuclear Regulatory Commission, Japan Lessons-Learned Project Directorate, JLD-ISG-2012-06. Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment. Interim Staff Guidance, Revision 0. January 2013, ADAMS Accession No. ML12271A036).

USGS, 2013a. U.S. Geological Survey, Seismic Seiches, Website: http://earthquake.usgs.gov/learn/topics/seiche.php; Abridged from Earthquake Information Bulletin, January-February 1976, Volume 8, Number 1; Accessed June 18, 2013.

USGS, 2013b. U.S. Geological Survey, Modified Mercalli Intensity Scale, Website: http://www.geo.mtu.edu/UPSeis /mercalli.html; Accessed June 19, 2013.

3.7 Ice-Induced Flooding

This section addresses the potential impact of ice-induced flooding at CNP (AREVA, 2014a). Ice-induced flooding analysis addresses the potential for flooding due to ice accumulation, forces and blockages.

3.7.1 Method

A potential ice-dam induced flood is evaluated for CNP consistent with the Hierarchical Hazard Assessment (HHA) approach of NUREG/CR-7046 (NRC, 2011). Further, NUREG/CR-7046 notes that at this time it is not possible to predict a probable maximum ice jam or dam accurately and, therefore, recommends that historical records of ice jams and dams be searched to determine the most severe historical event in the vicinity of the site.

Conditions warranting attention for this evaluation include:

- There are no perennial streams on the CNP site (CNP, 2013) or nearby (USGS, 2011) where ice could accumulate.
- The CNP site is adjacent to Lake Michigan (CNP, 2013).
- The CNP plant has no history of ice-induced flooding (CNP, 2014).

Per the HHA, Step 1, Lake Michigan is assessed based on the conservative assumption that ice formation might result in site flooding. Relative to ice-flooding issues, NUREG/CR-7046 notes that at this time it is not possible to predict a probable maximum ice jam or dam accurately and, therefore, recommends that historical records of ice jams and dams be searched to determine the most severe historical event in the vicinity of the site. The historical record is thus assumed as a basis for this report.

3.7.2 Results

3.7.2.1 Local and Regional Screening

There are no perennial streams on the CNP site (CNP, 2013) or nearby (USGS, 2011) where ice could accumulate.

Seasonal surface ice formation is typical on Lake Michigan. Surface ice formation typically proceeds from the shore outwards toward the center of the lake. Depending on the duration and intensity of freezing conditions on and around the lake, the extent of the ice cover can vary widely, depending on the severity of freezing conditions during the winter months. The extent of the ice cover on Lake Michigan is monitored in terms of the percentage of the surface area of the lake that is covered by ice.

While conditions exist for the formation of frazil ice along the Lake Michigan shoreline at the site and ice commonly forms along the lake shore in winter, neither that condition nor the potential for frazil ice is judged to provide a configuration that could promote site flooding. The elevation difference between the lake and Protected Area grade is 10 to 17 ft below the lowest area of plant grade at CNP at elevation 594 ft based on historical lake levels (NOAA, 2013). Thus the Protected Area grade is too far removed above the lake elevation to promote flooding due to ice formation on the lake or along its shoreline. Since no streams exist on the CNP site, damming of streams by ice is not a credible event.

3.7.2.2 Review of Historical Ice Events

Historical records of ice formation were reviewed for both Lake Michigan and local tributaries to the lake. Lake Michigan surface ice is common during winter and can vary over most of the lake's surface from 10% or less to 90% or more, with the surface ice cover forming from the shore outwards toward the center of the lake. But because the lake surface is well below the lowest elevation of plant grade, surface ice on the lake is not likely to provide any flooding impact on the CNP SSCs important to safety.

There are no perennial streams close to the site that would provide the potential of ice induced flooding at the CNP site. The nearest historical ice jams data on record in the site vicinity occurred on the St. Joseph River (AREVA, 2014a), more than 10 miles by water north of the site and thus impact on flooding for the CNP plant is not possible due to icing there.

The CNP plant has no historical records of flooding issues due to lake ice affecting the plant (CNP, 2014).

3.7.3 Conclusions

- Because the lake surface is well below the lowest elevation of plant grade, there is negligible risk that surface ice will result in any flooding impact on the CNP plant.
- There are no perennial streams close to the site that would contribute to the potential of ice induced flooding at the CNP site. Surface runoff is minor, and is restricted to a small intermittent stream that traverses the eastern portion of the site and discharges into Lake Michigan via Thornton Valley and the Grand Marais Lakes.
- Any potential for ice flooding at CNP, related to Lake Michigan, can inherently understood to be significantly bounded by flooding due to Storm Surge (AREVA, 2014b). As described in Sec. 3.8 of NUREG-7046 (NRC, 2011), such a condition eliminates further need for analysis for the ice-induced flood.

3.7.4 References

AREVA, 2014a. Ice Induced Flooding at the D.C. Cook Nuclear Power Plant Units 1 and 2, AREVA Document No.: 51- 9208865-000, CNP Document No.: MD-12 -FLOOD-007-N, Revision 0.

AREVA, 2014b. Surge and Seiche, Cook Nuclear Plant Flood Hazard Re-evaluation, AREVA Document 32-9208453-000, CNP Doc. No. MD-12-FLOOD-006-N.

CNP, 2013. "D.C. Cook Nuclear Plant Updated Final Safety Analysis Report (UFSAR)," Docket Nos. 50-315 and 50-316, Revision 25, September 9, 2013. (AREVA Doc. No. 38-9210897-001).

CNP, 2014. Lake Ice-Induced Flood History, AEP Design Information Transmittal DIT-B-03579-00, February 7, 2014 (AREVA Doc. No. 38-9219380-000).

NOAA, 2013. Great Lakes Water Level Dashboard Data Download Portal, Lake Michigan-Huron, National Oceanographic and Atmospheric Administration, date accessed August 12, 2013, http://www.glerl.noaa.gov/data/now/wlevels/dbd/GLWLDDataDownloads2.html.

NRC, 2011. U.S. Nuclear Regulatory Commission "NUREG/CR-7046: Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America", Springfield, VA, National Technical Information Service, 2011 (ADAMS Accession No. ML 11321A195).

USGS, 2011. Bridgman Michigan Topographic Quadrangle Map, Michigan-Berrien County, 7.5 Minute Series, 1:24,000, US Geological Survey.

3.8 Channel Migration or Diversion

Cooling water canals and channels are not part of the CNP plant design; therefore, this mechanism was not evaluated.

3.9 Groundwater Intrusion

This section addresses the potential flooding impact of at CNP due to groundwater intrusion (AREVA, 2014a). Groundwater analysis evaluated the potential for flooding due to an increase in groundwater level as a result of a site flood.

Groundwater intrusion into safety related structures is not considered a credible source during flooding events for CNP due to the inclusion of a water-proofing membrane on the exterior of subsurface foundations of the containment and auxiliary building structures. The effectiveness of that membrane waterproofing design is evaluated for this condition.

The portion of the containment building which is below the ground water table (GWT) has been waterproofed by means of a PVC 40 mil plastic membrane; the top of the membrane is at elevation 606 ft. Because of seasonal fluctuations in GWT, the membrane was applied well above the highest known GWT elevation (CNP, 2013a Section 5.2.2.6). The membrane placed under the mat extends up and around the walls and is taped to the membrane placed on the outside of the walls, thus providing a continuous waterproof surface (CNP, 2013a Section 5.2.2). This membrane extends at least 5 ft above the maximum known GW level. The water-proofing used provides adequate protection against flooding of areas located below the highest GW level (CNP, 2013a).

3.9.1 Method

Potential flooding due to groundwater level increase is evaluated for CNP consistent with the Hierarchical Hazard Assessment (HHA) approach of NUREG/CR-7046, Section 2 (NRC, 2011).

The method used to address this issue, by means of a beyond-design-basis (BDB) maximum groundwater level is to:

1. Review plant licensing documents and flooding walkdown results to determine if historical groundwater leakage with potential to impact safety-related plant structures has occurred or is anticipated to occur.
2. Estimate a BDB maximum groundwater level at the site based on existing groundwater monitoring data and related historic lake levels.
3. Compare designed groundwater protection features to BDB maximum groundwater levels at the site.

CNP does not have any site drainage or dewatering system that is relied upon to control the groundwater level. An increase in the groundwater elevation at the site is conservatively assumed for this analysis to be due to a depth of precipitation from the Local Intense Precipitation (LIP) event (17.5 inches) that was computed based on HMR 51 and HMR 52 and thus a value larger than the LIP level based on the site-specific PMP discussed in Section 3.1 of this report. All rainfall is assumed to infiltrate and raise the groundwater table by a proportional amount, modified for porosity percentage (43%). The membrane waterproofing is assumed to be functioning per design. A groundwater level at the shoreline of Lake Michigan is assumed to be equal to a probable maximum lake elevation of 583.24 ft (AREVA, 2014b).

A review of the groundwater protection program at CNP (CNP, 2012) interpolated a groundwater surface contour map for the site based on the site groundwater monitoring well network. Based on monitoring well data, the groundwater elevation at CNP site monitoring well MW-27 was 594.2 ft (CNP, 2012) in November 2012 had a mean Lake Michigan water level of 577.28 ft (NOAA, 2013), rounded to 576.3 ft. The November 2012 mean lake level is 6.0 ft lower than the probable maximum lake level of 583.24 ft (AREVA, 2014b).

Assumptions for this analysis were all verified:

- The increase in the groundwater elevation at the site is assumed to be equal to increases to the lake level consistent with standard groundwater behavior in porous soils.
- The depth of precipitation from the Local Intense Precipitation (LIP) event is assumed to infiltrate and raise the groundwater table by a proportional amount, modified for porosity percentage.
- The porosity of the dune sand water-bearing unit at CNP is assumed to be the arithmetic mean of porosity values for fine sands indicated in NUREG-3332 Table 4.3 (NRC, 1983). This value is 43%.
- The membrane waterproofing is assumed to be functioning per design.
- A groundwater level at the shoreline of Lake Michigan is assumed to be equal to a probable maximum lake level of 582.3 ft IGLD85. This is based on the Surge and Seiche, Cook Nuclear Plant Flood Hazard Re-evaluation calculation (AREVA, 2014b).

3.9.2 Results

Based on the conservative assumption that the maximum groundwater level varies directly with lake level, the maximum groundwater level at CNP can be inferred to be 600.2 ft NGVD29:

594.2 ft + 6.0 ft = 600.2 ft elevation

Therefore, total infiltration of the LIP rainfall is inferred to increase the potential MW-27 groundwater elevation by 3.4 ft to 603.6 ft (LIP depth divided by porosity).

17.5 inches / 0.43 = 40.7 inches / 12 inches/ft = 3.4 ft

600.2 ft + 3.4 ft = 603.6 ft elevation

A groundwater elevation of 603.6 ft is considered to be a potential maximum groundwater level at MW-27, which also represents a potential maximum groundwater level in the vicinity of safety-related plant structures.

Based on the potential BDB maximum groundwater elevation of 603.6 ft at monitoring well MW-27, safety-related structures at CNP have a minimum margin of 2.4 ft from the minimum membrane waterproofing protection elevation of 606 ft (CNP, 2013b).

Membrane Elevation 606 ft – Groundwater Elevation 603.6 ft = Margin 2.4 ft

3.9.3 Conclusions

Evaluation of the potential beyond design basis maximum groundwater elevation with respect to the minimum elevation of membrane waterproofing of safety-related structures indicates a minimum 2.4 ft physical margin.

3.9.4 References

AREVA, 2014a. Groundwater Assessment at Cook Nuclear Plant Site, AREVA Document No.: 51-9216206-000, CNP Document No.: MD-12 -FLOOD-008-N, Revision 0.

AREVA, 2014b. Surge and Seiche, Cook Nuclear Plant Flood Hazard Re-evaluation, AREVA Document 32-9208453-000, CNP Doc. No. MD-12-FLOOD-006-N.

CNP, 2012. "Hydrogeologic Review of Groundwater Protection Program", Donald C. Cook Nuclear Power Plant, Environmental Resources Management, December 2012. (AREVA Doc. No. 38-9217180-000).

CNP, 2013a. "D.C. Cook Nuclear Plant Updated Final Safety Analysis Report (UFSAR)," Docket Nos. 50-315 and 50-316, Revision 25, September 9, 2013. (AREVA Doc. No. 38-9210897-001).

CNP, 2013b. Containment and Auxiliary Building Exterior Waterproofing, AEP Design Information Transmittal, DIT-B-03572-00, December 17, 2013. (AREVA Doc. No. 38-9217092-000).

NOAA, 2013. "Great Lakes Water Level Dashboard", National Oceanic and Atmospheric Administration, http://www.glerl.noaa.gov/data/now/wlevels/dbd/, accessed December 6, 2013.

NRC, 1983. U.S. Nuclear Regulatory Commission, NUREG-3332, "Radiological Assessment; A Textbook on Environmental Dose Analysis", September 1983 (ADAMS Accession No. ML 091770419).

NRC, 2011. U.S. Nuclear Regulatory Commission "NUREG/CR-7046: Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America", Springfield, VA, National Technical Information Service, 2011 (ADAMS Accession No. ML 11321A195).

3.10 Combined Effect Flood

This section summarizes the Combined Effect Flood evaluation (AREVA, 2014a). All combined effect flood scenarios are evaluated and relevant combined-effects are addressed and quantified. Combined effect flood that is for a combination of flood causing mechanisms, is defined in NUREG/CR-7046, (NRC, 2011). In addition to those listed in NRC, 2011, additional plausible combined events are considered on a site specific basis and should be based on the impacts of other flood causing mechanisms and the location of the site.

3.10.1 *Method*

A potential combined effect flood is evaluated for CNP consistent with the Hierarchical Hazard Assessment (HHA) approach of NUREG/CR-7046 (NRC, 2011). Based on Section 3.9 and Appendix H of NRC, 2011 a screening for potential combinations of flooding hazards was made.

Dependent events such as wind waves, precipitation, snowpack, high tides, and storm surges (Appendix H of NRC, 2011) can occur concurrently. The five sets of Combined-Effect Floods potentially pertinent to CNP and listed in NRC, 2011 were evaluated:

- H.1 Floods Caused by Precipitation Events (on Rivers and Streams)
- H.2 Floods Caused by Seismic Dam Failures
- H.3 Floods along the Shores of Open and Semi-Enclosed Bodies of Water
- H.4 Floods along the Shores of Enclosed Bodies of Water
- H.5 Floods Caused by Tsunamis

Guidance also provides for analysis of local or site-specific flooding hazard combinations; in that case the Infiltration Pond (a natural pond) on the site was evaluated for overflow and pond bank stability in an LIP event.

Due to the location of CNP on the Lake Michigan shoreline and the absence of any perennial streams or rivers in its vicinity, only item H.4, Floods along the Shores of Enclosed Bodies of Water, and a site-specific issue of a precipitation causing flooding from the Infiltration Pond (a natural pond) on site were addressed.

Assumptions made for this work were all verified. They are:

- For CNP, 2013, General Notes: Elevations Indicate U.S.G.S. Datum". CNP Vertical Datum (U.S.G.S Datum) is assumed to be equivalent to NGVD29.
- For CNP, 1986, elevations are assumed to be consistent with other site drawings (in NGVD29 Vertical Datum).

3.10.2 Results

Results for combined effect flood categories screening are presented in Table 3-4 "Results for Combined Effect Categories Screening". The two relevant scenarios were addressed in detail.

3.10.2.1 H.4, Floods along the Shores of Enclosed Bodies of Water

CNP is located along the shore of an enclosed body of water (Lake Michigan). NRC, 2011, Section H.4 defines potential combined effects for a shore location as a combination of:

- Probable maximum surge and seiche with wind-wave activity
- The lesser of the 100-year or the maximum controlled water level in the enclosed body of water.

From the CNP Surge and Seiche Calculation (AREVA, 2014b), the Probable Maximum Surge and Seiche is 6.90 ft. Probable Maximum Wave Runup and Setup (wind-wave activity) is 3.0 ft (AREVA, 2014b).

The 1×10^{-6} exceedance Lake Michigan elevation, which is higher than the 100-year water level, is 583.24 ft. Adding the Probable Maximum Surge and Seiche and Probable Maximum Wave Runup and Setup with the Probable Maximum Lake level yields a combined effect flood level of elevation 593.3 ft.

The computed combined-effects surge and seiche, wind-wave activity, and Probable Maximum Lake level (elevation 593.3 ft) is lower than the lowest elevation of site grade at the CNP seawall, which was built at an elevation of 594.0 ft and lower than the CLB for flooding at CNP, elevation 594.6 ft.

3.10.2.2 Site-Specific Combined-Effects: *Infiltration Pond*

Site-specific combined-effects were evaluated for the Infiltration Pond (a natural pond) on the CNP site. The topography surrounding CNP is unique in that the undulating sand dunes on the east shore of Lake Michigan provide a disconnected topography which is characterized by hills and valleys occasionally forming isolated surface water bodies.

Distinctive topography and drainage patterns of the sand dunes in the vicinity of CNP results in a series of natural ponds located southeast from the CNP Protected Area. Figure 3-17 "Natural Ponds Southeast from CNP" shows the natural ponds in relation to the southern portion of the CNP Protected Area. The closest natural pond, shown in Figure 3-18 "Natural Pond Flowpath Away from CNP" is located approximately 500 ft southeast from the Protected Area at an elevation of 617.1 ft. The pond is used by the plant for the infiltration of clean plant discharge and is termed the Infiltration Pond.

The combined-effect investigated is an LIP leading to overflow from the Infiltration Pond or potential failure of the embankment separating the Infiltration Pond from the Protected Area. Such an overflow or failure could add to surface runoff to the Protected Area.

The following conditions exist for the Infiltration Pond shown in Figure 3-17 "Natural Ponds Southeast from CNP" and Figure 3-18 "Natural Pond Flowpath Away from CNP":

- A typical water surface elevation in the nearest natural pond is elevation 617.1 ft.
- The overflow drain at the southeast corner of that natural pond is at an elevation of 618.4 ft.
- The topographic saddle or lowest high point separating the natural pond from the CNP Protected area has an elevation of 647.0 ft.
- Overflow for the pond is away from the Protected Area

3.10.2.3 Infiltration Pond Capacity

Considering the topography surrounding the Infiltration Pond, a PMP event producing 20.2 inches of rain in 24 hours would not begin to challenge the maximum capacity of the pond nor would it come close to raising the Infiltration Pond water surface level to the crest of the 40 ft tall embankment which separates the Infiltration Pond from the CNP Protected Area. Overflow away from the CNP Protected Area towards the next natural pond (water surface elevation 611.6 ft, AREVA, 2014a) in a southeasterly direction begins at a pond elevation of 618.4 ft when the overflow becomes inundated.

3.10.2.4 Dune Slope Stability

A distance of 138 ft from the 647.0 ft elevation of the saddle (top of embankment) to the 612 ft elevation at the bottom of the hill southeast from the Supplemental Diesel Generators leads to a dune slope of 14 degrees on the plant side of the hill separating the nearest natural pond and the CNP Protected Area.

$$\text{Slope} = dy/dx = (647.0\text{ ft}-612.0\text{ ft})/138\text{ ft} = 0.25 \text{ or } 14°$$

An unvegetated dune slope of 14 degrees is considered to be stable since it is only half as steep as the minimum 30° angle of repose (the point at which natural sediment embankments begin to become unstable) of the non-cohesive sandy material tested by the U.S. Department of Transportation Federal Highway Administration in their Highways in the River Environment guidance (USDOT, 2001).

3.10.3 Conclusions

CNP is not susceptible to the H.4.1 Combined-Effect flooding hazard as the combined effect flood is lower than both the lowest site grade and the CLB for seiche flooding.

CNP is not susceptible to a flooding hazard resulting from overflow or slope failure of the natural pond used for infiltration at the south side of the CNP site (AREVA, 2014a).

3.10.4 References

AREVA, 2014a. Combined Effects Flooding, Cook Nuclear Plant Flood Hazard Re-evaluation, AREVA Document 32-9221721-000, CNP Doc. No. MD-12-FLOOD-010-N.

AREVA, 2014b. Surge and Seiche, Cook Nuclear Plant Flood Hazard Re-evaluation, AREVA Document 32-9208453-000, CNP Doc. No. MD-12-FLOOD-006-N.

CNP, 1986. "Topographic Survey March 1986 Sheet 4 of 9" (Status Approved). CNP Document No. 12-3000C, Revision 0.

CNP, 2013. "D.C. Cook Nuclear Plant Updated Final Safety Analysis Report (UFSAR)," Docket Nos. 50-315 and 50-316, Revision 25, September 9, 2013. (AREVA Doc. No. 38-9210897-000).

NRC, 2011. U.S. Nuclear Regulatory Commission "NUREG/CR-7046: Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America", Springfield, VA, National Technical Information Service, 2011 (ADAMS Accession No. ML 11321A195).

USDOT, 2001. "River Engineering for Highway Encroachments - Highways in the River Environment", U.S. Department of Transportation, Federal Highway Administration, Richardson, E.V., Simons, D.B., Lagasse, P.F. Publication No. FHWA NHI 01-004, December 2001.

Figure 3-17: Natural Ponds Southeast from CNP

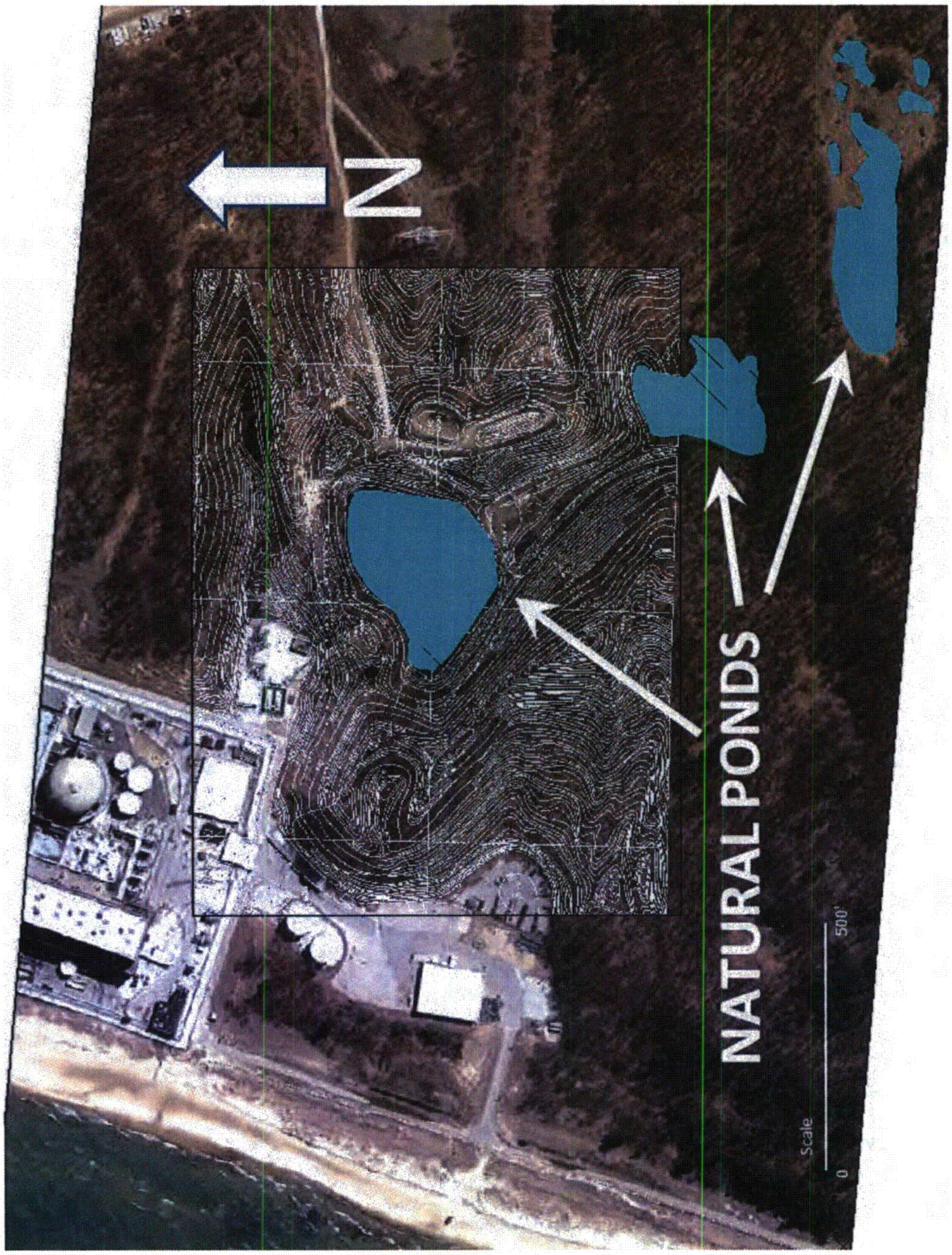


Figure 3-18: Natural Pond Flowpath Away from CNP

Any illegible text is not pertinent to the figure.

Table 3-4: Results for Combined Effect Categories Screening

	Screened as Not Applicable	Applicable and Addressed in Calculations
H.1 Floods Caused by Precipitation Events (River Flooding)		
H.1 Alternative 1	not streamside N/A	
H.1 Alternative 2	not streamside N/A	waves not an issue, snowpack addressed with LIP
H.1 Alternative 3	not streamside N/A	waves not an issue, snowpack addressed with LIP
H.2 Floods Caused by Seismic Dam Failures		
H.2 Alternative 1	no dams N/A	
H.2 Alternative 2	no dams N/A	
H.3 Floods Along the Shores of Open and Semi-Enclosed Bodies of Water		
H.3.1 Shore Location	not on Open Body of Water N/A	
H.3.2 Streamside Location Alt 1	not on Open Body of Water N/A	
H.3.2 Streamside Location Alt 2	not on Open Body of Water N/A	
H.3.2 Streamside Location Alt 3	not on Open Body of Water N/A	
H.3.2 Streamside Location Alt 4	not on Open Body of Water N/A	
H.4 Floods Along the Shores of Enclosed Bodies of Water		
H.4.1 Shore Location		Applicable and addressed
H.4.2 Streamside Location Alt 1	not streamside N/A	
H.4.2 Streamside Location Alt 2	not streamside N/A	
H.4.2 Streamside Location Alt 3	not streamside N/A	
H.5 Floods Caused by Tsunamis		
H.5.1 Shore Location	Inland Site Tsunami N/A	
H.5.2 Streamside Location Alt 1	Inland Site Tsunami N/A	
H.5.2 Streamside Location Alt 2	Inland Site Tsunami N/A	
H.5.2 Streamside Location Alt 3	Inland Site Tsunami N/A	
H.5.2 Streamside Location Alt 4	Inland Site Tsunami N/A	
Site Specific Combined-Effects		
Natural Ponds		Applicable and addressed

4.0 FLOOD PARAMETERS AND COMPARISON WITH CURRENT LICENSING BASIS

The current licensing basis (CLB) for CNP only considers a seiche flood (Section 2.3 of this report). The following flood mechanisms were addressed in response to the 10 CFR 50.54(f) letter (NRC, 2012a):

LIP

PMF

Dam Breaches or Failures

Storm Surge and Seiche

Tsunamis

Ice-Induced Flooding

Channel Migration or Diversion

Groundwater Intrusion

Failure of an onsite pond (Infiltration Pond)

Combined Effect Flood

All of the above flooding mechanisms were determined to be either screened out (not applicable) or below the CLB flood elevation of 594.6 ft with the exception of LIP. The findings from Enclosure 4 of the 50.54(f) letter (i.e., Recommendation 2.3 flooding walkdowns) support this determination. Details are provided in Section 4.1.

Enclosure 2 of the10 CFR 50.54(f) letter requests the licensee to perform an integrated assessment of the plant's response to the reevaluated hazard if the reevaluated flood hazard is not bounded by the CLB (NRC, 2012a). This section provides comparisons with CLB flood hazard and applicable flood scenario per Section 5.2 of JLD-ISG-2012-05 (NRC, 2012b), LIP:

1. Flood event duration parameters (per Figure 6 of NRC, 2012b, shown below,)
    a. Warning time (may include information from relevant forecasting methods (e.g., products from local, regional, or national weather forecasting centers) and ascension time of the flood hydrograph to a point (e.g. intermediate water surface elevations) triggering entry into flood procedures and actions by plant personnel).
    b. Period of site preparation (after entry into flood procedures and before flood waters reach site Protected Area grade).
    c. Period of inundation.
    d. Period of recession (when flood waters completely recede from site and plant is in safe and stable state that can be maintained).
2. Plant mode(s) of operation during the flood event duration.
3. Other relevant plant-specific factors (e.g. waterborne projectiles).

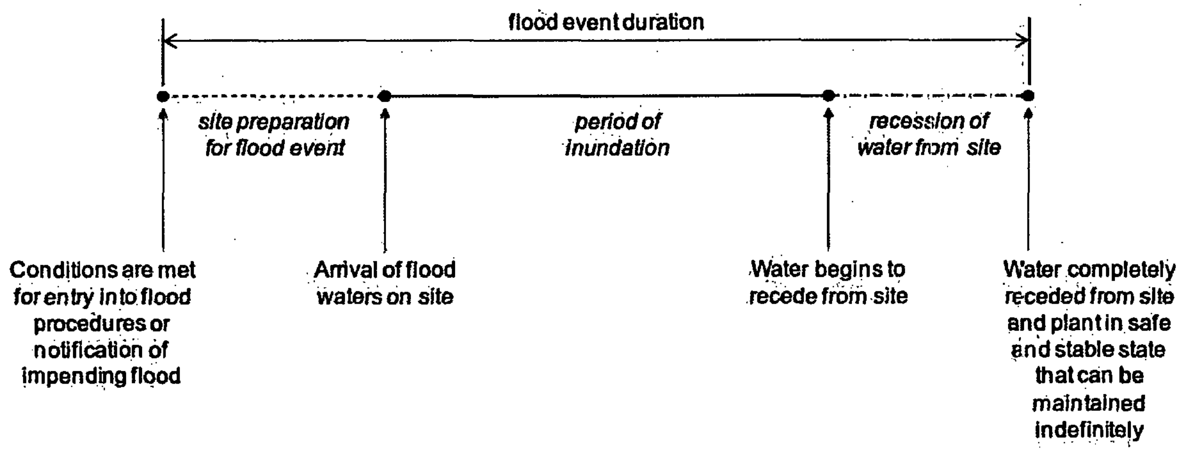


Illustration of Flood Event Duration (from Figure 6 of JLD-ISG-2012-05 NRC, 2012b)

Per Section 5.2 of JLD-ISG-2012-05 (NRC, 2012b), flood hazards do not need to be considered individually as part of the integrated assessment. Instead, the integrated assessment should be performed for a set(s) of flood scenario parameters defined based on the results of the flood hazard reevaluations. In some cases, only one controlling flood hazard may exist for a site. In this case, licensees should define the flood scenario parameters based on this controlling flood hazard. However, sites that have a diversity of flood hazards to which the site may be exposed should define multiple sets of flood scenario parameters to capture the different plant effects from the diverse flood parameters associated with applicable hazards. In addition, sites may use different flood protection systems to protect against or mitigate different flood hazards. In such instances, the integrated assessment should define multiple sets of flood scenario parameters. If appropriate, it is acceptable to develop an enveloping scenario (e.g., the maximum water surface elevation and inundation duration with the minimum warning time generated from different hazard scenarios) instead of considering multiple sets of flood scenario parameters as part of the integrated assessment. For simplicity, the licensee may combine these flood parameters to generate a single bounding set of flood scenario parameters for use in the integrated assessment.

4.1 Summary of Current Licensing Basis and Flood Reevaluation Results

This section compares the current and reevaluated flood-causing mechanisms. It provides a comparison of the CLB flood elevation to the reevaluated flood elevation for each applicable flood-causing mechanism. A comparison of the CLB elevations and the reevaluated flood elevations is provided in Table 4-1 "Flood Elevation Comparison".

4.1.1 Local Intense Precipitation

Flood hazard due to local intense precipitation was not evaluated as part of the CLB; therefore no comparison can be made with the present day LIP results at CNP. Table 4-2 "LIP Flood Heights at Select Locations" gives LIP flood elevations at select locations. LIP reevaluation analysis is provided in AREVA, 2015. The LIP elevations at some locations are above the CLB elevation of 594.6 ft.

4.1.2 Probable Maximum Flood on Rivers and Streams

Flood hazard due to probable maximum flood on rivers and streams was not evaluated as part of the CLB; and is not applicable to the present day site. Justification, including basis for inputs and assumptions, methodologies and other pertinent data, is provided in AREVA, 2014b.

4.1.3 Storm Surge & Seiche

Flood hazard from a weather-driven seiche (seiche) on Lake Michigan with a maximum height of 11 ft above record high lake level: a flood elevation of 594.6 ft is given in the CLB. The flood hazard reevaluation determined that a storm surge of 7.1 ft at a $1x10^{-6}$ recurrence level elevation of 590.3 ft is the controlling coastal event. PMS&S reevaluation analysis is provided in AREVA, 2014c. The reevaluated PMS&S elevation is below the CLB flood elevation of 594.6 ft.

4.1.4 Dam Breaches and Failures

Flood hazard due to dam breaches and failures was not evaluated as part of the CLB. The flood elevation due to dam breaches was conservatively determined to be 588.6 ft, 6 ft below the CLB elevation of 594.6 ft.

4.1.5 Tsunami

A flood hazard elevation due to a tsunami was not evaluated as part of the CLB. The flood elevation due to a tsunami was conservatively determined to be 593.7 ft (Section 3.6.3) which is below the CLB elevation of 594.6 ft.

4.1.6 Ice-Induced Flooding

Flood hazard due to ice-induced flooding was not evaluated as part of the CLB. Any potential for ice-induced flooding at CNP, related to Lake Michigan, would be significantly bounded by flooding due to Storm Surge (AREVA, 2014d); therefore, the flood elevation due to ice-induced flooding is below the CLB elevation of 594.6 ft.

4.1.7 Groundwater Induced Flooding

Potential for flooding due to groundwater intrusion was recognized for the original plant design and waterproofing membrane is installed on subgrade foundation walls of major structures extending at least 5 ft above the maximum known GW level (approximately elevation 585 ft). Groundwater induced flooding reevaluation is provided in AREVA, 2014e and indicates that groundwater is below the membrane waterproofing of SSCs important to safety; therefore no SSCs important to safety will be impacted by groundwater induced flooding.

4.1.8 Channel Migration or Diversion

Flood hazard due to channel migration or diversion was screened as part of the CLB and the Flood Hazard Reevaluation at CNP. No channels or diversions exist at the CNP site.

4.1.9 Combined Effect Flood

Flood hazard due to a combined effect flood was not evaluated as part of the CLB. Based on the reevaluation, the 1×10^{-6} exceedance Lake Michigan elevation, which is higher than the 100-year water level, is 583.24 ft. Adding the Probable Maximum Surge and Seiche and Probable Maximum Wave Runup and Setup with the Probable Maximum Lake level yields a combined effect flood level of elevation 593.3 ft.

The combined-effects surge and seiche, wind-wave activity, and Probable Maximum Lake level (elevation 593.3 ft) is lower than the lowest elevation of site grade at the CNP seawall, which was built at an elevation of 594.0 ft and lower than the CLB elevation of 594.6 ft. Combined Effects reevaluation analysis is provided in AREVA, 2014f.

The guidance for a combined effect flood assessment includes an evaluation of any other possible unique or site-specific flood mechanisms not included in the standard categories. For CNP, this includes the evaluation of a natural pond used for groundwater infiltration (Infiltration Pond) by the plant. The pond was determined to not be a source of flooding for the plant (AREVA, 2014f).

4.2 Conclusions

Flooding reevaluation for CNP found surge/seiche flooding at a lower elevation compared with the CLB flood elevation. The evaluation for LIP, not done for the licensing basis, was found to result in adverse conditions at nine locations at:

- Four rollup doors in the Turbine Building;
- A rollup door on the north side of the Auxiliary Building; and
- In the Unit 1 and 2 valve sheds associated with the RWST, PWST and CST tanks.

Reevaluated LIP flood water levels are above existing flood protection features or SSC elevations at the locations listed above. Per the results of this flood hazard re-evaluation for CNP, an Integrated Assessment will be required for LIP flooding only.

4.2.1 References

AREVA, 2014b. "Probable Maximum Flood (PMF) for Cook Nuclear Plant Flood Hazard Re-evaluation," AREVA Document No.: 51-9214479-000, CNP Document No.: MD-14-FLOOD-009-N, Revision 0, April, 2014.

AREVA, 2014c. Surge and Seiche, Cook Nuclear Plant Flood Hazard Re-evaluation, AREVA Document 32-9208453-000, CNP Doc. No. MD-12-FLOOD-006-N

AREVA, 2014d. Ice Induced Flooding at the D.C. Cook Nuclear Power Plant Units 1 and 2, AREVA Document No.: 51- 9208865-000, CNP Document No.: MD-12 -FLOOD-007-N, Revision 0.

AREVA, 2014e. Groundwater Assessment at Cook Nuclear Plant Site, AREVA Document No.: 51 9216206-000, CNP Document No.: MD-12 -FLOOD-008-N, Revision 0.

AREVA, 2014f. Combined Effects Flooding, Cook Nuclear Plant Flood Hazard Re-evaluation, AREVA Document 32-9221721-000, CNP Doc. No. MD-12-FLOOD-010-N, Revision 0.

AREVA, 2015. "Site-Specific Local Intense Precipitation (SS LIP) for D.C. Cook Nuclear Plant," AREVA Document No.: 32- 9221898-001, CNP Document No.: MD-14-FLOOD-014-N, Revision 1.

NRC, 2012a. U.S. Nuclear Regulatory Commission, "Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force

NRC, 2012a. U.S. Nuclear Regulatory Commission, "Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident," March 2012 (ADAMS Accession No. ML12053A340).

NRC, 2012b. U.S. Nuclear Regulatory Commission, Japan Lessons-Learned Project Directorate, "JLD-ISG-2012-05, Guidance for Performing the Integrated Assessment for External Flooding, Interim Staff Guidance," Revision 0, 2012. (ADAMS Accession No. ML12311A214).

Table 4-1: Flood Elevation Comparison

Mechanism	CLB Flood Height	Reevaluated Flood Height	Difference
Local Intense Precipitation	Not evaluated for CLB	Various across the site	above CLB Installed Feature (see Table 4-2)
PMF on Rivers and Streams	Not evaluated for CLB	Screened	NA
Dam Breaches and Failures	Not evaluated for CLB	588.6 ft	6 ft below CLB Installed Feature
Storm Surge	Not evaluated for CLB	590.3 ft	4.3 ft below CLB Installed Features
Seiche	594.6 ft MSL or NGVD29	590.3 ft	4.3 ft below CLB Installed Feature
Tsunami	Not evaluated for CLB	593.7	0.9 ft below CLB Installed Feature
Ice-Induced Flooding	Not evaluated for CLB	<Storm Surge of 590.3 ft	>4.3 ft below CLB Installed Feature
Channel Migration or Diversion	Not evaluated for CLB	Screened	NA
Combined Effect Flood	New Hazard Condition		
Stability and flood potential for site's natural pond	Not evaluated for CLB	Screened	NA
Storm surge, w/wave run-up and set-up (i.e. wind-wave activity)	Not evaluated for CLB	593.3 ft	1.3 ft below CLB Installed Feature

NA: Not applicable

Table 4-2: LIP Flood Heights at Select Locations

Critical Location	Location Designation	Threshold Elevation Description	Elevation (NGVD 29 ft)
CL1	Turbine Building Unit 1 West Rollup Door	Low point of berm	594.81
CL2	Turbine Building Unit 2 West Rollup Door	Low point of berm	595.20
CL3	Turbine Building Unit 2 East Rollup Door	Finish floor at tracks	608.95
CL4	Valve-shed	Approximate finish floor	608.37
CL5	Valve-shed	Approximate finish floor	608.40
CL6	Valve-shed	Approximate finish floor	608.88
CL7	Valve-shed	Approximate finish floor	608.43
CL9	Turbine Building Unit 1 East Rollup Door	Finish floor near tracks	609.00
CL10	Auxiliary Building North Rollup Door	Finish floor near tracks	608.91

5.0 INTERIM EVALUATION AND ACTIONS TAKEN OR PLANNED

Cases where the current design basis flood elevations do not bound the reevaluated hazards for all flood hazard mechanisms also require interim actions, taken or planned to address the reevaluated hazard prior to completing the Integrated Assessment. The following summarizes the interim evaluations and actions taken or planned.

5.1 Actions Taken

As described in Section 4, flooding from a local intense precipitation (LIP) event is not bounded by CNP's current design basis flood elevations. The hydrologic study, as part of the application for the initial construction of the plant, found that rainfall into the sandy surficial soils at the site was rapid and flooding conditions were non-existent. The CNP flood hazard design basis does not include precipitation flood elevations or precipitation flood protection features such as water-tight doors and hatches near grade elevation.

As described in Section 3.1, the site-specific probable maximum precipitation (PMP) analysis concluded that the 6 hour PMP depth is 20.2 inches, the 1 hour PMP depth is 12.8 inches and the 30 minute PMP depth is 9.8 inches. Review of historical rain records concluded the maximum recorded rainfall in the state of Michigan is 9.78 inches in a 24 hour period. This value was recorded in Bloomingdale, Michigan in 1914 (AREVA, 2014).

As described in Section 3.2, the peak water levels at critical locations (locations identified as the main flood ingress points) on the plant structure perimeter are greater than the threshold elevations. Considering the doors and hatches are not designed to be water-tight and the inundation levels are above the respective threshold elevations, water could intrude into the plant structures through doors and/or hatches near grade elevation during a LIP event.

Actual rain water infiltration of the plant due to precipitation has occurred at the site. Rain water had previously been observed to enter the Auxiliary Building through near grade doors and hatches. The intruding rain water moved to below-grade elevations of the Auxiliary Building, and into the Auxiliary Building interior floor drain system. As a result of this previous rain water intrusion, physical changes were implemented to reduce rain water intrusion into the Auxiliary Building. An exterior trench drain with connection to the yard drainage system was installed at the Auxiliary Building roll-up door (CL-9). This trench drain functions to collect and divert rain water prior to it entering the Auxiliary Building through the roll-up door (CNP, 2011).

5.2 Actions Planned

Additional interim evaluations and actions planned to address the reevaluated flood hazard prior to completion of the Flood Hazard Integrated Assessment as required by the 10 CFR 50.54(f) letter, Enclosure 2, Item 1.d are described in the NRC transmittal letter for this Flood Hazard Reevaluation Report.

5.3 References

AREVA, 2014. "Calculation of LIP Sensitivity Analyses , Cook Nuclear Plant Flood Hazard Re-evaluation," AREVA Document No.: 51-9227505-000, CNP Document No.: MD-14-FLOOD-013-N, Revision 0

CNP, 2011. "Auxiliary and Turbine Building Station Drainage Upgrades, CNP Document No.: EC-0000050971, AREVA Document No.: 38-9234603-000.

APPENDIX A: FLO-2D COMPUTER PROGRAM

A.1 FLO-2D for LIP Simulations

The example LIP calculation presented in Appendix B of NUREG/CR-7046 (NRC 2011) used HEC-HMS and HEC-RAS, developed by Hydrologic Engineering Center of US Army Corps of Engineers. The hydrologic part of the calculation was performed within HEC-HMS, whereas the hydraulic part of the calculation was performed within HEC-RAS. In this flood reevaluation study, FLO-2D was selected for calculation of the LIP-induced PMF at CNP. For the LIP calculation, rainfall runoff in the site area was calculated internally by FLO-2D and translated into overland flow within FLO-2D.

This appendix was prepared as per Section 5.3 of NUREG/CR-7046 (NRC, 2011).

A.1.1 Software Capability

The FLO-2D computer program was developed by FLO-2D Software, Inc., Nutrioso, Arizona. FLO-2D is a combined two-dimensional hydrologic and hydraulic model that is designed to simulate river and overbank flows as well as unconfined flows over complex topography and variable roughness, split channel flows, mud/debris flows and urban flooding.

FLO-2D is a physical process model that routes rainfall-runoff and flood hydrographs over unconfined flow surfaces using the dynamic wave approximation to the momentum equation. The model has components to simulate riverine flow including flow through culverts, street flow, buildings and obstructions, levees, sediment transport, spatially variable rainfall and infiltration and floodways. Application of the model requires knowledge of the site, the watershed (and coastal, as appropriate) setting, goals of the study, and engineering judgment. This software was used to simulate the LIP to establish LIP-induced maximum water surface elevations at CNP.

The major design inputs to the FLO-2D computer model are digital terrain model of the land surface, inflow hydrograph and/or rainfall data, Manning's roughness coefficient and Soil hydrologic properties such as the SCS curve number. The digital terrain model of the land surface is used in creating the elevation grid system over which flow is routed. The specific design inputs depend on the modeling purpose and the level of detail desired.

The following executable modules compose the FLO-2D computer program:

.exe File	Size
FLOPRO.exe	11.3 MB
GDS PRO.exe	6.6 MB
Mapper PRO.exe	3.25 MB

FLOPRO.exe is the model code that performs the numerical algorithms for the aforementioned components of the overall FLO-2D computer model.

GDS PRO.exe graphically creates and edits the FLO-2D grid system and attributes and creates the basic FLO-2D data files for rainfall – runoff and overland flow flood simulation. Mapper PRO.exe enables graphical viewing of model results and inundation mapping.

A description of the major capabilities of FLO-2D which will be used for this project is provided in Section A.1.2 below.

A.1.2 Model Components

A.1.2.1 Overland Flow Simulation

This FLO-2D component simulates overland flow and computes flow depth, velocities, impact forces, static pressure and specific energy for each grid. Predicted flow depth and velocity between grid elements represent average hydraulic flow conditions computed for a small time step. For unconfined overland flow, FLO-2D applies the equations of motion to compute the average flow velocity across a grid element (cell) boundary. Each cell is defined by 8 sides representing the eight potential flow directions (the four compass directions and the four diagonal directions). The discharge sharing between cells is based on sides or boundaries in the eight directions one direction at a time. At runtime, the model sets up an array of side connections that are only accessed once during a time step. The surface storage area or flow path can be modified for obstructions including buildings and levees. Rainfall and infiltration losses can add or subtract from the flow volume on the floodplain surface.

A.1.2.2 Rainfall – Runoff Simulation

Rainfall can be simulated in FLO-2D. The storm rainfall is discretized as a cumulative percent of the total. This discretization of the storm hyetograph is established through local rainfall data or through regional drainage criteria that defines storm duration, intensity and distribution. Rain is added in the model using an S-curve to define the percent depth over time. The rainfall is uniformly distributed over the grid system and once a certain depth requirement (0.01-0.05 ft) is met, the model begins to route flow.

A.1.2.3 Hydraulic Structures

Hydraulic structures including bridges and culverts and storm drains may be simulated in FLO-2D Pro. Storm drains are modeled using the EPA SWMM Model (AREVA, 2014b). FLO-2D Pro is linked to the EPA SWMM Model at runtime to exchange surface water and storm drain conveyance. FLO-2D Pro computes the surface water depth at grid elements prescribed with storm drains and then passes discharge inflow along to the storm drain system based on input storm drain geometry. The EPA SWMM model then computes the pipe network flow distribution and potential return flow to the surface.

A.1.2.4 Levees

This FLO-2D component confines flow on the floodplain surface by blocking one or more of the eight flow directions. A levee crest elevation can be assigned for each of the eight flow directions in a given grid element. The model predicts levee overtopping. When the flow depth exceeds the levee height, the discharge over the levee is computed using the broad-crested weir flow equation with a 3.1 coefficient. Weir flow occurs until the tailwater depth is 85% if the headwater depth. At higher flows, the water is exchanged across the levees using the difference in water surface elevations.

A.1.3 FLO-2D Model Theory

Governing equations and solution algorithm are presented in details in FLO-2D Reference Manual (FLO2D, 2013a). The general constitutive fluid equations include the continuity equation and the equation of motion (dynamic wave momentum equation) (FLO-2D, 2013a, Chapter II):

$$\frac{\partial h}{\partial t}+\frac{\partial h V}{\partial x}=i$$

$$S_f = S_o - \frac{\partial h}{\partial x} - \frac{V}{g}\frac{\partial V}{\partial x} - \frac{1}{g}\frac{\partial V}{\partial t}$$

where

h = flow depth;

V = depth averaged velocity in one of the eight flow directions;

x = one of the eight flow directions;

i = rainfall intensity;

S_f = friction slope based on Manning's equation;

S_0 = bed slope

g = acceleration of gravity

The partial differential equations are solved with a central finite difference numerical scheme, which implies that final results are approximate solutions to the differential equations. Details on the accuracy of FLO-2D solutions are discussed in FLO-2D Validation Report (FLO-2D, 2011).

A.1.4 Model Inputs and Outputs

Inputs to FLO-2D are entered through a graphical user interface (GUI), which creates ASCII text files used by the FLO-2D model (FLO-2D, 2013b). The ASCII text files can be viewed and edited by other ASCII text editors such as Microsoft WordPad.

Calculated results from FLO-2D simulations are saved in the ASCII text format in a number of individual files. The results can be viewed with the post-processor programs as follows:

- Mapper PRO to view grid element results such as elevation, water surface elevation, flow depth and velocity, to create contour maps and to generate shape files that can later be used by GIS mapping software such as ArcMap.

A.1.5 Conclusions

FLO-2D is a FEMA-approved software (FLO-2D, 2011). The model validation report prepared for FEMA and the FLO-2D software certification prepared for this Flood Reevaluation Project (AREVA, 2014a) has demonstrated its modeling capabilities and numerical accuracy. It is therefore judged to be an appropriate modeling tool for the CNP LIP flood reevaluation study where 2-dimensional overland flow is predominant.

A.1.6 References

A.1.6.1 **AREVA 2014a**. AREVA Document No. 38-9225054-000, Computer Software Certification – FLO-2D Pro Build No. 14.03.07, Alden, 2014.

A.1.6.2 **AREVA 2014b.** AREVA Document No. 38-9228225-000, SWMM Version 5.0.022 Computer Program Certification Report, Alden, 2014.

A.1.6.3 **FLO-2D, 2013a.** FLO-2D Pro Reference Manual, FLO-2D Software, Inc., 2013.

A.1.6.4 **FLO-2D, 2013b.** FLO-2D Data Input Manual, FLO-2D Software, Inc., 2013.

A.1.6.5 **FLO-2D, 2011.** FLO-2D Model Validation for Version 2009 and up prepared for FEMA, FLO-2D Software, Inc., June 2011.

A.1.6.6 **NRC, 2011.** U.S. Nuclear Regulatory Commission "NUREG/CR-7046: Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America", Springfield, VA, National Technical Information Service, 2011 (ADAMS Accession No. ML 11321A195).

APPENDIX B: LOCAL INTENSE PRECIPITATION FIGURES

Figure B-1: Water Surface Elevation Over Time CL1 (HHA Case 2)

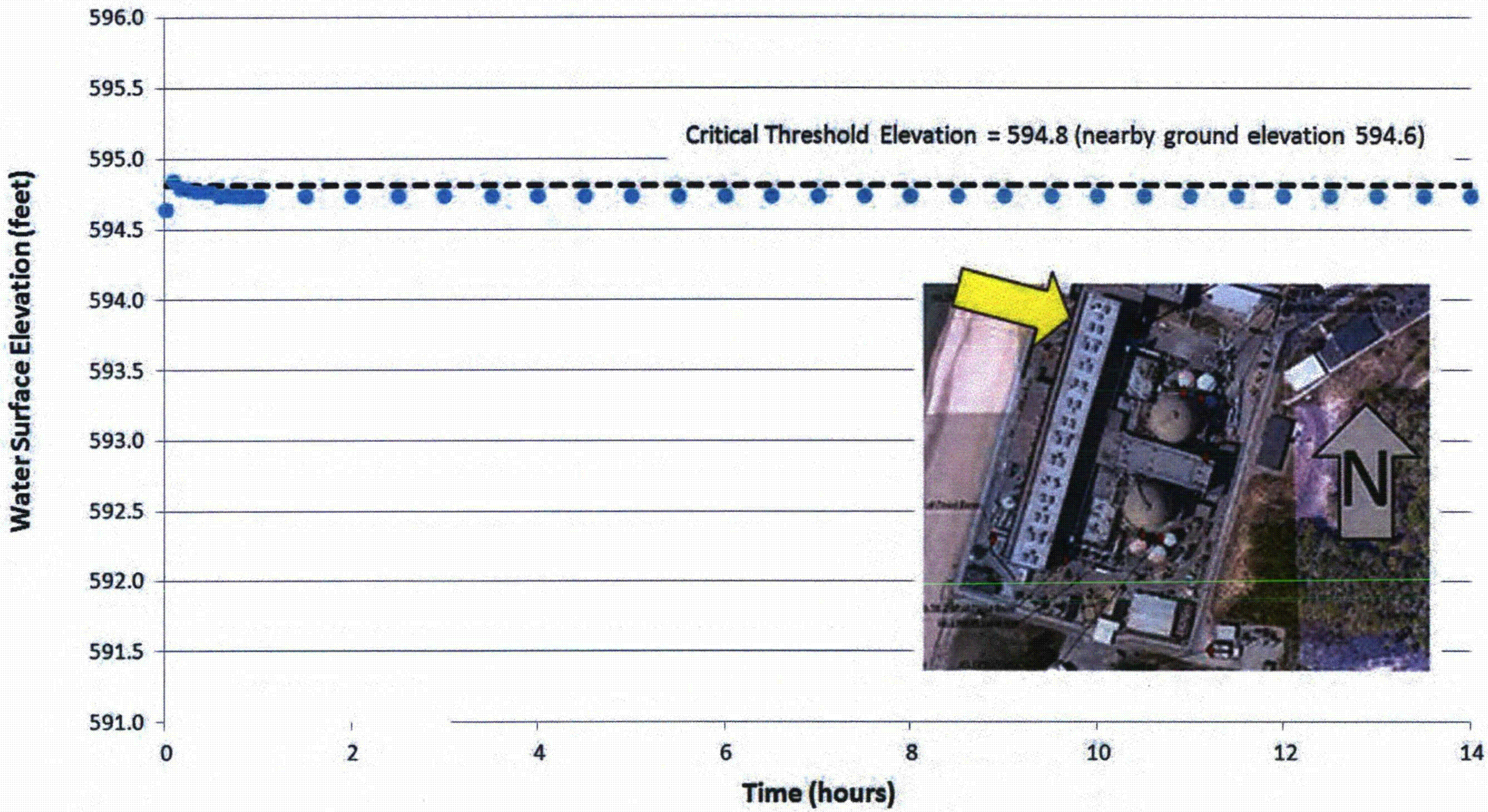


Figure B-2: Water Surface Elevation Over Time CL2 (HHA Case 2)

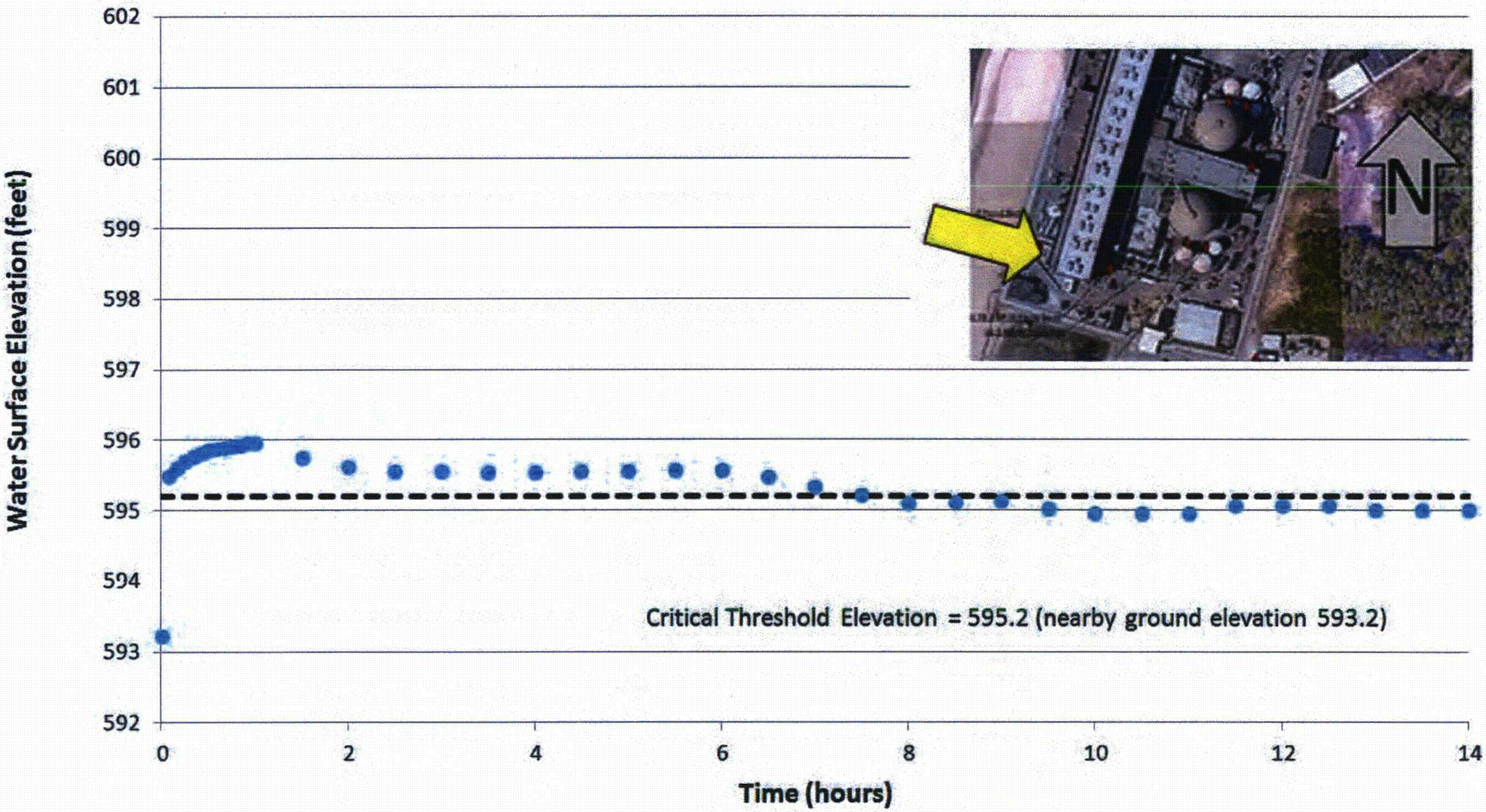


Figure B-3: Water Surface Elevation Over Time CL3 (HHA Case 2)

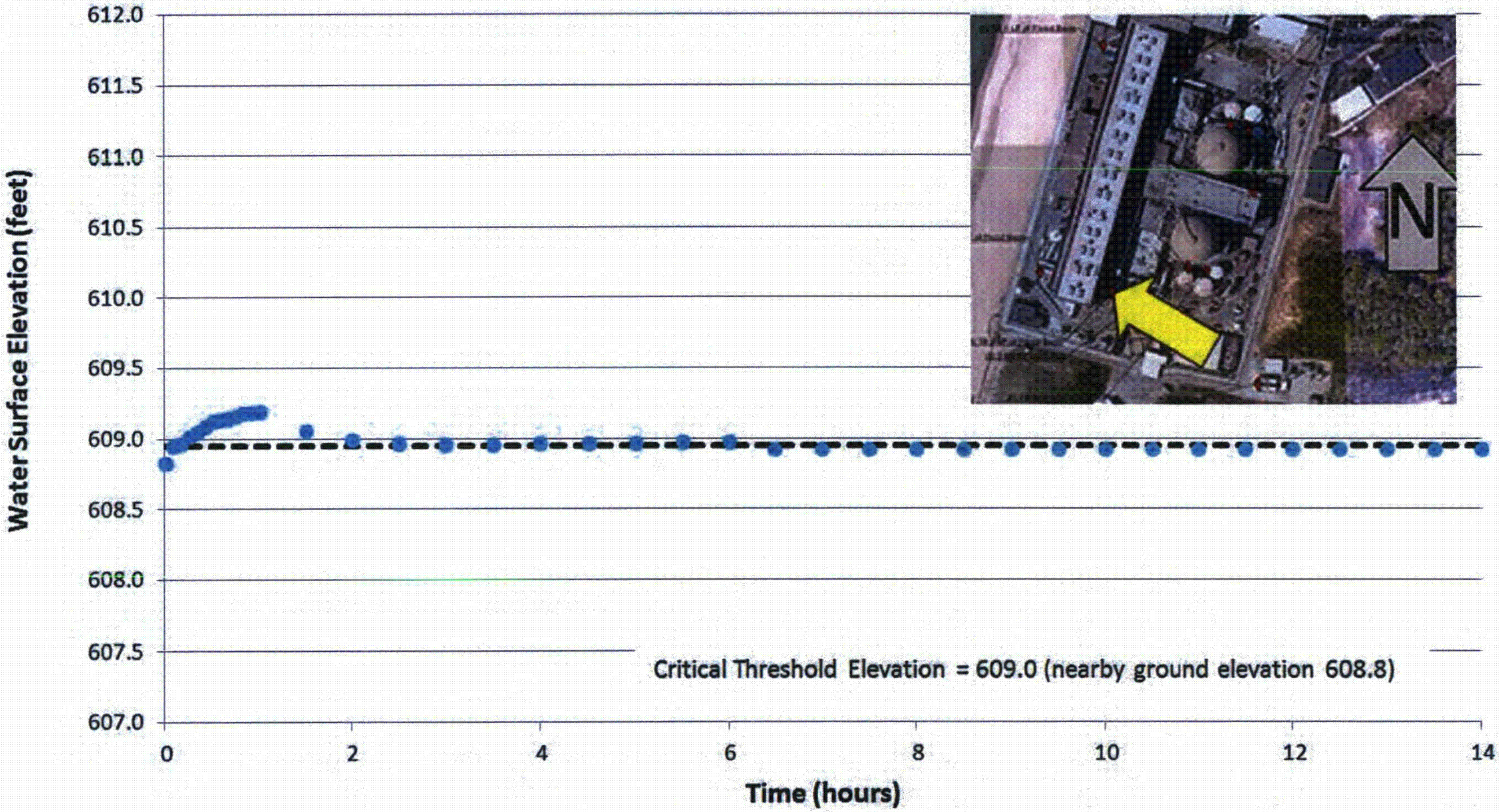


Figure B-4: Water Surface Elevation Over Time CL4 (HHA Case 2)

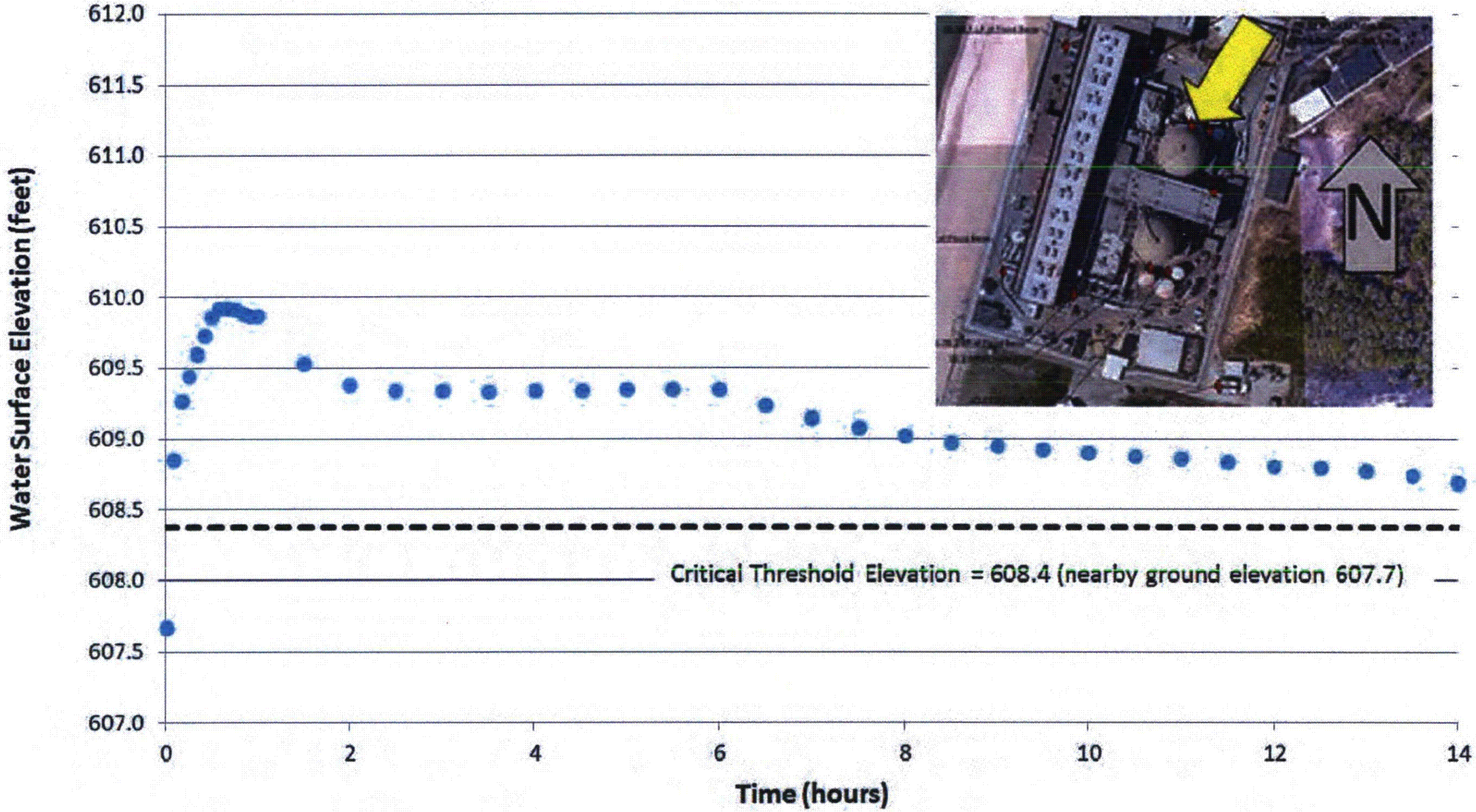


Figure B-5: Water Surface Elevation Over Time CL5 (HHA Case 2)

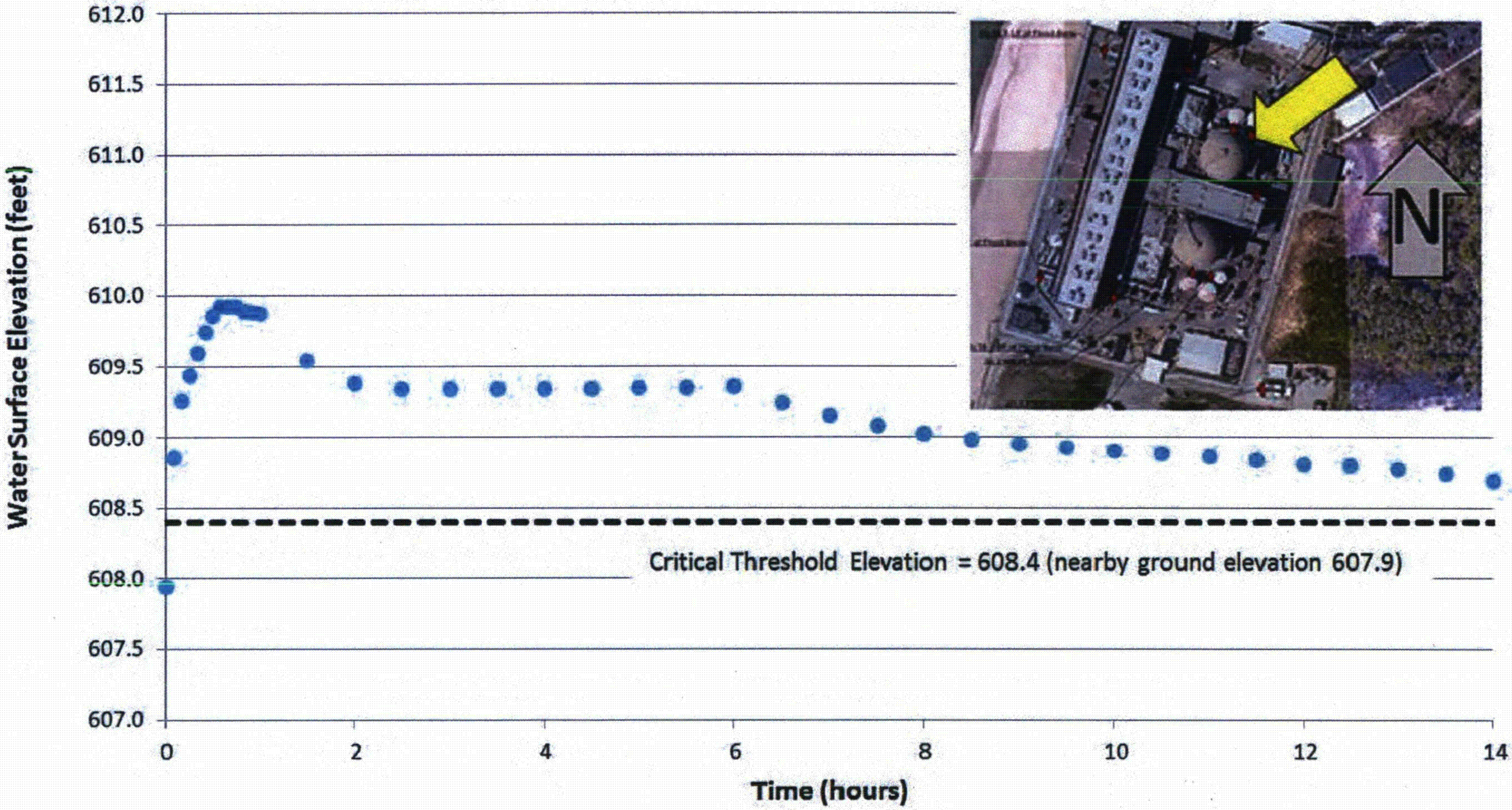


Figure B-6: Water Surface Elevation Over Time CL6 (HHA Case 2)

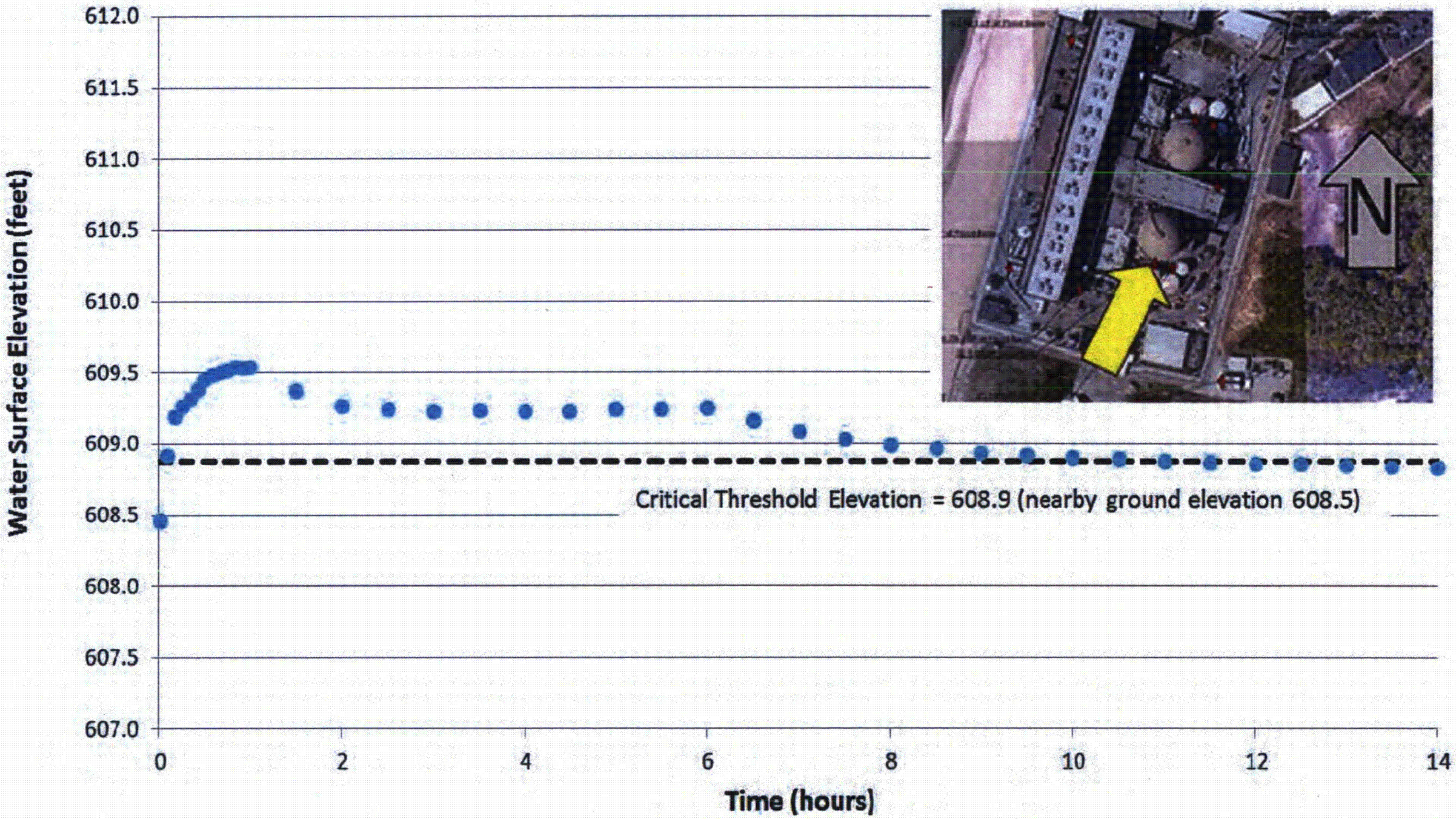


Figure B-7: Water Surface Elevation Over Time CL7 (HHA Case 2)

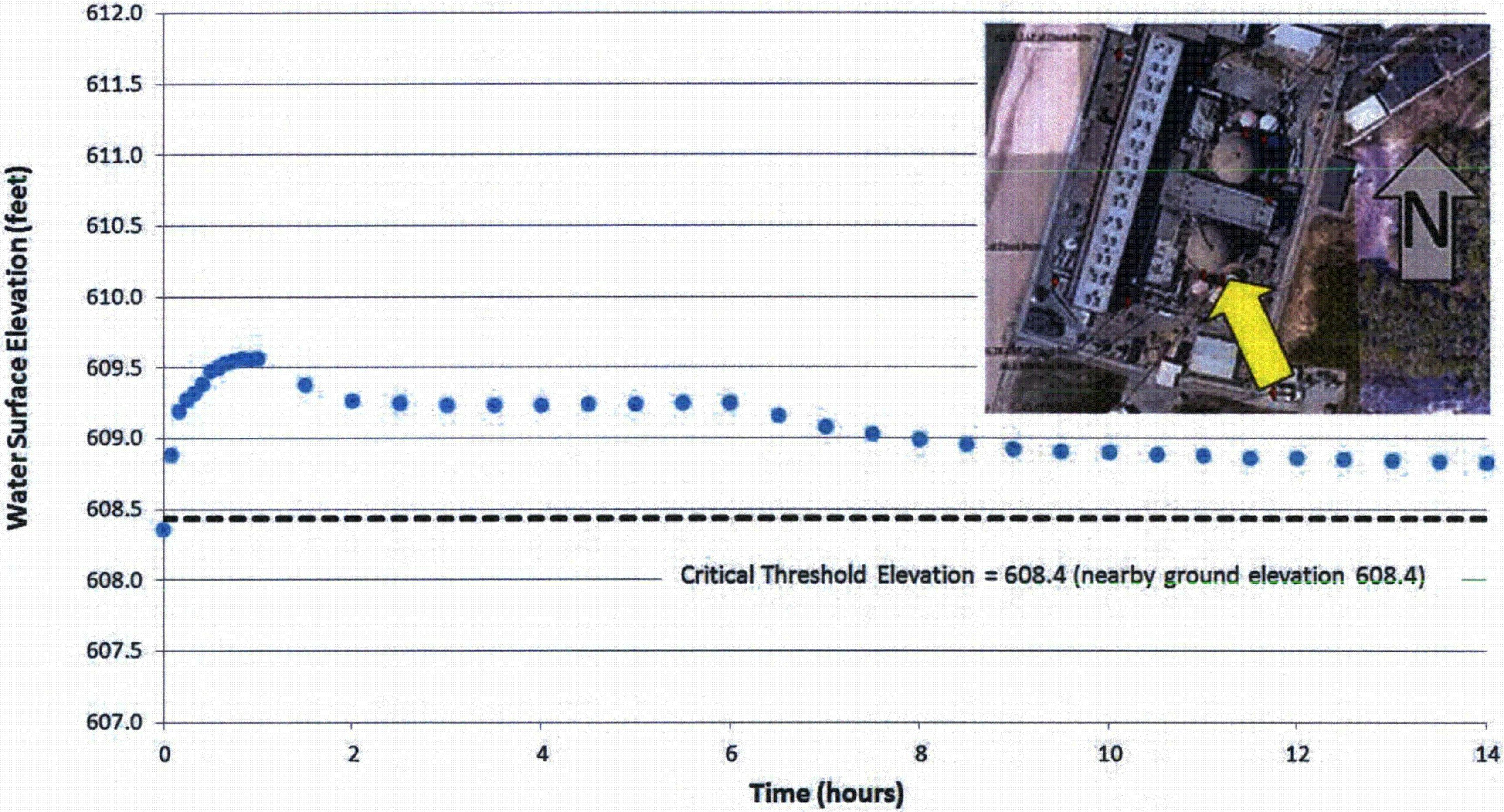


Figure B-8: Water Surface Elevation Over Time CL8 (HHA Case 2)

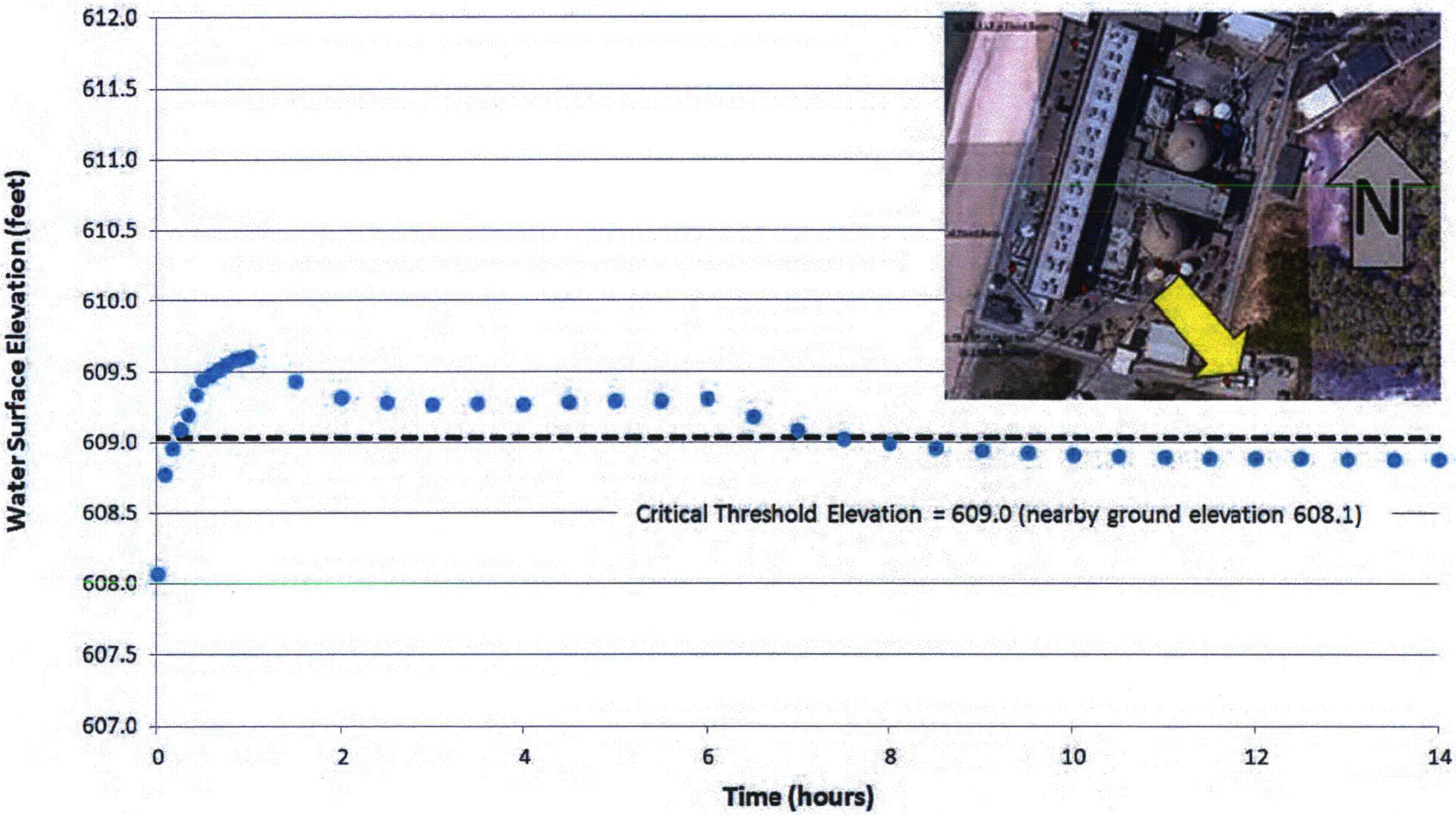


Figure B-9: Water Surface Elevation Over Time CL9 (HHA Case 2)

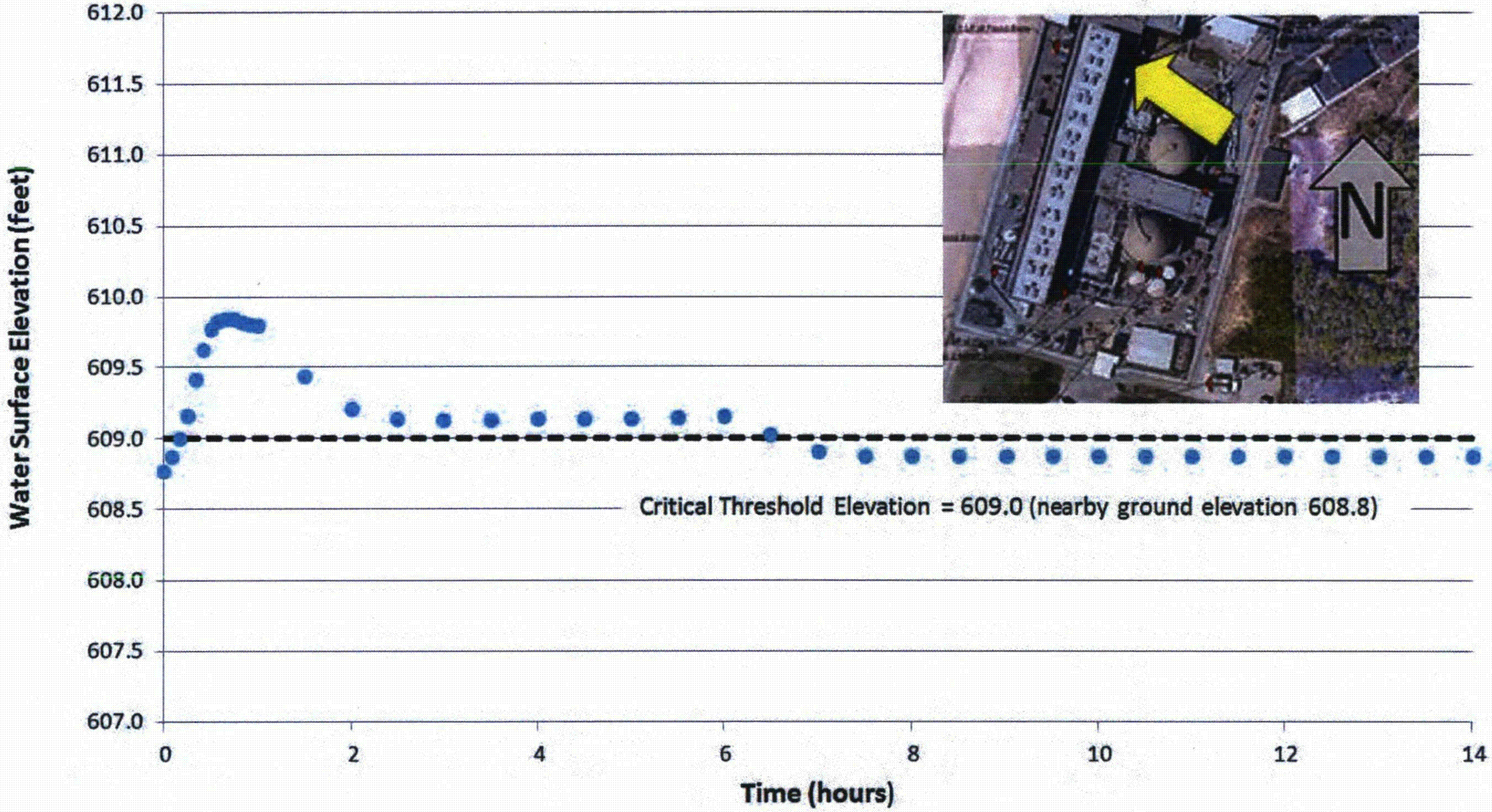
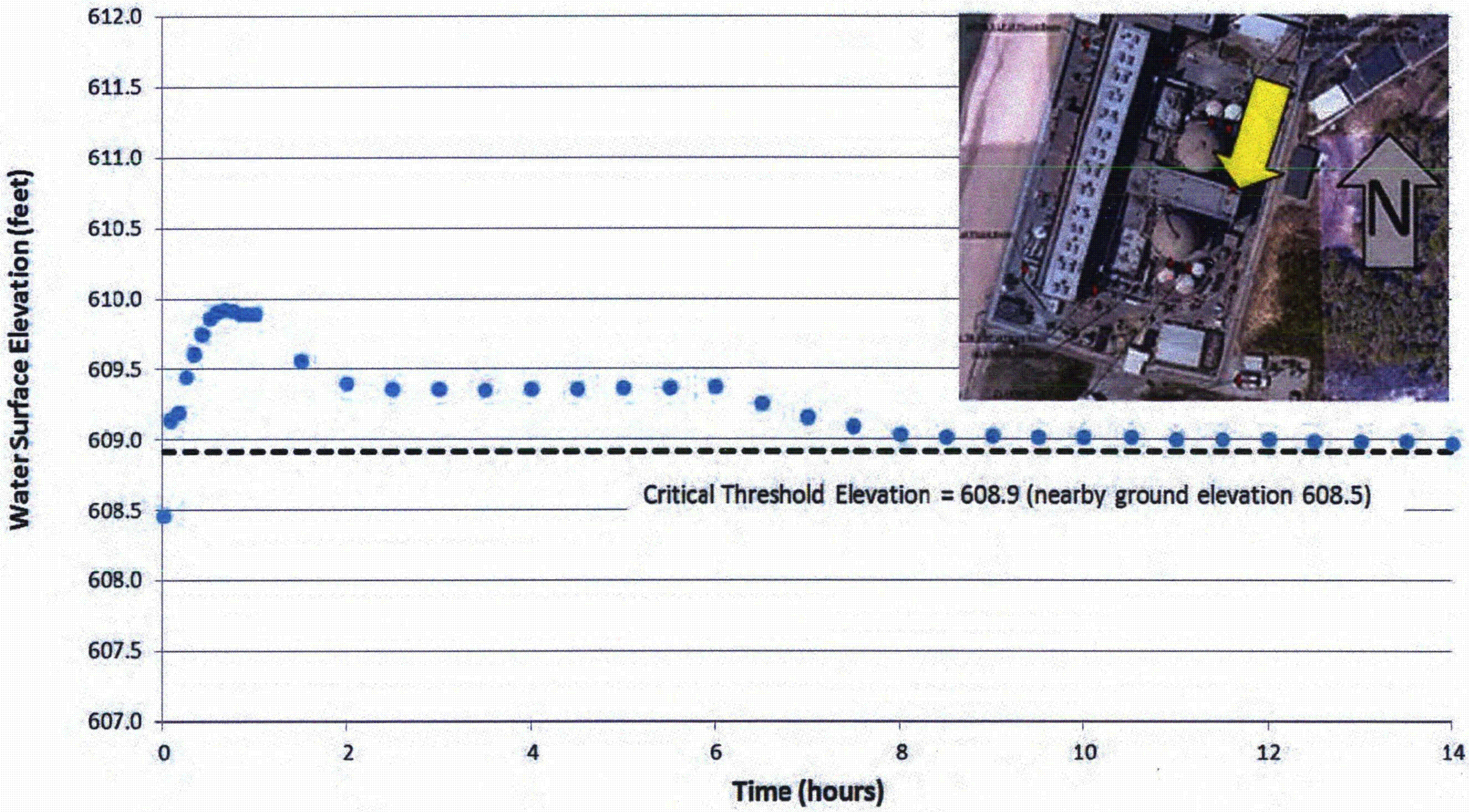


Figure B-10: Water Surface Elevation Over Time CL10 (HHA Case 2)



Enclosure 3 to AEP-NRC-2015-14

Interim Action Plan for Donald C. Cook Nuclear Plant

Background

The letter from E. J. Leeds, U. S. Nuclear Regulatory Commission (NRC), dated March 12, 2012, (Agencywide Documents Access and Management System Accession No. ML12073A348) requested that licensees submit a flood hazard reevaluation report for their facilities. Enclosure 2 to this letter provides the flood hazard reevaluation report for Donald C. Cook Nuclear Plant (CNP) Units 1 and 2. The flood hazard reevaluation determined that certain structures at CNP would be susceptible to inundation due to Local Intense Precipitation (LIP) which exceeds the flood level assumed in the current design basis. In the March 12, 2012, NRC letter, the NRC requested that licensees submit an interim action plan that documents actions planned or taken to address any flooding hazard that exceeds the design basis. This enclosure provides the Interim Action Plan for CNP.

Critical Locations

Ten critical locations (CLs) were identified that could provide an entry point for water during the postulated beyond-design-basis LIP. These CLs, their "curb" heights (i.e., height of flood limiting feature), potential inundation levels, and flood depths above the curb, are identified in the following table.

	Location	**Elevation – feet (ft.)**		**Depth above "Curb" – ft.**
CL1	Turbine Building Unit 1 West Rollup Door	Inundation Level: Curb Height:	594.8 594.8	0.0
CL2	Turbine Building Unit 2 West Rollup Door	Inundation Level: Curb Height:	596.0 595.2	0.8
CL3	Turbine Building Unit 2 East Rollup Door	Inundation Level: Curb Height:	609.2 609.0	0.2
CL4	Valve-shed (at Unit 1 Refueling Water Storage Tank (RWST))*	Inundation Level: Curb Height:	609.9 608.4	1.5
CL5	Valve-shed (at the Unit 1 Condensate Storage Tank (CST) & Primary Water Storage Tank (PWST))*	Inundation Level: Curb Height:	609.9 608.4	1.5
CL6	Valve-shed (at the Unit 2 RWST)*	Inundation Level: Curb Height:	609.5 608.9	0.6
CL7	Valve-shed (at the Unit 2 CST & PWST)*	Inundation Level: Curb Height:	609.6 608.4	1.2
CL8	Supplemental Diesel Generators (DGs)	Inundation Level: Curb Height:	609.6 609.0	0.6
CL9	Turbine Building Unit 1 East Rollup Door	Inundation Level: Curb Height:	609.8 609.0	0.8
CL10	Auxiliary Building North Rollup Door	Inundation Level: Curb Height:	609.9 608.9	1.0

* A flow path to the Auxiliary Building exists via piping penetrations in the floors of these valve sheds.

The structures of concern associated with these critical locations are the Turbine Building, the Auxiliary Building, and the Supplemental DG enclosures. The Supplemental DG enclosures were eliminated from concern because offsite power is assumed to be available in the postulated flooding scenario. The Turbine Building and Auxiliary Building are addressed below.

Turbine Building Flood Pathways

Indiana and Michigan Power Company's (I&M's) review determined that, due to their elevation, the Emergency Diesel Generator (EDG) rooms are the limiting important-to-safety components with respect to flooding in the Turbine Building. The EDGs are considered to be defense-in-depth features because the postulated LIP event would not be expected to cause a loss of off-site power. Flood water from the postulated LIP event could enter the Turbine Building through the four roll-up doors (CL1, 2, 3, and 9) and flow to the EDG rooms via two different pathways.

- Flood water could overfill the Turbine Room Sump and backflow through drain lines to EDG room and associated hallway floors at the 587 foot (ft.) elevation. Indiana and Michigan Power Company (I&M) will implement the interim measures described below to assure the EDGs are not rendered unavailable by flooding from this pathway.

- The water level in the Turbine Building could reach the 591.7 ft. elevation of the EDG room curbs and overflow in to the EDG Rooms. However, there is a large volume (greater than 2.2 million gallons) available for water retention in the Turbine Building below the 591.7 ft. elevation, and there is significant water ejection capability. The water ejection capability for the Turbine Building consists of the Turbine Room Sump Pumps, with a total capacity of 8000 gallons per minute (gpm), and the 30 inch (in.) diameter turbine room sump overflow pipe which discharges to the forebay, with a capacity of 17,731 gpm. These result in a total ejection flow rate capability of 25,731 gpm.

  Conservative estimates of combined flood water inflow rates through the Turbine Building roll-up doors indicate a flow rate as high as 34,800 gpm for the first two hours of the LIP event, falling to approximately 8500 gpm in the third hour of the event, and 7000 gpm for the remainder of the event. Although the estimated inflow rate for the first two hours would exceed the continuous ejection flow rate, the large retention capacity in the Turbine Building below elevation 591.7 ft. provides reasonable assurance that water level within the Turbine Building would not overtop the EDG room curb. Therefore, no interim actions are needed or planned for this pathway.

Auxiliary Building Flood Pathways

I&M's review determined that Residual Heat Removal (RHR) system pumps (elevation 576.5 ft.) are the limiting important-to-safety components in the Auxiliary Building with respect to flooding due to their elevation. Flood water can enter the Auxiliary Building via two different pathways, and there are no features that would provide for ejection of significant quantities of water from the Auxiliary Building in an expedited manner.

- The Unit 1 and Unit 2 RWST valve sheds (CL4 and CL6), and the Unit 1 and Unit 2 CST and PWST valve sheds (CL5 and CL7) are located in areas that could be inundated to a level of 0.6 to 1.5 ft. above the limiting curb elevation. A flow path to the lower levels of the Auxiliary Building exists through piping penetrations in the floors of these valve sheds. I&M will implement the interim measures described below to assure the RHR system pumps are not rendered unavailable by flooding from this pathway.

- The Auxiliary Building North Crane Bay Door (CL10) provides direct access from the outside ground elevation to the building interior through a 17 ft. wide rollup door. Floor drains, equipment drains, penetrations, and gaps around large in-floor access plugs provide flood water ingress paths to the Auxiliary Building lower elevations. I&M's evaluation shows that inundation levels at the door would be 1 ft. above the 608.9 ft. curb elevation. I&M will implement the interim measures described below to assure the RHR system pumps are not rendered unavailable by flooding from this pathway.

<u>Interim Measures</u>

I&M will implement the interim measures described below to assure that, although flood water may enter the Turbine Building or Auxiliary Building, components important to safety would not be rendered unavailable by a LIP event prior to completing an Integrated Assessment and any measures determined to be necessary by the assessment.

For the Turbine Building (CL1, 2, 3, and 9), I&M will determine the appropriate location(s) for, and configuration of, blocking mechanism(s) to preclude or minimize flood water entering the EDG rooms and hallways via backflow through the drain lines (21 per unit, nominal 4 to 8 in. diameter) to the Turbine Room Sump. I&M will determine if such mechanisms(s) will be normally installed, will be installed when needed, or a combination thereof. Based on this determination, I&M will install the blocking mechanism(s) and/or will complete actions necessary to assure such mechanism(s) would be installed when needed.

For the Auxiliary Building (CL4 through 7, and CL10), the interim mitigation strategy is to implement passive measures that do not rely on flood warning time, operator actions, or reactive deployment. The interim measures for protection of the limiting components, the RHR pumps, are as follows.

- For CL4 through 7, preclude or minimize flood water intrusion to the Auxiliary Building through the Unit 1 and Unit 2 RWST, and CST & PWST valve shed floor penetrations by:
  a) Blocking all spare or unused floor penetrations in the valve sheds.
  b) Installing or injecting blocking material in the gap area under the "top hat" of each rain guard for all pipe penetrations in the valve sheds.
  c) Installing or injecting blocking material in the gap around or under the manway hatch in each of the valve sheds.
- For CL10, preclude or minimize flood water intrusion to the Auxiliary Building lower levels. Flood water would be allowed to accumulate in the Crane Bay and the Spent Fuel Pit Heat Exchanger (HX) Room to an elevation of 609.9 ft. (approximately 1 ft. above the Crane Bay

Floor level). The following will be performed to preclude or minimize water drainage to lower levels.

a) Install floor drain plugs in all floor drains (total of 13, nominal 3 in. diameter) in the Auxiliary Building Crane Bay.

b) Install floor drain plugs in all floor drains (total of 7, nominal 3 in. diameter) located in the Spent Fuel Pit HX Room.

c) Install seals or devices to preclude or minimize water intrusion through the nominal 2 in. diameter drain cups located under the east end of the North and South Spent Fuel Pit HXs.

d) Install seals or devices to preclude or minimize water intrusion through the nominal 4 in. diameter drain cups located at the Spent Fuel Pit Skimmer Pump.

e) Install seals or devices to preclude or minimize water intrusion through the nominal 4 in. drain cups located at the North and South Spent Fuel Pit Pumps. This may be accomplished by functionally extending the drain cup to a height at least 1 ft. above the flood elevation.

f) Install seals or devices to preclude or minimize water intrusion to levels below the 609 ft. elevation through the gap around the nominal 9 ft. by 10 ft. removable concrete floor plug located in the Auxiliary Building Crane Bay.

g) Install seals or devices to preclude or minimize water intrusion to levels below the 609 ft. elevation through the gap around the nominal 4.5 ft. square removable floor plug located in the Auxiliary Building Crane Bay.

h) Install seals or devices to preclude or minimize water intrusion to levels below the 609 ft. elevation through the gap around the approximately 3 ft. square hatch in the Spent Fuel Pit HX Room.

i) Evaluate the need for additional administrative measures to preclude or minimize flood water flow through the Auxiliary Building Crane Bay elevation 609 ft. to elevation 587 ft. hallway stairway access fire door, and implement additional measures if needed.

I&M will implement administrative controls as needed to assure that future temporary or permanent configuration changes do not adversely affect the adequacy of the interim measures described in this enclosure.

As an additional interim measure, not specific to any structure, the CNP Storm Drain System (yard drainage) will be visually inspected to ensure the system is in good condition and is a minimum of 25 percent (%) functional, i.e. the piping is not more than 75% filled with sediment or debris. Any portion of the system not meeting the 25% requirement will be cleaned to a minimum of 50% open. This is consistent with the assumption in Enclosure 2 to this letter, and provides assurance that the consequences of the postulated LIP would be no worse than stated in Enclosure 2. The need for, and frequency of, future periodic inspections and cleaning would be determined as part of the Integrated Assessment.

Finally, the low likelihood of occurrence of the LIP event evaluated in Enclosure 2 to this letter prior to completing the Integrated Assessment, and the actions determined to be necessary by the assessment, provide assurance that the above interim measures would not be challenged. The LIP event evaluated in Enclosure 2 to this letter is based on a site-specific Probable Maximum Precipitation event that includes 20.2 ins. of rainfall in 6 hours. The occurrence of such an event is unlikely because the maximum recorded rainfall in Michigan was 9.78 ins. in 24 hours.

Schedule

I&M will implement the interim measures within the times frames indicated in Enclosure 4 to this letter.

Enclosure 4 to AEP-NRC-2015-14

REGULATORY COMMITMENTS

The following table identifies those actions committed to by Indiana Michigan Power Company (I&M) in this document. Any other actions discussed in this submittal represent intended or planned actions by I&M. They are described to the U. S. Nuclear Regulatory Commission (NRC) for the NRC's information and are not regulatory commitments.

Commitment	Date
I&M will determine the appropriate location(s) for, and configuration of, blocking mechanism(s) to preclude or minimize flood water entering the Emergency Diesel Generator rooms and hallways via backflow through the drain lines to the Turbine Room Sump. I&M will determine if such mechanisms(s) will be normally installed, will be installed when needed, or a combination thereof.	December 31, 2015
Based on the above described determination, I&M will install the blocking mechanism(s) and/or will complete actions necessary to assure such mechanism(s) would be installed when needed.	June 30, 2016
I&M will issue the Engineering Change(s) for the interim measures for the Auxiliary Building floor drains, gaps and penetrations associated with CL4 through 7, and CL10 identified in Enclosure 3 to this letter.	December 31, 2015
I&M will complete the modifications for the interim measures for the Auxiliary Building floor drains, gaps and penetrations associated with CL4 through 7, and CL10 identified in Enclosure 3 to this letter.	June 30, 2016
I&M will evaluate the need for additional administrative measures to preclude or minimize flood water flow through the Auxiliary Building Crane Bay elevation 609 feet (ft.) to elevation 587 ft. hallway stairway access fire door.	December 31, 2015
If needed, I&M will implement additional measures to preclude or minimize flood water flow through the Auxiliary Building Crane Bay elevation 609 ft. to elevation 587 ft. hallway stairway access fire door.	June 30, 2016.
I&M will implement administrative controls as needed to assure that future temporary or permanent configuration changes do not adversely affect the adequacy of the interim measures described in Enclosure 3 to this letter.	December 31, 2015
I&M will inspect and clean the yard drain system to ensure the system is in good condition and is a minimum of 25 percent (%) functional, i.e. the piping is not more than 75% filled with sediment or debris. Any portion of the system not meeting the 25% requirement will be cleaned to a minimum of 50% open.	April 1, 2015