FENOC™

FirstEnergy Nuclear Operating Company

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March 2, 2016
L-16-060

10 CFR 50.54(f)

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

SUBJECT:
Beaver Valley Power Station, Unit Nos. 1 and 2
Docket No. 50-334, License No. DPR-66
Docket No. 50-412, License No. NPF-73
FirstEnergy Nuclear Operating Company (FENOC) Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Flooding Aspects of Recommendation 2.1 of the Near-Term Task Force (NTTF) Review of Insights from the Fukushima Dai-ichi Accident

On March 12, 2012, the Nuclear Regulatory Commission (NRC) issued a letter titled, "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," to all power reactor licensees and holders of construction permits in active or deferred status. Enclosure 2 of the 10 CFR 50.54(f) letter addresses NTTF Recommendation 2.1 for flooding. One of the required responses is for licensees to submit a Hazard Reevaluation Report (HRR) in accordance with the NRC's prioritization plan. By letter dated May 11, 2012, the NRC placed the Beaver Valley Power Station, Unit Nos. 1 and 2 (BVPS), in Category 2 requiring a response by March 12, 2014.

By letter dated December 17, 2013, FirstEnergy Nuclear Operating Company (FENOC) requested NRC assistance to obtain information needed to complete the flood HRR for BVPS from the U.S. Army Corps of Engineers (USACE). By letter dated March 11, 2014, FENOC requested an extension for the completion and submission of the flood HRR based on the schedule to receive input information from the USACE. By electronic mail sent on March 26, 2014, the NRC staff requested additional information to complete its review of the extension request. By letter dated April 24, 2014, FENOC provided the requested information. By letter dated July 17, 2014, the NRC staff considered the revised schedule proposed by FENOC to be acceptable. Accordingly, the revised required response date for submitting the flood HRR for BVPS is 180 days after FENOC receives the USACE final analysis.

By letter dated September 10, 2015, the NRC transmitted to FENOC the USACE portion of the BVPS flood hazard reevaluation associated with the assessment of flood hazards due to flooding streams and rivers, including potential site flooding due to dam failure. In this letter, the NRC staff identified that the BVPS flood HRR is due to the NRC by March 10, 2016, and that if the USACE results show that the design basis flood levels at the BVPS site are exceeded by the flood levels resulting from the flood hazard reevaluation, FENOC must submit its planned interim actions to address the higher flood level to the NRC within 60 days of the date of the letter. By letter dated November 6, 2015, FENOC submitted information regarding interim actions.

The BVPS flood HRR is enclosed. As discussed in the report, two of the postulated reevaluated flood hazard events (wind-generated waves concurrent with Ohio River probable maximum flood and local intense precipitation) resulted in maximum flood water elevations that exceed current licensing basis flood levels. These postulated flood hazard events are beyond design basis events and do not constitute an operability concern. Actions taken and planned to address the reevaluated hazards are also described in the enclosed report.

There are no regulatory commitment contained in this letter. If there are any questions or if additional information is required, please contact Mr. Thomas A. Lentz, Manager – Fleet Licensing, at 330-315-6810.

I declare under penalty of perjury that the foregoing is true and correct. Executed on March 2, 2016.

Respectfully,

Marty L. Richey

Enclosure:
Flood Hazard Reevaluation Report

cc: Director, Office of Nuclear Reactor Regulation (NRR)
NRC Region I Administrator
NRC Resident Inspector
NRR Project Manager
Director BRP/DEP
Site BRP/DEP Representative

Enclosure
L-16-060

Flood Hazard Reevaluation Report
(29 pages follow)

FLOOD HAZARD REEVALUATION REPORT

IN RESPONSE TO THE 50.54(f) INFORMATION REQUEST REGARDING NEAR-TERM TASK FORCE RECOMMENDATION 2.1: FLOODING

for the

BEAVER VALLEY POWER STATION
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Revision 0

Submitted to FENOC: January 26, 2016

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1. PURPOSE

1.1. Background

In response to the nuclear fuel damage at the Fukushima Dai-ichi power plant due to the March 11, 2011 earthquake and subsequent tsunami, the United States Nuclear Regulatory Commission (NRC) established the Near Term Task Force (NTTF) to conduct a systematic review of NRC processes and regulations, and to make recommendations to the NRC for its policy direction. The NTTF reported a set of recommendations that were intended to clarify and strengthen the regulatory framework for protection against natural phenomena.

On March 12, 2012 the NRC issued an information request pursuant to Title 10 of the Code of Federal Regulations, Section 50.54 (f) (10 CFR 50.54(f) or 50.54(f) letter) which included six (6) enclosures:

1. NTTF Recommendation 2.1: Seismic
2. NTTF Recommendation 2.1: Flooding
3. NTTF Recommendation 2.3: Seismic
4. NTTF Recommendation 2.3: Flooding
5. NTTF Recommendation 9.3: EP
6. Licensees and Holders of Construction Permits

In Enclosure 2 of the NRC-issued information request (Reference NRC March 2012), the NRC requested that licensees reevaluate the flooding hazards at their sites against present-day regulatory guidance and methodologies being used for early site permits (ESP) and combined operating license reviews.

On behalf of FirstEnergy Nuclear Operating Company (FENOC) for the Beaver Valley Power Station (BVPS), this Flood Hazard Reevaluation Report (Report) provides the information requested in the March 12, 2012 50.54(f) letter; specifically, the information listed under the "Requested Information" section of Enclosure 2, paragraph 1 ('a' through 'e'). The "Requested Information" section of Enclosure 2, paragraph 2 ('a' through 'd'), Integrated Assessment Report, or other additional future assessments as necessary, will be addressed separately if the current design basis floods do not bound the reevaluated hazard for all flood-causing mechanisms.

1.2. Requested Actions

Per Enclosure 2 of the NRC-issued information request, 50.54(f) letter, FENOC is requested to perform a reevaluation of all appropriate external flooding sources for BVPS, including the effects from local intense precipitation (LIP) on the site, the probable maximum flood (PMF) on streams and rivers, lake flooding from storm surges, seiches, and tsunamis, and dam failures. It is requested that the reevaluation apply present-day regulatory guidance and methodologies being used for ESPs, combined operating license reviews, and calculation reviews including current techniques, software, and methods used in present-day standard engineering practice to develop the flood hazard. The requested information will be gathered in Phase 1 of the NRC staff's two-phase process to implement Recommendation 2.1, and will be used to identify potential "vulnerabilities" (see definition below).

For the sites where the reevaluated flood exceeds the design basis, addressees are requested to submit an interim action plan documenting planned actions or measures implemented to address the reevaluated hazards.

Subsequently, addressees shall perform an integrated assessment, or other additional future assessments as necessary, of the plant to fully identify vulnerabilities and detail actions to address them.

A definition of vulnerability in the context of Enclosure 2 is as follows: Plant-specific vulnerabilities are those features important to safety that when subject to an increased demand due to the newly calculated hazard evaluation have not been shown to be capable of performing their intended functions.

1.3. Requested Information

Per Enclosure 2 of the NRC-issued information request 50.54(f) letter, the Report should provide documented results, as well as pertinent BVPS information and detailed analysis, and include the following:

1. Site information related to the flood hazard. Relevant structure, systems, and components (SSCs) important to safety and the UHS are included in the scope of this reevaluation, and pertinent data concerning these SSCs should be included. Other relevant site data include the following:
    1. Detailed site information (both designed and as-built), including present-day site layout, elevation of pertinent SSCs important to safety, site topography, and pertinent spatial and temporal data sets;
    2. Current design basis flood elevations for all flood-causing mechanisms;
    3. Flood-related changes to the licensing basis and any flood protection changes (including mitigation) since license issuance;
    4. Changes to the watershed and local area since license issuance;
    5. Current licensing basis flood protection and pertinent flood mitigation features at the site; and
    6. Additional site details, as necessary, to assess the flood hazard (e.g., bathymetry and walkdown results).

2. Evaluation of the flood hazard for each flood-causing mechanism, based on present-day methodologies and regulatory guidance. Provide an analysis of each flood-causing mechanism that may impact the site, including LIP and site drainage, flooding in streams and rivers, dam breaches and failures, storm surge and seiche, tsunamis, channel migration or diversion, and combined effects. Mechanisms that are not applicable at the site may be screened out; however, a justification should be provided. A basis for inputs and assumptions, methodologies and models used, including input and output files, and other pertinent data should be provided.

3. Comparison of current and reevaluated flood-causing mechanisms at the site. Provide an assessment of the current design basis flood elevation to the reevaluated flood elevation for each flood-causing mechanism. Include how the findings from Enclosure 2 of the 50.54(f) letter (i.e., Recommendation 2.1, flood hazard reevaluations) support this determination. If

the current design basis flood bounds the reevaluated hazard for all flood-causing mechanisms, include how this finding was determined.

4. Interim evaluation and actions taken or planned to address any higher flooding hazards relative to the design basis, prior to completion of the integrated assessment or other additional future assessments, if necessary.

5. Additional actions beyond requested information item 1.d taken or planned to address flooding hazards, if any.

2. SITE INFORMATION

BVPS Unit 1 (BVPS-1) and BVPS Unit 2 (BVPS-2) are located in Shippingport Borough, Beaver County, Pennsylvania (BVPS-2 UFSAR, Section 2.1.1.1). The site is approximately one mile southeast of Midland, Pennsylvania, five miles east of East Liverpool, Ohio, and approximately 25 miles northwest of Pittsburgh, Pennsylvania. BVPS is located on the south side of the Ohio River at mile 34.7 at a location on the New Cumberland Pool that is 3.1 river miles downstream of the Montgomery Lock and Dam and 19.6 miles upstream of the New Cumberland Lock and Dam (BVPS-2 UFSAR, Section 2.4.1.2). The total drainage area upstream of the site is approximately 23,000 square miles. The general site area is characterized by sloping topography, with the exception of the northeast corner of the site (BVPS-2 UFSAR, Section 2.4.1.1). Ground elevations vary from 664.5 feet mean sea level (msl) (normal pool elevation) to a maximum elevation of 1,160 feet msl. Station grades are approximately 730 to 735 feet msl. Peggs Run, a small stream flowing through the eastern portion of the site, is channeled through a culvert near the station and enters the Ohio River. Note that the Updated Safety Analysis Report (USAR) presents elevations using a msl datum that is equivalent to the National Geodetic Vertical Datum of 1929 (NGVD 29). In this report, the NGVD 29 datum is referenced primarily; however, the two definitions could be used interchangeably. The present-day site layout is shown in Figure 2.0.1.

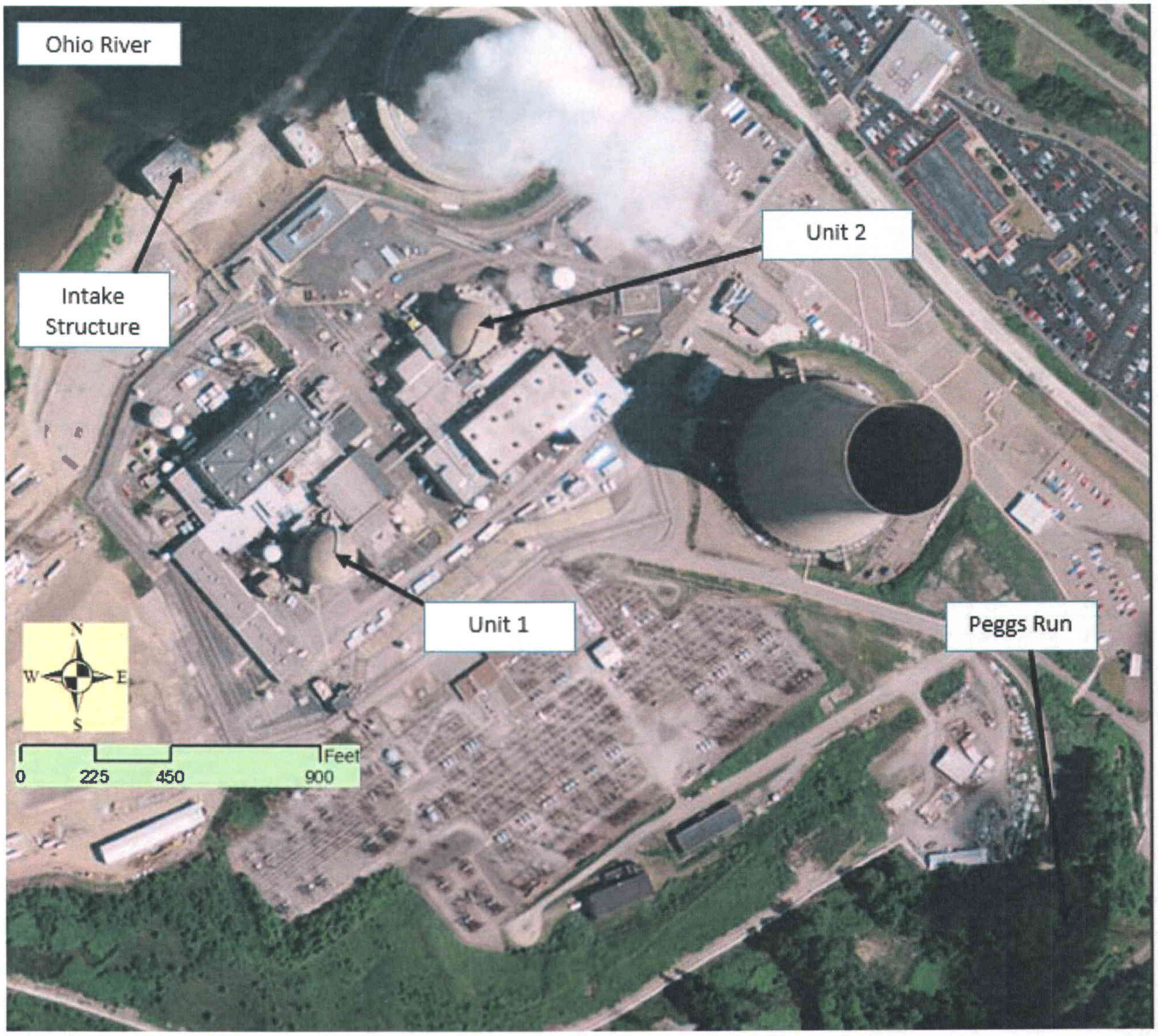

Figure 2.0.1 – Site Layout

2.1. Current Design Basis

The current design basis is defined in the BVPS UFSARs. The following is a list of flood-causing mechanisms and their associated water surface elevations that were considered for the BVPS current design basis.

2.1.1. Local Intense Precipitation (LIP)

The BVPS-1 UFSAR identifies the probable maximum precipitation (PMP) as 13 inches of rainfall in 72 hours (BVPS-1 UFSAR, Section 2.3.10). All roof and surface drainage around the site passes on directly to the storm drainage system which slopes northward until it discharges into the Ohio River at the Intake Structure. For intensities greater than 4 inches per hour some puddling will occur. However, since the site pitches through natural drainage lines, to the Ohio River and Peggs Run, surface drainage will aid the yard storm drainage system in minimizing the buildup of water to less than a few inches.

The BVPS-2 UFSAR identifies the all-season enveloping PMP for a 10- square mile area to be 31.3 inches over a 24-hour period (BVPS-2 UFSAR, Table 2.4-5). The 10-minute period of highest precipitation intensity, 3.5 inches corresponding to 21 inches per hour, is chosen for evaluation of the site drainage system (BVPS-2 UFSAR, Section 2.4.2.3.2). Peak water surface elevations were computed for the case of complete blockage of the yard drains and the roof drains. Site ground elevation surrounding all buildings is at or above elevation 730 feet msl with all safety-related building entrances set 6 inches above ground level, except for one door to the service building where the sill is at grade. Maximum water surface elevations range from 732.4 feet to 735.4 feet (BVPS-2 UFSAR, Table 2.4-6).

2.1.2. Flooding in Streams and Rivers

The UFSAR identifies that the PMF on the Ohio River has a peak flow rate of 1,500,000 cubic feet per second (cfs) with an elevation of 730.0 feet msl at Ohio River Mile 35.0 (BVPS-2 UFSAR, Section 2.4.3 and BVPS-1 UFSAR, Attachment 2.3A).

Peggs Run is evaluated for the effects of flooding due to local PMP. The 6-hour PMP having a maximum intensity of 9.3 inches per hour for a 1 hour duration results in water levels below the design basis flood of elevation 730 feet msl in the vicinity of safety related structures (BVPS-2 UFSAR, Section 2.4.2.3.1). Peggs Run flooding is not addressed in the BVPS-1 UFSAR.

2.1.3. Dam Breaches and Failures

Assumed failure of Conemaugh Dam coincident with the standard project flood results in a peak flow of 1,280,000 cfs and elevation 725.2 feet (BVPS-2 UFSAR, Section 2.4.4.2 and BVPS-1 UFSAR, Attachment 2.3A).

2.1.4. Storm Surge and Seiche

Storm surge and seiche are not applicable to the BVPS-2 site since the site is not located near a large body of water where surge and seiche flooding would be a significant consideration (BVPS-2 UFSAR, Section 2.4.5). The BVPS-1 UFSAR does not address storm surge and seiche.

2.1.5. Tsunami

Tsunami flooding is not applicable to the situation at the BVPS-2 site (BVPS-2 UFSAR, Section 2.4.6). The BVPS-1 UFSAR does not address tsunami flooding.

2.1.6. Ice-Induced Flooding

Based on historical events and the conditions in the BVPS-2 vicinity, it can be concluded that the formation of an ice jam that would cause a significant rise in the water elevation in the New Cumberland pool or that would physically block the Intake Structure is extremely unlikely to occur (BVPS-2 UFSAR, Section 2.4.7.1). The BVPS-1 UFSAR also draws a similar conclusion (BVPS-1 UFSAR, Section 2.3.9).

2.1.7. Channel Migration or Diversion

There is no potential for upstream diversion since the Ohio River Valley is deeply entrenched in bedrock of sandstones and shales (BVPS-2 UFSAR, Section 2.4.9). The BVPS-1 UFSAR does not address channel migration and diversion.

2.1.8. Combined Effect Flood (including Wind-Generated Waves)

Wind wave activity during the PMF was evaluated for the runup effects on a vertical wall of the Intake Structure. The associated wave runup is 6.7 feet above the standing water level of 730 feet msl (BVPS-2 UFSAR, Section 2.4.3.6 and BVPS-1 UFSAR, Section 2.3.8.4).

2.1.9. Low Water

The UHS for BVPS is the Ohio River. A design basis failure of the nearest downstream dam (the New Cumberland Dam) during a minimum flow of 4,000 cfs would result in a minimum water surface elevation at the site of 648.6 feet msl (BVPS-2 UFSAR, Section 2.4.11.1 and BVPS-1 UFSAR, Section 2.3.11). Plant shutdown is initiated when the river level falls to 654 feet msl.

2.2. Flood-Related Changes to the License Basis

There were no changes to the flood-related license basis since the initial license issuance.

2.3. Changes to the Watershed and Local Area since License Issuance

The watershed contributory to the Ohio River is determined to be 23,845 square miles based on the most current data available (Reference BVPS 2015b). The watershed contributory to Peggs Run is determined to be 3.6 square miles based on the most current data available (Reference BVPS 2015f). Based on aerial images of the watershed, the changes to the watershed include development within the watershed area, which is a small percentage of the overall watershed area. The changes to the local area sub-watershed for BVPS include buildings, parking lots, and security barrier upgrades that have been added to the site since license issuance. Changes to the watershed and local area are incorporated into the flood hazard reevaluation.

2.4. Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

The PMF, with an associated water level of 730 feet msl, is the design basis for all safety-related structures (BVPS-2 UFSAR, Section 2.4.14). The Intake Structure is flood protected to elevation 737 feet msl by extending the ventilation air intakes to this elevation, allowing for a 6.7 feet runup above the standing water level of 730 feet msl (BVPS-2 UFSAR, Section 3.4.1).

Furthermore, the maximum flood level from the LIP exceeds the 732.0 feet msl lowest access door sill of the safety-related service building (BVPS-2 UFSAR, Table 2.4-6). Since the sill is at grade, runoff water from local site flooding will seep under the door during the PMP until the site drainage system becomes operational or the water level dissipates. The accumulation of water in the service building has been calculated to be 1.3 inches deep (BVPS-2 UFSAR, Section 2.4.2.3.2). No safety-related equipment or electrical connections are located closer than 2 inches to the floor. Therefore, no mitigation actions were initiated or taken for flooding at the site.

3. SUMMARY OF FLOOD HAZARD REEVALUATION

NUREG/CR-7046, *Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America* (Reference NUREG/CR-7046), by reference to the American Nuclear Society (ANS), states that a single flood-causing event is inadequate as a design basis for power reactors and recommends that combinations should be evaluated to determine the highest flood water elevation at the site. For BVPS, the flooding mechanism that produces the highest flood water elevation at site safety-related structures is the LIP event as provided below.

The UFSAR reports elevation corresponding to a msl datum that is equivalent to the NGVD 29 vertical datum. The recent site survey, United States Geological Survey (USGS) topographic maps, and other reference documents report elevation in the North American Vertical Datum of 1988 (NAVD 88). In order to compare the reevaluated flood elevations with the existing design basis elevations reported in the UFSAR, the final pertinent elevations are converted to the NGVD 29 datum. The conversion from NAVD 88 to NGVD 29 at BVPS is represented as: feet NGVD 29 = feet NAVD 88 + 0.75 feet (Reference BVPS 2015g).

Calculation DSC-6794 (Reference BVPS 2015g) defines the maximum water surface elevation resulting from the LIP event. The maximum water surface elevation for BVPS-1, at plant structure openings potentially leading to safety related equipment, due to the LIP event is 735.9 feet NGVD 29. The LIP maximum water surface elevation exceeds one access door sill elevation of 735.5 feet NGVD 29 at BVPS-1 by 0.4 feet for up to 6 hours. Seven other access door sill elevations are exceeded by less depth and for a shorter duration. The maximum water surface elevation for BVPS-2, at plant structure openings potentially leading to safety related equipment, due to the LIP event is 735.7 feet NGVD 29. The LIP maximum water surface elevation exceeds one access door sill elevation of 732.0 feet NGVD 29 at BVPS-2 by 0.5 feet for up to 6 hours. Three other access door sill elevations of 735.5 feet NGVD 29 at BVPS-2 are exceeded by up to 0.2 feet for up to 1.25 hours.

The methodology used in the flooding reevaluation for BVPS is consistent with the following standards and guidance documents:

- NRC Standard Review Plan, NUREG-0800, revised March 2007 (Reference NUREG-0800)
- NRC Office of Standards Development, Regulatory Guides, RG 1.102 – “Flood Protection for Nuclear Power Plants,” Revision 1, dated September 1976 (Reference NRC RG 1.102) and RG 1.59-“Design Basis Floods for Nuclear Power Plants,” Revision 2, dated August 1977 (Reference NRC RG 1.59)
- NUREG/CR-7046, “Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America,” dated November 2011 (Reference NUREG/CR-7046)
- NUREG/CR-6966, “Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America,” dated March 2009 (Reference NUREG/CR-6966)
- “American National Standard for Determining Design Basis Flooding at Power Reactor Sites,” dated July 28, 1992 (Reference ANSI/ANS-2.8-1992)
- NEI Report 12-08, “Overview of External Flooding Reevaluations” (Reference NEI August 2012)
- NRC JLD-ISG-2012-06, “Guidance for Performing a Tsunami, Surge or Seiche Flooding Hazard Assessment,” Revision 0, dated January 4, 2013 (Reference JLD-ISG-2012-06)
- NRC JLD-ISG-2013-01, “Guidance for Assessment of Flooding Hazards due to Dam Failure,” Revision 0, dated July 29, 2013 (Reference JLD-ISG-2013-01)

The flood hazard reevaluation, including inputs and methodology, are beyond the current BVPS design and license basis. Consequently, the analytical results project beyond the capability of the current design basis. The following provides the flood-causing mechanisms and their associated water surface elevations that are considered in the BVPS flood hazard reevaluation:

3.1. Flooding in Streams and Rivers (Reference BVPS 2015a, BVPS 2015b, BVPS 2015c, BVPS 2015d, BVPS 2015f, and USACE 2015)

The PMF in rivers and streams adjoining the site is determined by applying the probable maximum precipitation (PMP) to the drainage basin in which the site is located. The PMF is based on a translation of PMP rainfall in the watershed to flood flow. The PMP is a deterministic estimate of the theoretical maximum depth of precipitation that can occur at a certain time of year for a specified area at a particular geographical location. A rainfall-to-runoff transformation function, as well as runoff characteristics, based on the topographic and drainage system network characteristics and watershed properties, are needed to appropriately develop the PMF hydrograph. The PMF hydrograph is a time history of the discharge and serves as the input parameter for other hydraulic models that develop the flow characteristics, including flood flow and elevation.

The PMF is a function of the combined events defined in NUREG/CR-7046 for floods caused by precipitation events.

Alternative 1 – Combination of:

- Mean monthly base flow
- Median soil moisture
- Antecedent or subsequent rain: the lesser of (1) rainfall equal to 40 percent of PMP and (2) a 500-year rainfall
- The All-Season PMP
- Waves induced by 2-year wind speed applied along the critical direction

Alternative 2 – Combination of:

- Mean monthly base flow
- Snowmelt from the probable maximum snowpack
- A 100-year, snow-season rainfall
- Waves induced by 2-year wind speed applied along the critical direction

Alternative 3 – Combination of:

- Mean monthly base flow
- Snowmelt from a 100-year snowpack
- Snow-season PMP
- Waves induced by 2-year wind speed applied along the critical direction

The PMF and dam failure analysis for the Ohio River were performed by the U.S. Army Corps of Engineers (USACE) under For Official Use Only (FOUO) restrictions (Reference USACE 2015). Therefore, details of the analyses and results are not provided. The Ohio River PMF results are based on basin wide site-specific PMP input. The basin-wide site-specific PMP details are provided below.

3.1.1. Basis of Inputs

Ohio River

Site-specific, all-season PMP analysis

- BVPS watershed location;
- USGS global multi-resolution terrain elevation data;
- Storm database sources including the National Oceanic and Atmospheric Administration (NOAA), the National Climatic Data Center (NCDC),

Hydrometeorological Reports, USACE Storm Studies, Environment Canada, state climate office publications, American Meteorological Society journals, storm lists from previous studies in the region, USGS Flood Reports, and supplemental data sources, such as Community Collaborative rain, Snow and Hail Network, Weather Underground, Forecast Systems Laboratories, and Remote Automated Weather Stations;
- Weather Service Radar WSR-88D NEXt generation RADar (NEXRAD) data;
- HYSPLIT model trajectories from the NOAA Air Resources Laboratory.

Peggs Run

The inputs used in the PMP, snowmelt, and PMF analyses for Peggs Run are based on the following:

All-Season PMP Analysis and Cool-Season PMP with Snowmelt Analysis

- Peggs Run watershed location;
- All-Season PMP from Hydrometeorological Report No. 51 (HMR 51) and HMR 52;
- Seasonal PMP from HMR 53;
- The 100-year, all-season point rainfall estimates from the NOAA Precipitation Frequency Data Server;
- Temperature and wind speed data from National Weather Service hourly reporting surface stations;
- Daily snow depth and density data downloaded from NOAA; and
- Snowmelt rate (energy budget) equations and constants are based on U.S. Army Corps of Engineers Engineering Manual EM-1110-2-1406.

PMF Analysis-Hydrologic and Hydraulic Analysis

- Peggs Run watershed location, area, boundary and configuration;
- Precipitation and associated snowmelt for the watershed area;
- Site topography developed from aerial photogrammetry;
- Digital elevation model (DEM) developed from the USGS National Elevation Dataset and USACE Ohio River Hydrographic Bathymetric Survey Data;
- Land Use: The land use information for the watershed is obtained from the U.S. Department of Agriculture (USDA) National Resources Conservation Service (NRCS) National Land Cover Dataset;
- Soil Type: The soil types within the project watershed are obtained from the USDA NRCS soil survey geographic database;
- Base flow: Historic flow rate data collected by USGS at gauge 03108000 (Raccoon Creek at Moffatts Mill, PA) and gauge 03109500 (Little Beaver Creek near East Liverpool, OH), which is used to determine the base flow for Peggs Run;
- Manning's roughness coefficients are based on a visual assessment of aerial photography and selected using standard applicable engineering guidance references.

3.1.2. Computer Software Programs

Ohio River

Site-specific, all-season PMP analysis

- ArcGIS Desktop 10.1
- Microsoft Excel
- SPAS 9.5

<u>Peggs Run</u>

PMP and Snowmelt analysis

- ArcGIS Desktop 10.1
- Microsoft Excel

PMF analysis

- AutoCAD Civil 3D 2012
- ArcGIS Desktop 10.0
- ArcGIS Desktop 10.1
- HEC-HMS 3.5
- HEC-RAS 4.1
- Microsoft Excel

3.1.3. Methodology

<u>Ohio River</u>

The site-specific PMP analysis applies a storm-based approach, consistent with the methodology of the World Meteorological Organization manuals and HMR 51, and includes the following general steps:

- Barrier analysis to quantify the effect of intervening topography.
- An extensive storm search to identify storms which could be used for PMP studies in the region.
- SPAS used to analyze storms and produce depth-area-duration rainfall data.
- Develop updated maximum average dew point climatology.
- Utilize HYSPLIT model trajectories to define moisture source locations.
- Largest precipitation events which are determined to be transpositionable to the BVPS watershed are then maximized in-place and transpositioned to the site.
- Rainfall amounts from all storms are enveloped to develop the depth-area-duration relationship for the site-specific, all-season PMP.

Site-Specific, All-Season PMP

The terrain within the BVPS watershed varies in elevation from the Ohio River to the Allegheny Mountains of West Virginia. Elevated terrain features located upwind and surrounding the watershed deplete atmospheric moisture before reaching the watershed. The barrier analysis quantifies the moisture depletion by upwind barriers when transpositioning storms into the watershed.

Storm databases are searched to identify historical upper limit rainfall storms that have occurred in meteorological and topographical similar regions surrounding the BVPS watershed. The search area extends from southern Canada, including parts of Ontario and Quebec, west to the Great Plains, east to the Appalachian crest, and south to latitude 35° N. The comprehensive storm search results in 25 events from 1878 to 2010.

Each storm is evaluated in detail to develop depth-area-duration data, in-place maximization factors, and transposition factors based on HMR 51 tables, USACE Storm Studies reports, Environment Canada analyses, or as developed during SPAS storm analyses. Maximization and transposition incorporate updated maximum dew point climatology and HYSPLIT model trajectories to define moisture source locations.

Each storm is then maximized by the in-place maximization factor to represent what the storm would have produced had the atmospheric conditions and moisture available for rainfall production been at maximum levels when the storm occurred versus what was actually observed. The in-place maximized values for each storm are then adjusted to transpose the storm from its original location to the BVPS watershed. The transposition calculation adjusts for differences in available moisture at the site versus the original storm location. Storms that are transpositioned across terrain barriers are also adjusted to account for the amount of precipitable water that would not be available to that storm.

Once the total storm adjusted rainfall values are determined, envelope curves for each duration are constructed to produce the complete depth-area-duration table representing the site-specific, all-season PMP for the BVPS watershed. The depth-area-duration table includes durations of 6-, 12-, 24-, 48-, and 72-hours.

Peggs Run

The Peggs Run PMF analysis includes the following steps:

- Delineate watershed and sub-watersheds and calculate sub-watershed areas for input into the HEC-HMS rainfall-runoff hydrologic computer model.
- Determine all-season PMP (Alternative 1).
- Determine probable maximum snowpack and snowmelt associated with the 100-year, cool-season rainfall (Alternative 2).
- Determine 100-year snowpack and snowmelt associated with the cool-season PMP (Alternative 3).
- Estimate HEC-HMS rainfall-runoff model input parameters: NRCS unit hydrograph method.
- Adjust unit hydrograph to account for the effects of nonlinear basin response.
- Perform PMF simulations using HEC-HMS model to determine the controlling alternative.
- Estimate water surface elevation using HEC-RAS unsteady-state model with the controlling alternative runoff hydrograph from the HEC-HMS model as an input.

Watershed Delineation

For the purposes of the hydrologic modeling effort, Peggs Run is evaluated using two sub-watersheds, delineated based on a combination of data from the USGS National Elevation Dataset and site topography.

Rainfall and Snowmelt

Each alternative contains rainfall defined either by the all-season PMP (Alternative 1), the 100-year, cool-season rainfall (Alternative 2), or the cool-season PMP (Alternative 3). Each rainfall event is considered to be a 72-hour duration event. Note that an antecedent rainfall occurs prior to the all-season PMP. Because of the small drainage area of Peggs Run and the 72-hour dry period between the antecedent storm and the PMP event, the antecedent storm is determined not to contribute to the PMP storm.

Snowmelt is included in the two cool season alternatives. Alternative 2 includes snowmelt from the probable maximum snowpack. Alternative 3 includes snowmelt from the 100-year snowpack. For rain-on-snow conditions dew point temperature and wind speed are obtained from the site-specific PMP analysis. The basin wind coefficient is conservatively assumed to maximize snowmelt.

The snowpack is assumed to be at its maximum at the onset of rainfall events and cover the entire watershed. Soil is assumed to be frozen with no precipitation losses during the cool-season months of October through April. For the probable maximum snowpack, the snowpack depth is assumed to provide continuous snowmelt for the entire duration of the coincident rainfall event.

Alternative 1 – All-Season PMP

The location of the Peggs Run watershed is within the domain of HMR 51 and HMR 52 guidance. The all-season PMP is determined by using the generalized PMP estimates for point precipitation defined by HMR 51 for durations from 6 to 72 hours and by HMR 52 for 1 hour and sub-hourly increments. Intermediate hourly incremental PMP depths are interpolated from the HMR estimates.

The temporal distribution of the PMP is arranged in accordance with recommendations in HMR 52, wherein individual rainfall increments decrease progressively to either side of the greatest rainfall increment. Various temporal distributions for each rainfall scenario are then evaluated to further maximize the runoff. Front, one-third, center, two-thirds, and end-loading temporal distributions are considered in an effort to capture the distribution that maximizes runoff.

Alternative 2 – Probable Maximum Snowpack and 100-Year Cool-Season Rainfall

While snowpack can be determined directly from the snow depth, adequate data is not available to extrapolate any historical observations up to the magnitude of the probable maximum event. To maximize snowmelt contribution, the probable maximum snowpack is conservatively assumed not to deplete during the duration of the coincident rainfall.

The 100-year, cool-season rainfall up to a duration of 72-hours is determined using the nearest NOAA precipitation station data located at the Montgomery Lock and Dam. NOAA Atlas 14 provides all-season point precipitation frequency estimates via the NOAA precipitation frequency data server. The NOAA Atlas 14 values are adjusted to reflect cool-season rainfall rather than all-season rainfall based on ratios of seasonal generalized PMP estimates defined by HMR 53. Hourly incremental rainfall depths are interpolated from the adjusted estimates.

The 100-year, cool-season rainfall is equivalent for all the cool-season months. The maximized dew point temperature and wind speed time series determined by site-specific analysis is applied to the cool-season months. To maximize snowmelt at each time step, the dew point temperature and wind speed are reordered to match the 72-hour temporal distributions of the rainfall.

Alternative 3 – 100-Year Snowpack and Cool-Season PMP

A 100-year snow depth is calculated by performing a statistical analysis based on the historical data obtained from the NOAA National Climatic Data Center daily snow depth records. A Fisher-Tippett Type I (FT-I) distribution frequency analysis is performed to determine the maximum snow depth with an annual exceedance probability of 1 percent (i.e., 100-year snow depth) for each month from October through April. The FT-I distribution is applicable for long-term statistical analyses and specifically for extreme value calculations. An average snowpack bulk density is applied to determine the available snow water equivalent.

The cool-season PMP is determined by using the generalized seasonal PMP estimates for point precipitation defined by HMR 53 for durations of 6-, 24-, and 72-hours. Ratios of cool-season PMP to all-season PMP are used to define intermediate durations less than

6 hours. Hourly incremental PMP depths are interpolated from the HMR estimates. To maximize snowmelt at each time step, the dew point temperature and wind speed, determined by site-specific analysis, are reordered to match the 72-hour temporal distributions of the rainfall.

Hydrologic Model (HEC-HMS)

The PMF is the flood resulting from the 72-hour duration all-season PMP or a combination of cool-season rainfall and snowmelt. The temporal distribution of the PMP is determined in accordance with the recommendations in HMR-52, wherein individual increments decrease progressively to either side of the greatest increment. Front, one-third, center, two-thirds, and end-loading temporal distributions are considered in an effort to capture the distribution that maximizes runoff. Because of the small drainage area of Peggs Run and the 72-hour dry period between the antecedent storm and the PMP event, the antecedent storm is determined not to contribute to the PMP storm.

USACE HEC-HMS hydrologic software is used to convert rainfall to runoff. A rainfall hyetograph is applied to each sub-watershed of Peggs Run and transformed to runoff using unit hydrograph methodology. Generally, a unit hydrograph is developed using historical data obtained from various rain and stream gauges in the watershed. The Peggs Run watershed is ungauged. Thus, no historical observations are available to use as a basis to create a unit hydrograph. Therefore, a synthetic unit hydrograph is developed. NRCS unit hydrograph methodology is used for rainfall-to-runoff transformation.

ANSI/ANS-2.8-1992 suggests that base flow should be based on mean monthly flow. As mean monthly flow is not available for Peggs Run, the base flow is approximated using the mean monthly flow for nearby watersheds. The USGS gauge stations for Raccoon Creek at Moffatts Mill, PA and Little Beaver Creek near East Liverpool, OH are used. Raccoon Creek and Little Beaver Creek are in the same hydrologic unit as Peggs Run and have similar watershed characteristics. Therefore, it is an acceptable approach to use the base flow information from nearby watersheds as the basis for estimation of the base flow for Peggs Run.

The NRCS curve number loss method is incorporated into the all-season PMF alternative analysis based on the hydrologic characteristics of the soils, land use, and land cover. No precipitation losses are incorporated into the cool-season PMF alternatives due to the assumption that the ground is frozen.

The unit hydrographs for each sub-watershed of Peggs Run are modified to account for the effects of nonlinear basin response in accordance with NUREG/CR-7046. The peak of each unit hydrograph is increased by one-fifth and the time-to-peak is reduced by one-third. The remaining hydrograph ordinates are adjusted to preserve the runoff volume to a unit depth over the drainage area.

Hydraulic Model (HEC-RAS)

The unsteady-state flow simulation module within the USACE HEC-RAS software is used to transform the time series outflow hydrograph of the HEC-HMS model for the controlling alternative into a water surface elevation hydrograph. Channel and floodplain geometry for Peggs Run is modeled by developing cross sections of the stream. The cross sections are placed at locations that define geometric characteristics of the stream and overbanks. Cross sections are also placed at representative locations where changes occur in discharge, slope, shape, and roughness, as well as at hydraulic and inline structures (e.g., bridges and culverts). The culvert at the downstream plant access road crossing is assumed blocked and modeled as an inline structure with all flow overtopping the road.

3.1.4. Results

Ohio River

The PMF for the Ohio River at BVPS was performed by the USACE under FOUO restrictions (Reference USACE 2015). Therefore, details of the analysis and results are not provided.

Peggs Run

The Alternative 1 PMF is the controlling combination and is a result of the all-season PMP. The two-thirds temporal distributions produces peak flow results and the maximum water levels. The maximum flow overtopping the plant access road is 24,000 cfs resulting in a maximum water surface elevation of 735.0 feet NGVD 29. The access road is not immediately adjacent to safety-related structures. Flows overtopping the access road will propagate toward the Ohio River, potentially contributing water to the LIP runoff. The contribution to LIP flooding is incorporated into the analysis discussed in Section 3.8.

3.2. Dam Assessment (Reference USACE 2015)

The dam failure analysis for the Ohio River was performed by the USACE under FOUO restrictions (Reference USACE 2015). Therefore, details of the analysis and results are not provided.

Assumed dam failure of the downstream New Cumberland Dam would lower the Ohio River used as the UHS. However, plant shutdown is initiated when the river level falls to 654 feet NGVD 29. The minimum flow of 4000 cfs in the Ohio River with the downstream dam failure is sufficient for plant use. Furthermore, downstream dam failure as a result of the beyond design basis PMF or dam failure event would be associated with higher flows and higher water levels than the current design basis. Therefore, low water as a result of hydrologic dam failure is bounded by the current design basis.

3.3. Ice-Induced Flooding (Reference BVPS 2015a, 2015e, and BVPS 2015h)

As identified by NUREG/CR-7046, ice jams and ice dams can form in rivers and streams adjacent to a site, and may lead to flooding by two mechanisms:

- Collapse of an ice jam or an ice dam upstream of the site can result in a dam breach-like flood wave that may propagate to the site; and
- An ice jam or an ice dam downstream of a site may impound water upstream of itself, thus causing a flood via backwater effects.

3.3.1. Basis of Inputs

- USACE ice jam database.
- Site topography.
- Digital elevation model (DEM) developed from the USGS National Elevation Dataset and USACE Ohio River Hydrographic Bathymetric Survey Data.
- USACE Lock and Dam manuals.
- Department of Transportation bridge geometry.
- USGS surface water data.
- Land use information obtained from the USDA NRCS Geospatial Data Gateway.

3.3.2. Computer Software Programs

- ArcGIS Desktop 10.1
- HEC-RAS 4.1
- Microsoft Excel

3.3.3. Methodology

Per NUREG/CR-7046, ice-induced flooding is assessed by reviewing the USACE ice jam database to determine the most severe historical events that have occurred. Historical records are available for the Ohio River and watershed tributaries. Based on ice jam occurrences recorded for rivers within the watershed, it is determined that ice jam events are possible.

The maximum ice jam is determined by selecting the historic event that produced the maximum flood stage relative to the normal water surface elevation at that location. Regardless of the specific conditions that produced the historic flood stage at a specific location, the full height is conservatively assumed to represent the ice jam.

An unsteady-state flow HEC-RAS hydraulic model is used to evaluate the effects of the ice jam. A HEC-RAS hydraulic model is constructed for a reach of the Ohio River and includes multiple locks and dams and river crossings. The hydraulic model is calibrated using USGS gauge data for historical extreme storms. Roughness coefficients are determined based on land use and land cover data and adjusted as part of the calibration process.

The maximum ice jam is transposed to the nearest upstream and downstream bridge locations, identified in Figure 3.3.1. Per NUREG/CR-7046, flooding due to an ice jam is not required to be combined with other extreme flooding events. However, to represent coincident flow in the Ohio River, one of the largest historical cool-season flood events with complete gauge data records is applied to the HEC-RAS hydraulic model.

For an upstream ice jam, the calibrated HEC-RAS hydraulic model is modified to include an inline structure at the upstream Shippingport Bridge. The inline structure is breached coincident with the peak historical inflow to determine the effects at the site. For a downstream ice jam, the calibrated HEC-RAS hydraulic model is modified to include an inline structure at the downstream Lincoln Highway Bridge to determine the backwater effects resulting from the applied historical inflow.

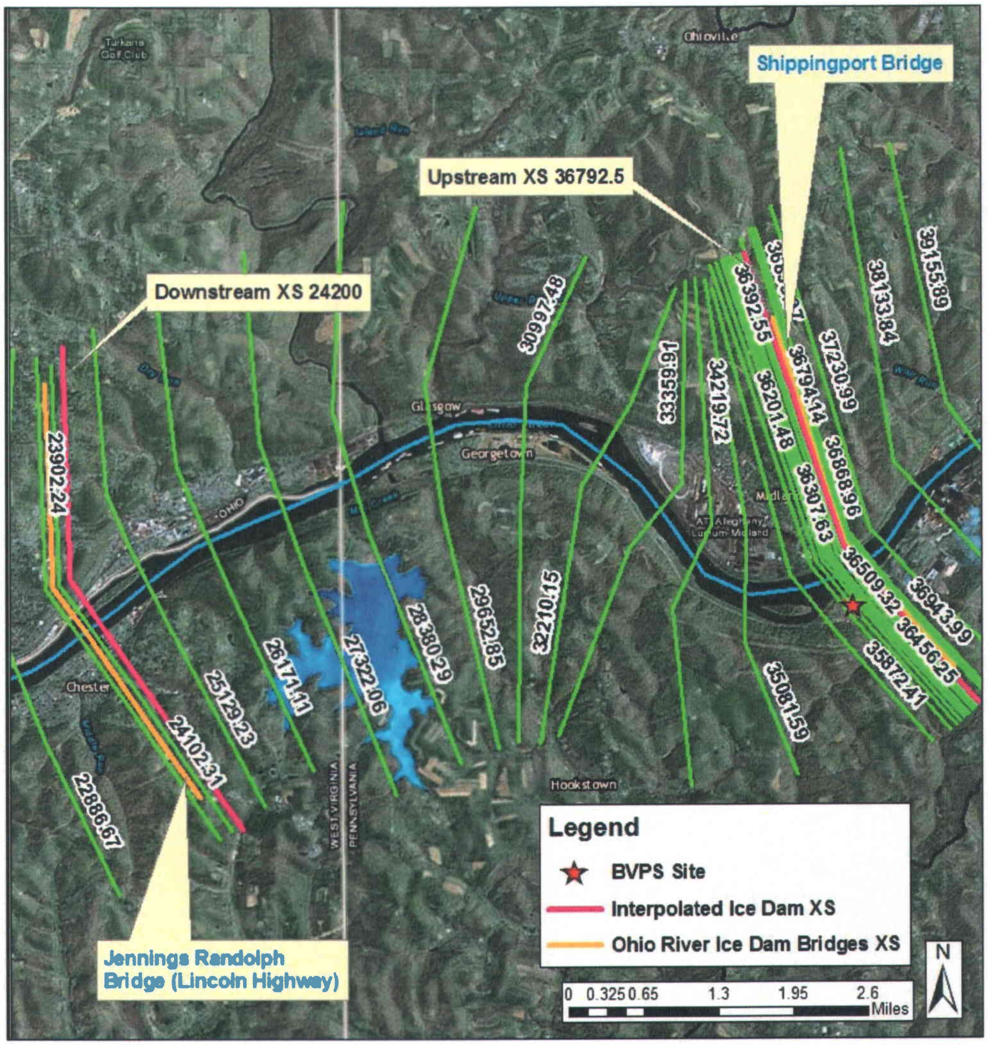

Figure 3.3.1 – Bridge Locations

3.3.4. Results

The maximum reported ice jam stage in the BVPS watershed is estimated to be 28.4 feet. The maximum water surface elevation at BVPS resulting from the upstream ice jam breaching is calculated to be 700.6 feet NGVD 29. The maximum water surface elevation at BVPS resulting from the downstream ice jam is calculated to be 719.3 feet NGVD 29. Ice-induced flooding at BVPS is bounded by the PMF, and no further consideration is required.

3.4. Channel Migration or Diversion (Reference BVPS 2015i)

NUREG/CR-7046 indicates historical records and hydrogeomorphological data should be used to determine whether an adjacent channel, stream, or river has exhibited the tendency to migrate towards the site.

3.4.1. Basis of Inputs

- USGS topographic quadrangle maps and aerial images

3.4.2. Computer Software Programs

- ArcGIS Desktop 10.1

3.4.3. Methodology

Historic and current topographic quadrangle maps and aerial images are reviewed to examine the condition and alignment of the Ohio River over time. Due to the small drainage area and distance to the site, channel migration of Peggs Run is not examined.

3.4.4. Results

Topographic maps for the years of 1901, 1954, and 2013 along with aerial images from 2004 and 2013 are reviewed to assess the potential for historic channel migration of the Ohio River. The extents of open water in the vicinity of the site from the 2013 topographic map are used as a benchmark for the assessment. The comparison of maps and aerial images from 1954 to 2013 indicates that channel migration has not occurred. Discrepancies do exist between the more recent data and the 1901 map. However, because of the inherent inaccuracy of the methods used to create the 1901 topographical map, channel migration based on the 1901 data cannot be determined. Because data sources provide no evidence that channel diversion has occurred, channel migration is not probable.

3.5. Storm Surge

In accordance with JLD-ISG-2012-06, all coastal nuclear power plant sites and nuclear power plant sites adjacent to cooling ponds or reservoirs subject to potential hurricanes, windstorms and squall lines must consider the potential for inundation from storm surge and waves. The BVPS site is not situated on a coast and is not located adjacent to cooling ponds or reservoirs. Therefore, storm surge and seiche are not applicable.

3.6. Tsunami Assessment

The BVPS site is not situated on a coast and is not located adjacent to cooling ponds or reservoirs. Therefore, tsunamigenic waves are not applicable.

3.7. Combined Effect Flood (including Wind-Generated Waves) (Reference BVPS 2015j)

The flood mechanism producing the maximum water surface elevation is evaluated for the combined effects of wind wave activity. The PMF for the Ohio River produces the maximum stillwater elevation at the site. Evaluation of floods caused by precipitation events is covered in Appendix H.1 of NUREG/CR-7046. The three alternatives are identified in flooding on streams and rivers (Section 3.1). Combined effect flooding evaluates the component of added waves induced by 2-year wind speed along the critical direction.

3.7.1. Basis of Inputs

Inputs include the following:

- PMF maximum water surface elevation from USACE (Reference USACE 2015)
- 2-year wind speed
- Site topography

3.7.2. Computer Software Programs

- ArcGIS Desktop 10.1

- Microsoft Excel

3.7.3. Methodology

Coincident wind-wave activity is determined for the critical flooding combination using the USACE guidance outlined in the USACE *Coastal Engineering Manual (CEM)*. The 2-year wind speed is applied to the longest fetch length based on the inundation area of the PMF obtained from the USACE (Reference USACE 2015) to calculate the significant wave height and wave period. Wave height and wind setup are determined in accordance with USACE CEM guidance. Significant wave height is used to determine wave runup in accordance with USACE CEM guidance and Miscellaneous Paper CERC-90-4 (Reference USACE 1990) that provides maximum periodic wave runup on smooth vertical slopes. Wind setup is the effect of horizontal stress on the water surface. Runup is the maximum elevation of wave uprush above stillwater level.

3.7.4. Results

Wind wave activity results are determined for the BVPS Intake Structure, Unit 1 Turbine Building, Unit 2 Reactor Building, and the FLEX Storage Building and Emergency Outfall Structure (EOS). Ohio River PMF coincident wind wave activity resulted in a maximum runup elevation of 733.99 feet NGVD 29 at the Intake Structure, 732.76 feet NGVD 29 at the Unit 1 Turbine Building, 734.01 feet NGVD 29 at the Unit 2 Reactor Building, and 734.52 feet NGVD 29 at the FLEX Storage Building and EOS location.

Wind waves runup the vertical face of the Intake Structure and the Unit 1 Turbine Building. Wind waves would break at the North wall of the Unit 1 Turbine Building. Broken waves with smaller wave heights propagating towards the interior flood barrier wall between the Service Building and the Turbine Building are estimated to be 729.65 feet NGVD 29. Unit 1 critical doors are not located below where runup would occur. The runup on the Intake Structure is bounded by the current design basis. Runup approaching the Unit 2 Reactor Building and the FLEX Storage Building and EOS location is maintained on the ground slope.

3.8. Local Intense Precipitation (Reference BVPS 2015a, BVPS 2015f, and BVPS 2015g)

The LIP is an extreme precipitation event (high intensity/short duration) at a given location. The duration of the event and the coverage area are needed to quantify an extreme precipitation event fully. Generally, the intensity of precipitation decreases with increasing duration and increasing area. NUREG/CR-7046 specifies that the LIP should be equivalent to the 1-hour, 1-square mile PMP at the location of the site. A site-specific LIP is developed for the analysis.

3.8.1. Basis of Inputs

- Site topography
- Runoff contributions from Peggs Run
- Site-specific LIP
- Manning’s roughness coefficients

3.8.2. Computer Software Programs

- ArcGIS Desktop 10.1
- FLO-2D Pro, Build 14.08.09
- HEC-HMS 3.5

- Microsoft Excel
- SPAS 9.5

3.8.3. Methodology

The LIP event is evaluated to determine the associated flooding elevations assuming the active and passive drainage features are non-functional. Runoff losses for the BVPS site area are also not included. The entire roof drainage is assumed to be contributing to surface runoff. The LIP evaluation is performed in accordance with the NUREG/CR-7046 and based on site-specific LIP input.

The site-specific LIP analysis applies a storm-based approach, consistent with the methodology of the World Meteorological Organization manuals and HMR 51, and includes the following general steps:

- An extensive storm search to identify storms which could be used for the LIP study.
- Derive the 1-hour, 1-square mile precipitation depth for storms previously analyzed.
- SPAS used to analyze storms and identify the 1-hour, 1-square mile precipitation depth.
- Precipitation is maximized in-place and transpositioned to the site.

The storm search resulted in 19 events from 1891 to 2011. Ten of these storms were previously analyzed in HMR 33 and HMR 51. Most of these storms did not contain explicit 1-hour, 1-square mile data. Therefore, HMR 52 ratios of 1 hour, 1-square mile data to 6-hour, 10-square mile data are used to derive the necessary data. The remaining nine storms are analyzed using SPAS.

The data is then maximized by the in-place maximization factor to represent what the storm would have produced had the atmospheric conditions and moisture available for rainfall production been at maximum levels when the storm occurred versus what was actually observed. The in-place maximized values for each storm are then adjusted to transpose the storm from its original location to the BVPS site. The transposition calculation adjusts for differences in available moisture at the site versus the original storm location. Sub-hourly increments of 5-, 15-, and 30-minutes are developed using the ratios provided by HMR 52.

The 1-hour site-specific LIP is extended to a 6-hour duration based on the relationship between the site-specific 1-hour LIP and the 1-hour HMR 52 PMP utilized for Peggs Run. The flow hydrograph contribution from Peggs Run, discussed in Section 3.1, is a 72-hour flow hydrograph. In order to align the Peggs Run input flow with the LIP, the Peggs Run HEC-HMS model is run using a front temporal distribution 6-hour PMP event. The resulting flow hydrograph is scaled up for the resulting peak flow to match the peak flow discussed in Section 3.1.

The runoff caused by the LIP event is estimated using FLO-2D software. The software uses shallow water equations to route stormwater throughout the site. FLO-2D depicts site topography using a digital elevation model (DEM) to characterize grading, slopes, drainage divides, and low areas of the site. The DEM is a grid model developed from composite ground surface information. The methodology used within the FLO-2D software includes the rainfall function and the levee function (to incorporate site security features which could impact the natural drainage characteristics of the site).

Active and passive drainage system components (e.g., pumps, gravity storm drain systems, small culverts, and inlets) are considered non-functional or clogged during the LIP event, per Case 3 in NUREG/CR-7046. The Manning’s roughness coefficient values are selected based on the land cover type using the guidance provided in the FLO-2D manual. Two types of obstructions are modeled: buildings/structures that completely block the water passage, and security wall barriers that could be overtopped if the water depth increases to above the top of the wall. A mild slope of 0.5 percent is introduced to roof surfaces to ensure runoff propagates from any point on a roof towards the edge and discharges to the ground.

Peggs Run is not immediately adjacent to the power block or safety-related structures. Peggs Run terminates at the switchyard access road culvert. As discussed in Section 3.1, the culvert is assumed to be blocked. Flooding overflows the access road and is generally directed to the Ohio River with the potential of contributing to the LIP runoff. The two-dimensional modeling allows the overflow of Peggs Run to follow topographic flow patterns to the Ohio River and combine with the LIP runoff to contribute to flooding of the power block area where applicable.

To determine the associated flooding elevations, the site-specific LIP is applied evenly across the site, the Peggs Run flow hydrograph is included as an input to the model, and the model is allowed to run for the 6 hour duration.

3.8.4. Results

The LIP water surface elevations at critical door locations, or doors leading to safety-related SSCs, are listed in Table 1 for BVPS Unit 1 and in Table 2 for BVPS Unit 2.

Table 1 – BVPS Unit 1 LIP Maximum Water Surface Elevations and Flood Durations

Building	Door Number	Door Elevation (NGVD 29)	Maximum Water Surface Elevation (NGVD 29)	Flood Duration (hours)
Main Steam Cable Vault	MS-35-1	736.0	735.5	-
Diesel Generator Building	G-35-2	735.5	735.3	-
	G-35-3	735.5	735.3	-
	Removable Shield (E)	735.3	735.2	-
	Removable Shield (W)	735.3	735.3	-
Coolant Recovery Tanks	TA-35-1	735.5	735.6	0.25
	Removable Panel	736.3	735.6	-
Safeguards	SG-47-1	747.0	735.4	-
Fuel Building	F-35-1, F-35-3[2]	735.5	735.9	6[1]
	F-35-2	735.5	735.6	1
	F-35-4	735.5	735.7	1.75
Decontamination Building	D-35-1	735.5	735.2	-
	D-35-2	735.5	735.3	-
Service Building	S-35-44	735.5	735.5	-
	S-35-48	735.5	735.5	-
	S-35-49	735.5	735.5	-
	S-35-67	735.5	735.5	-
Warehouse	W-35-1	735.5	735.5	-
Waste Gas Storage Area	DT-27-1	736.0	735.6	-
Containment	Equipment Hatch	767.2	735.2	-
Control Building	O-35-1	735.5	735.6	0.25
	S-35-71	735.5	735.6	0.25
	S-35-72	735.5	735.8	0.25
	S-35-74	735.5	735.6	0.25

- Indicates door elevation is not exceeded.
1 Flood duration is prolonged due to the door location in a semi-enclosed area.
2 F-35-1 and F-35-3 are arranged in series

Table 2 – BVPS Unit 2 LIP Maximum Water Surface Elevations and Flood Durations				
Building	**Door Number**	**Door Elevation (NGVD 29)**	**Maximum Water Surface Elevation (NGVD 29)**	**Flood Duration (hours)**
Main Steam Cable Vault	MS-35-3	735.5	732.5	-
Safeguards	SG-37-4	737.5	734.7	-
	SG-37-5	737.5	732.5	-
Diesel Generator Building	DG-32-1	732.5	732.5	-
	DG-32-4	732.5	731.9	-
	DG-32-5	732.5	732.3	-
	DG-32-6	732.5	732.3	-
	Removable Shield (N)	733.1	731.9	-
	Removable Shield (S)	733.1	732.1	-
Auxiliary Building	A-35-1	735.5	735.7	1.25
	A-35-3	735.5	735.6	0.75
	A-35-5	735.5	735.6	0.25
Fuel Building	F-35-1	735.5	735.5	-
	F-35-2	735.5	735.4	-
	F-35-3	735.5	735.3	-
Decontamination Building	D-35-1	735.5	735.3	-
	D-35-2	735.5	735.2	-
Service Building	SB-30-7	732.5	732.5	-
	SB-30-8	732.0	732.5	6[1]
Containment	Equipment Hatch	767.2	734.6	-

\- Indicates door elevation is not exceeded.
[1] Flood duration is prolonged due to the door location in a semi-enclosed area.

Coincident wind wave activity combined with the LIP is not designated by NUREG-CR/7046. Additionally, site obstructions, including structures and barrier blocks, and shallow water depths of flooding preclude development of significant fetch length and subsequent wave conditions.

4. COMPARISON WITH CURRENT DESIGN BASIS

The reevaluated maximum water surface elevations due to riverine flooding (Ohio River) are below the current design basis. The reevaluated maximum PMF water surface elevation coincident with a 2-year wind wave activity exceeds the current design basis. The reevaluated maximum water surface elevations due to the LIP exceed the current design basis.

The current design basis for LIP flooding incorporates a 10-minute PMP intensity of 3.5 inches into analysis of the site using one-dimensional, hydraulic modeling HEC-2 software (BVPS-2 UFSAR, Section 2.4.2.3.2). The reevaluation incorporates a 1-hour site-specific LIP of 15.4 inches, with a 5-minute intensity of 5.2 inches, using recent topography and two-dimensional hydraulic modeling (BVPS 2015g). As a result the reevaluation maximum water surface elevations due to the LIP exceed the current design basis.

In the interim, it is understood that an event of such magnitude to approach the postulated accumulation of rainfall is a low probability event. The Interim Actions discussed in Section 5 provide adequate protection until permanent solutions are implemented.

The comparisons of existing and reevaluated flood hazards are provided in Table 3. The PMF and dam failure analysis for the Ohio River were performed by the U.S. Army Corps of Engineers

(USACE) under For Official Use Only (FOUO) restrictions (Reference USACE 2015). Therefore, details of the analyses and results are not provided.

Table 3 – Comparison of Existing and Reevaluated Flood Hazards at BVPS

Flood-Causing Mechanism	Design Basis	Comparison	Flood Hazard Reevaluation Results
Flooding in streams and rivers	Ohio River PMF Elevation is 730 feet NGVD 29. PMF Flow is 1,500,000 cfs. Cool-season is not evaluated. Peggs Run (BVPS-2 only, not addressed for BVPS-1).PMF Elevation is less than 730 feet NGVD 29 in the vicinity of safety related structures. PMF Flow is 17,000 cfs. Cool-season is not evaluated.	Bounded Comparison included under LIP	Ohio River PMF analysis performed by the USACE under FOUO restrictions. Therefore, no details of the results are provided. Cool-Season not controlling. Peggs Run Reevaluated as part of LIP. All-Season PMF Flow is 24,000 cfs. Cool-Season PMF not controlling.
Dam breaches and failures	Ohio River Elevation is 725.2 feet NGVD 29. Flow is 1,280,000 cfs. Peggs Run Not addressed.	Bounded Not applicable	Ohio River Dam failure analysis performed by the USACE under FOUO restrictions. Therefore, no details of the results are provided. Peggs Run Not applicable
Storm surge	This flood-causing mechanism is identified as not applicable in the BVPS-2 UFSAR and is not addressed in the BVPS-1 UFSAR.	Not applicable	Not applicable

Table 3 – Comparison of Existing and Reevaluated Flood Hazards at BVPS (Continued)

Flood-Causing Mechanism	Design Basis	Comparison	Flood Hazard Reevaluation Results
Seiche	This flood-causing mechanism is identified as not applicable in the BVPS-2 UFSAR and is not addressed in the BVPS-1 UFSAR.	Not applicable	Not applicable
Tsunami	This flood-causing mechanism is identified as not applicable in the BVPS-2 UFSAR and is not addressed in the BVPS-1 UFSAR.	Not applicable	Not applicable
Ice-induced flooding	This flood-causing mechanism is identified as extremely unlikely in the UFSAR.	Bounded	Maximum water surface elevation is 719.3 feet NGVD 29. Ice-induced flooding is bounded by the all-season PMF event and design basis PMF level.
Channel migration or diversion	This flood-causing mechanism is identified as having no potential in the BVPS-2 UFSAR and is not addressed in the BVPS-1 UFSAR.	Not probable	Not probable
Combined effect flood (including wind-generated waves)	Wave runup on Intake Structure is 736.7 feet NGVD 29. Wave runup on site grade is not described in the UFSAR.	Bounded Not Bounded	Wave runup on Intake Structure is 733.99 feet NGVD 29. Wave runup on site grade is: 732.76 feet NGVD 29 at the Unit 1 Turbine Building North wall, 734.01 feet NGVD 29 at the ground slope approaching Unit 2 Reactor Building, and 734.52 feet NGVD 29 at the ground slope approaching the EOS.
LIP	BVPS-1 maximum water surface elevation not specifically identified. BVPS-2 Door sill exceeded at 1 location by 0.5 feet.	Not bounded. Exceeds current design basis.	BVPS-1 Door sills exceeded at 8 locations ranging from 0.1 feet to 0.4 feet. BVPS-2 Door sills exceeded at 4 locations ranging from 0.1 feet to 0.5 feet.

5. INTERIM AND PLANNED FUTURE ACTIONS

The Flooding Hazard Reevaluation Report evaluated the applicable flooding hazards for BVPS. Two of the postulated reevaluated flood hazard events, Wind generated waves concurrent with Ohio River PMF and the LIP, resulted in maximum flood water elevations higher than previously calculated for BVPS. Note that Peggs Run PMF flooding potentially contributes to LIP runoff effects and was incorporated into the LIP modeling. These postulated flooding events are considered beyond design basis events NTTF Recommendation 2.1 (Hazard Reevaluations): Flooding Revision C and do not constitute an operability concern.

As a result of the flood hazard reevaluation, the assessment of site buildings found a number of doors leading to areas containing safety-related equipment to be susceptible to postulated water infiltration from the LIP. The reevaluated flood levels are small increases with short durations.

The LIP maximum water surface elevation exceeds a BVPS-1 Fuel Building door sill elevation by a maximum depth of 0.4 feet for a total duration in excess of 6 hours. The flood duration is due to restricted runoff from the semi-enclosed area by buildings or curbs on three sides. The LIP exceeds door sill elevations at seven (7) additional BVPS-1 doors (Coolant Recovery Tanks, Fuel Building, and Control Building). The maximum exceedance at the additional doors is 0.1 feet to 0.3 feet and for a total duration from 0.25 hours to 1.75 hours.

The LIP maximum water surface elevation exceeds a BVPS-2 Service Building door sill elevation by a maximum depth of 0.5 feet for a total duration in excess of 6 hours. The flood duration is due to restricted runoff from the semi-enclosed area by buildings or curbs on three sides. The LIP exceeds door sill elevations at three (3) additional BVPS-2 doors (Auxiliary Building). The maximum exceedance at the additional doors is 0.1 feet to 0.2 feet and for a total duration from 0.25 hours to 1.25 hours.

As interim actions the results were documented in the Corrective Action Program (CAP). Additional assessments determined water infiltration volumes potentially entering under 10 of the 12 door sills to be inconsequential (Reference BVPS 2015k). This is due to the shallow depths and short durations that the door sills are exceeded by the LIP waters, as well as, the relatively large open floor areas within buildings minimizing depth accumulation. Therefore, no interim or future actions are planned at these 10 doors.

For the remaining two plant doors, one at the Unit 1 Fuel Building and one at the Unit 2 Service Building, sandbags were placed outside of the door openings as an interim action. An engineering change package has been developed and is currently scheduled to install flood barrier panels to a level above the maximum LIP water elevation at the doors. The modification is being tracked to completion within CAP. After implementation of the modifications the re-evaluated LIP results will be inconsequential to safety related SSCs. No additional actions beyond those currently in place are necessary at this time for the re-evaluated LIP event.

Wind generated waves concurrent with Ohio River PMF are above design basis levels at the Unit 1 Turbine Building North wall and at the slopes approaching the Unit 2 Containment Building and EOS.

As described in section 3.7.4 the re-evaluated wave run-up elevations do not reach levels which challenge SSCs. No interim actions or future actions are planned based on the re-evaluated wind generated waves concurrent with Ohio River PMF.

REFERENCES

(ANSI/ANS-2.8-1992) ANS, *American National Standard for Determining Design Basis Flooding at Power Reactor Sites*, Prepared by the American Nuclear Society Standards Committee Working Group ANS-2.8, 1992.

(BVPS 2015a) FENOC Calculation DSC-6786, *Beaver Valley Power Station PMF GIS Analysis*, Revision 0.

(BVPS 2015b) FENOC Calculation DSC-6787, *Beaver Valley Power Station All-Season Probable Maximum Precipitation Analysis*, Revision 0.

(BVPS 2015c) FENOC Calculation DSC-6788, *Beaver Valley Power Station Cool-Season Probable Maximum Precipitation Analysis*, Revision 0.

(BVPS 2015d) FENOC Calculation DSC-6791, *Beaver Valley Power Station Cool-Season Probable Maximum Flood and Snowmelt Analysis*, Revision 0.

(BVPS 2015e) FENOC Calculation DSC-6792, *Beaver Valley Power Station All-Season Probable Maximum Water Surface Elevation Analysis*, Revision 0.

(BVPS 2015f) FENOC Calculation DSC-6793, *Beaver Valley Power Station Peggs Run Probable Maximum Precipitation and Probable Maximum Flood Analysis*, Revision 0.

(BVPS 2015g) FENOC Calculation DSC-6794, *Beaver Valley Power Station: Effects of Local Intense Precipitation Analysis*, Revision 0.

(BVPS 2015h) FENOC Calculation DSC-6797, *Beaver Valley Power Station Ice Jam Analysis*, Revision 0.

(BVPS 2015i) FENOC Calculation DSC-6798, *Beaver Valley Power Station Channel Migration Analysis*, Revision 0.

(BVPS 2015j) FENOC Calculation DSC-6799, *Beaver Valley Power Station Coincident Wind Wave Analysis*, Revision 0.

(BVPS 2015k) FENOC Calculation DSC-0368, *10 CFR 50.54(f) Beyond Design Basis Local Intense Precipitation Event Internal Effects*, Revision 0.

(BVPS-1 UFSAR) Beaver Valley Power Station, Unit 1, Updated Final Safety Analysis Report, Revision 26.

(BVPS-2 UFSAR) Beaver Valley Power Station, Unit 2, Updated Final Safety Analysis Report, Revision 18.

(JLD-ISG-2013-01) NRC, Guidance for Assessment of Flooding Hazards due to Dam Failure, Revision 0, July 2013.

(JLD-ISG-2012-06) NRC, Guidance for Performing a Tsunami, Surge or Seiche Flooding Hazard Assessment, Revision 0, January 2013.

(NEI August 2012) NEI, Report 12-08, Overview of External Flooding Reevaluations, August 2012.

(NRC March 2012) NRC, Letter to Licensees, 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 12, 2012.

(NRC May 2012) NRC, Letter to Licensees, 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, May 11, 2012.

(NRC RG 1.59) NRC, *Design Basis Flood for Nuclear Power Plants*, Regulatory Guide 1.59, Revision 2, 1977.

(NRC RG 1.102) NRC, *Flood Protection for Nuclear Power Plants*, Regulatory Guide 1.102, Revision 1, 1976.

(NUREG-0800) NRC, NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition – Site Characteristics and Site Parameters* (Chapter 2), ML070400364, March 2007.

(NUREG/CR-7046) NRC, NUREG/CR-7046, PNNL-20091, *Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America,* ML11321A195, November 2011.

(NUREG/CR-6966) NRC, NUREG/CR-6966, *Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America,* National Technical Information Service, March 2009.

(USACE 2015) U.S. Army Corps of Engineers (USACE), *Evaluation of Upper Ohio River Basin Dams and Potential Flood Hydrographs at the Beaver Valley Nuclear Power Plant, Final Hydrographs*, August 2015.

(USACE 1990) U.S. Army Corps of Engineers (USACE), *Miscellaneous Paper CERC-90-4, Maximum Periodic Wave Runup on Smooth Slopes*, June 1990.