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2.4.11 Low Water Considerations

The Clinch River Nuclear (CRN) Site does not rely on the Clinch River arm of the Watts Bar Reservoir to support safety-related and risk-significant structures, systems and components (SSCs), including the ultimate heat sink (UHS) that provides emergency cooling water. However, the Clinch River arm of the Watts Bar Reservoir would be used as a water source for nonsafety-related SSCs, primarily the normal cooling system and water processing plant that feeds the demineralized water users and liquid radwaste treatment system. The reach of the Clinch River within Watts Bar Reservoir is between its confluence with the Tennessee River at the downstream end and Melton Hill Dam at its upstream end. Water from the Reservoir would also be used to supply other miscellaneous raw water users at the CRN Site. Figure 2.4.11-1 shows the location of CRN Site in relation to Melton Hill Dam.

The CRN Site is located on the Clinch River arm of the Watts Bar Reservoir between River Mile 14.5 and River Mile 19, and the nonsafety-related surface water demand on the reservoir would be supplied using a pump intake structure located at Clinch River Mile 17.9, approximately 5.2 river miles downstream from Melton Hill Dam. The peak withdrawal flow rate from the reservoir is estimated to be about 30,708 gallon per minute (gpm) (68.4 cubic feet per second [cfs]), majority of which is makeup water to compensate for evaporation and blowdown losses from the closed-cycle mechanical draft cooling tower system that would be used for normal cooling. The location of the intake structure is shown on Figure 2.4.11-2.

There would be return flow back to the Watts Bar Reservoir, via a discharge structure, from cooling tower blowdown, and effluents from downstream users of the water processing plant and miscellaneous raw water users. The peak discharge rate is estimated to be about 17,900 gpm (39.9 cfs). The net consumptive water use (withdrawal minus discharge) is therefore about 12,808 gpm (28.5 cfs).

2.4.11.1 Low Flow in Rivers and Streams

The portion of the Clinch River arm of the Watts Bar Reservoir, in the vicinity of Melton Hill Dam, meanders around the eastern, southern and western boundaries of the site. The Clinch River originates in the southwestern mountains of Virginia and flows in a northeasterly to southwesterly direction, passing through Norris and Melton Hill Dams, before emptying into the Tennessee River. The drainage area for the Clinch River upstream of Melton Hill Dam is about 3343 square miles. The Tennessee River watershed upstream of Watts Bar Dam has a drainage area of about 17,310 square miles.

Flow in the Clinch River arm of the Watts Bar Reservoir is mainly regulated by releases from Melton Hill Dam, and the water level is regulated by the Watts Bar Dam. The evaluation of water availability for the CRN Site includes assessments of both the historical low flow and low water level conditions in this reach of the Clinch River arm of the Watts Bar Reservoir.

2.4.11.1.1 Flow Release from Melton Hill Dam

Normal flow near the CRN Site is in the downstream, except when the water level in the lower reaches of Watts Bar Reservoir rises significantly enough to create a backwater effect. This flow reversal condition could occur when outflows from the Watts Bar and Melton Hill Dams are negligible and inflows from the upper Tennessee River watershed to the lower reaches of the Watts Bar Reservoir are significant. Runoff generated in the drainage area downstream of Melton Hill Dam also contributes to the flow, but is expected to be relatively minor, given that the distance between the CRN Site intake location and Melton Hill Dam is only about 5.2 river miles.

Construction of Melton Hill Dam started on September 6, 1960, and the dam was closed on May 1, 1963, when filling of the Melton Hill Reservoir began. The water level in the reservoir reached the normal maximum pool level of 795 ft National Geodetic Vertical Datum of 1929 (NGVD29) on May 30, 1963. Melton Hill Dam is operated for various purposes including navigation, hydroelectric power production, water supply, water quality and aquatic ecology enhancement, and recreation, but not flood control because of its limited storage capacity. The dam has a minimum release requirement of 400 cfs, on a daily average basis, for downstream water supply and water quality enhancement (Reference 2.4.11-1). From historical records (Reference 2.4.11-4), the occurrence of the minimum release flow (400 cfs) continuing for as long as seven days is found to be less than 0.1 percent, indicating that low flow conditions are infrequent for this reach of the Clinch River arm of the Watts Bar Reservoir. In addition, the average weekly discharge from Melton Hill Reservoir over the long term is about 4800 cfs, with a maximum weekly discharge of about 25,450 cfs, much higher than the projected nonsafety-related water demand (consumptive surface water use) of 28.5 cfs from the CRN Site. The unregulated flow at the dam site is estimated to be of the same order as the regulated discharge, about 4950 cfs for the period 1903 to 1999.

The rare occurrence of low flow conditions is further illustrated by examining the zero flow events downstream of Melton Hill Dam. Based on daily average outflow statistics at Melton Hill Dam from May 30, 1963 to October 31, 2013 (more than 50 years of record with 18,418 of data points), the total number of days with zero flows was 676 (3.7 percent) for the entire record, and 13 (0.14 percent) for the most recent 25 years of record (since 1989). With the adoption of the reservoir operations policy of 2004 (Reference 2.4.11-1), the frequency of zero flow days decreases to about 0.06 percent. Table 2.4.11-1 lists the number of zero flow days for the record years of 1963 to 2013.

2.4.11.1.2 Low Water in Watts Bar Reservoir

Construction of Watts Bar Dam started on July 1, 1939, and the dam was closed on January 1, 1942, at which time the reservoir began filling. The dam is operated for various purposes including navigation, flood control, hydroelectric power production, water supply, water quality, aquatic ecology, and recreation. The dam is required to release a minimum of 1200 cfs (daily average) for downstream water supply and water quality enhancement (Reference 2.4.11-1, Table A-03 in Vol. II).

There are two operating pool levels, normal minimum and normal maximum, at Watts Bar Reservoir that correspond to TVA reservoir operations during the winter and summer seasons, respectively (Reference 2.4.11-1). Because major floods in the Tennessee River system usually occur in the winter season, the normal pool in Watts Bar Reservoir is maintained at a level of 735 ft NGVD29 during winters to create more volume for flood storage. At this normal minimum operating level, the reservoir has a storage capacity of 401,310 day-second-feet (DSF) (or about 795,980 acre-feet). For the summer season, the normal operating pool level is at its maximum of 741 ft NGVD29, 6 ft higher than the normal minimum operating pool level, and the storage increases to about 509,200 DSF (or about 1,010,000 acre-feet). As demonstrated in the following, Watts Bar Reservoir has a substantial capacity at both of its normal operating levels that would provide adequate water supply to meet the relatively minor consumptive surface water use of 28.5 cfs projected at the CRN Site to sustain plant operation even under drought conditions with limited or zero inflow to the reservoir.

Reservoir Inflows and Outflows

The main inflow contributions to Watts Bar Reservoir include flow releases from Fort Loudoun Dam (on the Tennessee River) and flow from the Clinch River (Melton Hill Reservoir). Additional inflows of minor significance are direct rainfall on the reservoir, direct release from Tellico Dam,

groundwater inflow, and effluents from various municipal and industrial facilities, including electric power generation.

Outflows from Watts Bar Reservoir include primarily withdrawal for hydroelectric production, supply to the Watts Bar Nuclear Plant supplemental condenser cooling water (SCCW) system (Reference 2.4.11-2), and flood releases during high flow events. Total flow release from the Reservoir has to meet a minimum of 1200 cfs for downstream water supply and water quality (Reference 2.4.11-1). For a 71-year period between November 1, 1942 and October 31, 2013, the average daily outflow from Watts Bar Reservoir is about 27,262 cfs.

Typical daily average withdrawals and discharges from these users are provided in Table 2.4.11-2. It shows that the net daily average withdrawal rate (the difference between the daily average withdrawals and discharges) is about 15 cfs, excluding the SCCW withdrawal for the Watts Bar Nuclear Plant. Also included in Table 2.4.11-2 is the Kingston Fossil Plant, which is located near the confluence of Clinch and Emory Rivers. It uses Watts Bar Reservoir to support its once-through cooling system. The difference between the withdrawal and discharge rates of the plant (from year 2000 data) is negligible as listed in Table 2.4.11-2.

The withdrawal rate of the SCCW system at the Watts Bar Nuclear Plant from the Watts Bar Reservoir during the winter season (when the operating pool level is at 735 ft NGVD29) is estimated to be about 115,000 gpm (256 cfs) as described in Reference 2.4.11-2. Return flow from the Watts Bar Nuclear Plant is discharged to Chickamauga Reservoir downstream of the Watts Bar Dam.

Reservoir Water Level

Historical daily water level data for Watts Bar Reservoir for a period of more than 70 years from February 17, 1942, to October 31, 2013 was analyzed. The results, as shown in Table 2.4.11-3, indicate that the reservoir level was below 735 ft NGVD29 for 70 days (0.27 percent) out of the total of 26,190 days. Also, most of the low water events occurred in 1944, 1945 and 1963. Since 1968 (for about 46 years up to October 31, 2013) the reservoir level has not fallen below 735 ft NGVD29, the normal minimum operating pool level.

Table 2.4.11-4 lists the minimum water levels of Watts Bar Reservoir for the period between 1943 and 2012, and a graphical representation is shown in Figure 2.4.11-3. As shown, the lowest reservoir level for the period was 733.66 ft NGVD29, and occurred on March 20, 1945. The minimum reservoir level in recent years, from 2008 onward, was consistently above 735.5 ft NGVD29.

Also shown in Table 2.4.11-4, low water levels in Watts Bar Reservoir occur mostly in the winter season, when the normal operating pool level is kept at a lower level (735 ft NGVD29) to have a larger volume allocation for flood storage as the Tennessee River catchment receives most of its precipitation in the winter. Even though the operating pool level is at its lowest during the winter season, the amount of inflow is typically at its highest, sufficient to replenish the reservoir to meet the demands of water users. During the summer season, when precipitations are limited, the Reservoir is maintained at its maximum operating level (741 ft NGVD29) with significantly more water storage.

Reservoir Storage

To evaluate the surface water availability for CRN Site nonsafety-related SSCs, the depletion rate of the reservoir storage below the winter/normal minimum operating pool level was estimated using the stage-storage rating curve of Watts Bar Reservoir in conjunction with conservative assumptions on the expected water demands, reservoir inflows and outflows. The

scenario selected for evaluation is an extended period of severe drought when inflow to the Reservoir would be limited, but all existing users would continue their withdrawals.

For the inflows, direct precipitation, flow releases from Fort Loudoun and Tellico Dams and flow from the Emory River and other tributaries were conservatively assumed to be negligible. In addition, net groundwater inflow was not included. The only reservoir inflow is therefore the minimum required release flow of 400 cfs from the Melton Hill Reservoir. Although there is no mandatory or minimum release requirement from the Fort Loudoun and Tellico Dams (Reference 2.4.11-1, Table A-02 in Vol. II), the assumption of zero release from these two dams during drought conditions is reasonably conservative. Outflows used in the assessment include (i) Watts Bar Reservoir minimum required release rate of 1200 cfs; (ii) the net or consumptive withdrawal rate from the Reservoir,15 cfs, based on water use records of 2000, 2005 and 2010 as shown in Table 2.4.11-2; and (iii) the Watts Bar Nuclear Plant SCCW withdrawal rate of about 256 cfs. The natural evaporation loss from the Reservoir is also included as an outflow and is estimated to be about 24 inches (2 ft) for the CRN Site based on evaporation rate obtained from Reference 2.4.11-5 (National Oceanic and Atmospheric Administration (NOAA) data for free surface evaporation). With a reservoir surface area of 32,400 acres at the normal minimum operating level (735 ft NGVD29), the natural evaporation loss rate would be about 178 cfs. Given that the net water withdrawal rate (consumptive surface water use) for the CRN Site is projected at about 28.5 cfs, the combined net outflows from the Reservoir (inflows – outflows) is conservatively estimated to be about 1278 cfs (2535 acre-feet/day). The reservoir storage depletion rate during the hypothetic drought scenario is summarized in Table 2.4.11-5, which shows that it would take 11, 23 and 59 days to reduce Watts Bar Reservoir storage by 1, 2, 5 ft, respectively, below the winter/normal minimum operating pool level of 735 ft NGVD29. To accommodate the potential drops in the reservoir level during this highly conservative drought scenario, TVA can configure the intake structure to provide the flexibility to extend the operable range to lower levels as necessary.

It can be concluded from the above assessment that the amount of storage volume available in Watts Bar Reservoir, even during the worst drought condition when hypothetically the only inflow to the Reservoir is the minimum release from Melton Hill Dam, can conservatively sustain the continuous withdrawal of surface water to meet the nonsafety-related water demands of the CRN Site for extended periods of time, in addition to the continuous supply to other water users. In reality, it is expected that the Reservoir can sustain operations of the CRN Site and other water users for much longer durations because (a) the historical record of Watts Bar Reservoir indicates that the Reservoir was able to maintain the target minimum operating level of 735 ft NGVD29 level during historical droughts in the region, and (b) the Reservoir target operating level during an impending drought would most likely be at 741 ft NGVD29 (corresponding to summer pool level), i.e., with 6 ft more of equivalent storage volume than the 735 ft NGVD29 level assumed for the above assessment, given that droughts in this region typically happen in the summer months. Further, TVA would use appropriate reservoir regulation controls during severe drought conditions to manage the needs of all water users.

2.4.11.2 Low Water Resulting from Surges, Seiches, or Tsunamis

There is no safety impact on the CRN Site due to low water conditions generated by any mechanism because it does not rely on the Clinch River arm of the Watts Bar Reservoir for its safety-related water use. The nonsafety-related water supply is also not expected to be affected normally by low water conditions resulting from surges, seiches, tsunamis or other external events. According to Subsection 2.4.5, there are no conceivable meteorological conditions that would produce a surge or seiche that would reach the CRN Site grade. It follows that the risk of any surge or seiche event that would cause significant low water concerns is low. Tsunamis are not considered a risk also because there are no potential tsunamigenic sources that could affect the Site as indicated in Subsection 2.4.6.

Based on the evaluation in Subsection 2.4.7, low water conditions resulting from ice formation or accumulations could cause interruption of flow in the Clinch River arm of the Watts Bar Reservoir under extreme conditions. However, no safety-related or risk-significant SSCs at the CRN Site would be impacted.

Similarly, the unlikely failures of the Watts Bar Dam and Melton Hill Dam would potentially create a low water condition at the CRN Site, but there would be no safety-related or risk-significant impacts.

2.4.11.3 Historical Low Water

The Tennessee Department of Environment and Conservation's Drought Management Plan (Reference 2.4.11-3) indicates that the drought of 1986-87 was one of the worst in recorded Tennessee history. The other drought of significance was that of 2007. Because of several water use management actions that were implemented, the impact of the drought was not severe (Reference 2.4.11-3). The water level data for Watts Bar Reservoir for the years 1986, 1987 and 2007 do not indicate any unusual low water levels, in that the minimum water levels were all above 735 ft NGVD29. The main reason is that droughts usually occur in the summer time when the normal operating water level of Watts Bar Reservoir (741 ft NGVD29) is 6 ft above the winter normal operating water level of 735 ft NGVD29. Therefore, the historical water level record shows that, even during drought conditions, the water level and storage volume of Watts Bar Reservoir is able to meet the various water withdrawal demands, including the projected withdrawal of the CRN Site.

2.4.11.4 Future Controls

The CRN Site does not rely upon the Clinch River arm of the Watts Bar Reservoir for safety-related water use and therefore there would not be any safety impact as a result of future uses or controls in the Reservoir. For nonsafety-related water use, the storage capacity of Watts Bar Reservoir is adequate to sustain the continuous supply of surface water to meet the needs of the CRN Site through a drought event equivalent to the drought of record as discussed in Subsection 2.4.11.3. Any future water uses of the Clinch River arm of the Watts Bar Reservoir would be controlled by TVA, as the owner and operator, and any future agreements with water users would need to account for CRN Site water supply requirements. Thus, any future uses of the Clinch River or Watts Bar Reservoir are not expected to affect the water use at the CRN Site.

2.4.11.5 Plant Requirements

The capability of Watts Bar Reservoir to maintain a sufficient water level during periods of drought is described in Subsection 2.4.11.3. The operating pool level at Watts Bar Reservoir is monitored and maintained at a normal minimum at 735 ft NGVD29 (for the winter season). As needed, reservoir operation management measures would be employed to ensure that sufficient water level is maintained in the Reservoir to allow the CRN Site intake structure to operate.

2.4.11.6 Heat Sink Dependability Requirement

The UHS for the CRN Site does not rely on the Clinch River arm of the Watts Bar Reservoir to perform its function. A description of the UHS design basis and operation will be provided in the Combined License Application.

2.4.11.7 References

2.4.11-1. TVA, “Final Programmatic Environmental Impact Statement, Reservoir Operations Study, Volume I and Volume II,” February 2004, and “Programmatic Environmental Impact Statement, Reservoir Operations Study, Record of Decision,” May 2004.

2.4.11-2. TVA, Watts Bar Nuclear Plant Supplemental Condenser Cooling Water Project, “Environmental Assessment,” August 1998.

2.4.11-3. Tennessee Department of Environment and Conservation, “Drought Management Plan,” Revised February 2010.

2.4.11-4. TVA, Clinch River, “Small Modular Rector Site, Regional Surface Water Use Study,” Rev. 3, July 16, 2014.

2.4.11-5. NOAA, National Weather Service Office, “Evaporation Atlas for the Contiguous 48 United States,” NOAA Technical Report NWS 33 (Map 2 of 4), Washington D.C., June 1982.

Table 2.4.11-1
Yearly Number of Days with Zero Flow at Melton Hill Dam

Year	Days with Zero Flows	Year	Days with Zero Flows	Year	Days with Zero Flows
1963	32	1980	19	1997	0
1964	56	1981	72	1998	2
1965	16	1982	13	1999	1
1966	74	1983	21	2000	1
1967	24	1984	10	2001	2
1968	65	1985	7	2002	1
1969	72	1986	3	2003	1
1970	46	1987	1	2004	1
1971	34	1988	6	2005	0
1972	8	1989	2	2006	0
1973	10	1990	0	2007	0
1974	6	1991	0	2008	2
1975	18	1992	0	2009	0
1976	21	1993	0	2010	0
1977	17	1994	0	2011	0
1978	12	1995	0	2012	0
1979	0	1996	0	2013	0

Notes:

The 1963 data is from May 30 onward only.

The 2013 data is up to October 31 only.

The 2004 zero flow occurred before May 19, when the TVA reservoir operations policy (Reference 2.4.11-2) was adopted.

Table 2.4.11-2
Watts Bar Reservoir Daily Average Water Withdrawal and Discharge Rates

Facility	Withdrawal Rate (cfs)	Discharge Rate (cfs)
Municipal	37.3	27.5
Industrial	10.1	6.3
Irrigation	1	–
Thermal[a] (Kingston Fossil Plant)	1345	1345
Total	1393.4	1378.8

(a) Flow rates for the year 2000 are considered.

Notes:

The data in the table does not include withdrawal by the Watts Bar Nuclear Plant SCCW.

Withdrawals are the maxima and discharges are the minima for 2000, 2005 and 2010 data.

The maximum withdrawal rate and minimum discharge rate are for years 2000, 2005, and 2010.

Table 2.4.11-3
Yearly Watts Bar Reservoir Number of Days with Water Level Below 735 ft NGVD29

Year	Days with < 735 ft NGVD29	Year	Days with < 735 ft NGVD29	Year	Days with < 735 ft NGVD29	Year	Days with < 735 ft NGVD29
1942	0	1960	1	1978	0	1996	0
1943	0	1961	1	1979	0	1997	0
1944	9	1962	1	1980	0	1998	0
1945	22	1963	24	1981	0	1999	0
1946	2	1964	0	1982	0	2000	0
1947	3	1965	0	1983	0	2001	0
1948	0	1966	0	1984	0	2002	0
1949	1	1967	1	1985	0	2003	0
1950	2	1968	0	1986	0	2004	0
1951	1	1969	0	1987	0	2005	0
1952	0	1970	0	1988	0	2006	0
1953	0	1971	0	1989	0	2007	0
1954	0	1972	0	1990	0	2008	0
1955	0	1973	0	1991	0	2009	0
1956	0	1974	0	1992	0	2010	0
1957	0	1975	0	1993	0	2011	0
1958	2	1976	0	1994	0	2012	0
1959	0	1977	0	1995	0	2013	0

Notes:
The 1942 data is from February 17 onward only.
The 2013 data is up to October 31 only.

Table 2.4.11-4
Yearly Minimum Water Level at Watts Bar Reservoir (1943 to 2013)

Year	Water Level (ft NGVD29)	Date (month/day)	Year	Water Level (ft NGVD29)	Date (month/day)	Year	Water Level (ft NGVD29)	Date (month/day)
1942	736.06	2/17	1966	735.10	12/24	1990	735.63	3/7
1943	735.09	1/7	1967	734.80	12/26	1991	735.55	3/17
1944	734.86	1/25	1968	735.00	1/17	1992	735.32	1/14
1945	733.66	3/20	1969	735.16	1/6	1993	735.54	2/11
1946	734.91	12/12	1970	735.15	12/29	1994	735.34	3/10
1947	734.68	1/6	1971	735.23	1/1	1995	735.64	2/3
1948	735.10	3/15	1972	735.07	2/22	1996	735.59	12/25
1949	734.88	12/29	1973	735.00	1/8	1997	735.26	1/21
1950	734.90	12/17	1974	735.15	3/4	1998	735.21	12/22
1951	734.80	12/31	1975	735.12	2/17	1999	735.21	2/15
1952	735.00	2/3	1976	735.14	1/21	2000	735.28	1/31
1953	735.02	1/6	1977	735.16	3/28	2001	735.65	3/16
1954	735.07	2/8	1978	735.31	2/6	2002	735.22	3/10
1955	735.06	2/4	1979	735.43	4/1	2003	735.34	1/1
1956	735.04	12/23	1980	735.36	1/31	2004	735.43	12/20
1957	735.08	12/24	1981	735.38	2/7	2005	735.20	12/21
1958	734.93	1/2	1982	735.21	12/25	2006	735.35	1/15
1959	735.09	1/19	1983	735.38	2/20	2007	735.46	2/21
1960	734.97	1/25	1984	735.35	1/31	2008	736.00	1/28
1961	734.99	12/26	1985	735.47	1/24	2009	735.89	12/1
1962	734.86	3/8	1986	735.54	3/6	2010	735.88	3/7
1963	734.17	2/28	1987	735.44	3/18	2011	735.55	12/19
1964	735.08	1/31	1988	735.37	1/27	2012	736.73	2/15
1965	735.20	2/10	1989	735.70	3/31	2013	735.90	3/18

Notes:
The 1942 data is from February 17 onward only.
The 2013 data is up to October 31 only.

Table 2.4.11-5
Number of Days Required to Lower Watts Bar Reservoir Below 735 ft NGVD29

Reservoir Water Level (ft NGVD29)	Reservoir Storage Volume (ac-ft)	Depth Below 735 ft NGVD29 (ft)	Number of Days[b] to Lower the Reservoir Below 735 ft NGVD29
735[a]	796,000	0	–
734	766,000	1	11
733	736,000	2	23
730	646,000	5	59

(a) 735 ft NGVD29 is the winter/minimum operating level.
(b) The number of days is rounded down to whole days.

Notes:

Dash (–) = Not applicable.

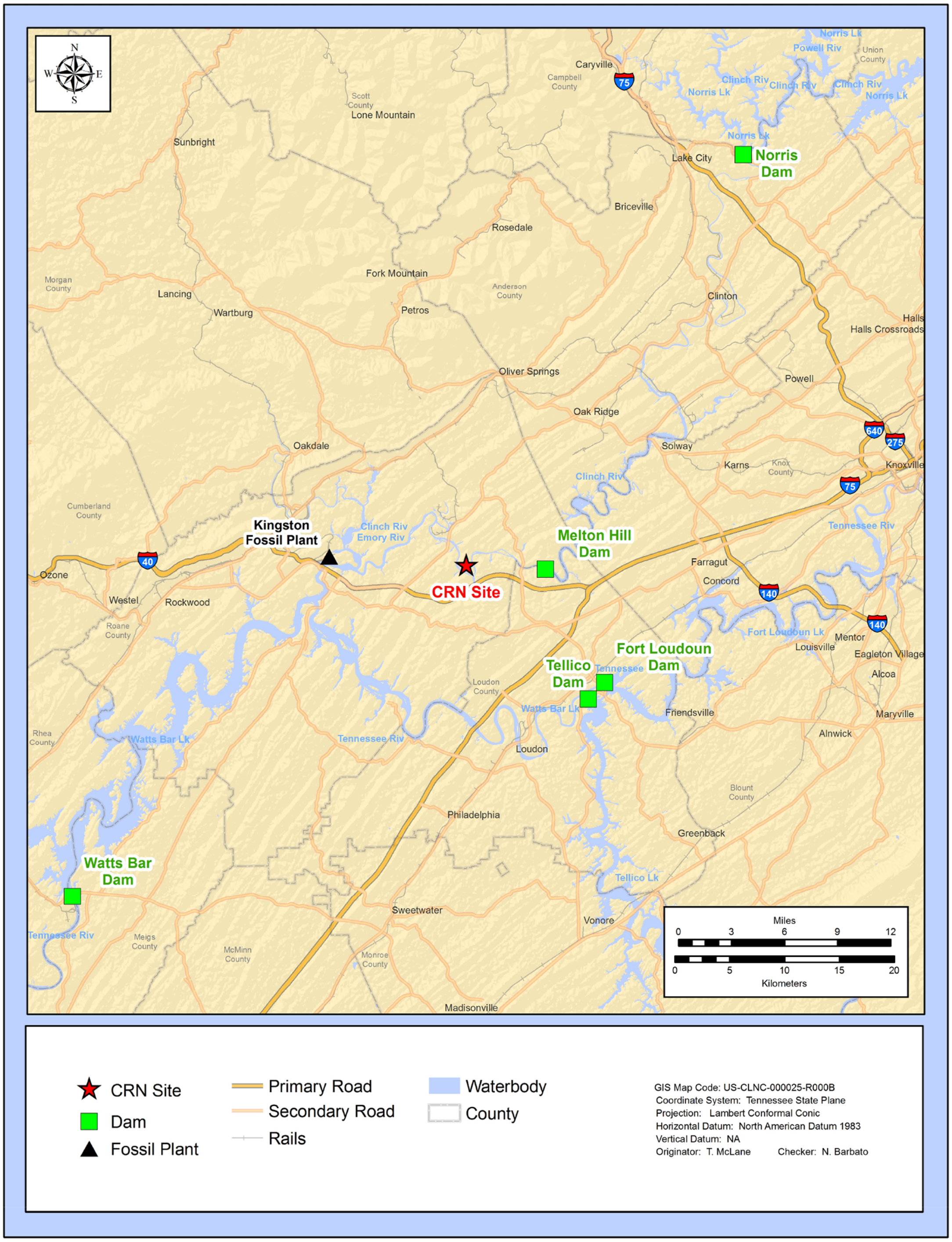

Figure 2.4.11-1. Locations of the Clinch River Nuclear Site and Nearby Dams

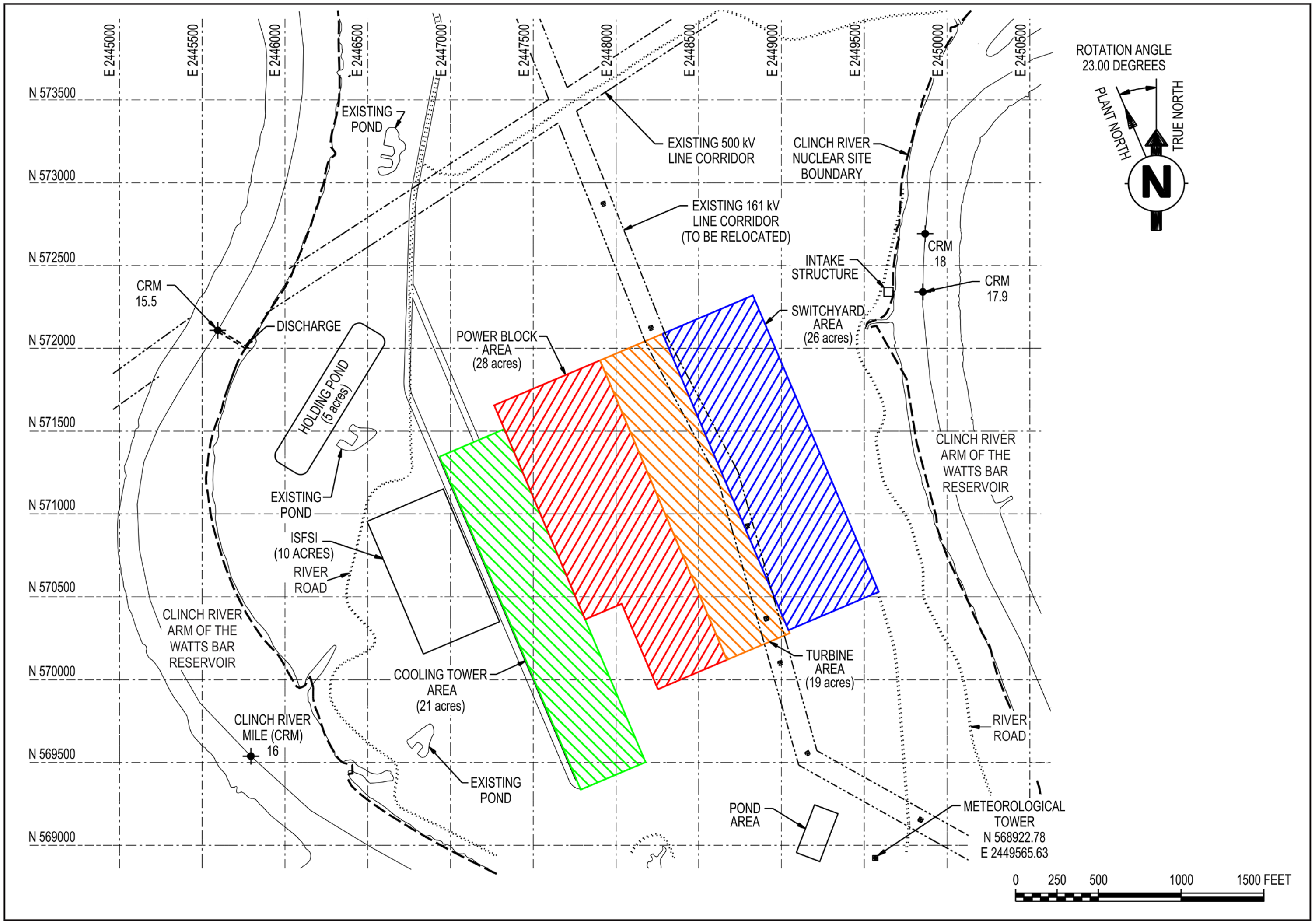

Figure 2.4.11-2. Location of the Clinch River Nuclear Site Intake Structure

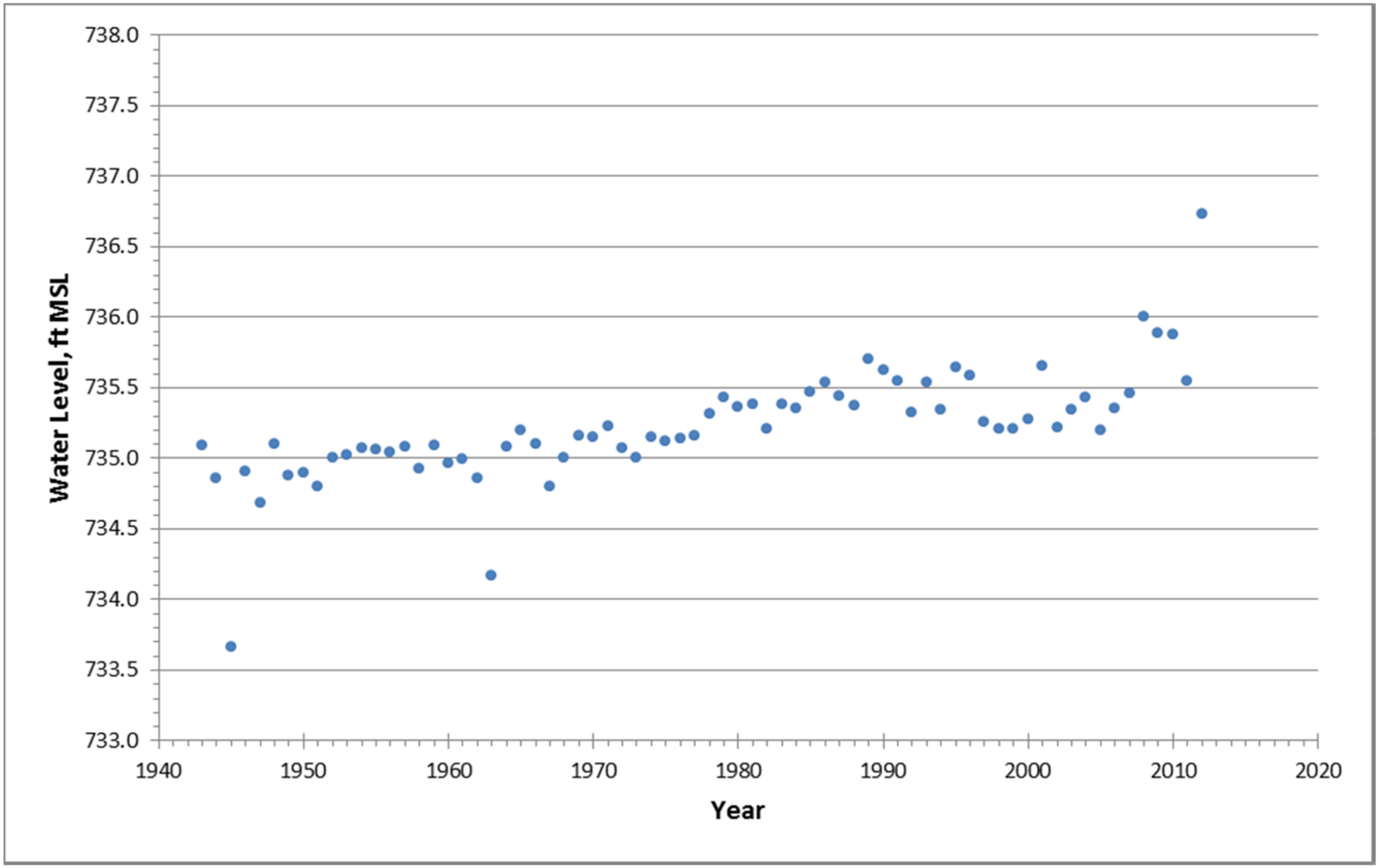

Figure 2.4.11-3. Yearly Minimum Water Level at Watts Bar Reservoir (1943 to 2012)