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2.4.2 Floods

2.4.2.1 Flood History

Based on historical flood profiles and flood reports, the floods listed in Table 2.4.2-1, regulated by upstream dams after 1936, were the largest known on the Clinch River arm of Watts Bar Reservoir. The flood under regulated conditions which produced the highest elevations on the Clinch River arm of Watts Bar Reservoir was in March 1973.

2.4.2.2 Flood Design Considerations

The types of events evaluated to determine the worst potential flood at the CRN Site included:

(1) Probable Maximum Precipitation (PMP) on the critical watersheds including potential consequent dam failures,

(2) dam failures in a postulated earthquake with specified concurrent flood conditions, and

(3) sunny day failure of Norris dam.

The potential events considered but not analyzed included:

Flooding from Surges and Tsunamis

Specific analysis of Watts Bar Reservoir flood levels resulting from ocean front surges and tsunamis was not required because of the inland location of the site.

Flooding from Snow Melt and Ice Jams

Snow melt considerations were also unnecessary because of the temperate zone location of the plant. While there is the potential for ice jams on the Clinch River, based on the section geometry and site elevation at the CRN Site an ice jam sufficient to cause CRN Site flooding is not credible.

Flooding from Landslides

Flood waves from landslides into upstream reservoirs required no specific analysis. A review of the borders of the Watts Bar and upstream reservoirs indicate the absence of major elevation relief in nearby reservoirs. Based on this review, the volume of material entering the nearby reservoirs from potential landslides is not significant compared to the available detention space in reservoirs. Any waves created from landslides would not result in side flooding due to the large difference in elevation between the maximum normal pool elevation at the CRN Site and the CRN Site plan elevation of 821.0 ft.

Flooding from Seiches

While a seismic seiche has been recorded in the Tennessee Valley it was of very small magnitude. The 9.2 magnitude, March 1964 Alaska Earthquake event, resulted in seiche being observed on about 25 percent of the 130 gages available in Tennessee at the time with a largest recorded seiche amplitude of 0.1 ft on Tennessee lakes, reservoirs, and/or ponds, and 0.6 ft in Kentucky (Reference 2.4.2-3). Reference 2.4.2-4 indicates that the CRN Site is within the Eastern Tennessee Seismic Zone. However, there has been no recorded seiche of any significant magnitude reported as a result of earthquake events in the Tennessee Valley. Examination of the slopes in the vicinity of the plant does not indicate instabilities or the potential for landslide. There also have been no recorded landslide generated seiche incidences in the TVA reservoir system. Wind generated seiches pose no flood threats to the CRN Site. This is because the river width at the site has a limited fetch length of 4.25 mi with a river sinuosity, lack of vertical barriers at the edge of water, gently sloped bottom and heavily vegetated, gently sloped floodplain that naturally damp standing waves. Combined with an elevation difference of approximately 79 ft between the summer operation guide high water surface elevation of 742 ft National Geodetic Vertical Datum of 1929 (NGVD29) (Watts Bar Reservoir summer guide maximum plus 1 ft) and a proposed plant grade of 821 ft North American Vertical Datum of 1988 (NAVD88), seiche from any source would not produce maximum water levels at the site.

Flooding from Migration and Diversion

The reservoir in the vicinity of the CRN Site has been stable for many years with no indication of the potential for migration or diversion. Historic floods have not produced any major changes in the reservoir configuration so specific analysis of channel diversion was not required. Further discussion of channel diversion is included in Subsection 2.4.9.

The following potential events were considered and analyzed for effects at the CRN Site:

Flooding from Rivers and Streams

The condition producing the most critical flood level calculated at the CRN Site is the 7980 square mile (sq mi) Bulls Gap centered March storm event. This storm event produces a maximum flood level of 799.9 ft NGVD29 with a peak discharge of 536,000 cubic feet per second (cfs) at the CRN Site. Dam failures associated with this event are discussed in Subsection 2.4.3.5. This elevation would result from the PMP critically centered on the watershed as described in Subsection 2.4.3. Consistent with Regulatory Guide 1.59, Watts Bar Dam was conservatively assumed to not fail even though the Watts Bar embankments are significantly overtopped.

Flooding from Combined Effects

Wind waves based on a calculated 2-year (yr) overwater wind speed of 33 miles per hour (mph) were assumed to occur coincident with the flood peak. This would create maximum wind waves up to 6.1 ft high (trough to crest). When the effects of wind wave and runup were added, the maximum Clinch River design PMF water level was established to be at elevation 806.0 ft NGVD29. The PMP and Flood Flow are discussed in Subsections 2.4.3.1 and 2.4.3.4. Dam failures associated with the combined effects of the PMF and wind are equivalent to the dam failures for the PMF alone. Dam failures associated with the PMF alone are discussed in Subsection 2.4.3.5.

The CRN Site and upstream reservoirs are located in the Southern Appalachian Tectonic Province and, therefore, subject to potential moderate earthquake forces with possible attendant failures (Reference 2.4.2-6). Upstream dams whose failure in a seismic event has the potential to cause flood problems at the CRN Site were investigated as described in Subsection 2.4.4.2.1. Studies to determine the potential failure of upstream dams from PMF conditions are described in Subsection 2.4.3. The half-10,000-yr Douglas centered seismic event with a coincident 500-yr flood produces a peak discharge of 162,000 cfs and a peak water surface elevation of 764.6 ft NGVD29.

Flooding from Dam Breaches and Failures

The calculated water surface elevation at the site resulting from the sunny day failure of Norris Dam and subsequent overtopping failure of Melton Hill Dam is 786.6 ft NGVD29. Sunny day failures of dams on streams above Watts Bar Dam but not above the CRN Site were also evaluated. However, the resulting elevation at the site, due solely to Watts Bar Dam backwater, was lower than the elevation produced by the failure of Norris Dam on the Clinch River. The sunny day failures are discussed in Subsection 2.4.4.

Local Intense Precipitation

Analysis of the general effects of local intense precipitation (LIP) was also performed based on preliminary site plans. However, the detailed site grades and stormwater conveyance facilities will be designed at Combined License Application (COLA) such that local intense precipitation will not flood the safety-related structures, systems and components of the plant.

The preliminary CRN plant grade is established at elevation 821 ft NAVD88, well above the calculated maximum flood level which is consistent with Regulatory Guide 1.59, Position 1.

2.4.2.3 Effects of Local Intense Precipitation

The final maximum water levels at buildings expected to result from the local intense precipitation are addressed at COLA. However, a preliminary calculation of the flood height resulting from the LIP was performed.

Given the physical site topography and the location of the CRN facility, it is reasonable to expect that the PMP-driven (as described in Subsection 2.4.2.3.1) Watts Bar Reservoir floodwater elevation at the locations adjacent to the power block area would be substantially less than that of the CRN plant grade elevation of 821 ft NAVD88. Therefore, runoff from the CRN Site is not restrained by tailwater effects at the reservoir.

The final graded CRN Site can reasonably take full advantage of the current topography and provide more than adequate runoff capability to the east, west and south with flow directed to the Clinch River arm of Watts Bar Reservoir. Watts Bar Reservoir would be affected to a much lesser extent by local intense rainfall events than a PMF event for which the maximum elevation is 799.9 ft NGVD29. The 21.5 ft elevation difference to the plant grade (821.4 ft NGVD29/821.0 ft NAVD88) ensures that slopes and drainage systems can be designed to adequately convey LIP-event flows to the Clinch River.

Because Watts Bar Reservoir is capable of accommodating CRN LIP-event flows without flooding the site, the potential and extent of flooding from a LIP event will be dependent upon facility design, final grading and drainage system design. Final CRN Site drainage systems may employ a number of techniques including grading slopes to efficiently convey runoff water, additional drainage channels, etc. Given the existing topography, the CRN power block area is favorably located to allow design of a fully effective site drainage system. It is therefore reasonable to expect that a fully effective drainage system would be designed as part of the COLA.

2.4.2.3.1 Precipitation Distribution

Temporal LIP distribution for the plant was determined from guidance presented in Hydro-Meteorological Report No. 56 and No. 52 (HMR-56 and HMR-52) (References 2.4.2-2 and 2.4.2-1, respectively). The guidelines set forth in HMR-56 and HMR-52 were followed to form the rainfall hyetograph of the 1-hour (hr), 1-sq mi PMP for CRN. PMP rainfall values in HMR-56 were chosen based on the terrain distribution roughness of the site, as shown in Figure 68 of Reference 2.4.2-2. The CRN Site falls in the rough zones in Figure 68. The base LIP hyetograph for the CRN Site is determined by adjusting the “rough terrain” precipitation depths in Table 6 of HMR-56 with the moisture index factor of 95.6 percent from HMR-56, Figure 20, representative of the CRN Site location.

No specific guidance was provided in HMR-52 or HMR-56 to calculate the temporal distribution for rainfalls of one hour duration. A temporal distribution similar to that used for 72-hr storms with 6-hr increments (Section 2.3 HMR-52, Reference 2.4.2-1) was used to calculate the rainfall hyetograph for the 1-hr, 1-sq mi LIP.

Three temporal distributions were reviewed, with the peak 20 minutes of precipitation located either at the beginning (early peak), middle (middle peak), or end (late peak) of the 1-hr storm. With each 5-minute incremental precipitation depth from the adjusted 60-minute base LIP hyetograph labeled as D1 (initial 5-minute duration with largest incremental precipitation depth) to D12 (last 5-minute duration with the smallest incremental precipitation depth), the incremental LIP precipitation distribution for each case is defined consistent with HMR-52, Section 2.3 guidance (Reference 2.4.2-1):

(1) Early distribution: D4, D1, D2, D3 (initial 20-minutes), D5, D6, D7, D8 (middle 20-minutes), D9, D10, D11, D12 (last 20-minutes)

(2) Middle distribution: D8, D7, D6, D5 (initial 20-minutes), D4, D1, D2, D3 (middle 20-minutes), D9, D10, D11, D12 (last 20-minutes)

(3) Late distribution: D12, D11, D10, D9 (initial 20-minutes), D8, D7, D6, D5 (middle 20-minutes), D4, D1, D2, D3 (last 20-minutes)

The cumulative rainfall values are summarized in Table 2.4.2-2. Additional analysis will be performed at COLA with consideration of LIP temporal distributions.

2.4.2.3.2 Runoff Model

The site layout and facilities at the CRN Site have not been finalized. Thus the runoff model has not been developed. This task would be performed as part of detailed engineering included with the COLA.

2.4.2.4 Site Drainage System

The site layout and facilities at the CRN Site have not been finalized. Thus the location and design of stormwater conveyance facilities have not been determined. These tasks would be performed as part of detailed engineering at COLA. Stormwater would be carried away from the plant area by a stormwater collection system comprising appropriate combinations of swales, open channels, or a subsurface system of catch basins, pipes and culverts. Runoff would be routed to the Watts Bar Reservoir. However, the finished grade for the site would slope away from buildings and be designed such that the peak discharges from the LIP would not flood safety-related facilities if the subsurface drainage system were plugged.

2.4.2.5 References

2.4.2-1. Hansen, E.M., L.C. Shreiner, and J.F. Miller, *Application of Probable Maximum Precipitation Estimates – United States East of the 105th Meridian, NOAA Hydrometeorological Report No. 52*, Hydrometeorological Branch, Office of Hydrology, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, U.S. Department of the Army, Corps of Engineers, Washington, D.C., August 1982.

2.4.2-2. Zurndorfer, E.A., F.K. Schwarz, E.M. Hansen, D.D. Fenn, and J.F. Miller, *Probable Maximum and TVA Precipitation Estimates with Areal Distribution for Tennessee River Drainages Less Than 3,000 Mi^2 in Area, Hydrometeorological Report No. 56*, Hydrometeorological Section, Office of Hydrology, National Weather Service, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, October 1986.

2.4.2-3. McGarr, Arthur and Robert C. Vorlis, The Alaska Earthquake, March 27, 1964: Effects on the Hydrologic Regimen, Seismic Seiches From the March 1964 Alaska Earthquake, Geological Survey Professional Paper 544-E, 1968.

2.4.2-4. Petersen, M.D., M.P. Moschetti, P.M. Powers, C.S. Mueller, K.M. Haller, A.D. Frankel, Yuehua Zeng, Sanaz Rezaeian, S.C. Harmsen, O.S. Boyd, Ned Field, Rui Chen, K.S. Rukstales, Nico Luco, R.L. Wheeler, R.A. Williams, and A.H. Olsen, 2014, Documentation for the 2014 Update of the United States National Seismic Hazard Maps: U.S. Geological Survey Open-File Report 2014–1091, p. 243, http://pubs.usgs.gov/of/2014/1091/pdf/ofr2014-1091.pdf.

2.4.2-5. TVA, Division of Water Control Planning, *Floods on the Clinch River and East Fork Poplar Creek in Vicinity of Oak Ridge, Tennessee*, Report 05922 Knoxville, Tennessee, September 1959.

2.4.2-6. TVA, Division of Water Management, Geological Services Branch, "Southern Appalachian Tectonic Study," Seay, William M., (ML082170494), Knoxville, Tennessee, January 1979.

Table 2.4.2-1
Floods on the Clinch River Arm of Watts Bar Reservoir

Flood Event	Elevation at CRM 16.0 (feet NGVD29)	Elevation at CRM 18.0 (feet NGVD29)
1867[a]	762.3	764.5
1886[b]	759.0	767.8
1918[b]	755.8	763.0
1973[c]	748.4	748.5
2003[c]	748.4	748.7

(a) Estimated from historical flood profiles in a 1951 TVA historical record drawing. Flood elevation occurred prior to the current regulated state of the Clinch River arm of the Watts Bar Reservoir.
(b) Estimated from a Clinch River flood report developed by TVA in 1959. Historical flood elevations were derived from various sources including flood markings from photographs and tree carvings found by the United States Army Corps of Engineers, and observations of river stages and gage data by the National Weather Bureau and United States Geological Survey. Flood elevations occurred prior to the current regulated state of the Clinch River arm of the Watts Bar Reservoir. Reference 2.4.2-5
(c) Estimated from HEC-RAS calibrations described in Subsection 2.4.3.4.3

Table 2.4.2-2
Clinch River Nuclear Site Local Intense Precipitation Values—1-hr, 1-sq mi Probable Maximum Precipitation

Duration		Cumulative PMP (in.)		
min	hr	Early Peak	Middle Peak	Late Peak
0	0.000	0.00	0.00	0.00
5	0.083	1.63	1.05	0.67
10	0.167	4.88	2.19	1.43
15	0.250	7.27	3.44	2.30
20	0.333	9.37	4.87	3.16
25	0.417	10.80	6.50	4.21
30	0.500	12.05	9.75	5.35
35	0.583	13.19	12.14	6.60
40	0.667	14.24	14.24	8.03
45	0.750	15.10	15.10	9.66
50	0.833	15.97	15.97	12.91
55	0.917	16.73	16.73	15.30
60	1.000	17.40	17.40	17.40

Notes:

PMP = Probable Maximum Precipitation