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2.4 HYDROLOGIC ENGINEERING

This section of the U.S. EPR FSAR is incorporated by reference with the following departures and/or supplements.

2.4.1 HYDROLOGIC DESCRIPTION

The U.S. EPR FSAR includes the following COL Item for Section 2.4.1:

> A COL applicant that references the U.S. EPR design certification will provide a site-specific description of the hydrologic characteristics of the plant site.

This COL Item is addressed as follows:

This section identifies the interface of {Callaway Plant Unit 2} with the hydrosphere. It also identifies the hydrologic causal mechanisms that will establish the design basis with respect to floods and water supply requirements. Information on surface water and ground water uses that may be affected by plant operation is also included in this section.

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.}

Sections 2.4.1.1 through 2.4.1.3 are added as a supplement to the U.S. EPR FSAR.

2.4.1.1 {Site and Facilities

{Callaway Plant Unit 2 will be located northwest of the existing nuclear power plant, Callaway Plant Unit 1, as shown in Figure 2.4-1.

The Callaway Site is located in Callaway County, Missouri, approximately 10 miles (16 km) southeast of Fulton and 80 miles (129 km) west of the St. Louis metropolitan area. The Missouri River flows in an easterly direction approximately 5 miles (8 km) south of the site at its closest point. The elevations of 530 ft (162 m) above mean sea level (msl) on the north and south sides of the river define the Missouri River floodplain, which is about 2.4 miles (3.9 km) wide in this area.

The Callaway Site is situated in an area of gently rolling upland, once part of an old glacial till plain. Erosion and down cutting of the Missouri River and its tributary streams have dissected the plain, leaving a nearly isolated plateau of approximately 8 sq mi (21 sq km). The Callaway Plant Unit 2 site is located on a plateau, which lies north of the Missouri River, at plant grade El. 845 ft (258 m) above msl. At the site, the Missouri River 100-yr floodplain is at about El. 533.4 ft (162.6 m) above msl (NOAA, 2007). Thus, the site lies about 311.6 ft (95.0 m) above the 100-yr floodplain of the Missouri River.

The area between the plateau and the Missouri River floodplain is highly dissected. Mud Creek and its intermittent stream branches have incised deeply into the southern flank of the plateau with steep stream gradients. Topographic relief varies from about 150 ft to 325 ft (46 m to 99 m) or more.

Surface drainage to the east and northeast is to Logan Creek. Mud Creek is a major drainage way from the south and southwestern side of the site. Auxvasse Creek, a major tributary to the Missouri River located about 2 miles (3 km) west of the site area, intercepts surface drainage from the western and northern flanks of the plateau.

The Callaway Site contains approximately 2,760 acres (1,117 hectares) of rural land owned by AmerenUE. Peripheral lands and the access corridor comprise an additional 4,589 acres (1,857 hectares) of land. The plateau has an area of about 8 sq mi (21 sq km). The boundaries of the site and the overall site layout are shown on Figure 2.4-1.

Dominant land uses within 6 miles (10 km) of the Callaway Site include grassland (18.5%), deciduous forest (52.5%), and cropland (16.4%).

The center of the Callaway Site is defined as the midpoint between the existing Callaway Plant Unit 1 reactor and the Callaway Plant Unit 2 reactor. The midpoint is at 38 degrees, 45 minutes, 45.53 seconds north latitude and 91 degrees, 46 minutes, 56.34 seconds west longitude.}

The Callaway Plant Unit 2 plant will be a U.S. Evolutionary Power Reactor (EPR). The U.S. EPR is a pressurized water reactor design. The Callaway Plant Unit 2 design is a four-loop, pressurized water reactor, with a reactor coolant system composed of a reactor pressure vessel that contains the fuel assemblies, a pressurizer including ancillary systems to maintain system pressure, one reactor coolant pump per loop, one steam generator per loop, associated piping, and related control systems and protection systems. The Callaway Plant Unit 2 Reactor Auxiliary Building and Turbine Building will be oriented side by side, with the Reactor Building oriented towards the east.

The Reactor Building will be surrounded by the Fuel Building, four Safeguard Buildings, two Emergency Diesel Generator Buildings, the Nuclear Auxiliary Building, the Radioactive Waste Processing Building, and the Access Building. Figure 2.4-2 shows the layout for Callaway Plant Unit 2, depicting main features: property boundary, Callaway Plant Unit 1 water intake, discharge pipelines, collector well river intake system, and Callaway Units 1 and 2 switchyards.

The Callaway Plant Unit 2 Reactor Building is a cylindrical reinforced concrete vertical structure, capped with a reinforced concrete enclosed spherical dome ceiling. The Reactor Building is 150 ft (46 m) in diameter with an overall height of 245 ft (75 m). The plant grade for Callaway Plant Unit 2 will be at an elevation of approximately 845 ft (258 m). With the bottom of the Reactor Building foundation 36 ft (11 m) below grade, the new Reactor Building will rise 209 ft (64 m) above grade. The top of the Reactor Building will be at an elevation of approximately 1,054 ft (321 m).

The cooling towers for Callaway Plant Unit 2 will be the tallest new structures at approximately 550 ft (168 m) above grade or about 360 ft (110 m) above the Reactor Building. Callaway Plant Unit 2 will have a closed-loop cooling system. The Callaway Plant Unit 2 Cooling Towers will be round concrete structures with a basin diameter of 414 ft (126 m) and an approximate height of 550 ft (168 m). Similar to Callaway Plant Unit 1, other Callaway Plant Unit 2 buildings will be concrete or steel with metal siding.

The Callaway Plant Unit 2 Ultimate Heat Sink (UHS)function will be provided by the mechanical forced draft Essential Service Water System (ESWS) cooling towers situated above the storage basin pools. Each of the four basins will normally be supplied with makeup water from the non-safety-related Callaway Plant Unit 2 Collector Well River Intake System via the site Water Treatment Plant.

In the event of a design basis accident, the basins will be supplied with water from the safety-related ESWEMS retention pond. The ESWS cooling towers will be 96 ft (29 m) tall.

Callaway Plant Unit 2 will share Callaway Plant Unit 1's Collector Well System and associated discharge piping at the Missouri River.

The design basis flood elevation for the Callaway Plant Unit 2 site is determined by considering a number of different flooding possibilities. The possibilities applicable and investigated for the site include the Probable Maximum Flood (PMF) on streams and rivers, potential dam failures, probable maximum surge and seiche flooding, probable maximum tsunami, and ice effect flooding. Each of these flooding scenarios was investigated in conjunction with other flooding and meteorological events, such as wind generated waves, as required in accordance with guidelines presented in ANSI/ANS 2.8-1992 (ANS, 1992). Detailed discussions on each of these flooding events and how they were estimated are found in Sections 2.4.2 through 2.4.7. Adequate drainage capacity will be provided to prevent flooding of safety-related facilities and to convey flood waters on the roofs of the buildings away from the plant site area.

All safety-related facilities for Callaway Plant Unit 2 are located between elevation El. 840 ft and 846 ft (256 m and 258 m) msl. The highest flood of record on the Missouri River near the site at Chamois was 33.3 ft (10.1 m) on July 31, 1993, (NOAA, 2007) resulting in a water level at Chamois of El. 535.8 (163.3 m) (gauge datum is set to 502.5 ft (153.2 m)). The Callaway Site is about 309.2 ft (94.2 m) higher; therefore, it is anticipated that the Missouri River flooding does not affect the plant. Since the plant site is dry with respect to major flooding on the Missouri River, only a localized Probable Maximum Precipitation (PMP) storm was considered for flood design protection of safety-related facilities.

The PMF analysis indicates that near the Callaway Site, the maximum PMF water surface elevation is 677.3 ft (206.4 m) msl for Logan Creek, 577.57 ft (176.04 m) msl for Mud Creek, and 704.33 ft (214.68 m) msl for Auxvasse Creek. As a result, the plant site is dry with respect to major flooding on Auxvasse Creek, Logan Creek and Mud Creek.

The potential of tsunami events that could affect the Callaway Site caused by local or distant seismic activities is negligible. The Callaway Site is approximately 860 miles (1,384 km) inland from the nearest coast, the Gulf of Mexico, which is too far inland from the coastal line to suffer from any tsunami flooding. Thus, probable maximum tsunami do not pose a flood risk to the Callaway Site.

Because of the location of the Callaway Site relative to the nearest coast and the elevation of the plant site relative to the Missouri River, storm surge and seiche flooding considerations are not applicable for this site.

The maximum water level due to local intense precipitation or the local Probable Maximum Precipitation (PMP) is estimated and discussed in Section 2.4.2.3. The maximum water level in the Callaway Plant Unit 2 power block area due to local PMP is El. 844.8 ft (257.5 m) msl. This water level becomes the design basis flood elevation for all safety-related facilities in the power block area. All safety-related buildings in the power block are located above this elevation. Since the plant facilities are located on the crest of a plateau that has a well-developed natural drainage system and because final grading of the site area is integrated with this natural system, potential local flooding, even from extremely heavy rainfall, will be controlled by the plant site drainage system as discussed in Section 2.4.2.3.2.}

2.4.1.2 Hydrosphere

2.4.1.2.1 Hydrological Characteristics

{The Callaway Site is located on a plateau about 5 miles (8 km) north of the Missouri River at River Mile 115 (185 km). The plateau sits within the Auxvasse Creek watershed, a part of the Missouri River basin. Since the plateau is the topographic high in the area, surface runoff from the site vicinity drains into small intermittent streams. These small streams are tributaries of local streams that include Logan Creek to the east, Mud Creek to the southwest, Cow Creek to the north, and Auxvasse Creek to the west. Mud Creek and Cow Creek are tributaries to Logan Creek and Auxvasse Creek, respectively. The Missouri River basin and the Auxvasse Creek watershed, as defined by the USGS, are illustrated in Figure 2.4-3. The USGS 14-digit hydrologic unit code (HUC) boundary delineation of the Auxvasse Creek watershed includes the area drained by Logan Creek located in the southeast corner, and has a direct discharge into the Missouri River. Figure 2.4-4 illustrates the subwatersheds of Auxvasse Creek.

Two stream gauges are located in the Auxvasse Creek: Big Hollow near Fulton, MO (USGS Station No. 06927200) and Doane Branch near Kingdom City, MO (USGS Station No. 06927100) (Figure 2.4-7). The drainage area of the Big Hollow station near Fulton, MO (USGS Station No. 06927200) is approximately 4.05 mi^2 (10.5 km^2), and the average annual flow from USGS daily mean data, recorded from a 14-year period, 1958-1971, is 3.0 cfs (0.08 m^3/s) (USGS, 2007c). Doane Branch station near Kingdom City, MO (USGS Station No. 06927100) drains a small area of 0.54 mi^2 (1.4 km^2). Only a few data points were recorded for the 24-year period from 1955 to 1979 (USGS, 2007d).

The closest gauging stations in the Missouri River are USGS stations at Boonville, MO, (USGS Station No. 06909000) and Hermann, MO, (USGS Station No. 06934500) which are upstream and downstream of River Mile 115 (185 km), respectively (Figure 2.4-7).

2.4.1.2.1.1 Auxvasse Creek

Auxvasse Creek flows towards the south until it converges with the Missouri River at River Mile 120.6 (194.0 km). At the creek's closest point, it draws within 2.5 miles (4.0 km) west of the site, yet the variation of the floodplain near the site to the mouth is only about ¼ to ½ of a mile. Auxvasse collects runoff from the western and northern portions of the plant site area which totals approximately 317 sq mi (821 sq km), not including the Cow Creek tributary. The creek has a difference in elevation of about 350 ft (107 m) over its entire length.

2.4.1.2.1.2 Cow Creek

Cow Creek, characteristically an intermittent stream, exhibits a milder slope than the streams that drain generally in a southerly direction in the vicinity of the site. It is located about 5 miles (8 km) north and northwest of the plant site and drains about 29.7 sq mi (76.9 sq km). Cow Creek flows generally in a westerly direction and is a major tributary of Auxvasse Creek.

2.4.1.2.1.3 Mud Creek

Mud Creek collects surface drainage in the vicinity of the south and southwest portions of the plant site, encompassing about 8.3 sq mi (21.5 sq km). Mud Creek, which is deeply incised within narrow valley walls, is an intermediate stream that begins around 1.5 miles (2.4 km) south of the plant site, and flows about 5 miles (8 km) until it converges with Logan Creek approximately 2.5 miles (4.0 km) south of the site. Mud Creek descends approximately 350 ft (107 m) throughout its course including a single ½ mile reach in which it drops more than 200 ft (61 m).

2.4.1.2.1.4 Logan Creek

Logan Creek, deeply incised in the plateau, drains the central and eastern segments of the plant site and is within 2 miles (3 km) of the plant at its nearest point. Draining about 16.7 sq mi (43.2 sq km), Logan Creek flows generally in the southerly direction about 11 miles (18 km) and joins the Missouri River at River Mile 114.7 (184.6 km). The Logan Creek floodplain is from 500 ft to 1,000 ft (152 m to 305 m) wide from the site to its mouth, and slopes from an elevation of about 570 ft (174 m) approximately 4.5 miles (7.2 km) above its junction with the floodplain of the Missouri River to about an elevation of 525 ft (160 m) where it joins the river floodplain (AmerenUE, 2003).

2.4.1.2.1.5 The Missouri River

The Missouri River is formed by the junction of the Jefferson, Madison, and Gallatin Rivers near Three Forks, Montana. It flows generally in a southeasterly direction for about 2,341 river miles (3,767 km) until its confluence with the Mississippi River about 15 miles (24 km) upstream from St. Louis, Missouri (USGS, 1998).

The Gasconade River enters the Missouri River at about Missouri River Mile 104.5 (168.1 km) (AmerenUE, 2003). The total drainage area for the Gasconade River is approximately 3,500 sq mi (9,061 sq km). The Osage River is a major tributary that joins the Missouri River at approximately Missouri River Mile 129.9 (209.0 km).

At the Hermann gauging station, located downstream approximately 17 river miles (27 km) at Missouri River Mile 97.9 (157.5 km), continuous streamflow records have been collected since October 1928 by the USGS (USGS, 2008b). The drainage area of the Missouri River at Hermann is approximately 522,500 sq mi (1,352,690 sq km), and the average annual flow from USGS daily mean data recorded from a 79-year period, 1928-2007, is 78,886 cfs (2,234 m^3/s). At the Hermann Station, the maximum recorded flow of 750,000 cfs (21,238 m^3/s) and the maximum recorded flood elevation of 518.53 ft (158 m) msl were both recorded on July 31, 1993. The minimum recorded flow was 4,200 cfs (119 m^3/s) recorded on January 10, 1940.

Monthly streamflows and mean, maximum and minimum daily streamflows at Hermann, MO, are presented in Table 2.4-1 through Table 2.4-4. Mean streamflow discharges are also presented in Figure 2.4-6 along with maximum and minimum monthly values.

At the Boonville gauging station, about 82 river miles (132 km) upstream from the site, streamflow records have been kept since October 1925 (USGS, 2008a). The drainage area of the Missouri River at Boonville is approximately 500,700 sq mi (1,296,253 sq km), and the average annual flow from USGS daily mean data, recorded from an 81-year period, 1926-2007, is 62,483 cfs (1,769 m^3/s). At the Boonville station, the maximum and minimum recorded flows were taken as 755,000 cfs (21,379 m^3/s) and 1,800 cfs (51 m^3/s) recorded on July 29, 1993, and January 10, 1940, respectively. The maximum recorded flood level of 602.52 ft (184 m) was recorded on July 29, 1993.

Monthly streamflows and mean, maximum, and minimum daily streamflows at Boonville, MO, are presented in Table 2.4-5 through Table 2.4-8. Mean streamflow discharges are also presented in Figure 2.4-7 along with maximum and minimum monthly values.

Historical data characterizing ice conditions in the Missouri River have been collected and the effects evaluated for the operation of Callaway Plant Unit 2 in Section 2.4.7. The ESWEMS retention pond is a safety-related structure and is subject to ice formation in winter. However, as discussed in Section 2.4.7.6, ice formation does not affect the operation of the ESWEMS retention pond.

The collector well water supply intake and water discharge structures on the Missouri River are not safety-related structures. The Collector Well River Intake draws water from the Missouri River and Missouri River Alluvial Aquifer. Thus, this design would not be subject to ice blockage or ice formed in the Missouri River.}

2.4.1.2.2 Dams and Reservoirs

{The Missouri River is the largest sub-basin in the Mississippi River Basin, covering more than 500,000 sq mi (1,300,000 sq km) and part or all of 10 states and numerous Indian tribal reservations (USEPA, 2007).

Damming and channelization has occurred on most of the Missouri River basin. Since the 1930s, the Army Corps of Engineers has built six dams in the upper basin of the Missouri River, creating Fort Peck Lake (Fort Peck Dam), Lake Sakakawea (Garrison Dam), Lake Oahe (Oahe Dam), Lake Sharpe (Big Bend Dam), Lake Francis Case (Fort Randall Dam), and Lewis & Clark Lake (Gavins Point Dam). Gavins Point Dam is located about 734 miles (1,181 km) upstream of the Callaway Plant Unit 2 site, while the other listed dams are located farther upstream in South Dakota, North Dakota, and Montana (USGS, 1998). Figure 2.4-8 shows major reservoirs within the Missouri River Basin.

These dams, their respective reservoirs, and the storage capacity of their reservoirs include Fort Peck Dam and Fort Peck Lake (18.7 million acre-feet of water (2.3E+10 m^3)) near Glasgow, Montana; Garrison Dam and Lake Sakakawea (23.8 million acre-feet of water (2.9E+10 m^3)) near Bismarck, North Dakota; Oahe Dam and Lake Oahe (23.1 million acre-feet of water (2.8E+10 m^3)) near Pierre, South Dakota; Big Bend Dam and Sharpe Lake (1.9 million acre-feet of water (2.3E+9 m^3)) near Fort Thompson, South Dakota; Fort Randall Dam and Lake Francis Case (nearly 5.4 million acre-feet of water (6.7E+9 m^3)) near Wagner, South Dakota; and Gavins Point Dam and Louis and Clark Lake (470,000 acre-feet of water (5.8E+8 m^3)) near Yankton, South Dakota (USACE, 2007a). Figure 2.4-8 depicts the locations of the six main stem dams on the Upper Missouri River Basin.

The largest dams and reservoirs closest to the Callaway Site are located in the Osage River: Harry S. Truman Dam and Bagnell Dam. Table 2.4-9 lists detailed information about these two dams.

The Osage Hydroelectric Power Plant, operated by AmerenUE, is located on the Osage River, approximately 35 miles (56 km) southwest of Jefferson City, MO, and approximately 80 miles (129 km) upstream of the confluence with the Missouri River. The Osage Plant is supplied by the reservoir known as the Lake of the Ozarks, which is created by Bagnell Dam. The Osage Plant and Lake of the Ozarks are operated primarily to generate electricity during peak demand periods, but also provide recreational opportunities and flood control.

Bagnell Dam is a concrete gravity structure located on the Osage River about 80 miles (129 km) above its confluence with the Missouri River (about 97 miles (156 km) from the Callaway Site). At the maximum pool elevation of 660 ft (201 m), the reservoir formed by the dam covers a volume of about 1,893,670 acre-feet (2.3E+9 m^3) (RIZZO, 2006). At full reservoir capacity, the lake extends to near the toe of the Harry S. Truman Dam.

The Harry S. Truman Dam is an earth-fill structure located upstream from the Bagnell Dam. The reservoir, also known as the Truman Lake, is located near Warsaw, Missouri, on the Osage River.

The Truman Dam and reservoir, completed in October 1979, covers 55,600 acres (22,500 hectares) at normal pool; however, when the pool is at the top of flood control the surface area increases to 209,300 acres (84,700 hectares). Truman Lake has an estimated storage capacity of more than 5 million acre-feet (6.2E+9 m^3). At full reservoir capacity, the water level at the dam will be about 126 ft (38 m) above the streambed (USACE, 2008).

In addition, there are several smaller dams/reservoirs within Callaway County. Thunderbird Lakes and Upper and Lower Canyon Lakes are within a 10-mile (16- km) radius of the Callaway Plant Unit 2 site and are closest to the site. Thunderbird Lakes are divided into lower and upper lakes, with a lake area of 20.0 acres and 19.0 acres (8.1 hectares and 7.7 hectares), respectively (MDNR, 2007f). Canyon Lakes are also divided into lower and upper lakes, with an area of 40.0 acres and 13.0 acres (16.2 hectares and 5.3 hectares), respectively (MDNR, 2007f). These dams were built in the late 1960s and early 1970s and are regulated by the Missouri Department of Natural Resources (MDNR), with the exception of Upper Canyon Lake.

A total of 57 reservoirs (Figure 2.4-11) are present within the Auxvasse Creek watershed. However, only 15 of these reservoirs (representing 66% of the total reservoir volume) were included as part of the dam break analysis. Each reservoir elevation-area relationship was computed and taken as an input into HEC-HMS 3.1.0 model to perform the PMP runoff analysis. Miller Lake Dam was not included in the analysis because this dam is located downstream from the Callaway Site and potential dam failure would not cause flooding at the site.

Due to their proximity to the site, a complete simultaneous failure of all dams, with the exception of Miller Lake Dam, within Auxvasse Creek watershed as shown in Figure 2.4-11 was assumed during the flood analysis under Section 2.4.2.

There are 6 stormwater runoff ponds located in the vicinity of the Callaway Plant Unit 2 site. These ponds were created during construction of Callaway Plant Unit 1 to control sediment runoff. The surface area of these ponds ranges from approximately 0.9 acres to 13.5 acres (0.36 hectares to 5.5 hectares)**}**.

2.4.1.2.3 Surface Water Users

{Surface water use data for Callaway County were obtained from MDNR. There are no state laws, regulations or policies that specify the quantity of surface water that any diverter may use. "Missouri is a riparian water law state, and all landowners touching or lying above water sources have a right to a reasonable use of that water" (MDNR, 2007a).

No water use permits are required. However, since 1983, any large quantity water withdrawals (100,000 gallons per day or more, from either surface water or groundwater) are required to be reported to the MDNR Water Resources Program (Major Water Users Registration) and are labeled as Major Water Users (MDNR, 2003). Figure 2.4-10 illustrates the total surface water withdrawals reported by Major Water Users in Callaway County.

As per Water Resources Report Number 64, the surface water use in the central region of Missouri (including Callaway County) indicates fluctuating demands. "Peak reported surface water use occurred in 1998 and lowest use occurred in 2000. Electrical power generation is the major surface water use category, averaging 99.9% of the total surface water withdrawals. Significant quantities of surface water were reported for domestic, municipal and fish and wildlife categories, even though together they represent less than 0.1% of the total. Surface water use in this central region alone represents over 56% of the total surface water used in the entire state" (MDNR, 2007b). As illustrated in Figure 2.4-9, peak reported surface water use in Callaway County occurred in 1996 and the lowest level of use was in 1998.

In the mid-Missouri region, water withdrawals are used for industrial and residential needs, power generation, and irrigation. However, except for the Central Electric Power Cooperative Chamois Plant, there are no major municipal or industrial water users located within five miles (8 km) of the Callaway Site (MDNR, 2007b). The nearest municipal users are in Chamois, Mokane, and Fulton but these municipal users rely on groundwater supply for their water consumption.

Table 2.4-10 identifies active surface water users within Callaway and Osage Counties and their withdrawal rates (MDNR, 2007c). Table 2.4-10 indicates that withdrawals are mainly for irrigation and power generation. None of the permitted withdrawals are for public water supply. Figure 2.4-11 shows the locations of all reported surface water intakes within a 50-mile (80 km) radius of the location of the Callaway Plant Unit 2 site. In the Callaway Site area, the predominant water withdrawal from the Missouri River is for power generation by Callaway Plant Unit 1 and the Central Electric Power Cooperative Chamois Plant. Callaway Plant Unit 1 is the largest water user in the area; the Central Electric Power Cooperative Chamois Plant is the second largest user. Local streams are presently used for irrigation and livestock watering.

In 2006, Callaway Plant Unit 1 reported an annual average withdrawal of 15,560 gpm (58,895 lpm) with a maximum daily withdrawal of 23,500 gpm (88,948 lpm). Most of the water withdrawn for Callaway Plant Unit 1 that is not lost to the atmosphere is returned back to the Missouri River after being circulated through the plant condensers. The monthly variation of the cooling water discharge rate from Callaway Plant Unit 1 is shown in Table 2.4-11, which represents the typical annual water use pattern by Callaway Plant Unit 1. The highest 2006 monthly average withdrawal was 19,110 gpm (72,331 lpm), and the highest monthly discharge rate from 2004-2007 was 5,310 gpm (20,098 lpm) (MDNR, 2007d; MDNR, 2007e).

Water use projections are assessed based on population trends in a given area. Since surface water is not a common source for drinking water in Callaway County, the surface water use projection in the county cannot be calculated. Excluding the plant water use of the Callaway Plant Unit 2, the future additional use of surface water will be extremely limited. Furthermore, the withdrawal of water from the Missouri River to be used in the cooling systems for Callaway Plant Unit 2 are not subject to provisions mandated by the MDNR. The discharge of blowdown from cooling towers, effluent from a sewage treatment plant, and storm water runoff will be subject to the MDNR operating permit.}

2.4.1.2.4 Ground Water Characteristics

{The local and regional groundwater characteristics are described in Section 2.4.12. A detailed list of current groundwater users, groundwater well locations, and the withdrawal rates in the vicinity of the Callaway Site is presented in Section 2.4.12.2.

The groundwater source to meet the water demand requirements during the operation of Callaway Plant Unit 2 is a collector well system which withdraws water from the Missouri River/Missouri River Alluvial Aquifer. Deep wells are used for demin water, potable water and fire protection. Additional information regarding the use of groundwater at the Callaway Site is presented in Section 2.4.12.2.5.

Construction water needs are expected to be satisfied by appropriating water from the Callaway Site by utilizing the existing site deep wells.**}**

2.4.1.3 References

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2.4.2 FLOODS

The U.S. EPR FSAR includes the following COL Item in Section 2.4.2:

> A COL applicant that references the U.S. EPR design certification will identify site-specific information related to flood history, flood design considerations, and effects of local intense precipitation.

This COL item is addressed as follows:

This section identifies historical flooding at the site and in the region of the site. It summarizes and identifies individual flood types and combinations of flood producing phenomena in establishing the flood design basis for safety-related plant features. This section also covers the potential effects of local intense precipitation. Although topical information is discussed in Section 2.4.3 through Section 2.4.7 and Section 2.4.9, the types of events considered and the controlling event are reviewed in this section.

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

Sections 2.4.2.1 through 2.4.2.4 are added as a supplement to the U.S. EPR FSAR.}

2.4.2.1 Flood History

{The anticipated location for the Callaway Plant Unit 2 plant sits on a plateau which is the topographic high in the area. Surface runoff from the site vicinity drains into small intermediate streams. These small streams are branches of local streams that include Logan Creek to the east, Mud Creek to the southwest, Cow Creek to the north, and Auxvasse Creek to the west (Figure 2.4-6). Mud Creek and Cow Creek are tributaries to Logan Creek and Auxvasse Creek, respectively. Logan Creek and Auxvasse Creek have relatively steep channel gradients and drain directly into the Missouri River.

The Auxvasse Creek watershed defined by the USGS is illustrated in Figure 2.4-6. The USGS 14-digit hydrologic unit code (HUC) boundary delineation of the Auxvasse Creek subwatersheds includes the area drained by Logan Creek located in the southeast corner, and has a direct discharge into the Missouri River.

The Probable Maximum Floods (PMF) from Auxvasse Creek, Logan Creek and Mud Creek are discussed in Section 2.4.3. As discussed in Section 2.4.1, two stream gauges are located in the Auxvasse Creek: Big Hollow near Fulton, MO (USGS Station No. 06927200) and Doane Branch near Kingdom City, MO (USGS Station No. 06927100) (Figure 2.4-7). The drainage area of the Big Hollow station near Fulton, MO (USGS Station No. 06927200) is approximately 4.05 sq mi (10.5 sq km), and the average annual flow from USGS daily mean data, recorded from a 14-year period, 1958-1971, is 3.0 cfs (0.08 m^3/s) (USGS, 2007c). Doane Branch station near Kingdom City, MO (USGS Station No. 06927100) drains a small area of 0.54 sq mi (1.4 sq km). Only a few data points were recorded for the 24-year period from 1955 to 1979 (USGS, 2007d).

The closest gauging stations in the Missouri River are USGS stations at Boonville, MO (USGS Station No. 06909000) and Hermann, MO (USGS Station No. 06934500) which are upstream and downstream of River Mile 115 (185 km), respectively (Figure 2.4-7). Peak Streamflow reported by the USGS at the Hermann and Boonville gauging stations are shown in Figure 2.4-12 (USGS, 2007a and b).

Continuous streamflow recording of the Missouri River at Hermann and Boonville gauging stations began in 1844. Despite a lack of records prior to that time, the flood of 1844 is considered to be a significant event reported for the lower Missouri River. This flood is estimated to have had a peak stream flow of about 700,000 cfs (19,822 m^3/s) at Hermann and 710,000 cfs (20,105 m^3/s) at Boonville (USGS 2007a and b). A flood of this discharge is estimated to reach elevation 539 ft (164 m) msl near the plant site at Missouri River Mile 115 under present channel conditions (AmerenUE, 2003).

However, the 1993 flood that occurred throughout the Midwest is known to be one of the most significant and damaging natural disasters. The critical factor affecting the record flooding was the near continuous nature of rainfall from June through August. High summer rainfalls produced record flooding on the upper Mississippi and lower Missouri Rivers, equaling or exceeding flood recurrence intervals of 100 years along portions of these rivers (NOAA, 2007a).

Based on the USGS (2007b) peak stream flow data at the Boonville gauging station, the maximum recorded flow was 755,000 cfs (21,379 m^3/s) on July 29, 1993. The flood level was recorded to be 602.5 ft (183.6 m) in which 565.4 ft (172.3 m) msl is considered to be gauge datum. At the Hermann gauging station (USGS, 2007a), the maximum recorded flow was recorded to be 750,000 cfs (21,238 m^3/s) on July 31, 1993. The flood level was recorded to be 518.53 ft (158.05 m) msl (the Hermann gauge datum is set at 481.56 ft (146.78 m)). Daily maximum stream flow records are presented and discussed for both stations in Section 2.4.1.

Flood stages on the Missouri River at Hermann have increased historically. Criss (2008) developed a simple graphical method to evaluate systematic historical changes in the Missouri River stage for peak annual flood events. Graphs of river stage versus year for annual floods on the Missouri River at Hermann, indicates that water stages for a given discharge have increased by 3.0 ft to 7.5 ft (0.9 m to 2.3 m) since 1929 (Criss, 2008).

The most common type of flooding that occurs in the lower Missouri River is the result of runoff from the large contributing drainage area due to heavy rainfall and snowmelt during the spring and early summer seasons. During a large flood, the Missouri River spills over its banks onto the broad floodplain areas of the valley. Consequently, numerous flood control programs have been instituted. Although many individual flood control projects were planned and constructed prior to 1944, it was in that year that the Pick-Sloan Plan for the Missouri River Basin was adopted as the 1944 Flood Control Act of the Federal Government (USGS, 1998). The original development plan called for a series of reservoirs to be built in order to lessen the effects of flooding in the lower basin and provide flows for navigation below Sioux City, Iowa. Upper basin benefits included irrigation and power generation.

As discussed in Section 2.4.7, ice sheets have formed on the Missouri River on more than one occasion. Despite the formation of ice on the Missouri River, there have been no instances of ice jams or ice induced flooding at the existing Callaway Site. Further details of historic ice sheets and ice effects are discussed in Section 2.4.7.

There are no records of any landslide (submarine or subaerine) or distant tsunami source induced flooding events at the Callaway Site. Historical tsunami events are discussed in Section 2.4.6.

2.4.2.2 Flood Design Considerations

The design basis flood elevation for the Callaway Site is determined by considering a number of different flooding possibilities. The possibilities applicable and investigated for the site include the probable maximum flood (PMF) on streams and rivers, potential dam failures, probable maximum surge and seiche flooding, probable maximum tsunami, and ice effect flooding. Each of these flooding scenarios was investigated in conjunction with other flooding and meteorological events, such as wind generated waves, as required in accordance with guidelines presented in ANSI/ANS 2.8-1992 (ANS, 1992). Detailed discussions on each of these flooding events and how they were estimated are found in Section 2.4.3 through Section 2.4.7. Adequate drainage capacity will be provided to prevent flooding of safety-related facilities and to convey floodwaters on the roofs and the buildings away from the plant site area.

The estimation of the PMF water levels on Auxvasse Creek, Logan Creek and Mud Creek, located near the Callaway Site is discussed in detail in Section 2.4.3. Section 2.4.3 describes the Auxvasse Creek watershed model developed to determine the hydrographs and peak flows. The scope of this calculation includes the PMF evaluation of the maximum all-season probable maximum precipitation. HEC-HMS 3.1.0 was used to evaluate potential flood elevations on the Auxvasse Creek watershed with the inclusion of dam breaks for all reservoirs located within the Auxvasse Creek watershed. These reservoirs were included as part of the dam break analysis and each reservoir elevation-area relationship was computed under HEC-HMS.

All safety-related facilities for Callaway Plant Unit 2 are located between elevations 840 ft and 845 ft (256 m and 258 m) msl (AmerenUE, 2003). The highest flood of record on the Missouri River near the site at Chamois was 33.3 ft (10.1 m) on July 31, 1993, (NOAA, 2007b) resulting in a water level at Chamois of El. 535.8 ft (163.3 m) (gauge datum is set to 502.5 ft (153.2 m)). The Callaway Site is about 309.2 ft (94.2 m) higher; therefore, Missouri River flooding does not affect the plant.

Since the plant site is dry with respect to major flooding on the Missouri River, only a localized PMP storm was considered for flood design protection of safety-related facilities. The plant is located more than 133 ft (40.5 m) above the PMF level of Auxvasse, Mud, and Logan Creeks, and extreme floods on these tributary creeks would not affect the site. However, potential flooding conditions in these creeks were analyzed in Section 2.4.3.

Probable maximum surge and seiche flooding on the Missouri River as a result of the probable maximum hurricane (PMH) is discussed in Section 2.4.5. Because of the location of the Callaway

Site relative to the nearest coast and its elevation relative to the Missouri River, storm surge and seiche flooding considerations are not applicable for the Callaway Site.

Section 2.4.6 describes the derivation of the probable maximum tsunami (PMT) flooding. The potential for tsunami events that could affect the Callaway Site caused by local or distant seismic activities is negligible. The Callaway Site is approximately 860 miles (1,384 km) inland from the nearest coast, the Gulf of Mexico; this is too far inland from the coastal line to suffer from any tsunami flooding. Thus, the PMT does not pose a flood risk to the Callaway Site.

The maximum water level due to local intense precipitation or the local probable maximum precipitation (PMP) is estimated and discussed in Section 2.4.2.3. Precipitation that falls on safety related structure roofs is directed to the storm drain culverts. The maximum water level in the Callaway Plant Unit 2 power block area (defined in Table 2.4-15 as Nuclear Island), due to a local PMP, is at El. 844.8 ft (257.5 m). This water level becomes the design basis flood elevation for all safety-related facilities in the power block area. All safety-related buildings in the power block are located above this elevation. Since the plant facilities are located on the crest of a plateau that has a well-developed natural drainage system and because final grading of the site area is integrated with this natural system, potential local flooding, even from extremely heavy rainfall, will be controlled by the plant site drainage system as discussed in Section 2.4.2.3.2. Because of the Collector Well River Intake system design, the possibility of scour or sedimentation in or around the cooling water intake structure (non-Category I) is not required and thus does not require provisions to minimize their effects.

2.4.2.3 Effects of Local Intense Precipitation

The design basis for the local intense precipitation is the all-season Probable Maximum Storm (PMS) as obtained from the U.S. National Weather Service (NWS) Hydrometeorological Report Number 52 (NOAA, 1982).

As described in Section 2.4.1, Callaway Plant Unit 2 is located adjacent to the existing Callaway Plant Unit 1. The site layout and drainage system are shown in Figure 2.4-13 and Figure 2.4-14, respectively. The grade elevation of all safety-related facilities is between El. 840 ft and 846 ft (256 m and 258 m).

Since the Callaway Plant Unit 2 safety related structures are at a higher elevation than the existing streams, flood flows in these streams will not affect the Callaway Plant Unit 2 location. However, local PMP analysis on these streams was performed in Section 2.4.3.

As indicated in Figure 2.4-13, the Reactor, Fuel and Safeguards Buildings are located in the center and along the high point of the Callaway Plant Unit 2 power block area. From the high point, site grading falls at a 1% slope to stormwater runoff ponds located near the construction lay down area.

Pond drainages are constructed with base materials that promote infiltration of runoff from low intensity rainfall events. However, for large storms, the infiltration capacity of the base materials would be exceeded and overflow pipes are provided to direct the runoff to unnamed tributaries to Logan Creek and Mud Creek as well as to Cow Branch located around the Callaway Site. For the assessment of the local PMP levels, the overflow pipes and culverts in the drainage system are assumed to be clogged as a result of ice or debris blockage. In that case, the drainage system was modeled as a reservoir and the PMP storm runoff from the area collected in the ditches would overflow.

Grading in the vicinity of the safety-related structures slopes away from the individual structures such that PMP ground and roof runoff will sheet flow away from each of these structures towards the stormwater runoff ponds. Thus, sheet flows are prevented from entering the structures.

The site drainage is illustrated in Figure 2.4-14. The site drainage areas were then subdivided into five sub-basins for the site drainage evaluations. The sub-basins are: Switchyard, Sub-line Area/Parking Lot, Nuclear Island, ESWEMS Retention Pond and ESWEMS Spillway Area. The drainage areas for these sub-basins are shown in Figure 2.4-14 and presented in Table 2.4-13. Each sub-basin represents the runoff discharges into the drainage ditches located at the site.

The effect of potential ice and debris blockage of storm drains, roof drains, culverts, and outlet pipes has been considered in the site PMP runoff analyses. Since roof drains are considered blocked, runoff from roofs is assumed to be sheet flow over the edge of the roofs and contributing to the sheet flow runoff from each sub-basin. The runoff model does not consider any detention or storage for roof runoff. All runoff from roofs is included as direct runoff from the sub-basin drainage areas.

Peak water levels in the Callaway Plant Unit 2 power block area were determined by performing a hydrologic runoff analysis. The U.S. Army Corps of Engineers (USACE) computer program HEC-HMS 3.1.0 (Hydrologic Engineering Center- Hydrologic Modeling System) (USACE, 2006) was used to develop the hydrologic model and determine peak discharges in the site drainage ditches. Ground cover in the power block consists of primarily two types of surface characteristics, namely: 1) developed impervious area and 2) gravel surface on compacted fills.

The methodologies suggested by the U.S. National Resources Conservation Service (NRCS) as given in TR-55 Manual (USDA, 1986) were used to estimate the times of concentration (T_c) for the various sub-basins. The lag time, estimated as 60% of T_c, (USACE, 2000) and the local intense precipitation presented in Table 2.4-12 were input to HEC-HMS 3.1.0 (USACE, 2006). A runoff curve number of 98, representing impervious surfaces (USDA, 1986), is conservatively used for the entire drainage area and also input into the HEC-HMS computer model. The NRCS dimensionless unit hydrograph option for the developments of the peak discharges from the various sub-basins in HEC-HMS was utilized. A schematic of the Callaway Plant Unit 2 site drainage HEC-HMS model is given in Figure 2.4-16 and resulting peak discharges for the Callaway Plant Unit 2 structures are presented in Table 2.4-14.

The water level in all ditches is assumed to be at the top, corresponding to a full ditch condition, at the commencement of the PMP storm event. With the ditches full during the 72-hr PMP, all the ditches overtop and start acting as a reservoir. In addition to site drainage ditches, the Vehicle Barrier System (VBS) was included as part of the 72-hr PMP storm analysis.

The VBS assumptions that were made to support the PMP analysis are:

1. The VBS will be 20 ft (6 m) (minimum) outside of the outermost fence (nuisance fence) and will follow the topography as per Figure 2.4-15,

2. The VBS is 40 inches (102 cm) high,

3. There will be a few 40 inch (102 cm) wide openings on the VBS perimeter that will be walk-thru openings. These openings were positioned to allow runoff to flow away from the safety-related structures.

The VBS wall will surround the nuclear island and the ESWEMS pond areas on three sides (north, west and east). The VBS openings have been modeled at strategic elevations to accommodate the PMP runoff.

The runoff analysis was divided into two models: Series 1 and Series 2. Series 1 takes into account the drainage areas from Switchyard and Sub-line Area/Parking Lot sub-basins. Series 2 uses the outflow from Series 1 as an input to accommodate the VBS outflow into the nuclear island and ESWEMS sub-basins. Figure 2.4-16 illustrates the model set up.

The discharges were developed from the HEC-HMS peak discharges in Table 2.4-14. Inflows from each VBS opening were added to the ditches and each sub-basin.

The safety-related structures in the Callaway Plant Unit 2 power block area consist of two ESWS cooling towers located in the northwest corner, two ESWS cooling towers located in the southeast corner, Emergency Power Generating buildings located north and south of the Nuclear Island, which consists of the Reactor, Fuel and Safeguards Buildings. The locations of the buildings are shown in Figure 2.4-13. The entrances to each of these structures are located at or close to the grade slab elevation (El. 846 ft (258 m)) for each structure. Table 2.4-15 gives the elevations at the various safety-related facilities and compares them with the PMP water levels near those facilities. The maximum computed PMP water level in the power block area is El. 844.8 ft (257.5 m), which is 1.20 ft (0.37 m) below the Nuclear Island slab elevation.

The runoff from Callaway Plant Unit 1 will not impact Unit 2 because of the grade elevation difference between Callaway Plant Unit 1 (El. 840 ft (256 m) msl) and Unit 2 (El. 845 ft (258 m) msl). Likewise, the 72-hr PMP evaluation of the Callaway Unit 2 site drainage concludes that there is no adverse impact to Unit 1 from the runoff results.

Based on the Callaway Plant Unit 2 power block grading, entrance locations, and peak PMP water levels in the site ditches, all safety-related facility entrances and the Essential Service Water Emergency Makeup System (ESWEMS) are located above peak PMP ditch water levels and PMP sheet flows are prevented from reaching safety-related entrances.

Flood protection measures are not required for the Callaway Plant Unit 2 ESWEMS. The grade level at the ESWEMS retention pond location is at El. 840 ft (256 m) and El. 840.5 ft (256.2 m) for the ESWEMS pumphouse. The PMP level at the ESWEMS retention pond is estimated to be at El. 838.26 ft (255.50 m). As a result, the top of the ESWEMS retention pond is 1.74 ft (0.53 m) above the estimated PMP water level. The maximum computed estimated PMP water level at the pumphouse area is El. 839.66 ft (255.93 m), thus the ESWEMS pumphouse is 0.84 ft (0.26 m) above the estimated PMP. Therefore, flood protection measures are not required for these structures.

A general arrangement of the ESWEMS pumphouse and retention pond are shown in Section 3.E and 9.2 along with plan views. Flood protection for the ESWEMS retention pond will consist of structural measures to withstand the static and dynamic flooding forces as well as waterproofing measures to prevent the flooding of the interior pumphouse structure.

Since the area surrounding the ESWEMS retention pond is graded so as to prevent surface runoff from entering the pond, the pond drains only its own water surface area of about 6.8 acres (2.8 hectares). A spillway will be provided to route excess water from the pond to the drainage ditches.

The Callaway Site drainage system is designed to convey runoff from a 100-year storm away from the plant area. The design rainfall intensities for a 100-year storm used for sizing drainage structures, culverts and ditches were determined from the U.S. Department of Commerce Weather Bureau's Technical Papers Nos. 25 and 40, "Rainfall Intensity -Duration Frequency Curves" and "Rainfall Frequency Atlas of the United States," respectively (AmerenUE, 2003).

Furthermore, six stormwater runoff ponds (Figure 2.4-17), surround the Callaway Site and were constructed on the small unnamed drainages radiating away from the plant. These stormwater runoff ponds were constructed as impoundments or catch basins during construction of Unit 1 facilities. Two new stormwater runoff ponds, in addition to the existing stormwater runoff ponds in the vicinity of Callaway Site, are planned to catch stormwater and sediment runoff from the various construction areas. Also one of the existing stormwater ponds will be closed. The stormwater runoff ponds will be sized so as to prevent fast flowing, sediment laden stormwater from reaching the nearby creeks or Missouri River prior to allowing the sediments to settle out. Maximum runoff draining to the stormwater runoff ponds during the PMP is estimated at 4,354 cfs (123 m^3/s).}

2.4.2.4 References

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USGS, 2007d. USGS 06927100 Doane Branch Near Kingdon City, MO, Website: http://waterdata.usgs.gov/mo/nwis/inventory/?site_no=06927100&amp ; Date accessed: November 2, 2007.}

2.4.3 PROBABLE MAXIMUM FLOOD (PMF) ON STREAMS AND RIVERS

The U.S. EPR FSAR includes the following COL Item in Section 2.4.3:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information to describe the probable maximum flood of streams and rivers and the effect of flooding on the design.

This COL item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

The Callaway Plant Unit 2 site is located on a plateau which lies about 5 miles (8 km) north of the Missouri River as shown on Figure 2.4-1. Sources of potential flooding at the site are local intense precipitation directly over the site. This section discusses the Probable Maximum Flood (PMF) on streams and rivers as a result of the Probable Maximum Precipitation (PMP) over the watershed.

The Callaway Site is located on a plateau within the Auxvasse Creek watershed, which is part of the Missouri River basin. Since the plateau is the topographic high in the area, surface runoff from the site vicinity drains into small intermittent streams. These small streams are tributaries of local streams that include Logan Creek to the East, Mud Creek to the southwest, Cow Creek to the north, and Auxvasse Creek to the west**.** Mud Creek and Cow Creek are tributaries to Logan and Auxvasse Creek, respectively. The Auxvasse Creek watershed and its subwatersheds are defined by the USGS as illustrated in Figure 2.4-6. The USGS 14-digit Hydrologic Unit Code (HUC) boundary delineation of the Auxvasse Creek watershed includes the area drained by Logan Creek located in the southeast corner, and has a direct discharge into the Missouri River.

Four streams are analyzed for the PMF: Auxvasse Creek, Logan Creek, Mud Creek, and Cow Creek. Auxvasse Creek flows towards the south until it converges with the Missouri River at river mile 120.6 (194.0 km). Auxvasse Creek collects runoff from the western and northern portions of the plant site area, which totals in the region of about 321.4 square miles (832.1 km^2). The creek has a difference in elevation of about 350 ft (107 m) over its entire length.

Mud Creek collects surface drainage in the vicinity of the south and southwest portions of the plant site which encompasses about 8.3 square miles (21.5 km^2). Mud Creek is an intermittent stream that begins around 1.5 miles (2.4 km) south of the plant site and flows about 5 miles (8 km) until its convergence with Logan Creek approximately 2.5 miles (4.0 km) south of the site. Mud Creek descends approximately 350 ft (107 m) throughout its course, including one ½ mile reach in which it drops more than 200 ft (61 m).

Logan Creek, deeply incised in the plateau, drains the central and eastern segments of the plant site and is within 2 miles (3.km) of the plant at its nearest point. Draining about 16.7 square miles (43.2 km^2), Logan creek flows generally in the southerly direction about 11 miles (18 km) and joins the Missouri River at river mile 114.7 (184.6 km). The Logan Creek floodplain is 500 ft to 1,000 ft (152 m to 305 m) wide from the site to its mouth, and slopes from an elevation of about 570 ft (174 m) approximately 4.5 miles (7.2 km) above its junction with the floodplain of the Missouri River to about an elevation of 525 ft (160m) where it joins the river floodplain. (AmerenUE, 2003).

All safety-related facilities for Callaway Plant Unit 2 are located at about El. 846 ft (258 m) msl. The highest flood of record on the Missouri River near the site at Chamois was 33.3 ft (10.1 m) on July 31, 1993, (NOAA, 2007), resulting in a water level at Chamois of El. 535.8 ft (163.3 m) msl (gauge datum is set to 502.5 ft (153.2 m)). The Callaway Site is still about 309.2 ft (94.2 m) higher; therefore, the Missouri River flooding does not affect the plant.

The PMF analysis indicates that near the Callaway Site, the maximum PMF water surface elevation is 677.3 ft (206.4 m) msl for Logan Creek, 577.57 ft (176.04 m) msl for Mud Creek, and 704.33 ft (214.68 m) msl for Auxvasse Creek (Table 2.4-21).

All safety-related structures, systems, and components of Callaway Unit 2 are on an upland plateau approximately 5 miles (8 km) north of the Missouri River at about El. 846 ft (258 m) msl. Thus, safety-related structures on the Callaway Plant Unit 2 are 168.7 ft (51.4 m) above the Logan Creek PMF, 268.4 ft (81.8 m) above the Mud Creek PMF, and 141.7 ft (43.2 m) above the Auxvasse Creek PMF. The PMF on the noted local streams will not affect the Callaway Plant Unit 2 plant site.

Sections 2.4.3.1 through 2.4.3.7 are added as a supplement to the U.S. EPR FSAR.}

2.4.3.1 Probable Maximum Precipitation

{The PMP was developed according to procedures outlined in the Hydrometeorological Report (HMR) Numbers 51 and 52 (NOAA, 1978 and 1982). The values are presented in Table 2.4-12. They have been estimated based on the size and shape of the Auxvasse Creek watershed drainage area in accordance with the procedures outlined in HMR Number 52 (NOAA, 1982). The total drainage area for the Auxvasse Creek watershed is 346.5 mi^2 (897.0 km^2). Figure 2.4-4 illustrates the six Auxvasse Creek sub-watersheds, as defined by the USGS. Within these six watersheds lie several sub-basins for various reservoirs and reaches.

The topography for each of the six Auxvasse Creek sub-watersheds is variable with elevations ranging from about 10 ft (3 m) to about 120 ft (37 m). Table 2.4-16 shows the approximate length and average gradient of streams located near the Callaway Site.

Reservoir Delineation

Because of the size and complexity of this watershed, not all of the 57 reservoirs listed in Callaway County (Table 2.4-18) that lie within the six sub-watersheds were modeled in HEC-HMS 3.1.0. The reservoirs included in the model were chosen based on the volume of water they could hold compared to the other reservoirs. The inclusion of all 57 reservoirs that fall within the six sub-watersheds that make up the Auxvasse Creek watershed would lead to an unreasonably large and unmanageable computer model.

The reservoirs included in the HEC-HMS model were chosen based on the volume of water they could hold compared to the other reservoirs. Each reservoir was modeled as a cone, where the volume of water "V" is 1/3 the product of the maximum surface area "*A*" of the reservoir and the dam height "*H*". The mean reservoir volume is 177.4 acre-ft (218,827 m^3) and the sum of all reservoir volumes is 10,112.8 acre-ft (12,474,398 m^3). By eliminating all of the reservoirs with "*V*" less than the mean value, the model becomes much more manageable with only 15 reservoirs. The reservoirs used in the HEC-HMS model are listed in Table 2.4-19.

However, while the number of reservoirs was greatly reduced, the volume of water to be simulated during a dam break analysis was not. The sum of the volumes for the 15 reservoirs used in the HEC-HMS model is 6,689.5 acre ft (8,251,670 m^3); therefore [(6,689.5)/(10,112.8) = 66%] 66 percent of the total volume of water contained in all 57 reservoirs was accounted for in the model by using only 15 reservoirs.

Reaches Delineation

The reaches were delineated based on the significance of the channel. Only reaches of the main channel and its significant branches were delineated as separate sub-basins. In several cases, a single reach was split into multiple reaches in order to accurately route the reservoir discharge to the appropriate junction. Table 2.4-17 shows the reaches with their associated sub-basins and drainage areas. The delineation of the sub-basins can be seen in the Figure 2.4-18.

Ground cover for all sub-basins primarily consists of woods and agricultural land. The drainage area for each sub-basin is listed in Table 2.4-17, and the sub-basin delineation is shown in Figure 2.4-18. A schematic of the HEC-HMS model representing its sub-basins is shown in Figure 2.4-19.

Since the Auxvasse Creek watershed drainage area is larger than 10 square miles (26 km^2), the all-season PMP depths from Hydrometeorological Report HMR-51 (NOAA, 1978) were used. These PMP depths are estimates of the greatest rainfall rates possible for specified durations. The all-season point PMP depths listed on Table 2.4-12 represent the maximum PMP depths that could occur at the site location at any time of the year. As a default, the storm orientation was computed by the HMR-52 computer model (USACE, 1984) to produce maximum precipitation on the drainage area.

The distribution of the PMP storm is obtained from the U.S. National Weather Service (NWS) Hydrometeorological Report Number 51 (NOAA, 1978). In this procedure, the values listed in Table 2.4-12 are input into the HMR-52 computer model (USACE, 1984) and an incremental time step of five minutes is selected for the calculation of the PMP for the Auxvasse Creek model. Rainfall depths for durations that are integer multiples of the selected time intervals are produced by interpolating the PMP depths in Table 2.4-12. Successive differences in the cumulative depths are then determined to compute a set of incremental precipitation depths. The maximum incremental depth is placed at the middle of the storm duration, with the remaining incremental depths arranged in descending order, alternating before and after the central incremental depth.

HEC-HMS 3.1.0 was used to model the hydrologic processes of the PMP, with the inclusion of 15 dam breaks, representing 66% of the total volume of reservoir within the Auxvasse Creek watershed.

Based on the historical snowfall information for the Callaway Site region in Section 2.3, snowmelt does not make a significant contribution to flooding situations. Therefore, antecedent snow-pack conditions have not been considered in the PMF analysis.}

2.4.3.2 Precipitation Losses

{Even after development of Callaway Plant Unit 2, most of the Auxvasse Creek watershed will consist of wooded and agricultural areas. Precipitation losses for the Auxvasse Creek watershed are determined using the Natural Resources Conservation Service (NRCS), formerly known as the Soil Conservation Service (SCS), runoff methodology (USDA, 1986). For this method, a composite runoff curve number (CN) is assigned to each sub-basin in the watershed. The CN is used to describe the sub-basin's capacity to absorb and retain precipitation or produce runoff. Runoff curve numbers range from about 30 to 100, with higher numbers producing more runoff and lower numbers producing more infiltration. Each composite CN is determined based on the sub-basin's surface soils, land cover, and antecedent moisture condition (dry, average, or wet). Percentages of impervious areas were selected based on cover conditions. Impervious areas include open water bodies and all paved surfaces. The composite CN and total impervious area for each sub-basin are the land cover parameters input into the HEC-HMS 3.1.0 model.}

2.4.3.3 Runoff and Stream Course Model

{A schematic of the HEC-HMS computer model for the Auxvasse Creek watershed is shown in Figure 2.4-19. Runoff hydrographs for each sub-basin are shown in Figure 2.4-20 to Figure 2.4-25.

The Clark unit hydrograph method (Clark, 1945 and Straub, el. al., 2000) was selected as the transform method in the computer program HEC-HMS 3.1.0 to transform rainfall to runoff by calculating discharge hydrographs for each sub-basin within the Auxvasse Creek watershed. There are two stream gauges located in the Auxvasse Creek watershed: Big Hollow near Fulton, MO, (USGS Station No. 06927200) and Doane Branch near Kingdom City, MO (USGS Station No. 06927100). The drainage area of the Big Hollow station near Fulton, MO, is approximately 4.05 square miles (10.5 km^2), and the average annual flow from USGS daily mean data, recorded from a 14-year period, 1958-1971, is 3.0 cfs (0.08 m^3/s) (USGS, 2007a). Doane Branch station near Kingdom City, MO, drains a small area of 0.54 square mile (1.4 km^2). Only a few data points were recorded for a period of 24-year period, 1955 to 1979 (USGS, 2007b).

There are no historical records available to verify the results of the runoff analysis. However, the Clark unit hydrograph method is accepted in many regions of the United States, including the Mid-Atlantic Region, to estimate basin runoff and peak discharges from precipitation events.

The 8-point Muskingum-Cunge Method was used for stream/floodplain routing through the stream network to the watershed outlet (Miller and Cunge, 1975; Ponce and Yevjevich, 1978).

HEC-HMS uses the geometry of the road crossing and the standard broad crest weir equation to determine the discharge relationship and thereby determine the water levels in the storage area for each sub-basin.

The inflow hydrograph is then routed through each sub-basin and based on the stage-storage-discharge relationship, the outflow hydrograph is computed in the HEC-HMS model. The resulting hydrographs for selected sub-basins for the PMP event are shown Figure 2.4-20 to Figure 2.4-25. In addition to the outflow hydrograph, Figure 2.4-26 also displays the inflow hydrograph to one reservoir area, Lower Thunderbird Lake (MO11426), as well as the storage volume and water surface elevation curve.

Figure 2.4-20 to Figure 2.4-25 also shows the precipitation hyetograph in addition to the runoff hydrograph for selected sub-basins.

Base flow for each sub-basin was estimated based on bank full condition for Auxvasse Creek and its tributaries. However, the flow is small enough compared to the PMF flows that the base flow has no impact on the calculated flood water levels.

A total of 15 reservoirs (Table 2.4-19; Figure 2.4-11) within the Auxvasse Creek watershed were included as part of the dam break analysis, and all reservoir elevation-area relationships were computed using HEC-HMS as part of the PMP runoff analysis. Table 2.4-17 does not show Miller Lake Dam because this dam is located downstream from the Callaway Site and potential dam failure would not cause flooding at the site.}

2.4.3.4 Probable Maximum Flood Flow

{The PMP peak flow rates calculated in HEC-HMS are summarized in Table 2.4-20. The highest Auxvasse Creek water levels occur in the bottom reaches of the creek as it flows downstream.

As shown in Table 2.4-20, the peak flow rates for the various sub-basins occur at different times. The flow rates for each sub-basin are obtained from the HEC-RAS 3.1.3 model output and are summarized by cross section in Table 2.4-21.}

2.4.3.5 Water Level Determination

{Maximum water levels along Auxvasse Creek, Logan Creek, Mud Creek, and Cow Creek are determined utilizing the standard step backwater method for natural channels as implemented in the HEC-RAS 3.1.3 computer program developed by the U.S. Army Corps of Engineers (USACE, 2005). Required input for HEC-RAS includes geometric cross section data, flow rates, roughness data, and boundary conditions.

Since no historic flood information is available for Auxvasse Creek, Logan Creek, Mud Creek and Cow Creek and calibration of the standard step backwater model is not possible, conservative values are estimated for roughness and weir coefficients.

The cross section data is obtained from topographic maps developed for the site and USGS topographic maps (USGS, 1985). The HEC-RAS computer model cross section locations for Auxvasse Creek, Logan Creek, Mud Creek and Cow Creek are shown in Figure 2.4-27.

Manning's roughness coefficients for the stream channel and floodplain are estimated based on visual observations and procedures outlined by the USGS (USGS, 1990). Roughness coefficient values of 0.035 for the main channel and 0.1 for the floodplain areas are used in the HEC-RAS model.

The downstream control point for the HEC-RAS computer model is the Missouri River. Auxvasse Creek has no stream connectivity with Logan Creek/Mud Creek, thus an individual model was set up for Auxvasse Creek and Logan/Mud Creeks.

Using HEC-Geo RAS 4.1.1, a GIS tool developed by the USACE (2006), the cross section cut lines were drawn through the stream centerline. The cross sections were then developed from the USGS 30-meter Digital Elevation Map (DEM), and selected at approximately 100 ft to 200 ft (30 m to 61 m) increments throughout the length of the waterbody.

The normal depth option, which computes the normal depth water level based on the cross section dimensions, flow rate, and a user defined channel slope, is used to determine the downstream boundary condition at the first cross section. As indicated in Section 2.4.3.1, the sensitivity analysis indicated that water levels at Callaway Plant Unit 2 are unaffected by differing water levels at the downstream control point.

The PMF flow rates for the Auxvasse Creek, Logan Creek, Mud Creek and Cow Creek profiles listed in Table 2.4-21 are input into the HEC-RAS model at the indicated cross section locations. Lengths of Auxvasse Creek, Logan Creek, Mud Creek and Cow Creek are modeled using HEC-RAS. The normal depth option in HEC-RAS is used to estimate the downstream starting water level. The mixed flow option, which computes both sub-critical and super-critical flow regimes, is used to model the flood profiles.

The computed water surface elevations for each profile are summarized in Table 2.4-21 and Figure 2.4-28 illustrates specific cross sections listed in Table 2.4-21.

The maximum PMF water surface elevation for each cross section is highlighted in bold in Table 2.4-21. The Auxvasse Creek surface water profile is shown in Figure 2.4-29.

From Table 2.4-21, the maximum water levels during the PMP event in Auxvasse Creek range from El. 704.33 ft (214.68 m) at Cross Section 37193 (upstream) to El. 533.04 ft (162.47 m) downstream at Cross Section 84. This maximum water level is about 141 ft (43 m) below the plant grade El. 845 ft (258 m). The plant grade elevation is about 167.7 ft (51.1 m) above the maximum Logan Creek PMF El. 677.3 ft (206.4 m) and 267.4 ft (81.5 m) above the maximum Mud Creek PMF El. 577.57 ft (176.04 m).}

2.4.3.6 Coincident Wind Wave Activity

{Because the difference in elevation of about 141 ft (43 m) to the Auxvasse Creek PMF, about 167.7 ft (51.1 m) to the Logan Creek PMF, and about 267.4 ft (81.5 m) to the Mud Creek PMF, the opportunity for significant wave height development does not exist. Thus, wave height estimation is not performed for the PMF elevations on Auxvasse Creek, Logan Creek and Mud Creek.}

2.4.3.7 References

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2.4.4 POTENTIAL DAM FAILURES, SEISMICALLY INDUCED

The U.S. EPR FSAR includes the following COL Item for Section 2.4.4:

> A COL applicant that references the U.S. EPR design certification will verify that the site-specific potential hazards to safety-related facilities due to the seismically-induced failure of upstream and downstream water control structures are within the hydrogeologic design basis.

This COL item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

The site for Callaway Plant Unit 2 is approximately 10 miles (16 km) southeast of Fulton, Missouri, in Callaway County, and 80 miles (129 km) west of the St. Louis metropolitan area. Callaway Plant Unit 2 is located on a plateau which lies about 5 miles (8 km) north of the Missouri River. As mentioned in Section 2.4.1, the Callaway Plant Unit 2 site is located on a plateau within the Auxvasse Creek watershed, which is part of the Missouri River basin.

This plateau is the topographic high elevation in the area, and surface runoff drains into small intermediate streams. These small streams are tributaries of local streams that include Logan Creek to the East, Mud Creek to the South-West, Cow Creek to the North, and Auxvasse Creek to the west. Mud Creek and Cow Creek are tributaries to Logan and Auxvasse Creek, respectively.

Due to the relatively high elevation of the plateau, none of these tributaries contribute to flooding at the site. The flooding source for the site is local intense precipitation. Figure 2.4-30 shows the locations of these surface water features relative to the site.

There are no dams on Auxvasse Creek. However, there are several dams located within a 10 mile (16 km) radius of the Callaway Plant Unit 2 site on Auxvasse Creek tributaries, with Thunderbird and Canyon Lakes being the closest to the Callaway Plant Unit 2 site. Upper and Lower Canyon dams are located about 5 miles (8 km) northwest from the Callaway Plant Unit 2 site. Thunderbird Lower and Upper dams are located 4 miles (6 km) northwest from the site on an unnamed tributary. Figure 2.4-31 shows the location of all reservoirs within a 10 mile (16 km) radius.

2.4.4.1 Reservoir Descriptions

The Missouri River is the largest sub-basin in the Mississippi River Basin, covering more than 500,000 sq mi (1,300,000 sq km) and part or all of 10 states and numerous Indian tribal reservations (USEPA, 2007).

Damming and channelization has occurred on most of the Missouri River basin. Since the 1930s, the Army Corps of Engineers has built six dams in the upper basin of the Missouri River, creating Fort Peck Lake (Fort Peck Dam), Lake Sakakawea (Garrison Dam), Lake Oahe (Oahe Dam), Lake Sharpe (Big Bend Dam), Lake Francis Case (Fort Randall Dam), and Lewis & Clark Lake (Gavins Point Dam). Gavins Point Dam is located about 734 miles (1,181 km) upstream of the Callaway Plant Unit 2 site, with the other listed dams being farther upstream in South Dakota, North Dakota, and Montana. (USGS, 1998). Figure 2.4-32 shows major reservoirs within the Missouri River Basin.

These dams, their respective reservoirs and the storage capacity of their reservoirs include Fort Peck Dam and Fort Peck Lake (18.7 million acre-feet of water (2.3E+10 m^3)) near Glasgow, Montana; Garrison Dam and Lake Sakakawea (23.8 million acre-feet of water (2.9E+10 m^3)) near Bismark, North Dakota; Oahe Dam and Lake (23.1 million acre-feet of water (2.8E+10 m^3)) near Pierre, South Dakota; Big Bend Dam and Sharpe Lake (1.9 million acre-feet of water (2.3E+9 m^3)) near Fort Thompson, South Dakota; Fort Randall Dam and Lake Francis Case (nearly 5.4 million acre-feet of water (6.7E+9 m^3)) near Wagner, South Dakota; and Gavins Point Dam and Louis and Clark Lake (470,000 acre-feet of water (5.8E+8 m^3)) near Yankton, South Dakota (USACE, 2007a). Figure 2.4-32 depicts the locations of the six main stem dams on the Upper Missouri River Basin.

The largest dams and reservoirs closest to the Callaway Plant Unit 2 site are located in the Osage River: Harry S. Truman Dam and Bagnell Dam.

The Osage Hydroelectric Power Plant, operated by AmerenUE, is located on the Osage River, approximately 35 miles (56 km) southwest of Jefferson City, MO, and approximately 82 miles (132 km) upstream of the confluence with the Missouri River. The Osage Plant is supplied by the reservoir known as the Lake of the Ozarks, which is created by Bagnell Dam. The Osage Plant and Lake of the Ozarks are operated primarily to generate electricity during peak demand periods, but also provide recreational opportunities and flood control.

Bagnell Dam is a concrete gravity structure located on the Osage River about 82 miles (132 km) above its confluence with the Missouri River (about 97 miles (156 km) from the Callaway Site). At the maximum pool elevation of 660 ft (201 m), the reservoir formed by the dam covers an area of about 1,893,670 acre-feet (2.3E+9 m^3) (RIZZO, 2006). At full reservoir capacity, the lake extends to near the toe of the Harry S. Truman Dam.

Harry S. Truman Dam is an earth-fill structure located upstream from the Bagnell Dam. The reservoir, also known as the Truman Lake, is located near Warsaw, Missouri, on the Osage River. The Truman Dam and reservoir, completed in October 1979, covers a surface area of 55,600 acres (225 km^2) at normal pool, but when the pool is at the top of flood control the surface area increases to 209,300 acres (847 km^2). Truman Lake has an estimated storage capacity of more than 5 million acre-feet (6.2E+9 m^3). At full reservoir capacity, the water level at the dam will be about 126 ft (38 m) above the streambed (USACE, 2007b).

In addition, there are several smaller dams/reservoirs within Callaway County (Figure 2.4-31). Thunderbird Lakes and Upper and Lower Canyon Lakes are within a 10 mile (16 km) radius of the Callaway Plant Unit 2 site and the closest lakes to the site. Thunderbird Lakes are divided into lower and upper lakes, each with a lake area of 20 acres and 19 acres (0.081 km^2 and 0.077 km^2), respectively (MODNR, 2007). Canyon Lakes are also divided into lower and upper lakes, each with an area of 40 acres and 13 acres (0.16 km^2 and 0.053 km^2), respectively (MODNR, 2007). These dams were built in the late 1960s and early 1970s and are regulated by the Missouri Department of Natural Resources, with exception of Upper Canyon Lake. Table 2.4-22 lists all dams within a 10 mile (16 km) radius.

A simultaneous failure of major reservoirs within Auxvasse Creek watershed (Figure 2.4-33) was assumed during the flood analysis under Section 2.4.3. These reservoirs were included as part of the dam break analysis and each reservoir elevation-area relationship was computed using HEC-HMS 3.1.0 as part of the PMP runoff analysis. The results show that failure of these reservoirs would not impact the Callaway Plant Unit 2 site.

2.4.4.2 Dam Failure Permutations

Fort Peck Lake (Fort Peck Dam), Lake Sakakawea (Garrison Dam), Lake Oahe (Oahe Dam), Lake Sharpe (Big Bend Dam), Lake Francis Case (Fort Randall Dam), and Lewis & Clark Lake (Gavins Point Dam) are located on the upper Missouri River Basin.

A NWS dam break model of the Missouri River Basin was developed to aid in forecasting inundations resulting in dam failures (NOAA, 2007a). A flood wave generated by a dam break would result in travel of about 3 to 4 miles per hour (5 to 6 km per hr). These six dams are located a minimum of 734 miles (1,181 km) upstream of the Callaway Plant Unit 2 site, which would result in the initial wave reaching Missouri River mile 115 after about 184 hours (assuming 4 miles per hour) after a postulated dam breach at the dam closest to the site.

Dam failures from any or all of these six dams located upstream in the Missouri River would have negligible flooding effect on the Callaway Plant Unit 2 site as the flood waves would be significantly dissipated in the 734 miles (1,181 km) and greater distances to the vicinity of Callaway Plant Unit 2. Flood waves approaching Missouri River Mile 115 would be attenuated by the size and upstream storage volume available within the Missouri River drainage basin, resulting in no actual flood impact on the Callaway Plant Unit 2 site. In addition, the Callaway Plant Unit 2 site is located at plant grade elevation of 845 ft (258 m) msl. A flood wave from 734 miles (1,181 km) upstream of the Missouri River Mile 115 (El. 497-502 ft (151-153 m)) would have to maintain a height greater than 343 ft (105 m) to inundate the site. A review of the USACE Emergency Action Plan (USACE, 2008; USACE, 2006 a-e) for these six dams shows that failure of any or all of the major dams in the upper Missouri basin will have no effect on the potential for flooding at or near the Callaway Site.

Bagnell and Harry S. Truman Dams are located in a low intensity earthquake region in which relatively few earthquakes have occurred (USGS, 2007). The history of recorded earthquakes near the Callaway Site is discussed in Section 2.5.2. The probability of dam failure from earthquakes is low due to the low probability of seismicity near the site, further taking into account the earthquake magnitude that would be required to result in a complete dam failure. Nevertheless, two dam failure permutations were hypothesized for the purpose of this study, and the consequential flood waves were evaluated.

To demonstrate that the plant and its safety-related components and structures would not be jeopardized even under the most extreme combination of flood causing events, two simulations were considered: the failure of Bagnell Dam and a combination of the failure of

Harry S Truman and Bagnell dams. The first scenario assumes the collapse of Bagnell Dam when the reservoir is at its full capacity. The second scenario considers a domino type failure of both Bagnell and Harry S Truman dams when both reservoirs are at full capacity.

In the first hypothetical case, it was conservatively assumed that Bagnell Dam would fail suddenly with the Lake of the Ozarks at its full capacity. Montgomery Watson Harza (MWH, 2004) conducted a dam break analysis for the Osage Hydroelectric Plant as part of analyses required by the Federal Energy Regulatory Commission (FERC Project No. 459). Among the four dam break scenarios simulated in MWH study, the two most extreme scenarios considered were the overtopping with dam failure during Probable Maximum Flood (PMF) and a 160 ft (49 m) wide breach for a sunny day failure.

For a hypothetical dam failure due to overtopping during the PMF, the time of the beginning of the breach was assumed to be immediately after the occurrence of peak outflow to produce the most conservative (highest) estimate for the outflow through breaching section. A computer model was used to predict the dam break floods and the resulting routing through the Osage River utilizing the BOSS DAMBRK application. MWH developed a model with the Inflow Design Flood (IDF) for the Bagnell Dam defined as the Probable Maximum Flood (PMF). The current Bagnell Dam spillway rating curve was used for flood routing through reservoir. Under these conditions, the maximum stage in the reservoir would be at El. 672.8 ft (205.1 m) and the maximum outflow would be approximately 255,740 cfs (7,242 m^3/s).

Table 2.4-23 shows the dam characteristics for Harry S. Truman and Bagnell Dams.

For the sunny day failure, the starting reservoir water level for the flood routing was equal to the normal maximum pool level at El. 660.0 ft (201.2 m). MWH assumed that for the sunny day failure mode more than two monoliths would breach due to foundation failure.

Table 2.4-24 shows the flood characteristics due to a 160 ft (49 m) wide breach for a sunny day failure and during a PMF with dam overtopping and failure (AmerenUE, 2006).

The highest estimated peak water surface elevation (MWH, 2004) at Missouri River Mile 110.7 is El. 544.6 ft (166.0 m) msl during PMF-overtop with failure. The Missouri River 100-year floodplain is about El. 533.4 ft (162.6 m) msl (NOAA, 2007b). Callaway Plant Unit 2 sits at El. 845 ft (258 m) msl and approximately 5 miles (8 km) north of the Missouri River mile 115. Thus, the Callaway Plant Unit 2 Site is approximately 300.4 ft (91.6 m) above the El. 544.6 ft (166.0 m) resulting from the Bagnell dam failure.

Although it is considered highly improbable, the second hypothetical case considers the effect of flood waves near the Callaway Plant Unit 2 site as the result of a domino-type failure of both the Harry S Truman and Bagnell dams. The conditions considered are an instantaneous failure of Bagnell Dam due to flood waves resulting from a sudden failure of the Harry S. Truman Dam.

As per USACE Emergency Action Plan of 1999 (USACE, 1999), the breach of Harry S. Truman dam was assumed to have a 400 ft (122 m) bottom width at El. 660.0 ft (201.2 m) msl. This breach was assumed to be fully developed one hour after the initiation of failure. In response to this failure, the Bagnell Dam embankment was assumed to fail catastrophically when the Lake of Ozarks pool reached El. 675.0 ft (205.7 m) msl, which is 5 ft (2 m) above the top of Bagnell Dam.

Five major Corps of Engineer projects are located upstream of Harry S Truman Dam (Stockton, Pomme de Terre, Melvern, Pomona and Hillsdale) on tributaries of the Osage River. As per

USACE Emergency Action Plan of 1999, it is stated that the computations indicate that Harry S. Truman dam and reservoir has sufficient flood control and surcharge storage to regulate the combined inflows from upstream dam failures and natural flood flows.

As part of the Emergency Action Plan (USACE, 1999), the inundation maps were provided as a basis for evaluating flood impacts. Table 2.4-25 shows the peak flood elevation at Missouri River Mile 118, which is 183.6 miles (295.4 km) downstream from Harry S. Truman dam.

The highest estimated water surface elevation at Missouri River Mile 118 is El. 544.5 ft (166.0 m) msl during a spillway design flood with dam failure. Callaway Plant Unit 2 sits at El. 845 ft (258 m) msl and approximately 5 miles (8 km) north of the Missouri River mile mark 115. Thus, the Callaway Plant Unit 2 Site is approximately 300.5 ft (91.6 m) above the El. 544.5 ft (166.0 m) resulting from Harry S. Truman dam failure.

2.4.4.3 Unsteady Flow Analysis of Potential Dam Failures

The postulated non-hydrologic failure of upstream non site related dams is discussed in Section 2.4.4.2. Consequently, unsteady flow analysis is not utilized herein.

2.4.4.4 Water Level at Plant Site

Flood water levels resulting from failures of the major dams located within the Auxvasse Creek watershed were included in the Auxvasse Creek watershed flood analysis in Section 2.4.3.

Several other dams are located on tributaries of Auxvasse Creek upstream of the Callaway Plant Unit 2 site (outside of the 10 mile radius). However, the impact of flooding from these dam failures on the Callaway Plant Unit 2 site would be negligible since flood waves would have to reach heights of 300.5 ft (91.6 m) (El. 845 – El. 544.5) to reach the site. However, Section 2.4.3 takes into account a simultaneous failure of all dams within the Auxvasse Creek (Figure 2.4-33). Once any flood wave reaches the Missouri River, water levels would be attenuated by the size and storage volume available in the Missouri River.

2.4.4.5 References

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USACE, 2006d. Dam Safety Surveillance & Emergency Action Plan, Gavins Point Dam, Yankton, South Dakota. USACE Omaha District, Date of Issue August, 2006.

USACE, 2006e. Project Operation & Maintenance Manual Appendix E & F. Dam Safety Surveillance & Emergency Action Plan, Oahe Dam, Lake Oahe Project, Missouri River, South and North Dakota. USACE Omaha District, Date of Issue August, 2006.

USEPA, 2007. Mississippi River Basin & Gulf of Mexico Hypoxia- Missouri, Website: http://www.epa.gov/msbasin/subbasins/mo/index.htm, Date accessed: December 18, 2007.

USGS, 2007. Preliminary Documentation for the 2007 Update of the United States National Seismic Hazard Maps. The National Seismic Hazard Mapping Report, Open File Report 2007.

USGS, 1998. Final Report Lower Missouri River Ecosystem Initiative 1994-1998. USGS Columbia Environmental Research Center, December, 1998.}

2.4.5 PROBABLE MAXIMUM SURGE AND SEICHE FLOODING

The U.S. EPR FSAR includes the following COL Item for Section 2.4.5:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information on the probable maximum surge and seiche flooding and determine the extent to which safety-related plant systems require protection. The applicant will also verify that the site-parameter envelope is within the design maximum flood level, including consideration of wind effects.

This COL item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

Sections 2.4.5.1 through 2.4.5.6 are added as a supplement to the U.S. EPR FSAR.

2.4.5.1 Probable Maximum Winds and Associated Meteorological Parameters

The Callaway Site is located in Callaway County, Missouri, approximately 10 miles (16 km) southeast of Fulton, Missouri. The Callaway Site is on a plateau at El. 840 ft (256 m) between nearby shallow river valleys. The Missouri River flows in a 2.4 mile (3.9 km) wide, east-west valley approximately 5 miles (8.0 km) south of the site (see sketch illustrated in Figure 2.4-34). At the site, the Missouri River 100-year floodplain is at about El. 533.4 ft (162.6 m) msl (NOAA, 2007a). Thus the Callaway Plant Unit 2 site is approximately 306.6 ft (93.5 m) msl above the Missouri River 100-year floodplain.

The Callaway Site is approximately 860 miles (1,384 km) inland from the nearest coast, the Gulf of Mexico. Thus, the Callaway Plant Unit 2 Site is not in a coastal plain.

Because of the location of the Callaway Site relative to the nearest coast and the elevation of the Callaway Site relative to the Missouri River, storm surge and seiche flooding considerations are not applicable for this Site.

Furthermore, because Callaway Plant Unit 2 is not located on an open or large body of water (such as lakes or reservoirs), surge and seiche flooding are not of concern. Safety related structures are located on the site plateau and storm surge and seiche water levels are not of concern.

Site-specific characteristics of the regional climatology, including wind speeds and wind direction, are discussed in FSAR Section 2.3.2.

Between 1851 and 2005, there have been 281 reported hurricanes that reached landfall on the continental U.S. (NOAA, 2007b). Table 2.4-26 lists the costliest hurricanes to strike the U.S. mainland from 1900-2006.

The Gulf of Mexico region has frequently been exposed to extreme mid-Atlantic hurricanes. According to NHC (2006), more than 35 hurricanes have affected the Gulf of Mexico costal line between1900 to 2005. Among those, hurricane Katrina in 2005 was one of the most devastating hurricanes in the history of the United States (NHC, 2006).

Katrina brought hurricane conditions to southeastern Louisiana, southern Mississippi, and southwestern Alabama. As per NHC (2006), "the Coastal Marine Automated Network (C-MAN) station at Grand Isle, Louisiana, reported 10-minute average winds with a speed of 87 mph (140 km per hr) on August 29 with gusts to about 114 mph (183 km per hr)". Hurricane Katrina brought storm surge flooding of 25 ft to 28 ft (8 m to 9 m) above normal tide level at the Mississippi coast and storm surge flooding of 10 ft to 20 ft (3 m to 6 m) above normal tide levels along the southeastern Louisiana coast. Hurricane conditions also occurred over southern Florida and the Dry Tortugas. The National Hurricane Center reported "sustained winds of 69 mph (111 km per hr) on August 26 with gusts to 87 mph (140 km per hr). Additionally, tropical storm conditions occurred along the northern Gulf coast as far east as the coast of the western Florida Panhandle, as well as in the Florida Keys. Katrina caused 10 inches to 14 inches (0.3 m to 0.4 m) of rain over southern Florida, and 8 inches to 12 inches (0.2 m to 0.3 m) of rain along its track inland from the northern Gulf coast. Thirty-three tornadoes were reported from the storm" (NHC, 2007).

Regulatory Guide 1.59, *Design Basis Floods for Nuclear Power Plant*, Revision 2, August 1977 (RG 1.59), Appendix C provides the distribution of probable maximum surge levels from hurricanes along the Atlantic coast and Gulf of Mexico. It shows maximum surge heights of 37.3 ft (11.4 m) at Eugene Island, Louisiana, located southwest of the Mississippi River estuary. If it is assumed that a storm surge of such a magnitude propagated into the Mississippi River moving inland, the surge height would dissipate before reaching the confluence of the Missouri River (about 690 miles upstream (1,110 km)), and consequently, reaching Callaway Plant Unit 2 site (at Missouri River Mile 115 and at grade El. 840 ft (256 m) msl).

There are several USGS gauging stations on the Missouri River (See Section 2.4.1 for more details). Among those gauging stations is Boonville (USGS station # 06909000), located upstream of the Callaway Plant Unit 2 site. The Missouri River high flood level recorded at Boonville gauging station is El. 602.52 ft (183.65 m) msl (USGS, 2007). Taking into account the combination of the highest water level in the Missouri River and the surge height of 37.3 ft (11.4 m) (without any dissipation), the resultant wave height would reach El. 639.82 ft (195.02 m) msl. The Callaway Plant Unit 2 site sits at grade El. 840 ft (256 m) msl, 200 ft (61 m) higher than even this improbable estimated surge height. As a result, the Callaway Plant Unit 2 site would not be impacted by any resultant flood. Also, because the Callaway Plant Unit 2 site is not located on a large enclosed body of water, flooding due to seiche is not possible.

The probable maximum surge data from Regulatory Guide 1.59 (U.S.NRC, 1997) does not include hurricanes after 1975. However, because Callaway Plant Unit 2 is approximately 860 miles (1,384 km) inland and at grade El. 840 ft (256 m) msl the effects of probable maximum surge at the estuary of Mississippi River would not be significant at the site, and would not be subject to flooding of any water-related phenomena associated with the Missouri River.

The design basis considerations for the Essential Service Water Emergency Makeup System (ESWEMS) (ANSI/ANS, 1992), including the derivation of probable maximum winds, are discussed in FSAR Section 2.4.8.

2.4.5.2 Surge and Seiche Water Levels

2.4.5.2.1 Historical Surges

Between 1851 and 2005, 281 hurricanes have been reported to hit the coast of the continental U.S. (NOAA, 2007b). But because the Callaway Plant Unit 2 site is located approximately 860 miles (1,384 km) inland, recorded storm surge and seiche water levels are not a factor which could cause flooding.

2.4.5.2.2 Estimation of Probable Maximum Storm Surge

The probable maximum storm surge (PMSS) at the site can be estimated by considering the most severe combination of the components of primary surge, cross wind effects, 10% exceedance high tide, and sea level anomaly. But because the site sits on a plateau at El. 840 ft (256 m) msl approximately 306.6 ft (93.5 m) above the Missouri River 100-year floodplain, and 860 miles (1,384 km) from the Gulf of Mexico, an analysis is not required.

2.4.5.3 Wave Action

The Essential Service Water Emergency Makeup System (ESWEMS) retention pond for Callaway Plant Unit 2 is the only main reservoir on the site. In the event of a design basis accident, the ESWEMS retention pond will provide water for the post-accident period beyond the first 72 hours. The Callaway Plant Unit 2 ESWEMS pond is excavated to a total depth of 22 ft (7 m) below normal grade with side slopes of 3 horizontal to 1 vertical. The storage capacity of the pond at the normal water level of El. 835.0 ft (254.5 m) msl is 76 acre-ft (93,748 m^3). During post accident conditions, the ESWEMS is utilized to supply makeup water to the ESWEMS cooling towers. The ESWEMS retention pond is a small body of water 76 acre-ft (93,748 m^3) and is not subject to significant surge and seiches.

Several recurrence intervals were considered coincident with the maximum probable water level. The information on Probable Maximum Precipitation (PMP) as provided in Section 2.4.2 is applicable to the ESWEMS Retention Pond.

For the ESWEMS Retention Pond with a water level of El. 836 ft (255 m), the probable maximum water level due to a 72-hour PMP on the pond reaches El. 838.26 ft (255.50 m), as discussed in FSAR Section 2.4.8.2.1.1. In FSAR Section 2.4.8, several recurrence intervals were considered coincident with the maximum probable water level of El. 838.26 ft (255.50 m) msl. Under the PMP water level of El. 838.26 ft (255.50 m) msl, the fastest annual wind of 63 mph (101 km per hr) results in a freeboard requirement of 0.82 ft (0.25 m) which brings to El. 839.08 ft (255.75 m) msl. For the 1,000 year recurrence interval, the freeboard requirement is 1.69 ft (0.52 m) bringing the water level at the ESWEMS retention pond to El. 839.95 ft (256.02 m) msl.

2.4.5.4 Resonance

Resonance of seiche oscillation will not occur as a seiche is not possible at the Callaway Plant Unit 2 site.

2.4.5.5 Protective Structure

Flood protection measures for the ESWEMS intake structure are discussed in Section 2.4.10.

Because the Callaway Unit 2 site is located on a plateau about 315 ft (96 m) above the Missouri River floodplain and approximately 5 miles (8 km) from the floodplain, progressive floodplain erosion will have no impact on this area (see Figure 2.4-34).

2.4.5.6 References

AmerenUE, 2003. Final Safety Analysis Report (FSAR) Callaway-SA Section 2.4, Hydrology, Rev.OL-13, May, 2003.

ANSI/ANS-2.8 1992. Determining Design Basis Flooding at Power Reactor Sites, American National Standard/American Nuclear Society, July 1992.

NHC 2006. Hurricane History, National Hurricane Center, Web site address:

http://www.nhc.noaa.gov/HAW2/english/history.shtml#hugo, accessed September 4, 2007.

NOAA, 2007 U.S. Department of Commerce, NOAA Earth System Research Laboratory, Website: http://www.cdc.noaa.gov/usclimate/map.html. Date Accessed: September, 2007.

NOAA, 2007a. Advanced Hydrologic Prediction Service, National Weather Service, Website: http://www.crh.noaa.gov/ahps2/hydrograph.php?wfo=lsx&gage=cmsm7&view=1,1,1,1,1,1,1,1&toggles=10,7,8,2,9,15,6&type=0, Date accessed: September 18, 2007.

NOAA, 2007b. List of Hurricanes Landfalling in the Continental United States, National Oceanic and Atmospheric Administration, Website: http://www.aoml.noaa.gov/hrd/hurdat/ushurrlist.htm, Date accessed: September 4, 2007.

NOAA, 2007c. Continental United States Hurricanes Landings, National Oceanic and Atmospheric Administration, Website: http://www.ncdc.noaa.gov/oa/climate/severeweather/hurricanes.html, Date accessed: September 18, 2007.

NWS 2007. NOAA Technical Memorandum NWS TPC-5, National Hurricane Center, Miami, Fl, April 2007.

USGS, 2007. National Water Information System, Boonville, MO. Website: http://waterdata.usgs.gov/mo/nwis/inventory/?site_no=06909000&amp , Date accessed: January 3, 2007.

U.S.NRC, 1977. Regulatory Guide 1.59: Design Basis Floods for Nuclear Power Plants, Revision 2, August 1977.}

2.4.6 PROBABLE MAXIMUM TSUNAMI FLOODING

The U.S EPR FSAR includes the following COL Item in Section 2.4.6:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information and determine the extent to which the plant safety-related facilities require protection from tsunami effects.

The COL Item is addressed as follows:

This section develops the geohydrological design basis to ensure that any potential hazards to the structures, systems, and components important to safety due to the effects of a probable maximum tsunami are considered in the plant design.

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

Sections 2.4.6.1 through 2.4.6.8 are added as a supplement to the U.S. EPR FSAR.

2.4.6.1 Probable Maximum Tsunami

{The site of Callaway Plant Unit 2 is approximately 10 miles (16 km) southeast of Fulton, Missouri, in Callaway County, and 80 miles (129 km) west of the St. Louis metropolitan area. The Missouri River lies 5 miles (8 km) south of the Site within a flood plain about 2.4 miles (3.9 km) wide.

The Callaway Plant Unit 2 site is located approximately at Missouri River Mile 115 on a plateau at plant grade elevation El. 840 ft (256 m) MSL (AmerenUE, 2003). At the Site, the Missouri River 100-year floodplain is at El. 533.4 ft (162.6 m) MSL (NOAA, 2007a). Thus, the Callaway Plant Unit 2 site is approximately 306.6 ft (93.5 m) above the Missouri River floodplain.

The Callaway Site is approximately 860 miles (1,384 km) inland from the nearest coast which is the Gulf of Mexico. Thus, the Callaway Plant Unit 2 site is not in a coastal plain.

The potential of Tsunami events that could affect the Callaway Plant Unit 2 site caused by local or distant seismic activities is negligible. The Callaway Site is far too inland from the coastal line (Pacific and Atlantic Oceans and the Gulf of Mexico) to suffer from any tsunami flooding.}

2.4.6.2 Historical Tsunami Record

{As per the National Geophysical Data Center (NGDC), there are no records of major Tsunamis in the USA with significant flooding impacts.

All recorded historical tsunamis in the eastern U.S. and Canada, Gulf of Mexico and western U.S. from 1755 to 2006 are shown in Table 2.4-27 to 2.4-29 (NOAA, 2006b). Figure 2.4-35 shows the location of geo-seismic tsunami source generators in the world.

The Atlantic and Pacific Ocean regions are characterized by infrequent seismic and volcanic activities, resulting in few recorded tsunamis. The majority of tsunamis in the Atlantic and Pacific Oceans and the Caribbean Sea have been either triggered by seismic (earthquake) activity or the result of volcanic eruption. The most notable Atlantic tsunami was generated by the Great Lisbon Earthquake of 1755 and the Indian Ocean Earthquake in 2004. The 1755 tsunami hit the coasts of Portugal, Spain, and northern Africa and traveled across the Atlantic Ocean with a 10 ft to 15 ft (3 m to 5 m) wave reportedly reaching the Caribbean coasts (Maine DOC, 2006; NOAA, 2006c). The Indian Ocean Tsunami recorded wave heights of 164 ft (50 m) (NOAA, 2006c).

Earthquakes have the potential to create tsunami-like waves and have occurred in the vicinity of the Mississippi River.

A sequence of powerful earthquakes struck the mid-Mississippi River Valley, central United States, in the winter of 1811-1812. The magnitude of these series of earthquakes, usually named the New Madrid, Missouri, earthquakes, was estimated to be between 7 magnitude to 8 magnitude on the Richter scale. There are estimates that the New Madrid earthquakes caused damage over a large area of approximately 231,760 mi^2 (600,000 km^2) (USGS, 2007a).

The New Madrid earthquakes generated large waves on the Mississippi River by fissures opening and closing below surface. Local uplifts of the ground and water waves moving upstream gave the illusion that the river was flowing upstream (USGS, 2007a). Ponds of water also were noticeably agitated.

As per witness accounts: "At first the Mississippi seemed to recede from its banks, its waters gathered up like mountains, leaving boats high upon the sands. The waters then moved inward with a front wall 15 to 20 ft (5 to 6 m). The river fell as rapidly as it had risen and receded within its banks…" (GSC, 2007).

The events are rare, but the effects of similar wave heights, such as the ones resulting from the New Madrid earthquake, in conjunction with the time of a maximum flood approaching the Missouri River, were considered.

Maximum flood levels were recorded in 1993 at USGS Boonville (USGS station #06909000) and Hermann (USGS Station # 06934500) gauging stations located upstream and downstream in the Missouri River from Callaway Plant Unit 2, respectively. On July 1993, flood levels were reported to have reached 602.52 ft (183.65 m) msl at the Boonville gauge and 518.53 ft (158.05 m) msl at Hermann station (USGS, 2007b and 2007c). Callaway Plant Unit 2 sits at plant grade El. 840 ft (256 m) msl (AmerenUE, 2003); therefore, taking into account the high flood levels recorded at Boonville station, a tsunami-like wave would have to reach a height greater than 238 ft (73 m) to inundate the Callaway Site, which is not credible.

In addition, even if there was a tsunami present in the Atlantic and/or Pacific coast, the Callaway Plant Unit 2 site is not located in a coastal region. The Gulf of Mexico is the nearest coastal line, and is approximately 860 miles (1,384 km) away. Assuming a "trigger" mechanism similar to the 2004 Indian Ocean tsunami in the Gulf of Mexico, the effects of any tsunami wave with similar height of 10 ft (3 m) (Great Lisbon Earthquake of 1755) or 164 ft (50 m) (Indian Ocean Earthquake of 2004) approaching the Mississippi River and then reaching the Missouri River would be dissipated before reaching Callaway Plant Unit 2 (located at approximately Missouri River Mile 115 at plant grade elevation of 840 ft (256 m) MSL). A tsunami wave would have to reach a height greater than 238 ft (73 m) to inundate the Callaway Site. Therefore, any affect from a tsunami-like wave is not credible.

2.4.6.3 Tsunami Source Generator Characteristics

An analysis is not required.

2.4.6.4 Tsunami Analysis

An analysis is not required.

2.4.6.5 Tsunami Water Levels

An analysis is not required.

2.4.6.6 Hydrography and Harbor or Breakwater Influences on Tsunami

An analysis is not required.

2.4.6.7 Effects on Safety-Related Facilities

An analysis is not required.

2.4.6.8 References

AmerenUE, 2003. Final Safety Analysis Report (FSAR) Callaway-SA Section 2.4, Hydrology, Rev.OL-13, May, 2003.

GSC, 2007. U.S. Natural Disasters, Gainesville State College, Georgia. Website: http://data.gsc.edu/home/32/924114332/tsunami.htm, Date accessed August 27, 2007.

Maine DOC, 2006. Tsunamis in the Atlantic Ocean, Maine Geological Survey, Maine Department of Conservation, Website: http://www.maine.gov/doc/nrimc/mgs/explore/hazards/tsunami/jan05.htm, Date accessed September 4, 2007.

NASA, 2007. Digital Tectonic Activity Map. Web site address: http:://denali.gsfc.nasa.gov.dtam/ , Date accessed: September 10, 2007.

NOAA, 2007a. Advanced Hydrologic Prediction Service, National Weather Service, Website: http://www.crh.noaa.gov/ahps2/hydrograph.php?wfo=lsx&gage=cmsm7&view=1,1,1,1,1,1,1,1 &toggles=10,7,8,2,9,15,6&type=0, Date accessed: September 18, 2007.

NOAA, 2006b. Historical Tsunami Record, Website: http://www.ngdc.noaa.gov/seg/hazard/tsu_db.shtml, Date accessed: September 4, 2007.

NOAA, 2006c. Tsunami, Tidal Waves and Other Extreme Waves, National Weather Service Forecast Office, Philadelphia/Mount Holly, National Oceanic and Atmospheric Administration,

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Website: http://www.erh.noaa.gov/er/phi/reports/tsunami.htm, Date accessed September 4, 2007.

USGS, 2007a. Earthquake Hazards Program, 1811-1812 Earthquakes in the New Madrid Seismic Zone, Unites Stated Geological Survey Website: http://earthquake.usgs.gov/regional/states/events/1811-1812.php, Date accessed August 27, 2007.

USGS, 2007b. National Water Information System, Hermann, MO. Website: http://nwis.waterdata.usgs.gov/mo/nwis/peak?site_no=06934500&agency_cd=USGS&format=html Date accessed: July 17, 2007.

USGS, 2007c. National Water Information System, Boonville, MO. Website: http://nwis.waterdata.usgs.gov/mo/nwis/peak?site_no=06909000&agency_cd=USGS&format=html Date accessed: July 17, 2007.}

2.4.7 ICE EFFECTS

The U.S. EPR FSAR includes the following COL Items for Section 2.4.7:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information regarding ice effects and design criteria for protecting safety-related facilities from ice-produced effects and forces with respect to adjacent water bodies.
>
> A COL applicant that references the U.S. EPR design certification will evaluate the potential for freezing temperatures that may affect the performance of the ultimate heat sink makeup, including the potential for frazil and anchor ice, maximum ice thickness, and maximum cumulative degree-days below freezing.

These COL items are addressed as follows:

As discussed in Section 2.4.1, the {Callaway Plant Unit 2 site is approximately 10 miles (16 km) southeast of Fulton, Missouri, in Callaway County and 80 miles (129 km) west of the St. Louis metropolitan area. Callaway Plant Unit 2 is located on a plateau which lies about 5 miles (8 km) north of the Missouri River.} Figure 2.4-39 indicates the location of the site.

{Reference to elevation values in this section are based of the National Geodetic Vertical Datum of 1929 (NGVD), values unless otherwise stated.

Sections 2.4.7.1 through 2.4.7.10 are added as a supplement to the U.S. EPR FSAR.

2.4.7.1 Ice Conditions

Ice at a nuclear power plant site could occur in any one of the following forms:

- Surface ice and its associated forces
- Anchor ice formation on components
- Frazil ice that could clog intake flow passages
- Ice jams that could affect flow path to the water supply intake

- Breach of ice jams causing flooding at site
- Ice accumulation on roofs of safety-related structures and components
- Ice blockage of the drainage system causing flooding
- Ice accumulation causing reduction in water storage volume

Historical data characterizing ice conditions at the Callaway Plant Unit 2 site have been collected and the effects evaluated for the operation of Callaway Plant Unit 2. These data include ice cover and thickness observations in the Missouri River, ice jam records, and long term air temperature measurements from the nearby Columbia Regional Airport station meteorological tower (WBANID 03945). The Columbia Regional Airport station is approximately 35 miles (56 km) west of the Callaway Plant Unit 2 site. The Columbia Regional Airport maintains meteorological data records from 1969 to present.

2.4.7.2 Description of the Cooling Water Systems

The Callaway Plant Unit 2 Circulating Water Supply System (CWS) is a closed-cycle system using natural draft cooling towers for the heat sink. Makeup water to the cooling tower basins is supplied by the Callaway Plant Unit 2 Collector Well River Intake Structure located along the Missouri River south of the Callaway Site. Callaway Plant Unit 2 Cooling Tower blowdown effluent is combined with Callaway Plant Unit 1 blowdown effluent and delivered to the Missouri River permitted outfall using a common discharge line.

The Callaway Plant Unit 2 Ultimate Heat Sink function will be provided by mechanical forced draft Essential Service Water System (ESWS) cooling towers situated above storage basins pools. Each of the four basins will normally be supplied with makeup water from the non-safety-related Callaway Plant Unit 2 Collector Well River Intake System via the site water treatment plant.

The Essential Service Water System (ESWS) provides flow for normal operating conditions, for shutdown/cooldown, and for Design Basis Accident (DBA) conditions. The ESWS pump in each train obtains water from the ESWS cooling tower basin of that train and circulates the water through the ESWS. Heated cooling water returns to the ESWS cooling tower to dissipate its heat load to the environment. Makeup water is required to compensate for ESWS cooling tower water inventory losses due to evaporation, drift, and blowdown associated with cooling tower operation. Makeup water to the ESWS cooling tower basins under normal operating and shutdown/cooldown conditions is provided by the Water Treatment Plant. Water is stored in the ESWS cooling tower basin, which provides at least 72 hours of makeup water for the ESWS cooling tower following a DBA. After 72 hours have elapsed under DBA conditions, emergency makeup water to the tower basins is provided by the safety-related ESWEMS Retention Pond and Pumphouse.

2.4.7.3 Intake and Discharge Structures

The Collector Well River Intake System will supply makeup water to the natural draft cooling tower basins for the non-safety related CWS and it also supplies makeup water to the Callaway Plant Unit 2 safety-related ESWEMS Retention Pond.

Each collector well design consists of a concrete caisson constructed to bedrock (approximately 100 ft (30 m) below grade) with approximately fourteen screened intake laterals installed around the perimeter of the caisson (Burns &McDonnell, 2008).

The Collector Well River Intake System draws water from the Missouri River and the Missouri River Alluvial Aquifer.

Plant effluent going back to the Missouri River from Callaway Plant Unit 2 consists of cooling tower blowdown from the CWS cooling towers and the ESWS cooling towers, and miscellaneous low volume wastewater streams from Callaway Plant Unit 2 Power Block. A 36 inches (91 cm) diameter outfall pipe runs along an existing rock wing dike to a discharge point approximately 100 ft (30 m) into the Missouri River. The pipe discharge is at elevation 493.5 ft (150.4 m) msl.

2.4.7.4 Historical Ice Formation

The climate at the Callaway Site is part of the Missouri River basin climate system. Based on air temperature data summaries collected at the Columbia, MO, regional airport (WBANID 03945) from 1970 through 1995, the monthly average air temperature in the region ranges from about 27.4°F (-2.6°C) in January to 77.4°F (25.2°C) in July, while the monthly average minimum air temperature for December is 10.9 °F (-11.7°C), for January is 5.8°F (-14.6°C) and for February is 10.4°F (-12.0°C) (USEPA, 2007). In the recent years (2004-2006) the minimum average temperature during winter months (December, January, and February) has been 24.3 °F (-4.3°C) (NOAA, 2007a).

Daily air temperatures measured at the Columbia regional airport meteorological station indicate that below freezing temperatures occur typically between the months of November and March. However, maximum accumulated freezing degree-days, as defined in Section 2.4.7.6, occur mostly in December, January and February.

There are 25 recorded instances of ice jams in the main stem of the Missouri River based on a search of the “Ice Jam Database” maintained by the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL). The closest to the site were ice jams recorded at Boonville, MO, on December 19, 1945 (USACE, 2007).

Ice accumulation on the transmission towers and switchyard of existing Callaway Plant Unit 1 has sporadically occurred during freezing rainfall (AmerenUE, 2003). To date, events such as these have not affected the operation of Callaway Plant Unit 1 and are not anticipated to affect operation of Callaway Plant Unit 2.

2.4.7.5 Frazil Ice

Research on the properties of frazil ice indicates that the nature and quantities of ice produced depends on the rate of cooling within a critical temperature range. Frazil ice forms when the water temperature is below 32°F (0°C), the rate of super cooling is greater than 0.018°F (-17.8°C) per hour in turbulent flows, and there is no surface ice sheet to prevent the cooling (USACE, 1991 and Griffen, 1973). This type of ice, which is in the shape of discoids and spicules (Griffen, 1973), typically forms in shallow flowing water when the flow velocity is approximately 2 ft/s (0.6 m/s) or higher (IAHR, 1970).

The ESWEMS Retention Pond arrangement with pump intakes approximately 30 ft (9 m) below the nominal surface grade prevents any interruption of emergency water supply to the ESWEMS.

Neither frazil ice nor anchor ice have been observed in the intake structure or Ultimate Sink Heat Pumphouse Structure of the existing Callaway Plant Unit 1 since the start of operation. There is no public record of frazil or anchor ice obstructing other water intakes in the Missouri

River. As a result, frazil ice or anchor ice is unlikely to occur to an extent that will affect the function of the makeup water intakes. The Collector Well River Intake System draws water from the Missouri River Alluvial Aquifer at 100 ft (30 m) below grade. Therefore, formation of frazil and anchor ice are not expected to impact operation of the Collector Well River Intake System.

2.4.7.6 Surface Ice Sheet

Ice may form on the surface of the Callaway Plant Unit 2 ESWEMS Retention Pond during severe winter periods. Ice formation, however, does not affect the operation of the ESWEMS Retention Pond for the following reason: when the retention pond operates with such ice cover, water from the pond is withdrawn at a point approximately 30 ft (9 m) below the nominal surface grade. Sufficient water volume is provided in the pond to preclude ice from reaching the pump intake during post-accident operation. This arrangement prevents any interruption of emergency water supply to the ESWS. Thus, there is no possibility for pump blockage by ice.

The pond structures at the water surface are in contact with surface ice that can form during prolonged subfreezing periods. Ice expansion and wind drag on the ice surface exert forces on these structures. The following sections address the approach used in evaluating the ice thickness and the forces on the ESWS pumphouse caused by the presence of ice.

Determination of the estimated ice thickness in the ESW Emergency Makeup Retention Pond is based on the analysis of monthly Accumulated Freezing Degree-Days (AFDD), defined as the summation of the difference between 32°F (0 °C) and all recorded daily air temperatures below freezing (or the average daily temperature obtained from hourly data on record) for the months of December, January, and February.

The Collector Well River Intake System for Callaway Plant Unit 2 will not be impacted by surface ice formation. Each collector well design consists of a concrete caisson constructed to bedrock (approximately 100 ft (30 m) below grade) with approximately fourteen screened intake laterals installed around the perimeter of the caisson. The collector well pump intakes are thus located approximately 100 ft (30 m) below grade in the Missouri River Alluvial Aquifer.

Detailed information about the layout of the Collector Well River Intake System is provided in Section 9.3.

The maximum ice thickness that could form in the Missouri River and the ESWEMS Retention Pond was estimated using historic air temperature data from the nearby Columbia Regional Airport station meteorological tower for the period of 1970 through 2006.

Surface ice thickness (t_i) can be estimated as a function of Accumulated Freezing Degree-Days (AFDD) using the modified Stefan equation (USACE, 2004), where C is a coefficient usually ranging between 0.3 and 0.6 and AFDD is in °F days. For the Missouri River, a coefficient of 0.15 was used in Equation 2.4.7-1 to provide a conservative estimation of the ice thickness ("average river with snow condition", USACE, 2004). A value of 0.7 was used to estimate the ice thickness in the ESWE Makeup Retention Pond ("average lake with snow condition", USACE, 2004).

Equation 2.4.7-1 $t_i = C\,(AFDD)^{0.5}$

Accumulated freezing degree-days are obtained by summing the Freezing Degree-Days (FDD) for each month (December, January, and February), which is the difference between the freezing point (32°F (0°C) and the average daily air temperature (T_a) :

Equation 2.4.7-2 $FDD = (32 - T_a)$

Table 2.4-30 summarizes the estimated monthly average Accumulated Freezing Degree-Days (AFDD) and the corresponding ice thickness estimate from 1970 to 2006 for the Missouri River. Table 2.4-31 summarizes the AFDD and its respective calculated ice thickness from 1970 to 2006 for the ESWEMS Retention Pond. As indicated in Table 2.4-30, the monthly average AFDD is 228 °F (109 °C) occurring in January with the corresponding ice thickness estimated to be approximately 2.25 inches (5.71 cm). Table 2.4-31 shows that the ESWEMS Retention Pond average monthly ice thickness occurring in January is estimated to be approximately 10.51 inches (26.70 cm).

The maximum thickness of ice that could form on the ESWEMS pons is calculated as described in Section 2.3.1.2.2.13. The loading on the ESWEMS Pumphouse is due to ice formation is evaluated as described in Section 3E.4.

To assure the Callaway Plant Unit 2 safety-related ESWEMS would not be affected by surface ice, the possibility of ice jam formation and the potential for frazil ice are examined by estimating the maximum surface ice thickness that could form during the worst icing condition expected at the site. The surface ice layer, when present, insulates and provides protection against the formation of frazil ice.

2.4.7.7 Ice Accumulation on the Intake and ESWS Cooling Tower Basin and Preventive Measures

The Collector Well River Intake System and water discharge structures on the Missouri River are not safety-related structures. Even though, the Missouri River is subject to ice formation during winter months, the Collector Well River Intake System is not impacted. The collector well pump intakes are located approximately 100 ft (30 m) below grade in the alluvial aquifer of the Missouri River. This design would not be subject to ice blockage or ice formed in the Missouri River.

Ice will not affect the discharge structure, as the warm discharge water will keep the outfall open.

For the ESWS cooling tower basins, measures will be taken to ensure that the basins underneath the cooling tower cells have a minimum of 72 hours water supply without the need for any makeup water during a design basis accident. As indicated in Section 2.4.7.2, any makeup water to the basin needed beyond the 72 hour, post accident period will be supplied from the new Callaway Plant Unit 2 ESW Emergency Makeup System. In order to assure the availability of a minimum of 72 hours water supply in the ESWS cooling tower basins, the minimum volume in each basin will be established considering: (a) losses due to evaporation and drift under design basis accident conditions and design environmental conditions; (b) minimum submergence to avoid formation of harmful vortices at the pump suction; and (c) the operational range for basins water levels. During extreme cold weather conditions, operational controls will be implemented, as required, to assure the availability of the required volume. Tower operations during cold weather will mitigate ice buildup consistent with vendor recommendations (e.g., periodic fan operation in the reverse direction). Therefore, operational controls, together with system design features, will prevent ice formation in the ESWS cooling tower basins as discussed in Section 9.2.5.

2.4.7.8 Effect of Ice on High and Low Water Levels and Potential for Ice Jam

Because water would be drawn from the Missouri River Alluvial Aquifer, ice-induced low and high water levels will not affect the operation of the Collector Well River Intake structure. The impacts of ice in the ESWEMS Retention Pond is described in Section 2.4.7.6 and the ESWS cooling tower basins are discussed in Section 2.4.7.7.

In addition, Callaway Plant Unit 2 is located on a plateau, which is the topographic high in the area, and surface runoff from the site vicinity drains into small intermittent streams located at lower elevations than the plant site. Streams close to the site have small drainage areas and would not pose the potential of ice flooding at the site.

2.4.7.9 Effect of Ice and Snow Accumulation on Site Drainage

Air temperature measurements at the Columbia Regional Airport Station meteorological station indicate that mean daily temperatures at the site had periodically fallen below freezing for multiple consecutive days in winter. This introduces the possibility of ice blockage of small catch basins, storm drains, culverts and roof drains. The flood protection design of the Callaway Plant Unit 2 safety-related facilities assumes that all catch basins, storm drains, and culverts are blocked by ice, snow, or other obstructions, rendering them inoperative during a local Probable Maximum Precipitation (PMP) event. Details of the local PMP analyses and flood protection requirements for the site are discussed in Section 2.4.2 and Section 2.4.10. Therefore, temporary blockage of site drainage areas will not affect the operation of safety-related facilities.

2.4.7.10 References

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USACE, 1991. Cold Regions Research and Engineering Laboratory, Frazil Ice Blockage of Intake Trash Racks, Technical Digest Number 91-1, U.S. Army Corps of Engineers, S. Daly, March 1991.

USACE, 2004. Method to Estimate River Ice Thickness Based on Meteorological Data, ERDC/CRREL Technical Note 04-3, U.S. Army Corps of Engineers, June 2004. http://www.crrel.usace.army.mil/library/technicalnotes/TN04-3.pdf

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USEPA, 2007. BASINS Model, Met-data 1970-1995, Website: http://www.epa.gov/waterscience/ftp/basins/wdm_data/, Date accessed: November 20, 2007.

Burns & McDonnell, 2008. Phase II Hydrogeologic Investigation Report Collector Well Siting Study.

USACE, 2007. Ice Jam Database, Cold Regions Research and Engineering Laboratory (CRREL). Website: https://rsgis.crrel/usace.army.mil/icejam/ Date accessed: December 26, 2007.}

2.4.8 COOLING WATER CANALS AND RESERVOIRS

The U.S. EPR FSAR includes the following COL Item for Section 2.4.8.:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information and describe the design basis for cooling water canals and reservoirs used for makeup to the UHS cooling tower basins.

This COL Item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless otherwise stated.

Sections 2.4.8.1 through 2.4.8.3 are added as a supplement to the U.S. EPR FSAR.

2.4.8.1 Cooling Water Design

Callaway Plant Unit 2 does not include any safety-related canals used to transport water. As discussed in Section 2.4.1.1, the Callaway Plant Unit 2 Collector Well River Intake Structures that provide makeup water to the non-safety related Circulating Water System (CWS) and the safety-related Essential Service Water Emergency Makeup System (ESWEMS), will be located on the Missouri River floodplain.

2.4.8.2 Reservoirs

The Essential Service Water Emergency Makeup System (ESWEMS) retention pond for Callaway Plant Unit 2 is the only main reservoir on the site. In the event of a design basis accident, the ESWEMS retention pond will provide water for the post-accident period beyond the first 72 hours. Callaway Plant Unit 2 ESWEMS retention pond is excavated to a depth of 22 ft (7 m) below nominal grade with side slopes of 3 horizontal to 1 vertical. The storage capacity of the pond at the normal water level of El. 835.0 ft (254.5 m) msl is 76 acre-feet (93,748 m^3). During post accident conditions, the ESWEMS is utilized to supply makeup water to the ESWS cooling towers.

Detailed description of the Callaway Plant Unit 2 ESWEMS is provided in Section 9.2.5. Hydrologic conditions during PMP and coincident wind wave activities are discussed in Section 2.4.8.2.1. Consideration of probable maximum wind is discussed in Section 2.4.8.2.2. Even though the nominal water level at the ESWEMS retention pond is El. 835.0 ft (254.5 m), the analysis is performed at El. 836 ft (255 m) to assure conservative assumption and adequate margin.

2.4.8.2.1 Water Level Determination

The ESWEMS Retention Pond's hydrologic design is controlled by the PMP and the resulting water level. The 72-hour PMP on the pond is distributed as shown in Table 2.4-32, utilizing Hydrometeorological Report 52 (NOAA, 1982). The resulting rainfall is converted to equivalent inflow discharge to the pond and is routed through storage to determine the maximum resulting water level. The outlet structure, which is a 6.0 ft (1.8 m) long broad-crested spillway, has a crest elevation of 836.5 ft (255.0 m) msl. The discharge coefficient used in the weir equation is 2.65 (Brater and King, 1976). The flood routing is based on the initial pond water level at the spillway crest. Flood routing indicates that the probable maximum water level in the pond will reach El. 838.26 ft (255.50 m) msl with a peak outflow of about 36.99 cfs (1.05m^3/s) based upon an initial water level corresponding to 836 ft (255 m) msl.

The information on Probable Maximum Precipitation (PMP) as provided in Section 2.4.2 is applicable to the ESWEMS Retention Pond. For the ESWEMS Retention Pond with a water level of El. 836 ft (255 m) msl, the probable maximum water level due to a 72-hour PMP of 40.0 in (101.6 cm) (Table 2.4-32) on the pond reaches El. 838.26 ft (255.50 m) msl, as discussed in Section 2.4.8.2.1.1. Several wind recurrence intervals were considered coincident with the maximum probable water level of El. 838.26 ft (255.50 m). Results of these scenarios are presented in Table 2.4-33 and Table 2.4-34. Under the PMP water level of El. 838.26 ft (255.50 m) msl, the fastest annual wind of 63 mph (101 km per hr) results in a wave runup requirement of 0.82 ft (0.25 m) which brings the ESWEMS water level to El. 839.08 ft (255.75 m) msl. For the 1,000 yr recurrence interval the wave runup requirement is 1.69 ft (0.52 m) bringing the water level at the ESWEMS retention pond to El. 839.95 ft (256.02 m) msl, as discussed in Section 2.4.8.2.1.2.

2.4.8.2.1.1 Coincident Wind Wave Activity

Discussion of wind wave activities is limited to Callaway Plant Unit 2 ESWEMS Retention Pond as the only safety-related hydrologic element at the site which is subject to wind wave activity.

As a conservative approach, the fastest mile wind speeds with a mean recurrence interval of 10, 25, 50, 100, and 1,000 years were taken into account as occurring coincidentally with the probable maximum water level at its peak elevation. At this evaluated water level of 838.26 ft (255.50 m) msl, the Unit 2 ESWEMS retention pond has a water surface length of 684.6 ft (208.7 m), a width of 389.56 ft (118.74 m), and a depth of 20.26 ft (6.18 m).

Wind setup is calculated by following USACE (1997) guidance.

$$S = \frac{U^2 F}{1400D}$$

Where U is average wind velocity in miles per hour, F is wind tide fetch in miles, and D is the average depth in feet. The wind tide fetch F is usually taken to be twice the distance of the effective fetch F_e, which is the distance over which wind can travel unobstructed across a body of water. The maximum effective wind fetch (F_e) was estimated to be the maximum water surface length of 684.6 ft (208.7 m). The maximum fetch distance was doubled to obtain wind tide fetch F. Table 2.4-33 shows the wind velocity, effective fetch, wind tide fetch, average depth and wind setup for each of the scenarios.

Several hydrometeorological events were considered in the analysis occurring coincidentally with the probable maximum water level at El. 838.26 ft (255.50 m) msl.

The calculation of wave runup involves finding the significant wave height and period based on fetch length and wind speed. Then, the determination of the wave runup is based on the characteristics of the wave and embankment slope. USACE (2006) provides guidance for this process. USACE (2006) describes the following procedure for calculation of shallow water wave heights and periods:

1. Determine the straight line fetch and over water wind speed;

2. Using the fetch and wind speed from (1), estimate the wave height and period of deepwater nomograms;

3. Compare the predicted wave period from (2) to the shallow water limit as per:

$$T_p \approx 9.7\left(\frac{d}{g}\right)^{\frac{1}{2}}$$

   a. If the predicted wave is greater than the limiting value, reduce the predicted wave period to the limiting value. The wave height may be found by noting the dimensionless fetch associated with the limiting wave period and substituting this fetch for the actual fetch in the wave growth calculation.

   b. If the predicted wave period is less than the limiting value, retain the deepwater values from (2).

4. If the wave height exceeds 0.6 times the depth, wave height should be limited to 0.6 times the depth.

Wave runup was then calculated using equations and suggested coefficients from USACE (2006). Table 2.4-34 shows resulting wind setup, wave runup and freeboard requirement values.

The freeboard requirement is defined as the height above the still water surface that the wind setup combined with the wave runup will impact. Note that $R_{u2\%}$ is the wave runup that 2% of the waves will exceed and is the most conservative value attainable by using USACE (2006).

Based on the results shown in Table 2.4-34, the overflow protection is adequate during the PMP and the wave action does not adversely affect the Unit 2 ESWEMS Retention Pond embankments.

2.4.8.2.2 Probable Maximum Wind Design Considerations

2.4.8.2.2.1 Probable Maximum Winds

Using the method of Thom (1968), the annual extreme fastest mile wind speed at the Callaway Site at different recurrence intervals is indicated in Table 2.4-35. These extreme fastest mile wind speeds are computed at 30 ft (9 m) above ground level. The Thom method assumes that:

   a. Surface friction is uniform for a fetch of 25 miles (40 km);

   b. Extreme winds result only from extratropical cyclones or thunderstorms; and

   c. Extreme winds from tornados are not included in this analysis.

Maximum winds in the site area are associated mainly with thunderstorms and squall lines rather than hurricanes or other cyclonic storms. Although these winds are usually considered local in nature, they can cause wind setup and generate large waves in water bodies.

The probable maximum wind was determined based on the method of Thom (1968). Thom used meteorological data collected over a 21-year period from 150 monitoring stations to provide isotachs of the 0.50, 0.10, 0.04, 0.02, and 0.01 quantiles for the annual extreme fastest wind speed for the United States. Thom then provides an empirical method to use these data to determine the fastest wind speed for other quantiles at any U.S. location. This method was used to determine the fastest wind speed likely to occur at the 0.001 quantile; the 1,000 – year mean recurrence interval. Table 2.4-35 shows the extreme fastest mile wind speed at different recurrence intervals obtained from Thom (1968).

It is believed that a wind speed with a return period of 1,000 years constitutes a conservative design basis for safety related elements. Based on Thom's model, this design wind speed applicable to the site was computed to be 118 mph (190 km per hr) with duration of 1-minute (Table 2.4-35).

Thom's isotach's and statistics are based on a specific 21-year database, more recent data can not be taken into account, except as a comparison of actual extreme wind speeds with those predicted by Thom (1968).

Table 2.4-36 lists the extreme observed wind speeds at Columbia Regional Airport, located about 30 miles (48 km) from the Callaway Plant Unit 2 site. The fastest annual extreme wind speed was recorded in 1952 at 63 mph (101 km per hr). As an example, this 63 mph (101 km per hr), compares with Table 2.4-35 values determined from Thom's method of 72 mph (116 km per hr) (50-year recurrence interval) and 85 mph (137 km per hr) (100-yr recurrence interval).}

2.4.8.2.2.2 Wave Action

{Several recurrence intervals were considered coincident with the maximum probable water level of El. 838.26 ft (255.50 m) msl. Results of these scenarios are presented in Table 2.4-34.

In the analysis of wave action, an extreme wind speed with a 1,000-year return interval occurring coincidentally with a maximum probable water level of 838.26 ft (255.50 m) msl is considered to be a conservatively postulated combination of hydrometeorological events. The nominal surface level of water in the pond is El. 836 ft (255 m) msl. This design wind for a 1,000 year return interval, as discussed in Section 2.4.8.2.2.1, has the extreme fastest mile wind speed of 118 mph (190 km per hr).

The design for the ESWEMS pond slope protection is based on a 4 foot wave height. In the analysis of wave action, an extreme wind speed with a 1,000 year return interval occurring coincidentally with a UHS retention pond water level corresponding to an elevation of 836.0 feet are considered. The normal surface level of water in the pond is Elevation 835.0 feet.

The riprap thickness was determined using the procedure outlined in the U.S. Army Corps of Engineers, EM 1110-2-2300 (1971b). A double bedding layer, designed according to the criteria presented in the U.S. Bureau of Reclamation, Design of Small Dams (1973), is required to provide a free-draining transition to minimize effects of erosion, and prevent the riprap from settling into the natural soils.

Wave runup results using the methods described in Section 2.4.8.2.1.2 are shown in Table 2.4-34. At the 1,000 year wind event, and for a riprapped slope of 3 horizontal to 1 vertical designed to resist this wave action, the maximum wave run up ($R_{u2\%}$) is calculated to be 1.56 ft (0.48 m). Including the wind setup value (S) of 0.13 ft (0.04m), the total run up ($S+R_{u2\%}$) would be 1.69 ft (0.52 m) and would reach El. 839.95 ft (256.02 m) msl. The riprap design is also based on the wave runup analysis.

2.4.8.2.3 Design Bases for Unit 2 ESWEMS Retention Pond

The riprap and bedding design configuration for the pond slope is shown on Figure 3E.4-6. The riprap stone layer thickness is 18 inches (0.46 m). The double bedding thickness is 12 inches (0.3 m) consisting of 6 inches (0.15 m) of fine bedding and 6 inches (0.15 m) of coarse bedding. The protection extends from the top of the slope at (Elevation 840.0-845.0 feet) (256-257.6 m) to Elevation 828.0 feet (252.4 m). The gradation requirements for the riprap and bedding are shown on Figure 3E.4-6.

The riprap consists of dumped stone – hard, durable, and angular in shape. The specification for the stone requires a percentage loss of not more than 40 after 500 revolutions as tested by ASTM C 535, Resistance to Abrasion of Large Size Coarse Aggregate by Use of the Los Angeles Machine. The stone sizes vary from a maximum of approximately 18 inches (0.46 m) to a minimum of 1 inch (2.59 cm) to fill voids, and have a 50-percent size of 12 inches (0.3 m). The maximum stone weight is 500 pounds (226.8 kg), and the specific gravity is greater than 2.60.

The fine bedding layer is placed on the prepared embankment slope in a single lift. The fine bedding gradation shown on Figure 3E.4-6 satisfies the requirements of ASTM C 33, Concrete Aggregates.

The coarse bedding layer is placed in a single lift on top of the finished fine bedding layer, which has a surface free from mounds or windrows. The coarse bedding gradation shown on Figure 3E.4-6 satisfies the requirements of ASTM D 448, Standard Sizes of Coarse Aggregate for Highway Construction, Size No. 467.

Stone for riprap is placed on the surface of the finished coarse aggregate bedding layer in a manner which produces a reasonably well-graded mass of stone with the minimum practicable percentage of voids. Riprap is placed to its full course thickness in one operation if possible to avoid displacing the underlying material. All material comprising the riprap is placed and distributed such that there are no large accumulations of either the larger or smaller sizes of stone.

2.4.8.2.4 Resonance

At the evaluated level of El. 836 ft (255 m) msl, the Callaway Plant Unit 2 ESWEMS retention pond has an approximate length of 671 ft (205 m) and an average depth of 18.0 ft (5.5 m). The ESWEMS pond side slopes are covered with riprap which acts as a wave energy absorber. For these reasons, resonance of the pond is not anticipated (AmerenUE, 2003).

2.4.8.3 References

AmerenUE, 2003. Final Safety Analysis Report (FSAR) Callaway-SA Section 2.4, Hydrology, Rev.OL-13, May, 2003.

Brater, E.F. and King, H.W, 1976. Handbook of Hydraulics, McGraw-Hill, New York 5th Edition.

NOAA, 1982. Application of Probable Maximum Precipitation Estimates – United States East of the 105th Meridian, Hydrometeorological Report Number 52, National Oceanic and Atmospheric Administration, August 1982.

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U.S.NRC, 1976. Ultimate Heat Sink for Nuclear Power Plants, Regulatory Guide 1.27, Revision 2, Nuclear Regulatory Commission, January 1976.

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USACE, 2006. Coastal Engineering Manual, EM 1110-2-1100, June 2006.

USACE, 1984. Hydrometeorological Report No 52 (HMR-52): Probable Maximum Storm (Eastern United States), March 1984.

USACE, 1978. Hydrometeorological Report No 51 (HMR-51): Probable Maximum Precipitation Estimates, United States East of the 105th Meridian, June 1978.

USACE, 1997. Hydraulic Engineering Requirements for Reservoirs, EM 1110-2-1420, October 1997.}

2.4.9 CHANNEL DIVERSIONS

The U.S. EPR FSAR includes the following COL Item for Section 2.4.9:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information and demonstrate that in the event of upstream diversion or rerouting of the source of cooling water, alternate water supplies will be available to safety-related equipment.

This COL item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

Callaway Plant Unit 2 will be located on a plateau which lies about 5 miles (8 km) north of the Missouri River. As mentioned in Section 2.4.1, the Callaway Plant Unit 2 site is located on a plateau within the Auxvasse Creek watershed, which is part of the Missouri River basin. Since the plateau is the topographic high in the area, surface runoff from the site vicinity drains into small intermittent streams. These small streams are tributaries of local streams that include Logan Creek to the East, Mud Creek to the Southwest, Cow Creek to the North, and Auxvasse Creek to the West**.** Mud Creek and Cow Creek are tributaries to Logan and Auxvasse Creek, respectively. The Missouri River basin and the Auxvasse Creek watershed, defined by the USGS, are illustrated in Figure 2.4-3. The USGS 14-digit hydrologic unit code (HUC) boundary delineation of the Auxvasse Creek watershed includes the area drained by Logan Creek located in the southeast corner, and has a direct discharge into the Missouri River.

The Missouri River is defined from the confluence of the Jefferson, Madison, and Gallatin Rivers near Three Forks, Montana, to its confluence with the Mississippi River near St. Louis. It flows generally in a southeasterly direction for about 2,341 river miles (3,767 km) until its confluence with the Mississippi River approximately 15 miles (24 km) upstream from St. Louis, Missouri. The river drains a 529,350 sq mi (1,370,424 sq km) basin covering high mountain regions in Montana of about 4,050 ft (1,234 m) and plains that are only 380 ft (116 m) above sea-level (USGS, 1998)

Sections 2.4.9.1 through 2.4.9.8 are added as a supplement to the U.S. EPR FSAR.

2.4.9.1 Historical Channel Diversions

The Callaway Plant Unit 2 Site is approximately located at Missouri River Mile 115 (185 km) on a plateau at plant grade elevation El 845 ft (258 m) msl. At the site, the Missouri River 100-yr floodplain is at about El. 533.4 ft (162.6 m) msl (NOAA, 2007). Thus the Callaway Plant Unit 2 Site is approximately 311.6 ft (95.0 m) above the Missouri River 100-year floodplain. The area between the plateau and the Missouri River flood plain is highly dissected. Since the plateau is the highest topographic elevation in the area, surface runoff from the site vicinity drains into small intermediate streams.

The Missouri River channel and its tributaries are regulated within the jurisdiction of State and Federal agencies. The United States Army Corps of Engineers (USACE) has general management authority over the river and its dams.

The Collector Well River Intake System is the source of cooling water for nuclear power generation operations. Because the collector well system is located directly adjacent to and beneath the Missouri River channel, the concern of potential channel diversion must include consideration of multiple purpose usage of the river including navigation, recreation, water supply, flood control, and power generation. It is extremely improbable that naturally occurring or man-made diversions would be allowed to continue unchecked or uncontrolled.

There are many water management projects on the Missouri River. The upper river basin (defined as the headwaters up to Sioux City, IA) has been impounded by six large dams that can hold up to 74 million acre-feet (9.1E+10 m^3) of water in the reservoirs (USGS, 1998). The lower river basin, defined as the 735 miles (1,183 km) of river downstream from Sioux City, IA, to St. Louis, MO, has been channelized, reducing the river to a tenth of its original width and separating the river from its floodplain (USGS, 1998).

Todd (1914) characterized the river as mature because of channel features that include meanders, oxbow lakes, and cutoffs. In terms of dynamic equilibrium, a newer concept proposed by Hack (1975), the river adjusted to the erodibility of the relatively soft rock into which the channel was cut. Channelization worked against the natural tendency (or dynamic equilibrium) to maintain these features (Hack, 1975).

Given the seismic, topographical, and geologic evidence in the region (See Section 2.5.2), there is very limited potential for upstream diversion or rerouting of the Missouri River (due to channel migration, river cutoffs, ice jams, or subsidence) and as a result adversely impacting safety-related facilities or water supplies.

2.4.9.2 Regional Topographic Evidence

Due to extensive management of the Missouri River for navigation, flood control, and power generation, the river channel has undergone dramatic physical changes. Historically, with its shifting, braided channel and abundant un-vegetated sandbars, the Missouri riverbed provided a wide variety of hydraulic environments and a large quantity of connected and non-connected off-channel water bodies.

With abundant braided channels, riparian lands, chutes, islands, sandbars, and backwater areas, the pre-development Missouri River was one of North America's most diverse ecosystems. Erosion and deposition created and continuously reshaped the main channel and its floodplain. In the 1940s, two programs, the *Pick/Sloan Plan* (1944) and the *Missouri River Bank Stabilization and Navigation Project* (1945), were started to control navigation and flooding. These programs transformed the free-flowing river into a system of main stem reservoirs in the upper river and highly altered riverine reaches influenced by self-channelization, bank stabilization, and regulated flows in the lower river. Currently, 35% of the Missouri River is impounded, 32% has been channelized, and 33% is unchannelized (USGS, 2007b). Furthermore, reservoir regulation of the Missouri River has significantly changed the annual flow and temperature regime, sediment loads, and nutrient budgets (USGS, 2007a).

In addition to the main channel modifications, the river is influenced by construction of levees along the lower river and major tributaries, channelization of floodplain tributaries, and an extensive reservoir system in the large tributary basins of the Missouri River.

The downstream 735 miles (1,183 km) of the Lower Missouri River is heavily engineered with wing dikes and revetments to form a stable, self-maintaining navigation channel (USGS, 2007a).

The Upper Missouri River contains deep water reservoirs replacing the free-flowing river. In the lower river, channelization has eliminated sandbars, depth diversity, and river connections with off-channel side channels and backwaters. The historical flow pattern has been significantly altered, with high spring flows now stored in reservoirs and low summer and fall flows augmented with reservoir releases controlled by the Army Corps of Engineers (USGS, 2007b).

2.4.9.3 Diversions Caused By Ice

A review of the Pleistocene history of the Missouri River shows that the presence of ice (having considerable thickness) developed during the continental glaciation had a significant effect upon the hydrologic system of the Missouri River (Todd, 1914).

Before glaciation, the landscape of North America was eroded mainly by running water. Well-integrated drainage systems collected runoff and sediment load and transported them to the ocean. Much of North America was drained by rivers flowing northeastward into Canada because the feature of the regional slope throughout the north-central part of the continent was to the northeast. The preglacial drainage patterns are not known in detail. Before glaciations, the major tributaries of the upper Missouri and Ohio Rivers were part of a northeastward-flowing drainage system (Todd, 1914).

As the glaciers spread over the northern part of the continent, they dammed up the northward-flowing tributaries along the ice front. This damming created a series of lakes along the glacial margins. As the lakes overflowed, the water drained along the ice front and established the present courses of the Missouri and Ohio Rivers. This process established the present drainage pattern over much of North America. There is extensive and convincing evidence of these changes in South Dakota (Spooner, 2001). There, the Missouri River flows in a deep, trench-like valley, roughly parallel to the regional contours. All important tributaries enter from the west. East of the Missouri River, pre-glacial valleys are now filled with glacial debris, marking remnants of pre-glacial drainage, illustrating the effect of increased discharge from glacial meltwaters.

With the appearance of the modern Missouri and Ohio Rivers, water that formerly discharged into the Arctic Sea and Atlantic Ocean was redirected to the Gulf of Mexico through the Mississippi River.

Even though the Missouri River is subject to varying amounts of floating ice during the winter months, the Collector Well River Intake System, a non-safety related structure, draws water from the Missouri River alluvial aquifer at approximately 100 ft (30 m) below grade in the general area of the Intake System. Ice or ice flooding will not cause a problem at the plant discharge, as the warm discharge water will keep the outfall open (AmerenUE, 2003). A further discussion on the formation of surface ice and the potential for an ice jam is provided in Section 2.4.7.

2.4.9.4 Site Flooding Due to Channel Diversion

Site flooding as a result of channel diversion does not affect the Callaway Plant Unit 2 site. However, the design basis flood elevation for the Callaway Plant Unit 2 site is determined by considering a number of different flooding possibilities. The possibilities applicable and investigated for the site include the Probable Maximum Flood (PMF) on streams and rivers, potential dam failures, probable maximum surge and seiche flooding, probable maximum tsunami, and ice effect flooding. Each of these flooding scenarios was investigated in conjunction with other flooding and meteorological events, such as wind generated waves, as required in accordance with guidelines presented in ANSI/ANS 2.8-1992 (ANS, 1992). Detailed discussions on each of these flooding events and how they were estimated are found in Section 2.4.2 through Section 2.4.7. Adequate drainage capacity will be provided to prevent flooding of safety-related facilities and to convey flood waters on the roofs and the buildings away from the plant site area.

All safety-related facilities for Callaway Plant Unit 2 are located at about elevation 846 ft (258 m) msl. The highest flood of record on the Missouri River near the site at Chamois was 33.3 ft (10.1 m) on July 31, 1993, (NOAA, 2007) bringing the water level at Chamois to El. 535.8 (163.3 m) (gauge datum is set to 502.5 ft (153.2 m)). The Callaway Site at plant grade elevation 845 ft (258 m) is still about 309.2 ft (94.2 m) higher; therefore, it is anticipated that the Missouri River flooding will not affect the plant. The plant site is dry with respect to major flooding on the Missouri River, and only a localized PMP storm was considered for flood design protection of safety-related facilities.

The PMF analysis indicates that near the Callaway Site, the maximum PMF water surface elevation is 677.3 ft (206.4 m) msl for Logan Creek, 577.57 ft (176.04 m) msl for Mud Creek, and 704.33 ft (214.68 m) msl for Auxvasse Creek. As a result, the plant site is dry with respect to major flooding on the Auxvasse Creek, Logan Creek, and Mud Creek.

The maximum water level due to local intense precipitation or the local probable maximum precipitation (PMP) is estimated and discussed in Section 2.4.2.3. The maximum water level in the Callaway Plant Unit 2 power block area, due to a local PMP, is at El. 844.8 ft (257.5 m). This water level becomes the design basis flood elevation for all safety-related facilities in the power block area. All safety-related building entrances in the power block are located above this elevation. Since the plant facilities are located on the crest of a plateau that has a well-developed natural drainage system and because final grading of the site area is integrated with this natural system, potential local flooding, even from extremely heavy rainfall, will be controlled by the plant site drainage system, as discussed in Section 2.4.2.3.

2.4.9.5 Human-Induced Channel Flooding

Human-induced channel flooding of the Missouri River is not anticipated because the Missouri River is a major tributary for the Mississippi River and flooding is monitored and controlled by the U.S. Army Corps of Engineers. At this moment, there are no reported Federal projects to channel or dam any portion of the Missouri River. The tributaries adjacent to the Callaway Plant Unit 2 site are not anticipated to be channelized or dammed.

2.4.9.6 Alternate Water Sources

An alternate water source is not required for the Callaway Plant Unit 2 design.

Section 9.2.5 of the Design Document Criteria states that following a postulated accident, the emergency safety-related water supply to the Essential Service Water System is initially supplied from basins that are located beneath each of the four UHS cooling towers. Each of the four cooling tower basins holds sufficient volume of water to supply the ESW system for 72 hours. After the initial 72 hours, the Essential Service Water Emergency Makeup System (ESWEMS) retention pond supplies makeup water to the UHS basins for use by the ESW system during the following 27 days of the postulated accident duration.

As discussed in Section 2.4.11, there is no potential of blockage of the safety-related ESWEMS makeup water intake due to channel diversions. Non-safety related water sources, such as water from the non-safety related Collector Well System; and groundwater wells are also available if needed.

2.4.9.7 Other Site-Related Evaluation Criteria

The potential for channel diversion from seismic or severe weather events is not considered to result in a loss of cooling water supply (AmerenUE, 2003). All Category I structures are designed for a seismic event and located on a plateau. A seismic event would result in the bulk of the collapsed material being deposited at the shoreline location of the failure. Normal waves would disperse this material slowly over a wide area. A severe storm could relocate shoreline sands and soils but is again dispersed over a wide area. In addition, the USACE periodically conducts dredging to maintain navigational status of the Missouri River. A severe storm or collapse of nearby shoreline cliffs may result in the need for more frequent maintenance dredging of the Missouri River. Because the Collector Well System draws water from the Missouri River Alluvial Aquifer, collapsed materials and severe storms would not result in loss of cooling water supply.

2.4.9.8 References

AmerenUE, 2003. Final Safety Analysis Report (FSAR) Callaway-SA Section 2.4, Hydrology, Rev.OL-13, June, 2003.

ANS, 1992. American National Standard, ANSI/ANS-2.8-1992, Determining Design Basis Flooding at Power Reactor Sites, American National Standard Institute/American Nuclear Society, July 1992.

Hack, J. T. 1975. Dynamic Equilibrium and Landscape Evolution, Melhorn, W. N. & Flemal, R. C. (eds) op cit. 87 - 102.

NOAA, 2007. Advanced Hydrologic Prediction Service, National Weather Service, Website: http://www.crh.noaa.gov/ahps2/hydrograph.php?wfo=lsx&gage=cmsm7&view=1,1,1,1,1,1,1,1&toggles=10,7,8,2,9,15,6&type=0, Date accessed: September 18, 2007.

USGS, 1998. Final Report Lower Missouri River Ecosystem Initiative 1994-1998. Columbia USGS Environmental Research Center, December, 1998.

USGS, 2007a. River-Corridor Habitat Dynamics Research Lower Missouri River, Website: http://infolink.cr.usgs.gov/RSB/Hab/ , Date accessed: November 15, 2007.

USGS, 2007b. Missouri River Story, Website: http://infolink.cr.usgs.gov/The_River/MORstory.htm , Date accessed: November 15, 2007.

Spooner, J. 2001. The Evolution of the Lower Missouri River: Preliminary Results of NMD Research at Lisbon Bottom, Open File Report 01-368, United States Department of Interior, USGS.

Todd, J.E. 1914. The Pleistocene History of the Missouri River, Science Vol. 39, Issue 999, pp. 263-274.}

2.4.10 FLOODING PROTECTION REQUIREMENTS

The U.S. EPR FSAR includes the following COL Item in Section 2.4.10:

> A COL applicant that references the U.S. EPR design certification will use site-specific information to compare the location and elevations of safety-related facilities, and of structures and components required for protection of safety-related facilities, with the estimated static and dynamic effects of the design basis flood conditions.

This COL item is addressed in the following section:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.}

This section discusses the locations and elevations of safety-related facilities to identify the structures and components exposed to flooding. The safety-related facilities are compared to design basis flood conditions to determine if flood effects need to be considered in plant design or in emergency procedures.

{All safety-related facilities for Callaway Plant Unit 2 are located at minimum elevation 840.5 ft (256.2 m) MSL. The highest flood of record on the Missouri River near the site at Chamois was 33.3 ft (10.1 m) on July 31, 1993, (NOAA, 2007) resulting in a water level at Chamois of El. 535.8 (163.3 m) (gauge datum is set to 502.5 ft (153.2 m)). The Callaway Site is still about 304.7 ft (92.9 m) higher; therefore, Missouri River flooding does not affect the plant. The plant site is dry with respect to major flooding on the Missouri River, and only a localized PMP storm was considered for flood design protection of safety-related facilities.

The PMF analysis indicates that near the Callaway Site, the maximum PMF water surface elevation is 677.3 ft (206.4 m) msl for Logan Creek, 577.57 ft (176.04 m) msl for Mud Creek, and 704.33 ft (214.68 m) msl for Auxvasse Creek. As a result, the plant site is not impacted due to major flooding on the Auxvasse Creek, Logan Creek, and Mud Creek.

Grading in the power block area around the safety-related facilities is such that all grades slope away from the structures at a minimum of 1% towards collection ditches (AmerenUE, 2003).

The safety-related Essential Service Water Emergency Makeup System (ESWEMS) retention pond is located to the west of Callaway Plant Unit 2, as shown on Figure 3E.4-5. Grading around the ESWEMS retention pond is sloped to keep storm surface water from entering the pond. To prevent an overflow caused by malfunction of the makeup system or by rainfall accumulation in the ESWEMS retention pond, an outlet structure and spillway are provided to drain excess storage when the water surface in the pond exceeds the outlet crest elevation of 836.5 ft (255.0 m). For other information related to potential flooding from the ESWEMS retention pond see FSAR Section 2.4.8.

Additionally, the maximum estimated water surface elevations resulting from all design basis flood considerations, as discussed in Section 2.4.2 through Section 2.4.7, are well below the entrance and grade slab elevations for the power block safety-related facilities. Therefore, flood protection measures are not required in the Callaway Plant Unit 2 power block area.

A general arrangement figure of the Callaway Plant Unit 2 ESWEMS area is provided in Figure 3E.4-5**.** Flood protection for the ESWEMS will consist of structural measures to withstand the static and dynamic flooding forces to prevent the flooding of the interior of the structures where pump motors and electrical or other equipment associated with the operation of the pumps are located (AmerenUE, 2003).

The Callaway Plant Unit 2 ESWEMS is designed to accommodate for the static water pressure from the maximum flood elevation, the uplift pressures on the pump deck as well as uplift pressures on the entire intake structure, and the dynamic wave forces on the structure walls. A detailed description of these forces and other design basis loadings, including seismic loadings and the structural measures incorporated to withstand them, is found in Section 3.8.

The Collector Well River Intake System at Missouri River Mile 115.4 (185.7 km) is not a safety-related facility. However, the collector well intakes are located approximately 100 ft (30 m) below grade. The above ground components and structures of the collector well system will be designed to take into account the 200-yr flood elevation of 539 ft (164 m) MSL.

In summary, the safety related facilities are designed to withstand the combination of flooding conditions and wave-run up, including both static and dynamic flooding forces, associated with the flooding events discussed in Sections 2.4.2 through 2.4.8.

2.4.10.1 References

AmerenUE, 2003. Final Safety Analysis Report (FSAR) Callaway-SA Section 2.4 Rev.OL-13, June, 2003.

NOAA, 2007. Advanced Hydrologic Prediction Service, National Weather Service, Website: http://www.crh.noaa.gov/ahps2/hydrograph.php?wfo=lsx&gage=cmsm7&view=1,1,1,1,1,1,1,1 &toggles=10,7,8,2,9,15,6&type=0, Date accessed: September 18, 2007}

2.4.11 LOW WATER CONSIDERATIONS

The U.S EPR FSAR includes the following COL Item in Section 2.4.11:

> A COL Applicant that references the U.S. EPR design certification will identify natural events that may reduce or limit the available cooling water supply, and will verify that an adequate water supply exists for operation or shutdown of the plant in normal operation, anticipated operational occurrences, and in low water conditions.

The COL Item is addressed as follows:

This section investigates natural events that may reduce or limit the available cooling water supply to ensure that an adequate water supply exists to shut down the plant under conditions requiring safety-related cooling. Specifically, any issues due to a low water level in the {Missouri River are investigated in this section.

Callaway Plant Unit 2 is approximately 10 miles (16 km) southeast of Fulton, Missouri, in Callaway County, and 80 miles (129 km) west of the St. Louis metropolitan area. The Missouri River lies 5 miles (8 km) south of the site within a flood plain about 2.4 miles (3.9 km) wide.}

References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.

Sections 2.4.11.1 through 2.4.11.7 are added as a supplement to the U.S. EPR FSAR.}

2.4.11.1 Low Flow in Rivers and Streams

{Callaway Plant Unit 2 is located on a plateau within the Auxvasse Creek watershed (Figure 2.4-36). This plateau is the topographic high in the area, surface runoff drains into small intermediate streams. These small streams are tributaries of local streams that include Logan Creek to the East, Mud Creek to the South-West, Cow Creek to the North, and Auxvasse Creek, to the west. Mud Creek and Cow Creek are tributaries to Logan Creek and Auxvasse Creek respectively.

Callaway Plant Unit 2 utilizes the Missouri River to supply water for safety-related and non-safety-related purposes. Callaway Plant Unit 2 does not draw water from any streams or creeks located in the vicinity of the site; thus, low water conditions resulting from the low flow in these water bodies does not apply.

The Missouri River encompasses one of the largest drainage basins in the country, about 529,300 mi^2 (1,370,295 km^2). Moreover, there are no dams downstream of the site for consideration. A description of the site and facilities is provided in Section 2.4.1.

Drought conditions in the area will affect the amount of water flowing in the Missouri River and its tributaries. As discussed in Section 2.4.11.3, historical low water levels in the Missouri River have been caused by combinations of low flows resulting from drought and/or ice blockage (AmerenUE, 2003).

The blowdown discharge pipe extends approximately 80 ft (24 m) into the Missouri River where the bottom depth is 493.5 ft (150.4 m). Therefore, extreme low water level conditions observed at Chamois station (NOAA, 2007) of -5.7 ft (-1.7 m) recorded on December 22,1963, at approximately Missouri River Mile 115, brings the water elevation to 496.8 ft (151.4 m) (Chamois gage datum is set to El. 502.5 ft (153.2 m)). The elevation of 496.8 ft (151.4 m) will not uncover the discharge pipe or affect the non-safety-related or safety-related makeup water supplies.

2.4.11.2 Low Water Resulting from Surges, Seiches, Tsunamis, or Ice Effects

The Callaway Plant Unit 2 site is located on a plateau above the Missouri River floodplain. The Missouri River water levels are controlled by the United States Army Corps of Engineers.**}** Drawdown effects from storm surge and tsunami are described in detail in Sections 2.4.5 and 2.4.6. Since the effect from seiches and tsunamis on the site are negligible, as described in Section 2.4.5 and Section 2.4.6, respectively, these effects are not taken into account for the low water consideration. Section 2.4.7 includes a description of cases of ice formation or ice-jams that may result in low water level. However, as concluded in Section 2.4.7, the possibility of ice jam formation on the Missouri River will not adversely affect the ability of the safety related Essential Service Water Emergency Makeup System (ESWEMS) pond to function properly.

Impacts of backwater influence and low flow past the Callaway Site due to dam failure is not applicable, because there are no dams in the Missouri River located downstream from the Callaway Site (Figure 2.4-32).

2.4.11.2.1 Storm Surge Effect

The site of Callaway Plant Unit 2 is approximately 10 miles (16 km) southeast of Fulton, Missouri, in Callaway County, and 80 miles (129 km) west of the St. Louis metropolitan area. The Missouri River lies 5 miles (8 km) south of the Callaway Site within a floodplain about 2.4 miles (3.9 km) wide.

The Callaway Plant Unit 2 site is approximately located at Missouri River Mile 115 on a plateau at plant grade elevation El. 845 ft (258 m) msl. At the site, the Missouri River 100-year floodplain is at about El. 533.4 ft (162.6 m) MSL (NOAA, 2007). Thus, the Callaway Plant Unit 2 site is approximately 311.6 ft (95.0 m) above the Missouri River 100-year floodplain.

The Callaway Site is approximately 860 miles (1,384 km) inland from the nearest coast, which is the Gulf of Mexico. Thus, the Callaway Plant Unit 2 site is not in a coastal plain.

Because of the location of the Callaway Site relative to the nearest coast and the elevation of the Callaway Site relative to the Missouri River, storm surge and seiche flooding considerations are not applicable for this site.

Furthermore, because Callaway Plant Unit 2 is not located on an open or large body of water (such as lakes or reservoirs), surge and seiche flooding are not a threat. Safety related structures are located on the site plateau and a review of recorded storm surge and seiche water levels are not a factor which could cause flooding. Refer to Section 2.4.5 for more information.

2.4.11.2.2 Tsunami Effect

Tsunami sources in the U.S. were investigated in Section 2.4.6 to determine the impacts of a tsunami flooding at Callaway Plant Unit 2.

The Callaway Site is approximately 860 miles (1,384 km) inland from the nearest coast, the Gulf of Mexico. The potential of tsunami events that could affect the Callaway Plant Unit 2 site caused by local or distant seismic activities is negligible. The Callaway Site is too far inland from the coastal line (Pacific and Atlantic Oceans and the Gulf of Mexico) to suffer from any tsunami flooding. In addition, the Callaway Plant Unit 2 site is approximately 311.6 ft (95.0 m) above the Missouri River 100-year floodplain. Details of the tsunami effects are given in Section 2.4.6.

2.4.11.3 Historical Low Water

The low water level based on the historical data is determined using the statistical method. Regulatory Guide 1.206 (U.S.NRC, 2007) does not mention the specific return period for the extreme low water level, but mentions the use of the 100-year drought as a design basis. The 100-year low water level is the appropriate design level for the non-safety-related makeup water intake for the Circulating Water System (CWS).

Table 2.4-37 lists the data range for USGS gauging stations at Hermann and Boonville, located downstream and upstream of the Callaway Plant Unit 2 site in the Missouri River (USGS, 2007a and 2007b). Historic low water stages on the Missouri River have been caused by combinations of low flows resulting from drought and/or ice blockage (AmerenUE, 2003). The lowest annual water levels in the Missouri River and their corresponding stages on the Missouri River at Hermann and Boonville are listed in Table 2.4-38 and Table 2.4-39.

The lowest observed annual water level in the Missouri River at Hermann was 0.05 ft (0.02 m) on November 16, 2006. The lowest annual water level observed at Boonville was 1.77 ft (0.54 m) on

January 22, 2007. Figure 2.4-37 and Figure 2.4-38 illustrate the low flow stage discharge curve for Boonville and Hermann, respectively.

The lowest observed discharge in the Missouri River at Hermann was 4,200 cfs (119 m^3/s) and 1,800 cfs (51 m^3/s) at Boonville on January 10, 1940. These flows may be considered as the probable minimum flow in the Missouri River at this station for the period of record prior to regulated flow conditions.

The raw data mentioned above were analyzed using three different frequency analysis methods: Weilbull, Gumbel and Log Pearson Type III distributions. These three probability distributions were considered before selecting the probability distribution that best fits the data. The equations for each probably density distribution can be found in the Flood Frequency Analysis (Linsley, Ray K., et.al., 1992, USGS, 2008).

Goodness-of-fit of the distributions was evaluated to achieve a 95% confidence interval. From the analysis, none of the distributions fit the data very accurately for return periods higher than 10-years. Therefore, the 100-year low water level was conservatively determined by the regression curve of the plotted data and is found to be 0.38 ft (0.12 m) above station datum for Boonville (Figure 2.4-39) and 0.002 ft (0.001 m) above station datum for Hermann (Figure 2.4-40).

As a conservative approach, the 100-year low water level at the Callaway Plant Unit 2 site is selected based on the Hermann station, which is lower than Boonville (Figure 2.4-39). Therefore, the 100-year estimated low water of 0.002 ft (0.001 m) and the collector wells placed at approximately 100 ft (30 m) below grade, the low water will not impact the collector well system.

FSAR Section 2.4.12.3.3.2, discusses the impacts of the 100-year drought and its impacts on the Collector Wells River Intake System. FSAR Section 9.2 states that the Collector Wells River Intake pump design will be driven by system head requirements over the anticipated range of groundwater levels including low river elevation of approximately 489 ft (149 m) MSL based on a 30-year historical record, and high river elevation of approximately 539 ft (164 m) MSL based on the 200-year flood event probability.

2.4.11.4 Future Controls

The Missouri River is the largest sub basin in the Mississippi River Basin, covering more than 500,000 sq mi (1,300,000 sq km) and part or all of 10 states and numerous Indian tribal reservations (USEPA, 2007).

The Missouri River channel and its tributaries are regulated within the jurisdiction of State and Federal agencies. The United States Army Corps of Engineers (USACE) has general management authority over the river and its dams.

Damming and channelization has occurred on most of the Missouri River basin. Since the 1930s, the Army Corps of Engineers has built six dams in the upper basin of the Missouri River. The closest dam is located about 734 miles (1,181 km) upstream of the Callaway Plant Unit 2 site (USGS, 1998). The goal of these dams was to regulate water levels of the Missouri River flow and to generate electrical power.

It is this series of reservoirs which is used to control floods and to increase the navigability of the Missouri River in times of low flow or drought. Periods of low river flow are controlled only during a 9-month navigation season, which extends from March through November. The criteria for control of the river during the navigation season are that the USACE tries to maintain a flow of 40,000 cfs (1,133 m^3/s) at Kansas City and does not permit the flow to fall below 35,000 cfs (991m^3/s). Should the river flow ever fall below this level, most commercial navigation would be suspended (AmerenUE, 2003).

Because USACE has operational control of the Missouri River, policies affecting future flow control are dictated primarily by environmental, recreation, commercial and economic factors. These needs are assessed and administered through the various state and federal agencies and their related coordinating and advisory committees. Currently, there are no future controls on the Missouri River that could affect the availability of water and the water levels in the Missouri River.

2.4.11.5 Plant Requirements

2.4.11.5.1 Minimum Safety-Related Cooling Water Flow

In terms of plant requirements, the Essential Service Water System (ESWS) provides flow for normal operating conditions, for shutdown/cooldown, and for Design Basis Accident (DBA) conditions. The ESWS pump in each train obtains water from the ESWS cooling tower basin of that train and circulates the water through the ESWS. Heated cooling water returns to the ESWS cooling tower to dissipate its heat load to the environment. Makeup water is required to compensate for ESWS cooling tower water inventory losses due to evaporation, drift, and blowdown associated with cooling tower operation. Makeup water to the ESWS cooling tower basins under normal operating and shutdown/cooldown conditions is provided by the site Water Treatment Plant. Water is stored in the ESWS cooling tower basin, which provides at least 72 hours of makeup water for the ESWS cooling tower following a DBA. After 72 hours have elapsed under DBA conditions, emergency makeup water to the tower basins is provided by the safety-related ESWEMS retention pond.

During normal operation, the ESWS pumps take suction from the ESWS basins and supply cool water to remove heat from designated plant loads. Each ESWS train has a nominal flow rate of 19,200 gpm (72,672 lpm). Under normal operating and normal shutdown/cooldown conditions, the ESWS cooling tower storage basins will be supplied with non-safety-related makeup water pumped from the natural draft cooling tower basins at a rate of 1,882 gpm (7,123 lpm) (assuming 2 trains in operation). This makeup rate of 1,882 gpm (7,123 lpm) accommodates evaporation (940 gpm (3,558 lpm)), drift (2 gpm (81 lpm)), and blowdown (940 gpm (3,558 lpm)). During normal plant shutdown/cooldown operation, 4 trains may be in operation with a total of 3,764 gpm (14,247 lpm). Makeup to the ESWS basins will be pumped from the supply to the natural draft cooling tower basin during normal operation.

Following a postulated accident, the ESWS basins contain sufficient water to accommodate 3 days of operation without makeup. A total of 40,000 pound mass of basin seepage loss is assumed for the first 3 days of the accident. The 144,330 ft^3 (4,087 m^3) of water remaining in the basin after 72 hours is sufficient to satisfy minimum requirements. Two trains of ESWS are assumed to be in operation to respond to an accident. After 3 days of post-accident operation, makeup flow is required to be supplied to the two operating ESWS basins. The required makeup flow rate will reduce over time as heat loads get lower. The required makeup rate to each ESWS basin will be 300 gpm (1,136 lpm) considering design conditions. Makeup will be supplied from the ESWEMS retention pond to the ESWS basins for 27 days, which combined with the initial 3 day inventory will fulfill the 30-day post-accident ESWS requirement. Post-accident makeup to the ESWS cooling tower basins is pumped from the ESWEMS retention pond using pumps located in the ESWEMS pump house.

2.4.11.5.2 Minimum Normal Operating Water Flow

2.4.11.5.2.1 Plant Requirements

The Callaway Plant Unit 2 plant water consumption will be about 23,561 gpm (89,178 lpm) when the unit is operating at base load. This water will be drawn from the Missouri River through the Collector Well System located about 5.5 miles (8.8 km) southeast of the plant. The water will then be pumped to a water treatment plant located at the plant site and then to the plant facilities as required.

2.4.11.5.2.2 Missouri River Flow

Table 2.4-40 shows the low flow statistics for Hermann and Boonville USGS gauging stations.

Based on the interpolation between the gauging stations and the Callaway Plant Unit 1 water supply intake located at Missouri River Mile 115 (185 km), the 1-day, 30-year average low flow (Q1,30) was estimated as 5,917 cfs (168 m^3/s).

Based on comparison of the low flow conditions discussed previously, and because of the degree of regulated flow conditions on the lower Missouri River, the Collector Well River Intake System is expected to have continuously supply of water from the Missouri River alluvial aquifer. Detailed information regarding the Missouri River alluvial aquifer storage capacity is available in FSAR Section 2.4.12.

The supply is anticipated to be adequate for the life of the project. Extreme high- or low-flow levels in the Missouri River will not affect plant operation.

2.4.11.5.2.3 Water Supply Intake and Pumphouse Structure (Collector Well System)

The Collector Well System is located near Missouri River mile 115. The pumps will supply an average flow of 24,160 gpm (54 cfs) to the water treatment plant at a design head of 430 ft (131 m). The water treatment plant is located on the plant site at about El. 850 ft (259 m) msl.

2.4.11.5.2.4 Water Treatment Plant Clearwell Pumps Station

Clarified water from the water treatment plant will flow into the clearwell. The clearwell will provide water to the CWS natural drafting cooling tower basins, the ESW cooling tower basins, the ESWEMS retention pond, and for other plant uses. Since the water treatment plant is the "midpoint" of the water-use system, water level indication is provided to the main control room operators to allow determination of the extent that the water supply system is not maintaining flow for plant requirements (AmerenUE, 2003).

2.4.11.5.2.5 Circulating Water System (CWS)

The U.S. EPR uses a Circulating Water System (CWS) to dissipate heat. A closed-cycle, wet cooling system is used for Callaway Plant Unit 2 similar to the existing Callaway Plant Unit 1 cooling system. The average makeup rate to the CWS is 22,283 gpm (84,341 lpm) (see ER Section 3.3 for the water diagram usage rate).

Water for the CWS will be taken from the Collector Wells by pumps at a maximum rate of approximately 34,305 gpm (129,844 lpm). This is based on maintaining the CWS and supplying the Essential Service Water System (ESWS) Cooling Towers with a maximum of 3,764 gpm (14,247 lpm). Cooling water for the turbine condenser and closed cooling heat exchanger for normal plant operating conditions is provided by the Circulating Water System (CWS), which is a non-safety-related interface system. Makeup water to the CWS cooling tower is required due to evaporation and blowdown. The CWS discharges the heated water from the condenser to the CWS cooling tower. For the closed-loop CWS cooling tower, approximately three-fourths of the makeup water will be lost to the atmosphere as evaporation and to cooling tower drift. The other one-fourth will be released as blowdown. The average consumptive use of the collector well water during normal operating conditions will be approximately 1.06 E+09 gpm (4.01 E+09lpm). Consumptive rates should not fluctuate during droughts as might occur if the source for water were a river or variable lake. Consumptive rates will vary with temperature and humidity. During normal operating conditions, the maximum flow of water required by the CWS will be 30,511 gpm (115,484 lpm).

2.4.11.5.3 Plant Water Effluent

The plant water effluent will consist mainly of the blowdown from the cooling towers. The effluent will enter the Missouri River from a submerged pipe, terminating at the left bank, located about 400 ft (122 m) downstream of the water supply intake. Discharge velocity will be sufficient to mix the effluent with the river water for a 7-day, 10-year low flow condition (11,237 cfs; 318 m^3/s), in order to minimize thermal effects. These anticipated discharge conditions meet the existing Missouri Water Quality standards.

2.4.11.6 Heat Sink Dependability Requirements

The normal source of water for the Essential Service Water System (ESWS) is from the Collector Wells via the Water Treatment Plant Clearwell. The ESWEMS retention pond will be the emergency source of water for the ESWS. The plant water requirements are supplied from the Missouri River Alluvial Aquifer. The low flow conditions in this river do not influence the dependability of the ESWEMS retention pond, as the minimum required initial level the pond is designed to provide required ESWS makeup during the 30 day post-DBA period..

The ESWEMS retention pond is excavated below the surrounding plant grade and thus cannot lose water due to dam failure. Flooding of the pond and related structures is precluded since the pond is about 133.5 ft (40.7 m) above the Auxvasse Creek and site grading is designed to direct runoff, including that from probable maximum precipitation, away from the pond.

Design basis heat loads for various plant modes are provided in Section 9.2.5. Makeup water flow rate requirements for the UHS trains are based not only on providing sufficient inventory in the cooling tower basins for safe operation of the ESWS pumps but also on maintaining basin water chemistry, and takes into consideration maximum ESWS cooling tower evaporation, drift, and seepage losses. The Regulatory Guide 1.27 (NRC, 1976) criteria to provide water inventory for UHS operation during the 30 day post accident period have been incorporated into the Callaway Plant Unit 2 UHS design: Each ESWS cooling tower basin will have sufficient inventory to permit operation of the associated ESWS train for 72 hours following an accident without the need for additional makeup water. At the end of 72 hours, a safety-related train of makeup water will be put in operation to feed the basin (each train of UHS has a dedicated safety-related makeup water train as a backup to the normal non-safety source).

There are no other uses of water drawn from the ESWEMS, such as fire water or system charging requirements. There are no other interdependent safety-related water supply systems to the UHS, such as reservoirs or cooling lakes. There is no potential of blockage of the safety-related UHS makeup water intake due to ice or channel diversions as discussed in Sections 2.4.7 and 2.4.8.

2.4.11.7 References

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2.4.12 GROUND WATER

The U.S. EPR FSAR includes the following COL Item in Section 2.4.12:

> A COL applicant that references the U.S. EPR design certification will provide site-specific information to identify local and regional ground water reservoirs, subsurface pathways, onsite use, monitoring or safeguard measures, and to establish the effects of ground water on plant structures.

This COL Item is addressed as follows:

{This section provides a description of the regional and local hydrogeology relevant to the Callaway Site. This section describes the regional and local groundwater aquifer resources (including on-site use) that potentially could be affected by the construction and operation of Callaway Plant Unit 2. Temporal trends as well as seasonal variations in these aquifer characteristics, including droughts, are presented. The site-specific data from the hydrogeological field investigation are presented and utilized to evaluate the existing groundwater conditions and to identify pathways of groundwater flow toward downgradient surface water bodies and surface water and groundwater users. Groundwater flow velocities and travel times are estimated for the existing conditions. Planned groundwater monitoring and safeguards are discussed. Finally, potential construction and post-construction operational changes to groundwater conditions are evaluated.

Sections 2.4.12.1 through 2.4.12.6 are added as a supplement to the U. S. EPR FSAR.

2.4.12.1 Description and Use

2.4.12.1.1 Hydrogeologic Setting

Except as otherwise noted, the information presented in this section is summarized from the United States Geological Survey (USGS) Ground Water Atlas of the United States, Segment 3 (USGS, 1997), which contains Kansas, Missouri, and Nebraska. Across the three-state area, there are four physiographic provinces: the Great Plains, the Central Lowland, the Ozark Plateaus, and the Coastal Plain as shown on Figure 2.4-41. In general, the land surface across the three-state area slopes gradually from west to east. In the Great Plains Physiographic Province, the altitude of the relatively flat land surface is about 5,000 ft (1524 m) above mean sea level (msl) in westernmost Nebraska. By contrast, in the flat Coastal Plain Physiographic Province of eastern Missouri, the altitude is about 500 ft (152 m) msl. The land surface is gently rolling in the Central Lowland Province except where major rivers and their tributaries are deeply incised. In the Ozark Plateaus Physiographic Province, rugged topography has developed where the underlying rocks have been uplifted and deeply eroded.

According to Figure 2.4-41, Callaway is located in the Ozark Plateaus Physiographic Province; however, this is due to its sharing of deeper bedrock units with areas in southern Missouri. In the shallower geologic sections, Callaway is associated with the glaciated areas of northern Missouri, which extend approximately to the Missouri River as shown on Figure 2.4-42. Glacial and subsequent alluvial erosion and deposition have left both coarse-grained and fine-grained surficial deposits across northern Missouri, which is categorized by the Missouri Department of Natural Resources (MDNR) as the Dissected Till Plains sub-province of the Central Lowland Province (MDNR, 1997).

The regional extent of glaciation determined the present-day drainage patterns across the three-state region. The major rivers that drain the three states are the Niobrara, Platte, Kansas, Arkansas, and Missouri. The Mississippi River flows along the eastern boundary of the area. These rivers supply water for many uses, but groundwater is the source of slightly more than one-half of the total water withdrawn for all uses within the three-state area (USGS, 1997). The aquifers consist of consolidated sedimentary rocks and unconsolidated deposits that range in age from the Cambrian through Quaternary periods.

Figure 2.4-43 shows the vertical sequence of aquifer systems across the three-state region. The surficial aquifer system consists of stream valley aquifers along major drainages as well as glacial drift aquifers in northern Missouri, eastern Nebraska, and northeastern Kansas. These aquifers are composed primarily of unconsolidated sand and gravel.

The High Plains aquifer consists of the Ogallala Formation in Nebraska and western Kansas and Quarternary beds in south-central Kansas. The aquifer underlies and is hydraulically connected to parts of the surficial aquifer system in Kansas and Nebraska. Beneath the High Plains aquifer is the Great Plains aquifer system.

The Mississippi embayment aquifer system directly underlies the surficial aquifer system in southeastern Missouri.

In southern Missouri, the Ozark Plateaus aquifer system is a large fresh-water system. Equivalent rocks of the Western Interior Plains aquifer system, however, contain little to no fresh-water due to high mineralization of slowly moving groundwater. The Mississippian aquifer of northern Missouri is equivalent to rocks in the upper part of the Ozark Plateaus aquifer system; however, it has little or no hydraulic connection to the Ozark system. Beneath the Mississippian aquifer in northern Missouri, the Cambrian-Ordovician aquifer is equivalent to rocks in the middle part of the Ozark Plateaus aquifer system, and these systems may be, at least in part, hydraulically connected.

Figure 2.4-44 shows a generalized aquifer section trending west (northwest) to east (southeast) across Missouri. The Ozark Plateaus aquifer system in southern Missouri (primary aquifer is the Ozark aquifer) transitions to equivalent sections in the Western Interior Plains aquifer system in Western Missouri, Kansas, and Nebraska and to equivalent sections in the Mississippian and Cambrian-Ordovician aquifers of northern Missouri. Figure 2.4-45 shows these relationships conceptually by geologic age. A key difference between the sections in northern and southern Missouri is the relatively thick confining unit and thinner Cambrian-Ordovician aquifer in northern Missouri in contrast to the relatively thin confining unit and thick Ozark aquifer in southern Missouri. Beneath these aquifers is the pre-Cambrian crystalline bedrock that serves as a basement confining unit.

2.4.12.1.2 Regional Hydrogeologic Description

Important aquifer systems of interest to the Missouri region are the surficial aquifer system, the Ozark Plateau aquifer system in southern Missouri, and the Mississippian and Cambrian-Ordovician aquifers in northern Missouri. Beneath the surficial aquifer system, the usability of the bedrock aquifers is defined by the freshwater-saline water transition zone as shown on Figure 2.4-46. North of this demarcation, groundwater is too highly mineralized for potable use.

2.4.12.1.2.1 Surficial Aquifer System (Missouri)

The surficial aquifer system consists of stream-valley aquifers and glacial-drift aquifers. These aquifers are hydraulically connected in some places. For example, many of the glacial-drift aquifers in northern Missouri, northeastern Kansas, and eastern Nebraska occupy ancient stream channels that have been eroded into bedrock. At locations where modern streams follow the ancient drainage patterns, the alluvial deposits of sand and gravel may lie directly on glacial outwash that also consists of sand and gravel; therefore, they may be difficult to distinguish. Most of the water in the surficial aquifer system is under unconfined conditions.

Stream-Valley Aquifers

The stream-valley aquifers consist of narrow bands of fluvial and alluvial sediments, which fill or partly fill the valleys of meandering to braided streams that have eroded shallow channels into glacial deposits, older unconsolidated alluvium, or bedrock. Locally, the stream-valley aquifers may be hydraulically connected to bedrock aquifers, but, in most places, they are separated from the bedrock aquifers by low permeability beds of clay or shale.

The stream-valley aquifers consist mostly of sand and gravel of Holocene age but locally include sediments of Pleistocene age. The average thickness of the aquifers is about 90 ft to 100 ft (27 m to 31 m), but locally they are as much as 160 ft (49 m) thick. The average thickness of saturated alluvial material generally ranges from 50 ft to 80 ft (15 m to 24 m).

Most of the water in the stream-valley aquifers is under unconfined conditions. Locally, where coarse-grained aquifer sediments are capped by poorly permeable silt or clay, confined (artesian) conditions exist. The stream-valley aquifers are in direct hydraulic connection with adjacent streams, and water levels in the aquifers are closely related to river levels. Aquifer and river water levels rise following precipitation events.

Recharge to a typical stream-valley aquifer is by precipitation that falls directly onto the aquifer, seepage through the beds of streams and of reservoirs and canals constructed in the stream valleys, downward percolation of applied irrigation water, and groundwater inflow from underlying, permeable bedrock. The aquifer discharges by leakage to streams and canals, pumping from wells, and evapotranspiration. A small amount of water is consumed by crops and vegetation.

The stream-valley aquifers are reliable sources of groundwater because of the coarse-grained nature and high permeability of the aquifer material. Yields that range from 100 gpm to 1,000 gpm (380 lpm to 3,800 lpm) commonly are reported for wells completed in these aquifers; maximum yields of more than 2,500 gpm (9,500 lpm) are reported locally in Missouri. Reported transmissivity values for these aquifers, as calculated from aquifer tests, range from 8,000 sq ft per day to 80,000 sq ft per day (740 sq m per day to 7,400 sq m per day).

The chemical quality of the water in the stream-valley aquifers generally is suitable for most uses. Typically, the water is hard and a calcium bicarbonate type. Dissolved-solids concentrations generally are less than 500 parts per million (ppm) but locally are as much as 7,000 ppm; the larger concentrations reflect an influx of water with large chloride or sulfate concentrations from underlying aquifers (north of the freshwater-saline transition zone) or from irrigation return flow. Large iron concentrations are common.

The unconsolidated sand and gravel deposits that compose the stream-valley aquifers are thicker, more widespread, and more productive in the valleys of the larger rivers than those of smaller streams. In Missouri, the stream-valley aquifers along the Missouri and the Mississippi Rivers and their tributaries are important sources of freshwater for many communities and industries.

Missouri River Valley Alluvial Aquifer

Alluvial deposits along the Missouri River form an important stream-valley aquifer from the Iowa-Missouri State line to the junction of the Missouri and the Mississippi Rivers. The deposits partly fill an entrenched bedrock valley that ranges from about 2 miles to 10 miles (3 km to 16 km) wide. In many places in northern Missouri, the bedrock contains slightly saline to saline water, and the stream-valley aquifers, along with aquifers in glacial drift, are the only sources of fresh groundwater.

The Missouri River stream-valley aquifer along the Missouri River between Jefferson City and St. Charles, Missouri, is shown on Figure 2.4-47. This portion of the stream-valley aquifer consists of clay, silt, sand, and gravel. Gravel and sand generally are most common in the lower parts of the aquifer. Poorly permeable silt and clay are prominent in the upper part of the aquifer and locally create confined conditions. From the Boone County line eastward, the bedrock consists of Ordovician limestone and dolomite. In upland areas north of the Missouri River, glacial deposits overlie the bedrock.

The alluvial material of the Missouri River stream-valley aquifer averages about 90 ft (27 m) in thickness but is locally as much as 160 ft (49 m) thick. The saturated thickness of the aquifer averages about 80 ft (24 m). Reported yields of wells completed in the aquifer range from less than 100 gpm to about 3,000 gpm (380 lpm to 11,400 lpm).

Recharge to the stream-valley aquifer is by infiltration of precipitation, seepage of water from the Missouri River to the aquifer during periods of high streamflow, and inflow from bedrock aquifers. Discharge from the aquifer is by evapotranspiration, withdrawals by wells, and seepage to the Missouri River during periods of low streamflow. The general direction of water movement in the stream-valley aquifer is downstream and toward the river as shown on Figure 2.4-47.

During 1990, an average of about 147 million gallons of water per day (MGD) (559 million liters per day (MLD)) was withdrawn from the Missouri River stream-valley aquifer. About 45% of this amount, or about 66 MGD (251 MLD), was used for public supply. Industrial, mining, and thermoelectric power withdrawals amounted to about 48 MGD (181 MLD), and agricultural withdrawals were about 24 MGD (91 MLD). The remainder of the water withdrawn (about 9 MGD (34 MLD)) was used for domestic and commercial purposes.

Glacial Drift Aquifers

The maximum southern extent of glacial ice and glacial-drift deposition was approximately the present location of the Missouri River in Missouri. Although deposits of glacial drift extend over wide areas, most were laid down directly by the ice; are fine grained, poorly sorted, or both; and, therefore, yield only small amounts of water to wells. Melt-water created an extensive stream network in front of the advancing ice, and the streams deposited gravel, sand, and finer sediments as alluvium along the courses of pre-glacial bedrock valleys.

Complex inter-bedding of fine- and coarse-grained material is characteristic of the glacial deposits. The lens-like shape of some of the beds is the result of meandering of the melt-water streams across their valley floors and of periodic changes in stream-channel locations. However, in parts of Missouri, the glacial-drift aquifers are not complexly inter-bedded. For example, in Daviess County, Missouri, the basal part of the deposits that fill glacial stream channels is coarse grained, and the upper part generally consists of poorly permeable silt, clay, or till. Such aquifers are called buried channel or buried valley aquifers and contain water under confined or semi-confined conditions. The thickness of glacial deposits ranges from 0 ft to 50 ft (0 m to 15 m) near the Missouri River where erosion has removed the original deposits to as much as 400 ft (122 m) in northernmost areas of Missouri.

Groundwater flow directions reflect topography. Movement of water in the glacial-drift aquifers is from recharge areas to discharge areas along the streams. Some groundwater follows longer flow paths and discharges to larger streams. A small amount of the water percolates downward and enters underlying bedrock aquifers.

Yields of wells completed in the glacial-drift aquifers are highly variable and range from less than 10 gpm to about 1,000 gpm (38 lpm to 3,800 lpm). Groundwater generally is obtained from sand beds that range from 20 ft to 40 ft (6 m to 12 m) in thickness. Large diameter wells that penetrate several thick, saturated, highly permeable sand beds yield the most water. Highly variable transmissivity values that range from 200 sq ft per day to 13,000 sq ft per day

(19 sq m per day to 1,200 sq m per day) have been reported from aquifer tests in glacial-drift aquifers in Kansas.

The chemical quality of the water in the glacial-drift aquifers generally is suitable for most uses. The water is hard and commonly is a calcium bicarbonate type although in many places in Missouri, and locally in Kansas, it is a sodium sulfate type. Dissolved-solids concentrations in water from these aquifers usually are less than 500 ppm but exceed 4,000 ppm in places (north of freshwater-saline transition zone). Locally, concentrations of as much as 30 ppm of iron have been reported in Missouri.

2.4.12.1.2.2 Ozark Plateaus Aquifer System (Southern Missouri)

The Ozark Plateaus aquifer system underlies most of southern Missouri and a small part of extreme southeastern Kansas, a large area in northwestern Arkansas, and a small part of northeastern Oklahoma. The water-yielding rocks in the Ozark Plateaus system are mostly comprised of limestone and dolomite, but some sandstone units are productive. Confining units within the aquifer system are typically shale or dolomite. The lithology of the individual aquifers and confining units and their hydraulic characteristics are consistent over large areas.

Groundwater in the aquifer system locally moves from topographically high recharge areas toward streams. Regional movement is northwestward, eastward, and southward from the St. Francois Mountains and other topographically high areas in southern Missouri. The water moves upward at the transition zone between the Ozark Plateaus and the Western Interior Plains aquifer systems and discharges either to streams as base flow or to shallow stream valley alluvial aquifers. Water that moves northward in the lower part of the Ozark aquifer discharges mostly to the Missouri River.

The aquifers in the Ozark Plateaus aquifer system from shallowest to deepest are the Springfield Plateau aquifer, the Ozark aquifer, and the St. Francois aquifer. Confining units in the system are named the same as the aquifers they overlie.

Springfield Plateau Aquifer

The Springfield Plateau aquifer is the uppermost aquifer of the Ozark Plateaus aquifer system and consists almost entirely of limestone of Mississippian-age. The thickest and most productive water-yielding geologic formations are the Keokuk and Burlington Limestone Formations. North of the Missouri River, the Keokuk and Burlington also yield water but are considered to be a separate aquifer, the Mississippian aquifer. The thickness of the Springfield Plateau aquifer ranges from less than 200 ft to more than 400 ft (less than 60 m to more than 120 m) and averages about 200 ft (60 m). Locally, the aquifer may be discontinuous or absent.

Most of the water in the Springfield Plateau aquifer occurs in and moves through secondary openings, such as fractures and bedding planes. The slightly acidic ground water that moves through these openings has dissolved part of the limestone and has resulted in a network of solution channels. This dissolution activity is reflected at the land surface by springs, caves, and sinkholes, and by sparse surface drainage. These features are characteristic of a type of topography called karst topography, which commonly is developed in areas underlain by limestone.

Recharge to the Springfield Plateau aquifer is mostly from precipitation onto outcrop areas of the aquifer. After the recharge water percolates downward to the water table, most of it moves laterally along short flow paths to discharge as base flow to nearby streams. Some of the water follows flow paths of intermediate length and discharges to large streams, and a small part of the recharge moves laterally into deep, confined parts of the aquifer.

The chemical quality of water in the Springfield Plateau aquifer generally is suitable for most uses where the aquifer is unconfined or where the confining unit that overlies the aquifer is thin. The water commonly is a calcium bicarbonate type and is moderately hard. Dissolved-solids concentrations generally are less than 1,000 ppm but are higher where the aquifer is confined. Concentrations of sulfate generally are low except in the lead-zinc mining district of southwestern Missouri, southwestern Kansas, and northeastern Oklahoma where concentrations of more than 500 ppm are reported near some mining areas. These large concentrations result from oxidation and leaching of the sulfide minerals that contain the lead and zinc.

Most of the water withdrawn from the Springfield Plateau aquifer is used for domestic and stock-watering supplies. Yields of wells completed in the aquifer generally are less than 20 gpm (76 lpm).

Ozark Confining Unit

The Ozark confining unit underlies the Springfield Plateau aquifer and hydraulically separates this aquifer from the deeper Ozark aquifer. The Ozark confining unit consists mostly of shale but locally includes limestone of minimal permeability. The confining unit generally is less than 100 ft (30 m) thick except in small areas. Where the shale content of the confining unit is greater, the confining unit can more effectively retard the vertical movement of water between the Springfield Plateau and the Ozark aquifers. North of the Missouri River, rocks equivalent to the Ozark confining unit separate the Mississippian and the Cambrian-Ordovician aquifers.

Ozark Aquifer

The Ozark aquifer is the primary source of water in the Ozark Plateaus Physiographic Province, is the middle aquifer of the Ozark Plateaus aquifer system, and consists of numerous geologic formations that range in age from Devonian to Cambrian (Figure 2.4-45). The rocks of the aquifer are mostly dolomite and limestone, but there are also some beds of sandstone, chert, and shale. The aquifer provides water for municipal, industrial, and domestic supplies. The main water-yielding formations in the Ozark aquifer are the Potosi Dolomite, Gasconade Dolomite, and the Roubidoux Formation. The Potosi Dolomite is the most permeable of these three formations.

The Ozark aquifer is less than 1,000 ft (300 m) thick across most of southern Missouri but thickens to more than 3,000 ft (900 m) in southeastern Missouri just north and east of the bootheel. The Ozark aquifer pinches out against the flanks of the St. Francois Mountains, and its thickness is irregular where it has been eroded in outcrop areas.

Caves, sinkholes, and other types of solution features characteristic of karst topography have developed in the carbonate-rock units, primarily where they are exposed at the land surface or are covered by a thin layer of soil. Springs are common in the Ozark and Springfield Plateau aquifers. Missouri has eight first-order springs (greater than 100 cubic feet per second (cfs) (3 cubic meters per second (cms)); all of which issue from the Ozark aquifer.

Groundwater is generally unconfined in the Ozark aquifer. Where the water is unconfined, water levels in the aquifer respond rapidly to changes in precipitation due to solution openings in the carbonate rocks that allow large volumes of water to enter the aquifer quickly. Recharge is mostly from precipitation at aquifer outcrop areas. Small volumes of water recharge the aquifer by downward leakage from the shallower Springfield Plateau aquifer. Groundwater flow moves from topographically high recharge areas to discharge at nearby streams.

In most places, water in the Ozark aquifer is not highly mineralized, and the chemical quality of the water is suitable for most uses. Dissolved-solids concentrations are less than 1,000 ppm except in the westernmost parts of the aquifer and locally near the Mississippi River. Groundwater generally is a calcium bicarbonate type but locally may be a sodium bicarbonate type.

Total fresh groundwater withdrawals from the Ozark Plateaus aquifer system during 1990 were 330 MGD (1,254 MLD), 8 MGD (30 MLD) of which was withdrawn in Kansas. About 139 MGD (528 MLD) was withdrawn for agricultural purposes, about 88 MGD (334 MLD) was used for public supply, and about 53 MGD (201 MLD) was withdrawn for industrial, mining, and thermoelectric power uses. Withdrawals for domestic and commercial supplies were about 50 MGD (190 MLD).

St. Francois Confining Unit

The St. Francois confining unit underlies the Ozark aquifer and separates it from the underlying St. Francois aquifer. The confining unit consists primarily of dolomite of minimal permeability but includes limestone, shale, and siltstone. Where the confining unit contains more shale and siltstone, it more effectively retards the movement of groundwater between the two aquifers. The Davis Formation and the Derby-Doe Run Dolomite are the geologic formations that compose the St. Francois confining unit. The thickness in the eastern two-thirds of the confining unit generally is greater than 200 ft (61 m); in the western third, it is about 100 ft (30 m) thick. However, the thickness of the unit is variable.

St. Francois Aquifer

The St. Francois aquifer is the lowermost aquifer in the Ozark Plateaus aquifer system and is exposed at the land surface only in the St. Francois Mountains. Away from the mountains, the top of the aquifer slopes into the subsurface in all directions and becomes buried beneath the more productive Ozark aquifer. The St. Francois aquifer is accordingly used as a source of supply only in and near the St. Francois Mountains.

The St. Francois aquifer consists of the Bonneterre Dolomite and the Lamotte Sandstone and its lateral equivalent, the Reagan Sandstone, all of which are of Cambrian-age. The Lamotte Sandstone is the most productive and yields as high as 500 gpm (1,900 lpm) have been reported. Yields of wells completed in the Bonneterre Dolomite are reported to range between 10 gpm and 50 gpm (38 lpm to 190 lpm). The water-yielding capability of the Reagan Sandstone is not well known. The Lamotte Sandstone and the Bonneterre Dolomite occur north of the Missouri River, but their water-yielding properties are not known; accordingly, no aquifer equivalent to the St. Francois aquifer is mapped there.

The thickness of the St. Francois aquifer is generally between 300 ft and 500 ft (90 m to 150 m) in south-central Missouri west of the St. Francois Mountains. The thickness of the aquifer is greater than 700 ft (213 m) in several places to the north, east, and southeast of the mountains. The aquifer thins near its western and southern limits. Water is withdrawn from the St. Francois aquifer only where the aquifer crops out or is buried to shallow depths. Sparse water-level data indicate that flow in the aquifer in and near outcrop areas primarily is controlled by topography. Water enters the aquifer as recharge from precipitation that falls on topographically high outcrop areas. Most of the water moves along short flow paths and discharges as base flow to nearby streams. A small volume of water moves along slightly longer flow paths into confined parts of the aquifer and discharges to shallower aquifers by upward leakage.

The chemical quality of the water in the St. Francois aquifer in and near the aquifer outcrop areas generally is suitable for most uses. The water is a calcium magnesium bicarbonate type with dissolved-solids concentrations reported to range between 200 ppm and 450 ppm. Chloride concentrations in the water generally are less than 60 ppm, and sulfate concentrations are 150 ppm or less. Freshwater has been reported from the St. Francois aquifer as far west as Jasper and Pettis Counties, Missouri, which indicates a regional ground-water flow system in the aquifer.

2.4.12.1.2.3 Mississippian and Cambrian-Ordovician Aquifers (Northern Missouri)

From the three-state regional perspective, the aquifers of northern Missouri are generally described as equivalent, less significant aquifers to those in southern Missouri and therefore much less detail is reported in the USGS Ground Water Atlas. The information presented below has been supplemented by "The Ground-Water Flow System in Northern Missouri with Emphasis on the Cambrian-Ordovician Aquifer" (USGS, 1985) and "Groundwater Resources of Missouri" (MDNR, 1997). The Missouri Department of Natural Resources has divided the state into seven groundwater provinces and two sub-provinces. Information here is cited for the Northeast province (MDNR, 1997).

Mississippian Aquifer

The Mississippian aquifer in northern Missouri is stratigraphically equivalent though hydraulically unconnected to the Springfield Plateau aquifer in southern Missouri. The Keokuk, Burlington, Fern Glen, Sedalia, and Chouteau Limestones compose the aquifer; of these formations, the Keokuk and the Burlington are the principal water-yielding rocks and are generally considered to be one unit. Both formations consist of crystalline limestone and yield water primarily from solution cavities. In most places, typically to the north, the aquifer is overlain by a confining unit of Pennsylvanian shale and sandstone and is everywhere underlain by a confining unit of Mississippian shale.

The thickness of the Mississippian aquifer averages about 200 ft (60 m) but locally exceeds 400 ft (121 m) in northwestern Missouri. The aquifer is thickest as it extends northward into Iowa and is thinnest near the Mississippi and the Missouri Rivers where it has been dissected or removed by erosion.

The Mississippian aquifer receives recharge by vertical leakage from the overlying glacial drift aquifers. Most of the water in the Mississippian aquifer moves along flow paths toward small and large streams, into which it discharges as base flow. Groundwater flow patterns largely reflect the topography of the area. Groundwater yields are realistically 5 gpm to 15 gpm (19 lpm to 57 lpm).

The chemical quality of the water in the Mississippian aquifer varies considerably. The aquifer contains freshwater only in the eastern one-third of Missouri. Elsewhere, it contains slightly saline to very saline water. Dissolved-solids concentrations of water from the aquifer generally are greatest where the aquifer is overlain by a thick confining unit and least where it is unconfined or overlain by a thin or leaky confining unit. In southern Carroll and Chariton Counties and western Howard County, the aquifer contains water with dissolved-solids concentrations of greater than 10,000 ppm.

Upper Confining Unit

The Upper Confining Unit in northern Missouri is stratigraphically equivalent, much thicker than and hydraulically unconnected to the Ozark Confining Unit in southern Missouri. The Upper Confining Unit is not a single unit, but a sequence of shale and limestone formations from the Lower Mississippian to the Upper Ordovician periods. Across northern Missouri, the nomenclature and thicknesses of the formations vary, but in Callaway County, the significant formations are the Snyder Creek Formation (shale unit), Callaway Limestone, and Cotter-Jefferson City (CJC) Formation. Where these formations have thick, buried sections, they function overall as a leaky, confining aquitard that separates the overlying and underlying aquifers.

Cambrian-Ordovician Aquifer System (Northern Missouri)

North of the Missouri River, formations that are equivalent to the Ozark aquifer are called the Cambrian-Ordovician aquifer. Like the Ozark aquifer, the Cambrian-Ordovician aquifer consists mostly of dolomite and limestone; however, it also includes beds of sandstone and shale. Vertically, the aquifer is not continuous as it contains both permeable and semi-permeable rock units, which function as alternating intervals of aquifers and aquitards. The Potosi and Eminence Dolomites are the main water-yielding formations, but the Roubidoux Formation and Lower Gasconade Dolomite are also important due to the presence of permeable sandstone bodies. Most wells completed in the Cambrian-Ordovician aquifer are open to more than one water-yielding unit.

The thickness of the Cambrian-Ordovician aquifer averages about 1,200 ft (365 m) but is as great as 1,800 ft (550 m) in St. Charles County. Groundwater conditions are mostly confined. Groundwater is fresh across a small area in east-central Missouri but is slightly-to-moderately saline in northern and northwestern Missouri where the aquifer is more deeply buried by confining units. Groundwater divides prevent the regional saline water to the west from entering the freshwater area. Recharge to the aquifer is from precipitation at aquifer outcrop areas and to some extent from downward leakage of water from the overlying aquifers through the Upper Confining Unit. Groundwater flow directions generally reflect topography. Groundwater flows toward local streams as well as regionally toward the Missouri and Mississippi Rivers where discharge provides base-flow.

Well yields from the major units range from approximately 50 gpm to 500 gpm (190 lpm to 1,900 lpm) and are used for municipal and industrial supply. Smaller yields from minor, less permeable units range from 10 gpm to 25 gpm (38 lpm to 95 lpm) are used for domestic and farm wells. Estimated values of transmissivity range from 250 sq ft per day to 1,500 sq ft per day (23 to sq m per day to 140 sq m per day).

Groundwater in the freshwater areas has total dissolved solids that range from 350 ppm to 750 ppm. Groundwater to the north and west regional-flow system is saline with total dissolved solids greater than 10,000 ppm.

2.4.12.1.3 Local and Callaway Site-Specific Hydrogeology

2.4.12.1.3.1 Callaway Plant Unit 1 Investigation-Local Hydrogeology and Conceptual Flow Model

The field investigation for Callaway Plant Unit 2 was based on the local hydrogeological description and conceptual model developed for the Callaway Plant Unit 1 Final Safety Analysis Report (FSAR) (AmerenUE, 2003). Callaway is located five miles north of the Missouri River in Callaway County. The site sits on a plateau at an approximate elevation of 840 ft to 850 ft (256 m to 259 m) msl as shown on Figure 2.4-49. The plateau serves as the headwater area for four sub-watersheds shown to extend from the 820 ft (250 m) msl contour line toward the drainage boundaries. Unnamed tributaries drain away from the plateau toward Logan Creek, Mud Creek, Cow Creek, and Auxvasse Creek, all of which ultimately drain to the Missouri River. No one drainage pattern accurately describes the creek watersheds. Surface water moves radially from the topographic high toward the heads of tributaries that ring the plateau. The tributaries that ultimately drain to Mud Creek roughly follow a parallel drainage pattern; those to Logan Creek a trellis drainage pattern, and those to Auxvasse Creek a dendritic drainage pattern. The elevation of the Missouri River in the vicinity of the site is approximately 525 ft (160 m) msl, which indicates that the topographic relief of the area is approximately 315 ft to 325 ft (96 m to 99 m).

Figure 2.4-48 shows a section of the important hydrogeologic units and their associated formations beneath the site either identified during site investigation or expected based on the regional hydrogeology. The relevant aquifers from the regional discussion of Northern Missouri are the surficial aquifer system, the Mississippian aquifer, and the Cambrian-Ordovician aquifer. From the plateau surface to approximately 2,000 ft (610 m) below ground surface (bgs), the geologic formations can be combined into three overall hydrostratigraphic units that generally are consistent with the regional scale. There is a shallow aquifer (Mississippian or stratigraphically equivalent to the Mississippian) that extends to approximately 80 ft (24 m) bgs, underlain by a leaky, confining aquitard (Upper Confining Unit) that is approximately 250 ft (76 m) thick, which in turn is underlain by a Cambrian-Ordovician confined aquifer system that is approximately 1,500 ft (457 m) thick atop the Pre-Cambrian bedrock.

In the Callaway Plant Unit 1 FSAR, the shallow aquifer was described as an unconfined aquifer that consists of surface quaternary deposits such as loess, clay, and clayey glacial till underlain by the Graydon Chert conglomerate (either Pennsylvanian or Mississippian in age), and the Mississippian Burlington Limestone and Bushberg Sandstone. These units extend to approximately 80 ft (24 m) bgs, although the Bushberg Sandstone is relatively thin (0 ft to 8 ft (0 m to 2.4 m) thick across the area of study) and discontinuous. Due to the low permeability of these units, well yield was estimated as less than 1 gpm (3.8 lpm).

Recharge enters the aquifer through local precipitation. The Callaway Plant Unit 1 FSAR described the Bushberg Sandstone as a drainage conduit at the base of the shallow aquifer due to its higher hydraulic conductivity. In stream valleys, the Bushberg Sandstone may be exposed with water seeping from it into creek beds. At lower elevations, outside of the facility boundary, these units may not be present nor are they necessarily present along the major streams where they have been eroded and replaced by modern day alluvial deposits.

In the area of the Callaway Site, the aquitard (Upper Confining Unit) consists of the Snyder Creek Formation underlain by the Callaway Limestone, the St. Peter Sandstone, and the upper portion of the CJC Dolomite. These units extend to approximately 350 ft (107 m) bgs. Within the Callaway and upper CJC Formations, both saturated and unsaturated zones were identified. It was reported that overall the aquitard has slow vertical leakage to the saturated zones and that horizontal flow is not occurring.

The deeper, confined artesian Cambrian-Ordovician aquifer system consists of many hydrogeologic units with highly varying yields beginning with the middle to lower portion of the CJC Formation and extending approximately 1,500 ft (457 m) downward to Pre-Cambrian bedrock. The Callaway Plant Unit 1 investigation penetrated the CJC but presented information about the deeper units from the regional literature. The units consist of the Middle to Lower CJC Dolomite (referred to here as the CJC aquifer), Roubidoux Sandstone, Gasconade Dolomite and Gunter Sandstone, Eminence Dolomite, Derby-Doe Run, Davis and Bonneterre Dolomites, and Lamotte Sandstone. The CJC aquifer is considered to be a minor aquifer with well yields less than 10 gpm (37.9 lpm) and is expected to crop out along stream valleys and discharge water into the alluvial material along the Missouri River. Along the smaller creeks, this formation is exposed along the streambeds.

2.4.12.1.3.2 Callaway Plant Unit 2 Local Hydrogeology and Conceptual Flow Model

The Callaway Plant Unit 2 field investigation was developed to support the following objectives:

- Provide an understanding of the hydrogeological characteristics of the shallow aquifer. Due to the Callaway Plant Unit 1 construction, surface materials have been removed, stormwater drainage has been constructed, and areas have been covered and paved. Additionally, an excavation pond is located between Callaway Plant Unit 1 and Callaway Plant Unit 2, and stormwater runoff ponds for Callaway Plant Unit 1 construction remain on the plateau downgradient of both the Callaway Plant Unit 1 and Callaway Plant Unit 2 facility operation areas.

- Provide an understanding of the hydrogeological characteristics of the intermediate aquitard. The Callaway Plant Unit 1 investigation found that the aquitard yielded little to no water over significant depth; however, it is important to investigate the potential interaction of the shallow and deeper aquifers and the extent of vertical versus horizontal migration of groundwater through the aquitard.

- Provide an understanding of the hydrogeological characteristics of the deeper confined aquifer, specifically the portion of the CJC aquifer that potentially discharges to local streams. On the plateau, the CJC aquifer is expected to be present approximately 350 ft to 400 ft (107 m to 122 m) bgs, whereas along the study area boundary this aquifer is expected to be present at a similar elevation but nearer to the ground surface beneath modern alluvial deposits.

- Provide an understanding of the hydrogeological characteristics of the Missouri River alluvial aquifer, because make-up water may be supplied by a groundwater collector well system constructed on the Missouri River floodplain.

The data collected during the investigation were utilized to:

- Evaluate the seasonal precipitation changes on groundwater elevations across the study area;

- Evaluate the extent that shallow groundwater on the plateau is traveling radially toward downgradient streams versus leaking through the aquitard to the deeper aquifer;

- Evaluate the connection between groundwater and surface water;

- Evaluate the possible groundwater conditions for the construction and post-construction groundwater periods for Callaway Plant Unit 2;

- Evaluate potential pathways for liquid releases and provide a basis for evaluating the transport of hypothetical release scenarios; and

- Evaluate the seasonal and long-term drawdown of the horizontal well intake in the alluvial aquifer and its potential impact to other surface water and groundwater users.

The study area extends across nearly 50 sq mi (130 sq km) from the facility plateau to surface water boundaries as shown by the dashed line on Figure 2.4-49. Field locations for the hydrogeological investigation are shown on this figure and Figure 2.4-50 shows more detail on the plateau. The field work activities were as follows:

- Utilized site reconnaissance to identify formation outcrops and potential seeps along the stream drainages that originate from the plateau and lead toward the major streams.
- Utilized coring, geophysics, and packer tests in one 400 ft (122 m) deep borehole on the plateau to investigate the fracture and water-bearing characteristics and associated depths of the consolidated rocks to the Cambrian-Ordovician CJC aquifer. The purpose was also to verify the conceptual model developed for Callaway Plant Unit 1 and allow the field personnel to identify the rock and aquifer characteristics prior to proceeding with drilling at additional locations.
- Results from drilling and testing at the first borehole indicated that the shallow aquifer was located approximately 30 ft (9 m) bgs yet exhibited confined, artesian conditions; an intermediate interval in the aquitard may yield some water, and the CJC aquifer was approximately 350 ft (107 m) bgs and exhibited confined, artesian conditions. The field personnel noted dry, moist, and wet at intervals along the entire section.
- Installed 25 monitoring wells in the shallow and deep aquifers, 1 well in the aquitard, and 10 monitoring wells in the alluvial aquifer along the Missouri River floodplain.
- Installed/surveyed 28 staff gauges or permanent structures at streams, ponds, and lakes.
- Measured seasonal water levels, water quality, and surface water flow velocities.
- Monitored water levels continuously for 1 month at select shallow wells on the plateau.
- Performed slug and pumping tests.
- Analyzed soil samples for physical characteristics and adsorption properties (results of adsorption properties are presented in Section 2.4.13).

Preliminary assessment of the field data allowed for the development of an alternate conceptual model of groundwater recharge, flow, and subsequent discharge to downgradient surface water (refer to Figure 2.4-48). The primary change to the Callaway Plant Unit 1 conceptual model is that the shallow aquifer is under confined conditions within the chert to a depth of approximately 70 ft (21.3 m) bgs. During the Callaway Plant Unit 2 field investigation, field personnel identified the chert as a moderate water-bearing unit with the glacial till acting as the confining unit above the chert and the Burlington Limestone acting as the confining unit and top of the aquitard beneath the chert. It is believed that the site investigation wells during the Callaway Plant Unit 1 investigation were screened across multiple units and thus artesian water within the chert was construed as unconfined, saturated groundwater within the loess and till. The Callaway Plant Unit 2 investigation found that the loess and till as well as the deeper Burlington Limestone were dry to partially saturated to saturated and these units did not make water. These findings are consistent with the construction phase of Callaway Plant Unit 1 when minimal seepage occurred in excavations below the base of the glacial till and no de-watering was required (AmerenUE, 2003). It is believed that on-site ponds not present during the Callaway Plant Unit 1 investigation likely provide enhanced groundwater recharge and hydraulic head to the underlying materials, thus explaining the artesian conditions.

Beneath the Burlington Limestone, the Bushberg Sandstone was either not present or very thin and dry to partially saturated. It is not likely that the Bushberg acts as the base of the shallow aquifer except in places where the Burlington is not present. Beneath these units, the Callaway Plant Unit 2 field investigation findings were consistent with the conceptual model developed during the Callaway Plant Unit 1 investigation, although the CJC aquifer was characterized as a dolomitic limestone during the Callaway Plant Unit 2 investigation.

A detailed description of the Callaway Plant Unit 2 field investigation results and evaluations to meet the regulatory objectives are provided in Section 2.4.12.3. Subsurface data from the Callaway Plant Unit 2 geotechnical investigation are summarized in Section 2.5.

2.4.12.2 Sources

This section provides a description of the groundwater use at, and in the vicinity of, the Callaway Plant Unit 2 site. The objective of this section is to present the U.S. Environmental Protection Agency (EPA) sole source aquifers within the region, groundwater use in central Missouri, current users in Callaway and Osage Counties, current Callaway Plant Unit 1 groundwater use, expected future demands for central Missouri and Callaway and Osage Counties, and anticipated Callaway Plant Unit 2 groundwater use.

2.4.12.2.1 Regional Groundwater Use

Groundwater is extensively used as a source of potable water across the state of Missouri. Important aquifers of Missouri are described in Section 2.4.12.1. All of the potable groundwater in storage in Missouri originated as and is recharged by relatively local precipitation. It is estimated that during normal weather cycles the volume of potable groundwater in storage is:

Aquifer Storage	Missouri - Mississippi Alluvial	Glacial (northern Missouri only)	Sand/Gravel (Missouri southeastern boot-heel area only)	Bedrock (south of transition zone only)	Total
Rounded trillion gallons	26	9	44	421	500
Rounded trillion liters	98	34	166	1,594	1,892

Reference: Groundwater Resources of Missouri (MDNR, 1997).

To assess Missouri's groundwater resources, the state has been divided into seven major groundwater provinces and two sub-provinces (MDNR, 1997). The boundaries are based on aquifer area, type of groundwater system, groundwater flow patterns, groundwater quality, and other factors. The CallawaySite and all of Callaway County are located within the Northeast groundwater province with aquifers as described in Section 2.4.12.1 for northern Missouri. Five miles south of Callaway Plant Unit 2, the Missouri River alluvial aquifer is considered to be a part of the Mississippi and Missouri River groundwater sub-province. It is planned that water will be drawn from a collector well system located in this sub-province on the Missouri River floodplain. Across from the intake area on the southern side of the Missouri River, Osage County is located within the Salem Plateau groundwater province with aquifers as described in Section 2.4.12.1 for southern Missouri.

2.4.12.2.2 Sole Source Aquifers

The Sole Source Aquifer (SSA) Program, which is authorized by the Safe Drinking Water Act, allows for protection of an aquifer when a community is dependent on a single source of drinking water and there is no possibility of a replacement water supply to be found. The U.S.

EPA defines a sole or principal source aquifer as one which supplies at least 50% of the drinking water consumed in the area overlying the aquifer (USEPA, 2007a).

The Callaway Site is located in EPA Region 7 (Nebraska, Iowa, Kansas, and Missouri). There are no sole source aquifers in this region.

2.4.12.2.3 Missouri Groundwater Use

As part of the Missouri State Water Plan, Callaway and Osage Counties are managed by the Jefferson City Regional Office of MDNR, which oversees the “Central Missouri” region (MDNR, 2002b), as shaded on Figure 2.4-46.

Estimated water usage (surface water and groundwater) for central Missouri in 1995 by use was:

Use	Domestic	Agricultural	Commercial	Industrial	Total
Billion gallons	15.3	6.3	3.2	0.3	25.1
Billion Liters	58.0	23.8	12.1	1.1	95.0

Reference: Topics in Water Use: Central Missouri (MDNR, 2002b).

Central Missouri is home to a large number of universities and Missouri state government offices. The percentage of publicly supplied water allocated to commercial and public uses (85.5%) is higher than the statewide average (65.2%). Industrial water use was less than 2% of the public water supply as compared to the state-wide average of 24.4% (MDNR, 2002b).

Three-fourths of the population in central Missouri is connected to a public water supply. Of this group, two-thirds received public water supplied by groundwater. The Missouri River and a number of small public water supply lakes supply the remaining one-third. For private supply, nearly 100% of self-supplied domestic water withdrawals come from groundwater sources, although a small percentage of users (1 to 2%) obtain water from surface water sources such as springs, creeks, lakes, or cisterns.

Farmers in central Missouri draw water for both irrigation and livestock. Surface water sources account for approximately 70% with the balance supplied by groundwater.

For power production, water usage by four thermoelectric power generation plants in central Missouri was approximately 31 billion gallons (117 billion liters) in 2000 (MDNR, 2002b). The AmerenUE Callaway Plant Unit 1 in Callaway County, withdraws surface water from the Missouri River and one groundwater well; the Central Electric Power Cooperative in Osage County withdraws surface water from the Missouri River and from two groundwater wells; while the University of Missouri at Columbia and the City of Columbia (Columbia Power and Light) withdraw their water from groundwater wells.

MDNR divides water supply wells into classes for regulatory purposes. These are public water systems (community public water supply wells, transient non-community public water supply wells, and non-transient non-community public water supply wells), private wells (domestic and multiple-family), petroleum distribution, high yield, Grade A dairy, unconsolidated material irrigation, and bedrock irrigation (MDNR, 2007a).

The service description of public wells as quoted from the MDNR guidelines is as follows:

- Community. A public water system which serves at least 15 service connections or regularly serves an average of at least 25 residents on a year-round basis. Examples are cities, towns, and mobile home parks.

- Transient Non-community. A public water system that is not a community water system which has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days of the year. Examples are restaurants, motels, convenience stores, and campgrounds.

- Non-transient Non-community. A public water system that is not a community water system, and that regularly serves at least 25 of the same persons over six months per year. Examples are schools and factories.

The service description of private wells as quoted from the MDNR guidelines is as follows:

- Domestic. A private water supply well that is constructed to meet minimum standards and is equipped with a pump that does not have the capacity to produce more than 70 gallons of water per minute and services three or less service connections. A private domestic water supply well that produces less than 70 gallons of water per minute regardless of the use is a domestic well. This allows for 1 to 3 families.

- Multi-family. A private water supply well constructed for the purpose of serving more than three dwellings, but having less than 15 service connections and serving less than 25 individuals daily at least 60 days out of the year. This allows for multiple family and small industry (non-drinking).

All public water supply wells must be drilled by permitted well drillers and well construction is regulated by the MDNR. The MDNR Department of Environmental Quality - Public Drinking Water Program administers and must approve engineering plans and specifications for all community and non-transient non-community public water supply wells. They provide general guidelines for constructing transient non-community public water supply wells. The Division of Geology and Land Survey assists by providing casing and total depth information. Private well construction standards, as well as those for monitoring wells and heat pump wells, are published by the MDNR Division of Geology and Land Survey (DGLS) in Missouri Well Construction Rules (MDNR, 2007a). Construction of private water supply wells is administered by the MDNR Division of Geology and Land Survey. Once private wells are constructed, there are no further administrative or reporting requirements with MDNR.

2.4.12.2.4 Callaway and Osage Counties Groundwater Use

In Callaway County, it is estimated that approximately 10,000 billion gallons (37,850 billion liters) of potable groundwater are in storage. This total is estimated from several aquifers as follows:

Aquifer Storage	Mississippian	Cambrian-Ordovician	St. Francois	Missouri Alluvial	Total
Rounded billion gallons	250	9,650	0 (limited or unknown extent)	100	10,000
Rounded billion liters	945	36,530	0	375	37,850

Reference: Groundwater Resources of Missouri (MDNR, 1997).

In Osage County, it is estimated that approximately 6,400 billion gallons (24,230 billion liters) of potable groundwater are in storage. This total is estimated from several aquifers as follows:

Aquifer Storage	Springfield Plateau	Ozark	St. Francois	Missouri Alluvial	Total
Rounded billion gallons	Not present	5,700	640	60	6,400
Rounded billion liters	Not present	21,600	2,400	230	24,230

County	Domestic	Municipal	Irrigation	Recreation	Industrial	Elec. Power	Fish and Wildlife	Total
Callaway								
Million gallons	286	959	186	0	0	151	0	1,582
Million Liters	1,082	3,630	704	0	0	572	0	5,988
Osage								
Million gallons	0	180	0	0	0	97	0	277
Million Liters	00	681	0	0	0	367	0	1,048

Reference: Major Water Use in Missouri 1996-2000 (MDNR, 2003).

Table 2.4-41 summarizes both active and closed public water systems listed in the Safe Drinking Water Information System (SDWIS) (USEPA, 2007b) for Callaway and Osage Counties. The active systems are consistent with those tracked by the MDNR. Table 2.4-42 summarizes the number of wells, population served, and usage reported for the active public water systems in Callaway and Osage Counties as reported in the 2007 Census Report (MDNR, 2007b). In some cases, the individual wells for a particular public water supply system may not be located near each other. The largest providers in Callaway County are the Callaway Public Water Supply District (PWSD) #1, Callaway PWSD #2, and the city of Fulton, which combined serve nearly 35,000 people. The largest providers in Osage County are the Osage PWSD #1 and the city of Linn, which are the only ones to serve more than 1,000 people.

Table 2.4-43 summarizes the individual public and private water wells within the hydrogeologic study area boundary and within approximately 1 mile (1.6 km) of the boundary. The sources of the data are the MDNR drilling records of public and private wells (referenced by the DGLS number), the AmerenUE Land Use Census Report of local groundwater wells (AmerenUE, 2006a), communication with AmerenUE (AmerenUE, 2007a), and a request to the MDNR (MDNR, 2007c). The MDNR DGLS records for each well contain the drilling log, well depth, casing depth, and yield at time of drilling. Information from private wells identified by AmerenUE is limited to the location. Information from the MDNR request contains the well type, section/township/range location, and in some cases, information about the well depth, casing depth, and yield at time of drilling. It should be noted that there is not a common number or reference that allows these three sources of data to be cross-referenced. Therefore, the table summarizes all of the information from each source of data and is sorted by the data source. Well locations from each data source except the MDNR request are shown on Figure 2.4-51. Locations from the MDNR request were limited to section, township, and range, and therefore, they could not be placed on the figure with any reasonable accuracy.

Review of the MDNR well logs indicates that all wells in Callaway County for which the well logs are available are drilled into the Cambrian-Ordovician aquifer. In Osage County, well logs are not available, but limited information was available per personal communication (MDNR, 2007d). The depth and open length of the wells are variable and depend on the ground surface elevation at the well location, which varies by approximately 300 ft (90 m), and the yield required. Generally, private wells are shallower and end within the Cotter or Cotter-Jefferson

City (CJC) formations, which have a yield of approximately 5 gpm to 35 gpm (20 lpm to 130 lpm). Public wells are deeper and extend to the Roubidoux, Eminence, or Derby-Doe Run formations, which have yields of approximately 200 gpm to 600 gpm (750 lpm to 2,300 lpm). Estimated yields are based on cumulative yield over extended lengths of the well.

The distance from Callaway Plant Unit 2 to the local groundwater wells is shown on Table 2.4-43. The closest non-AmerenUE well is classified as an irrigation well (although it is believed to be used to fill sprayer tanks and for washing equipment) and is located approximately 0.8 miles (1.3 km) north (and downgradient) of Callaway Plant Unit 2. This well was verified by AmerenUE to be an active well (AmerenUE, 2007b). This well is 375 ft (114.3 m) deep and is likely drawing water from the Cotter-Jefferson City aquifer. Additional verification of the two wells at the Central Electric Power Station located across the Missouri River and Osage County indicate that there are two active wells that are utilized for cooling water and boiler operations, but are not used as drinking or irrigation water as indicated in the MDNR records (Central Electric Power, 2008). These wells are screened in the alluvial aquifer, are located approximately 75 ft (22.9 m) from the river, and provide approximately 75 gpm to 100 gpm (285 lpm to 380 lpm).

2.4.12.2.5 Callaway Plant Unit 1 Groundwater Use

The existing source of cooling water for Callaway Plant Unit 1 is a surface water intake located along the Missouri River. The water is pumped up the water line corridor, utilized by the plant, and discharged down the water line corridor to a location approximately 450 ft (135 m) downstream of the water intake. In the late 1980s, a shallow well was installed in the alluvial aquifer to supply lubrication water to the intake pumps. It has a depth of 103 ft (31 m) below ground surface (bgs) and withdraws water from the Missouri River alluvial aquifer. Yield has been estimated at 300 gpm (1,100 lpm). Later, in the late 1990s, a deep well was installed to supply lubrication water to the intake pumps and the shallow well was maintained as a back-up well (AmerenUE, 2007a). The deeper well is cased to 350 ft (107 m) and has a total depth of 854 ft (260 m). Estimated yield is 665 gpm (2,517 lpm).

During the Callaway Plant Unit 1 construction, three water supply wells were installed from approximately 1,100 ft to 1,510 ft (335 m to 460 m) below ground surface into the Cambrian-Ordovician aquifer. These wells are shown on Table 2.4-43. These wells are open across multiple formations from the CJC aquifer through either the Eminence Formation or deeper to the Derby-Doe Run formation (AmerenUE, 2007c; AmerenUE, 2007d). Initially, the three wells were used for potable water, a concrete batch plant, and for on-site lab services. Presently, only one well, Well #3 (DGLS # 028347), is utilized for potable water. The estimated average total groundwater use is 50 gpm (190 lpm), with a break-down as follows: potable water usage is 15 gpm (57 lpm), fire make-up water is 6 gpm (23 lpm), demineralization make-up water is 15 gpm (57 lpm), and miscellaneous water use is 10 gpm to 15 gpm (38 lpm to 57 lpm). Due to the small amount of water withdrawn relative to the estimated yield of the well from the drilling record (approximately 565 gpm (2,139 lpm)), there has been no MDNR reporting requirement (AmerenUE, 2007d).

2.4.12.2.6 Central Missouri Groundwater Demands

The Missouri State Water Resources Plan attempts to identify water use problems and opportunities related to drinking water, agricultural, industrial, recreational, and environmental needs. The central region has relatively abundant surface water and groundwater resources and, as a result, water use concerns are primarily focused on water quality and resource protection. These concerns include surface water and groundwater protection from non-point sources, including municipal, industrial, sewer, septic tank, and agriculture-related potential contaminant sources (MDNR, 2002b).

Central Missouri usually has enough snow and rainfall to replenish the water supply in principal aquifers, but during years of drought, water levels in aquifers decline. Water conservation is common during droughts, and mandatory curtailment of water use sometimes becomes necessary in severe, persistent droughts. Mandatory curtailment of water use must be ordered by the governor, under state emergency declarations. Missouri has no statute that requires curtailment in certain circumstances. However, citizens can file suit under the “reasonable use” doctrine to curtail what is alleged to be unreasonable or excessive use (MDNR, 2002b).

The Missouri Drought Plan was first published in 1995. Beginning in the summer of 1999 through the summer of 2000, many parts of Missouri experienced drought conditions and the Plan was activated. Especially hard hit were agriculture and water supply reservoirs in north central and northwestern Missouri. The lack of precipitation was compounded by marginal water reserves in several community reservoirs that supplied drinking water. Many local water supplies imposed voluntary or mandatory restrictions on water use. Additional pipelines were laid to allow water to be drawn from local streams to meet the water demand. Through the implementation of the original Plan and subsequent revisions, rainfall, stream flow, and groundwater level monitoring and reporting were improved to near-real time (MDNR, 2002c).

Drought is defined by five categories that pertain to indicators that are important to various water users as follows: agricultural, hydrological, meteorological, land use, and socio-economic. Based on these indicators, Missouri divided the state into three regions according to drought susceptibility, as shown on Figure 2.4-52. Region A has minor surface water and groundwater supply drought susceptibility. It is a region underlain by saturated sands and gravels (alluvium). Surface and groundwater resources are generally adequate for domestic, municipal, and agricultural needs. Region B has moderate surface and groundwater supply drought susceptibility. Groundwater resources are adequate to meet domestic and municipal water needs but due to required well depths, irrigation wells are very expensive. The topography is generally unsuitable for row-crop irrigation. Region C has severe surface and groundwater supply drought vulnerability. Surface water resources usually become inadequate during extended drought. Groundwater resources are naturally of poor quality and typically only supply enough for domestic needs. Irrigation is generally not feasible and groundwater withdrawal may affect other users. Central Missouri and Callaway and Osage Counties fall into Region B, except along the Missouri River, which falls into Region A.

The MDNR has been monitoring groundwater levels throughout Missouri since the mid-1950s. The 1950s were a time of severe regional drought. Many shallow wells were failing due to declines in water level. The initial monitoring network consisted of about 23 wells. The network is operated by the MDNR’s Water Resources Center, and currently consists of more than 100 wells that vary from less than 30 ft (9 m) deep to more than 1,800 ft (550 m) deep. These wells are summarized in Table 2.4-44 (MDNR, 2007e). They monitor aquifers ranging from shallow, unconfined alluvial and glacial drift aquifers to deep confined bedrock aquifers. Some of these were constructed by the MDNR specifically for measuring groundwater levels. Most, however, began as water supply wells whose use was later discontinued.

Approximately 50 new groundwater-level monitoring wells are planned to be added to the network bringing the total number of monitoring wells to about 155. Many of these are being placed in areas of high groundwater use to help better document water-level changes caused by all types of development. Other monitoring wells will be placed in areas not currently monitored to help fill data gaps. Several of the wells are being placed in areas far from significant groundwater use to monitor the variations in groundwater levels under natural conditions (MDNR, 2002c).

Water levels for the last five years are shown on Figure 2.4-53 through Figure 2.4-55 for monitoring wells located in Audrain, Boone, Callaway, Gasconade, Montgomery, and Osage Counties (USGS, 2007). These surround Callaway County and monitor the Cambrian-Ordovician aquifer north of the Missouri River and Ozark aquifer south of the Missouri River, except for the Callaway County station in Jefferson City, which monitors the Missouri River alluvial aquifer. These wells are highlighted in Table 2.4-44.

Annual precipitation for the same period (2002 through 2007) at the Columbia Regional Airport weather station, which is located in Callaway County approximately 25 miles (40 km) from the site, was as follows (NOAA, 2007):

Year	2002	2003	2004	2005	2006	2007	Normal [1]
Precipitation (inches) (cm)	42.30 107.44	39.43 100.15	45.95 116.71	41.21 104.67	30.12 76.51	32.92 83.62	40.28 102.31

[1]normal as reported in the 2006 annual report (NOAA, 2007).

From 2002 through 2005, precipitation levels were considered to be normal to above normal. However, precipitation for 2006 and 2007 was well below normal. These below normal precipitation levels are reflected in the overall decrease in groundwater levels monitored in Audrain, Boone, and Montgomery Counties in the Cambrian-Ordovician aquifer north of the Missouri River. Within each year, groundwater levels increase from late summer through spring and then decrease from late spring through late summer. For the monitoring station at Jefferson City, the alluvial aquifer appears to be more responsive to recharge from individual flood events or series of events, such as the flood that occurred in the spring of 2007 when the groundwater levels in the aquifer re-bounded almost entirely from the low levels of 2006.

2.4.12.2.7 Callaway Plant Unit 2 Groundwater Use

For Callaway Plant Unit 2, Wells #1 and #2 (DGLS # 027975 and # 028076), which are not currently supplying water to Callaway Plant Unit 1, will be used during construction activities. Their yields are estimated as approximately 200 gpm (760 lpm) each, such that the combined yield of the three wells (refer to Section 2.4.12.5 for discussion of Well #3) is approximately 965 gpm (3,650 lpm). It is currently estimated that a peak water supply of up to 700 gpm (2,660 lpm) will be required during Callaway Plant Unit 2 construction activities (demands include those for the construction workforce, concrete mixing, dust control, and hydro testing and flushing). This is based on an estimate of 150 gpm (570 lpm) for normal operations of Callaway Plant Unit 1 and anticipated construction requirements for Callaway Plant Unit 2, de-mineralization plant full operation of 500 gpm (1,900 lpm), and concrete plant and miscellaneous construction of 50 gpm (190 lpm). Average construction demand would be less.

Increasing groundwater withdrawals for construction needs from the three on-site production wells is not expected to exceed the well yields. The wells are open across multiple formations of the Cambrian-Ordovician aquifer system from the casing depths of 380 ft to 405 ft (115.8 m to 123.4 m) bgs to depths of approximately 1,100 ft to 1,510 ft (335 m to 460 m) bgs. Groundwater extraction from these wells is expected to yield water from the relatively high yielding formations that are present in the lower portion of the regional aquifer system. Generally, private wells in the area are shallower and end within the CJC aquifer, a minor aquifer that is the upper-most aquifer in the Cambrian-Ordovician aquifer system. Because the deeper aquifers are expected to have higher storativity, groundwater flow to the wells will be recharged more readily by these deeper formations rather than the CJC aquifer. Therefore, it is not expected that withdrawals from the Callaway Site production wells will impact local private users.

Projected average needs for Callaway Plant Unit 2 operation (after construction) are 20 gpm (76 lpm) for potable water, 3 gpm (11 lpm) for fire water make-up, and 80 gpm (300 lpm) for demineralization make-up (AmerenUE, 2007d). Therefore, it is expected that the supply requirement for Callaway Plant Unit 2 operations can be met from the existing wells. Any lowered Cambrian-Ordovician aquifer water levels will rebound as post-construction groundwater needs are much less than that needed for construction activities and much less than the aquifer yield.

AmerenUE is planning to construct a collector well system along the Missouri River to supply makeup cooling water for Callaway Plant Unit 2 (and additional water for Callaway Plant Unit 1). Collector wells have been constructed in alluvial aquifers elsewhere along the Missouri River to produce large yields of water for municipal entities such as a system serving the Kansas City area (USGS, 1996). Conceptually, each collector well would be constructed of a 20 ft (6.1 m) diameter caisson extending through the alluvial aquifer to bedrock with approximately 14 well-screen laterals extending radially to 200 ft (61 m) from the caisson. Each collector well could potentially supply 15,000 gpm to 20,000 gpm (57,000 lpm to 76,000 lpm). Three collector wells are being planned for the two units (Burns & McDonnell, 2008a). Average water requirements are expected to be 16,000 gpm (60,800 lpm) for Callaway Plant Unit 1 (based on current use) and 24,160 gpm (91,446 lpm) for Callaway Plant Unit 2 (AmerenUE, 2007d). Water would be pumped through a common line up the corridor and be split for usage by the two plants. The collector wells will be distributed along the edge of the Missouri River separated by approximately 1,500 ft (450 m) to limit interference of water production among wells. It is expected that 85% of the water will be derived from surface water recharge to the aquifer, while 15% will be derived from upgradient sources of groundwater (Burns & McDonnell, 2008a).

No significant hydrologic alteration of the Missouri River alluvial aquifer during construction of the collector well system is anticipated. The caisson is constructed “wet” and during projection and development of the lateral intake lines, water production to the caisson will be much less than what occurs during normal operation (Burns & McDonnell, 2008b). Operational changes to the alluvial aquifer are described in Section 2.4.12.3.3.2.

2.4.12.3 Subsurface Pathways

The Callaway Plant Unit 2 site hydrogeological field activities and conceptual model are introduced in Section 2.4.12.1.3. Figure 2.4-49 and Figure 2.4-50 show the monitoring well, pumping well, and surface water gauging locations. This section describes the analysis and results of the site-specific field investigations. The surveyed horizontal reference datum is NAD83 State Plane feet, and the surveyed vertical reference datum is NAD88 feet.

2.4.12.3.1 Monitoring Well and Surface Water Gauging Data

Table 2.4-45 shows construction characteristics for the Callaway Plant Unit 2 monitoring wells. The wells are divided into five groups:

- Eleven (11) shallow wells on the plateau are screened within or primarily within the Graydon Chert. PW-1 and MW-18 are centrally located for Callaway Plant Unit 2; MW-8 through MW-12 are located radially outward from the central part of the plateau; and MW-2S, MW-3S, MW-5S, and MW-6S are located further radially outward near the perimeter of the plateau. At MW-2S, the well is screened above the chert due to saturated groundwater over a consistent section at this location. At MW-18, the top of the well screen is placed partially in glacial till for the same reason. A shallow well at the MW-4D location was not installed due to field conditions (refer to Section 2.4.12.3.3.1 for more detail).

- One (1) intermediate well as part of a cluster centrally located on the plateau is screened within the aquitard (MW-1I).
- Six (6) deep wells on the plateau are screened within the Cotter-Jefferson City (CJC) aquifer. MW-1D through MW-6D are paired with shallow wells (except a shallow well was not installed with MW-4D due to field conditions). One (1) additional well, MW-7D, is located on a separate plateau northwest of the site. This well was installed to evaluate the groundwater potential in the CJC aquifer on the western side of Auxvasse Creek.
- Seven (7) shallow wells along the study area boundary are screened within the CJC aquifer. MW-13 through MW-17, PW-2, and PW-3 are located downgradient of the plateau near surface water boundaries. There are 6 additional piezometers (3 each at the pumping wells PW-2 and PW-3) that were used as observation wells during pumping tests.
- Ten (10) wells on the Missouri River floodplain. FMW-1S and FMW-1D is a cluster, which consists of two wells screened in the alluvial and CJC aquifers, respectively. FMW-5 through FMW-12 are screened in the deeper portion of the alluvial aquifer. There were 5 additional soil borings (FSB-2 through FSB-4, FSB-13, and FSB-14) logged in the floodplain.

Depth to and thickness of the identified formations are shown on Table 2.4-46 (refer to Section 2.5 for depths and thicknesses of formations from the geotechnical investigation beneath Callaway Plant Unit 2 structures). Water levels in the monitoring wells were measured to characterize groundwater elevations, hydraulic gradients, flow directions, flow velocities, and seasonal variations in these characteristics. Monitoring of these wells began in March 2007 and is reported through February 2008. Measured depths to groundwater and calculated groundwater elevations are presented in Table 2.4-47. Field parameters for water quality were measured on a seasonal basis and are presented in Table 2.4-48 for June, August, and November of 2007 and January of 2008. Additionally, 28 surface water locations were monitored for surface water elevations, flow velocities, depths, flow rates, and field water quality characteristics. These locations can be grouped as follows:

- Auxvasse Creek stream gauges (SG-A1 through SG-A5)
- Logan Creek stream gauges (SG-L1 through SG-L4)
- Mud Creek stream gauges (SG-M1 through SG-M5)
- Logan Camp Branch stream gauges (SG-LB1 and SG-LB2)
- Pond gauges (PG-1 through PG-7, PG-9, PG-10)
- Lake gauges (LG-1 through LG-3)

The streams were monitored to evaluate the interaction of surface water with the CJC aquifer groundwater along the study area boundary. Stream monitoring locations were monitored by utilizing surveyed reference points at bridge crossings. Pond gauges were installed to evaluate the interaction of surface water with the chert aquifer groundwater on the plateau. The lake gauges were installed to monitor surface water elevations in the large lakes north of the site.

PG-1 is located in a pond on private property. PG-2 through PG-7 and PG-9 are located at ponds that were constructed at the headwater of historical drainages for control of runoff and sediment during construction of Callaway Plant Unit 1. These ponds are unlined, likely situated on top of a relatively thin layer of fine-grained alluvial or glacial material, and in many cases (PG-2 through PG-5 and PG-9) within 5 ft to 10 ft (1.5 m to 3.1 m) of the top of the chert. Carbonate rocks were emplaced around their perimeter. A gauge was planned as PG-8 in a small pond near PG-9, but it was inaccessible due to a receding water line and mucky conditions, so it was not installed. PG-10 is located in an excavation trench that was slated for a possible Callaway Plant Unit 2 that was subsequently cancelled. This pond is approximately 15 ft to 20 ft (4.6 m to 6.1 m) deep and, based on the elevation of the chert at PW-1, MW-18 and MW-9, it extends to within 10 ft (3.1 m) of the top of the chert. This pond has a rip-rap boundary surrounded by a paved ground surface.

Table 2.4-49 presents the surface water elevations that were measured in conjunction with the groundwater elevations. Average flow depths, average flow velocities, and average flow rate are provided in Table 2.4-50. Table 2.4-51 shows the field water quality data for these locations. The following aquifer groundwater characteristics, potentiometric surface trends, and groundwater-surface water interaction evaluations are based on this information.

2.4.12.3.1.1 Graydon Chert Aquifer

Across the plateau, the Graydon Chert is considered to be the shallow aquifer. There are localized areas where the overlying material may be a part of this aquifer, but on the whole it was found that saturated conditions are confined within the chert. The Graydon Chert lies unconformably atop the Burlington Limestone and unconformably below the glacial till so its elevation and thickness vary. Across the plateau, the depth of the Graydon Chert ranges from 15 ft to 39 ft (4.6 m to 11.9 m) below ground surface (bgs) and averages approximately 27 ft (8.2 m) bgs. Its thickness ranges from 16 ft to 61 ft (4.9 m to 18.6 m) and averages approximately 38 ft (11.6 m). At the centrally located MW-18 well (beneath the power block area), the depth to the Graydon Chert is 30 ft (9.1 m) and its thickness is 40 ft (12.2 m).

The chert itself is present in several forms, which are described in more detail in Section 2.5. Although the chert is not wholly consolidated, it is very hard and has definite intervals of consolidation. The top of the chert is a partially weathered, friable sandstone, although considered to be unconsolidated, with chert nodules. The middle section is a hard, crystalline quartz sandstone with very large chert inclusions that is mildly fractured and yields little groundwater. The lower section lying on the Burlington Limestone is also somewhat weathered likely due to groundwater flowing on top of the aquitard. Depending on the thickness and water-yielding nature of the chert at each location, in most cases the 20 ft (6.1 m) well screen extends down to the base of the chert and sits on top of the aquitard.

In the central part of the plateau, groundwater is present in fractures in the chert and is consistently confined. Due to confined groundwater conditions, groundwater elevations measured at the monitoring wells rise above the top of the chert to within approximately 7 ft to 15 ft (2.1 m to 4.6 m) of the ground surface.

Local conditions varied at MW-11. At MW-11, the well was installed across an interval that demonstrated the highest chance of monitoring shallow groundwater. However, after several months of monitoring, the water at the base of the well was determined to be stagnant, trapped in the "shoe" of the well, and not indicative of an aquifer at that location. Groundwater elevation data was recorded, but it was not utilized in the evaluations. A second borehole was then drilled to determine if shallow groundwater was present either higher or lower in the section. However, yielding groundwater was not found during the second drilling effort at this location.

Around the perimeter of the plateau, the geology and thickness of the overlying materials are more variable and the shallow groundwater is more affected by the presence and configuration of local drainages; hence, the groundwater conditions are less consistent. For example, the MW-4D location was placed along a southern extension of the plateau where no shallow well was installed due to the absence of shallow groundwater. The ground surface is relatively high, but there are steep valleys that drop to the west, east, and south; hence, runoff is high and any groundwater recharge is likely to discharge to local drainages. This is indicative of what is expected along the perimeter of the plateau where shallow groundwater is not consistently present across an area and any water that does infiltrate discharges to local drainages.

Temporal trends of groundwater elevation data for the Graydon Chert aquifer are shown on Figure 2.4-56. Precipitation data for the NOAA Columbia Regional Airport station are shown on Figure 2.4-57, and surface water elevations at the plateau ponds PG-1 through PG-7, PG-9 and PG-10 are shown on Figure 2.4-58. Overall, groundwater elevations do not vary much through the year, typically by less than 1 ft to 2 ft (0.3 m to 0.6 m) across the central part of the plateau and several feet in the shallow wells around the perimeter of the plateau. The relatively larger, yet at some locations inconsistent, variations in groundwater elevations along the perimeter reflect the localized variations as discussed above. Pond elevations mostly varied by about 1 ft to 2 ft (0.3 m to 0.6 m) during the year.

The precipitation shown on Figure 2.4-57 is plotted with the total precipitation for each month. Groundwater elevations at some locations, such as at MW-2S, MW-6S, MW-9 and MW-12, fluctuate from a high in the late spring after spring rains and infiltration of water from melting snow through the month of June to a low in late summer. Groundwater elevations at locations such as MW-8 and MW-10 have a delayed response to the rain in the spring, and groundwater elevations at PW-1 have little sensitivity to seasonal fluctuations in precipitation.

In order to assess sensitivity to precipitation in the central portion of the plateau over a shorter time frame, pressure transducers monitored groundwater elevations at PW-1, MW-8, and MW-10 from late May to late June while rainfall was recorded with an on-site rain gauge. The data are shown on Figure 2.4-59. The transducers were not vented (i.e., they measured absolute pressure), so changes in groundwater elevations due to daily changes in barometric pressure were recorded. There does not appear to be a consistent correlation between a rain event and an increase in groundwater elevations; rather the data indicate that barometric pressure changes affect the groundwater elevations by approximately 1 ft (0.3 m). These short-lived oscillations are consistent with fluctuations that could be expected for confined groundwater such that as atmospheric pressure increases, groundwater potentiometric head decreases (Freeze & Cherry, 1979).

The groundwater elevation data were used to develop potentiometric surface contour maps for the Graydon Chert aquifer on a seasonal basis with four rounds of data (May, August, and November of 2007 and January of 2008. These maps are presented on Figure 2.4-60 through Figure 2.4-63, respectively. Pond elevations are shown but were not used in the contouring.

Generally, groundwater has the potential to move through the chert radially from the central portion of the plateau from an area that encompasses MW-18 and PW-1 toward the perimeter and associated drainages. It is expected that the ponds provide localized, enhanced recharge and hydraulic head to the aquifer. The groundwater potentiometric contours do not change much from one season to the next due to relatively small temporal variations in the groundwater elevations.

Field personnel looked for evidence of groundwater discharge around the perimeter of the plateau and in the upper portions of the drainages down to approximately 700 ft (213 m) msl. Drainages are consistently dry throughout the year (refer to additional discussion in Section 2.4.12.3.1.3. However, a seep was noted in a drainage to the east of the MW-2 well cluster. There are numerous small ponds in this general location just below 780 ft (238 m) msl.

Horizontal hydraulic gradients were estimated for the Graydon Chert aquifer and results for the four seasonal rounds are shown on Table 2.4-52. Horizontal gradients were estimated between upgradient and downgradient groundwater elevations of well pairs from the central part of the plateau (power block area) outward toward the perimeter (refer to Note 1 in the table for exceptions).

The horizontal hydraulic gradients do not vary much seasonally and there does not appear to be a consistent trend seasonally in the various directions. It is expected that during drier months horizontal hydraulic gradients would be higher and this is mostly the case for gradients in the central area of the plateau but not at the periphery. Therefore, average horizontal hydraulic gradients are appropriate for further evaluation.

In the central area of the plateau, the average horizontal hydraulic gradients range from 0.00121 to 0.00419. The steepest gradients are toward the west-northwest (WNW) and south-southeast (SSE) from the MW-18 well (power block area). Toward the periphery of the plateau, the average horizontal hydraulic gradients range from 0.00325 to 0.00837. In general, these are steeper than those in the central area of the plateau.

Vertical hydraulic gradients were estimated at well clusters between the Graydon Chert aquifer and the CJC aquifer. Results are shown on Table 2.4-52. Seasonally, the vertical hydraulic gradients are very consistent. Therefore, average vertical hydraulic gradients are appropriate for further evaluation. The average vertical hydraulic gradients range from 0.815 to 0.848. Both horizontal and vertical groundwater flow will be evaluated in Section 2.4.12.3.3.

Groundwater quality was monitored at each well screened in the chert and surface water quality was monitored at each pond gauge location on the plateau. For groundwater, the pH ranges from 6.85 to 7.27 and is indicative of normal groundwater conditions (pH range 6 to 8.5). The groundwater is considered to be fresh (salinity less than 1 part per thousand (ppt)) and with a total dissolved solids (TDS) concentration that is in the majority of cases slightly higher than the 0.5 ppt indicator of acceptable aesthetic quality. The dissolved oxygen (DO) concentrations are consistent with normal values of 5 ppm to 10 ppm for shallow groundwater that is recharged through infiltration. However, the temperature of the groundwater is approximately (18° Fahrenheit (10° Celsius) colder than the pond surface water (refer to discussion below), which indicates that recharge is relatively slow. The oxidation-reduction potential (ORP) is positive for all wells, which indicates an oxidizing environment. Seasonally, water quality changes but not consistently from one well to the next.

For surface water in the ponds, the pH ranges from 7.20 to 9.97; this is higher than the groundwater. The higher pH is attributable to a higher aeration of the surface water and contact with carbonate materials (the ponds have carbonate rocks along their perimeter that were emplaced during construction). The pond water is considered to be fresh (salinity less than 1 ppt) and with a TDS that is in most cases below the 0.5 ppt indicator of acceptable aesthetic quality. Generally, dissolved oxygen concentrations are higher than the groundwater but within the same range of 5 ppm to 10 ppm. The temperature of the ponds is approximately (18° Fahrenheit (10° Celsius) warmer than the groundwater and in most cases reflects the expected seasonal changes in atmospheric temperature. The ORP is positive for all ponds, which indicates an oxidizing environment.

2.4.12.3.1.2 Aquitard

During the drilling of the first borehole at MW-1D, a packer test and geophysical logging were performed to assess qualitatively the fracture characteristics of the rocks found beneath the chert within the aquitard and deeper CJC aquifer. These tests resulted in the identification of a potential water-bearing zone within the aquitard at approximately 165 ft (50.3 m) bgs and extending to approximately 180 ft to 182 ft (54.9 m to 55.5 m) bgs. A monitoring well (MW-1I) with a 15 ft (4.6 m) screened section was installed across this interval from 167 ft to 182 ft bgs (50.9 m to 55.5 m).

After the MW-1I monitoring well was installed, it was developed and it was found that the well went dry very quickly and did not readily recharge. This indicates that recharge to this zone and groundwater flow to the well are limited and that fractures that were identified in the downhole tests are not connected across an extensive area. During the drilling of the deep monitoring wells, conditions through the aquitard were monitored and the conditions were similar at the different locations. Through the aquitard, there are intervals of dry, moist, and wet conditions, with wet conditions correlating to zones of increased fracturing. However, there was no specific depth interval where water-yielding zones were consistently encountered. These findings are consistent with results from the Callaway Plant Unit 1 FSAR investigation where groundwater yield was found to be very low during a failed pumping test; the pumping well produced a yield of less than 1 gpm (3.8 lpm).

Based on the drilling of the monitoring wells across the plateau, the top of the aquitard begins with the top of the Burlington Limestone. Based on the drilling of the deep monitoring wells MW-1D through MW-7D, the aquitard extends through the Bushberg Sandstone (only identified at the MW-4 and MW-5 well locations), Snyder Creek Formation (shale), Callaway Limestone, and upper portion of the CJC Dolomitic Limestone. The demarcation between the upper CJC (aquitard) and the lower CJC (aquifer) was identified during the drilling process whenever water-yielding fractures were encountered in the lower portion of the formation.

The depth to the top of the aquitard is 60 ft (18.3 m) at MW-1D and averages 68 ft (20.7 m) across the plateau based on the other deep boreholes. It ranges in thickness from 252 ft to 289 ft (76.8 m to 88.1 m) (MW-1D, MW-3D through MW-6); however, it is only 180 ft (54.9 m) thick at MW-2D and 237 ft (72.2 m) thick at MW-7D. MW-2D is at an elevation that is approximately 65 ft (19.8 m) lower than the top of the plateau and the deeper aquifer was encountered at a shallower depth. MW-7D is located on an adjacent plateau with an elevation that is approximately 65 ft (19.8 m) lower than the Callaway Plant Unit 2 site.

Temporal trends of groundwater elevation data for the MW-1I well are shown on Figure 2.4-64. Groundwater elevations vary by less than 1 ft (0.3 m) through the year. These elevations indicate that the groundwater is within 2 ft (0.6 m) of the bottom of the well throughout the year. When compared to the groundwater elevation at the shallow well at this cluster, PW-1, the groundwater elevation in the aquitard is approximately 166 ft (50.6 m) lower throughout the year. Further evaluation of the interaction between the shallow aquifer and the aquitard is presented in Section 2.4.12.3.3. Groundwater quality was not monitored at this well, because when the well is purged at a low rate, it goes dry.

As discussed in the previous section, vertical gradients between the Graydon Chert aquifer and the CJC aquifer are similar at the well clusters located in the center and around the periphery of the plateau. This narrow range of gradients is generally indicative of a uniform depositional and weathering history across the area of the plateau, which translates to relatively similar recharge rates and hydrogeologic properties of the units beneath all areas of the plateau.

2.4.12.3.1.3 Cotter-Jefferson City Aquifer

As stated in the previous section, the demarcation between the aquitard and the CJC aquifer was identified by a zone of water yielding fractures that were found consistently in the lower portion of the CJC Formation. At monitoring well MW-1D, the aquifer was encountered at a depth of 349 ft (106.4 m) bgs. The borehole was extended to 400 ft (121.9 m) and the aquifer extended to this depth. The well screen was installed from 345 ft to 375 ft (105.2 m to 114.3 m) bgs. At the remaining locations, the borehole was extended 20 ft to 25 ft (6.1 m to 7.6 m) below the top of the aquifer and the well was installed. Yields during drilling were estimated to be 3 gpm to 5 gpm (11.4 lpm to 19 lpm), but over some intervals up to 15 gpm to 20 gpm (57 lpm to 76 lpm) was encountered.

The depth to the CJC aquifer is 349 ft (106.4 m) bgs at MW-1D and ranges from 325 ft to 345 ft (99.1 m to 105.2 m) bgs at MW-3D through MW-6D, is 260 ft (79.2 m) bgs at MW-2D, and is 315 ft (96.0 m) bgs at MW-7D (located on the adjacent plateau). Based on the well logs for the three AmerenUE industrial wells, the thickness of the CJC aquifer beneath the plateau is approximately 300 ft (91.4 m), which would extend the aquifer to a depth of approximately 650 ft (198 m) bgs at MW-1D. Regionally, the CJC aquifer is considered to be a minor aquifer and represents the top of the Cambrian-Ordovician aquifer system, which consists of intervals of minor aquifers and major aquifers with intermittent aquitards to depths up to 2000 ft (610 m) bgs.

Along the study area boundary near streams, monitoring wells were installed in the CJC aquifer, again, by the identification of water-yielding fractures (MW-13 through MW-17, PW-2, and PW-3). The ground surface elevations at these locations range from 533 ft to 570 ft (162.5 m to 173.7 m) msl, which is approximately 300 ft (91.4 m) below the top of the plateau. Stream drainages are eroded into the upper and lower portions of the CJC Formation, and erosion and fracturing make them indistinguishable. Alluvium has been deposited and re-worked in more recent geological time above the eroded surface of the CJC Formation.

A comparison of the screened interval elevations of the deep plateau wells and the study area boundary wells shows that these two sets of wells are monitoring a comparable interval of the CJC aquifer and that the top of the aquifer is relatively consistent across the study area. The well screens range from an elevation of 447 ft (136.3 m) msl at the base of MW-4D to 511 ft (155.8 m) msl at the top of MW-2D for the deep plateau wells and from 426 ft (129.8 m) msl at the base of MW-15 to 538 ft (164.0 m) msl at the top of PW-3 for the study area boundary wells.

Temporal trends of groundwater elevation data for the CJC aquifer are shown on Figure 2.4-65. Precipitation data for the NOAA Columbia Regional Airport station is shown on Figure 2.4-57 and surface water elevations at the stream and lake gauges are shown on Figure 2.4-66 and Figure 2.4-67. At the deep cluster wells, beneath the plateau, the groundwater elevations appear to respond to seasonal changes in precipitation, however, they vary only by approximately 1 ft (0.3 m) (similar to the wells screened in the Graydon Chert aquifer). The monitoring wells along the stream boundaries also respond to seasonal changes. In some cases, groundwater elevations vary by approximately 2 ft (0.6 m) (MW-13 and PW-3), but at other locations by up to 5 ft (1.5 m) (MW-14 through MW-16) and up to 10 ft to 15 ft (3.1 m to 4.6 m) (MW-17 and PW-2). The relatively larger variations in groundwater elevations along the stream boundaries probably reflect localized conditions of increased fracturing and enhanced interaction with the streams.

The lakes, where gauged to the north of the site, have a minimal response to seasonal changes; water levels varied up to 1 ft (0.3 m) over the one year of monitoring.

For Auxvasse Creek, at the gauge location SG-A1, the surface water elevation is nearly equal throughout the year. However, there was a response recorded to a large rain event that occurred in May. Surface water elevations at the remaining downstream locations are more responsive to seasonal changes with a range of approximately 10 ft (3.1 m) at SG-A2, 15 ft (4.6 m) at SG-A3, and 25 ft (7.6 m) at SG-A4 and SG-A5. Surface water along Mud and Logan Creek also vary considerably during the year, although the upstream locations are dry through the summer months. The largest change in surface water elevation of approximately 11 ft (3.4 m) occurs at the most downstream gauging location of Logan Creek (SG-L4). These large changes at the downstream locations of Auxvasse and Logan Creek are the result of the deeper channels, flatter terrain, and influence from the Missouri River.

Along Auxvasse Creek, there is water at all gauged locations throughout the year, although its flow is likely more influenced by the larger portion of its drainage area that is north of the study area boundary. Mud, Logan, and Logan Camp Branch (a minor tributary of Mud Creek) Creeks remain dry through the summer to early fall and in some cases until January. Estimated flow velocities and discharge were highest in January at most locations, which is the one round where water was flowing at all gauged locations due to an intense rain event. Estimated flow velocities and discharge were lowest in August at most locations; August was the round when there was only pooled water and no flow in Mud, Logan, and Logan Camp Branch Creeks.

The groundwater elevation data were used to develop potentiometric surface contour maps for the CJC aquifer on a seasonal basis with four rounds (May, August, and November of 2007 and January of 2008). These maps are presented on Figure 2.4-68 through Figure 2.4-71. Surface water elevations are shown but were not included in the contouring.

Generally, groundwater moves toward Auxvasse Creek and to some extent toward the Missouri River. The relatively high groundwater elevations at MW-17 and MW-16 (which are further downstream along Logan and Mud Creeks, respectively) relative to those at MW-14 and PW-2 (which are further upstream along Auxvasse Creek) demonstrate that the fracturing, weathering and erosion along Auxvasse Creek and its tributaries have a significant impact on the directional movement and subsequent drainage of groundwater. The relatively high groundwater elevation at PW-3 is located furthest from Auxvasse Creek and there are no major drainages to the east within 20 miles (32.2 km).

Deep groundwater elevations across the plateau are relatively similar. The general shape of the groundwater contours do not change much from one season to the next. However, in the spring the higher groundwater elevation at MW-17 (higher than MW-16) creates a stronger gradient toward Auxvasse Creek, whereas in August the lower groundwater elevation at the same location (lower than MW-16) creates a gradient more toward the Missouri River.

Groundwater elevations can be compared seasonally to surface water elevations at locations where there is a well and stream monitoring gauge together. For the May round, groundwater discharges to the streams at all locations except at MW-15, SG-A5, and SG-A4 (recall that SG-A4 and SG-A5 locations are influenced by the Missouri River demonstrated by large fluctuations in water elevations). For the August round, stream flow along Auxvasse Creek (other streams were dry) has the potential to recharge groundwater. Evidence of a spring was identified in August between SG-M1 and SG-M2 where water was flowing; it disappeared below the dry stream bed and no water was apparent further south down to the mouth of Mud Creek.

Horizontal hydraulic gradients were estimated for the CJC aquifer and results for the four seasonal rounds are shown on Table 2.4-52. Hydraulic gradients were estimated from upgradient and downgradient groundwater elevations of well pairs from the deep CJC wells at the periphery of the plateau toward CJC wells near the study area boundary.

Seasonally, the horizontal hydraulic gradients do not vary much. Generally, the gradients are steeper during the drier months of August and November, but this is not true in each case. The average horizontal hydraulic gradient ranges from 0.00060 to 0.00348. The mildest gradients are to the northwest (NW) and southwest (SW) while the steepest gradient is to the west (W) (from the plateau toward PW-2 along Auxvasse Creek). Downward vertical hydraulic gradients from the Graydon Chert aquifer to the CJC aquifer are presented and described in Section 2.4.12.3.1.1. Both horizontal and vertical groundwater flow will be evaluated in Section 2.4.12.3.3.

Groundwater quality was monitored at each well screened in the CJC aquifer and surface water quality was monitored at each stream gauge location. For groundwater, the pH ranges from 6.85 to 7.48 and is indicative of normal groundwater conditions (pH range 6 to 8.5). There is little difference between the wells beneath the plateau and those along the study boundary. The groundwater is considered to be fresh (salinity less than 1 ppt) and with TDS concentrations that are either slightly above or slightly below the 0.5 ppt indicator of acceptable aesthetic quality. DO concentrations are low with most values below 1 ppm. The ORP is slightly positive to negative, which indicates a slightly oxidizing to reducing environment. The temperature of the groundwater in the deep plateau wells ranges from 57.2° to 71.6° Fahrenheit (14° to 22° Celsius) as compared to the temperature of the groundwater along the study area boundary, which ranges from 57.2° to 64.4° Fahrenheit (14° to 18° Celsius). Stream temperatures, which range from 42.8° to 87.8° Fahrenheit (6° to 31° Celsius), are at times colder and warmer than the deep plateau and boundary area study wells, as would be expected, due to the streams contact with the atmosphere. Seasonally, water quality changes but not consistently from one well to the next.

For surface water in the streams, the pH ranges from 7.17 to 8.16; this is higher than the groundwater. The higher pH is attributable to a higher aeration of the surface water and contact with carbonate materials. The stream water is considered to be fresh (salinity less than 1 ppt) and with a TDS concentration that is in all cases below the 0.5 ppt indicator of acceptable aesthetic quality. Generally, DO concentrations are higher than the groundwater but with a relatively low range of approximately 2 ppm to 6 ppm. The ORP is positive for all streams, which indicates an oxidizing environment. The temperature of the streams is variable from one round to the next and is likely dependent on short-term rain events and weather patterns.

2.4.12.3.1.4 Missouri River Alluvial Aquifer

Based on the regional understanding of the Missouri River alluvial aquifer (summarized in Section 2.4.12.1.2), it was expected that groundwater elevations within the aquifer would mimic surface water elevations along the Missouri River and the lower reach of Auxvasse Creek. When a collector well system became a consideration for the water intake of Callaway Plant Unit 2, it was determined that a more thorough investigation of the aquifer would be required. A Phase I investigation included the monitoring wells and borings shown on Figure 2.4-49. A

Phase II investigation performed by Burns & McDonnell (Burns & McDonnell, 2008) included two large-scale pumping tests, which included additional installation of the test pumping wells and observation wells in the vicinity of the test wells.

For the Phase I work, the monitoring wells and borings were drilled to the top of the CJC Formation. Alluvial material was encountered in all wells and borings along the Missouri River (both north and south sides) to a depth of 91 ft to 104 ft (27.7 m to 31.7 m) bgs. At the upgradient borings and monitoring well (FSB-2, FSB-4, and FMW-5), the depth to bedrock varied (85 ft, 101 ft, and 50 ft (25.9 m, 30.8 m, and 15.2 m) bgs, respectively). This suggests that during glaciation, the bedrock surface was eroded irregularly along the edge of the original valley. Subsequent aggradation of the valley by the Missouri River has created a relatively flat floodplain surface that likely has been filled-in further over the last 100 years for agricultural purposes. Prior to those changes, the Auxvasse Creek likely had a deltaic transition that splayed into the Missouri River floodplain.

At FMW-1D, the borehole was drilled through a thin, fractured zone of a few feet into the CJC Formation to competent bedrock, and the well was set from 114 ft to 134 ft (34.7 m to 40.8 m) bgs. Based on the depth to bedrock and the depth to saturated groundwater, the thickness of the alluvial aquifer along the Missouri River is approximately 80 ft to 85 ft (129 m to 137 m) thick. However, the aquifer is expected to be thinner at locations further north of the current Missouri River channel, especially in the areas of FSB-2 (70 ft (21.3 m) thick) and FMW-5 (35 ft (10.7 m) thick).

Temporal trends of groundwater elevation data for the alluvial aquifer are shown on Figure 2.4-72. Precipitation data for the NOAA Columbia Regional Airport station is shown on Figure 2.4-57. Groundwater elevations fluctuated by approximately 2 ft to 3 ft (0.6 m to 0.8 m) from August through February. Two large-scale pumping tests were performed in mid-to-late November to investigate the feasibility of the collector well system that will be used for cooling water intake. Groundwater elevation trends indicate that the wells screened in the alluvial aquifer rebounded prior to the December round of water levels. However, the groundwater elevation at FMW-1D was still depressed during the December round but rebounded prior to the January round. Additional analysis will be provided in Section 2.4.12.3.3.

The groundwater elevation data was used to develop potentiometric surface contour maps for the Missouri River alluvial aquifer on a seasonal basis with three rounds (August and November of 2007 and January of 2008). These maps are presented on Figure 2.4-73 through Figure 2.4-75. The groundwater contours indicate that groundwater flows through the alluvial aquifer toward the Missouri River but with a downstream component as well. This is consistent with the regional contours shown at the top of Figure 2.4-47 where the groundwater contours indicate flow toward the river but with a downstream direction as well. The groundwater elevation at FMW-1D is slightly higher than at FMW-1S, which indicates a slightly upward vertical gradient and the potential for groundwater to discharge from the CJC aquifer to the alluvial aquifer.

Groundwater quality was monitored at each well. The pH for the 9 wells installed in the alluvial material along the Missouri River ranges from 6.92 to 7.10 and is indicative of normal groundwater conditions (pH range 6 to 8.5). At the bedrock well, the pH ranges from 7.37 to 7.40. The groundwater is considered to be fresh (salinity less than 1 ppt) and with a TDS concentration that is either slightly above or slightly below the 0.5 ppt indicator of acceptable aesthetic quality. The DO concentrations are low with most values below 1 ppm. The ORP is negative, which indicates a reducing environment. These parameters indicate that the water quality of the alluvial aquifer is similar to that of the CJC aquifer. The temperature in the alluvial aquifer is warmer than that in the CJC aquifer but colder than the surface water temperatures measured in the creeks.

2.4.12.3.2 Hydrogeologic Properties

Falling head slug tests were performed at all of the monitoring wells, except MW-11 and MW-1I due to their lack of water production and the dry well determination of MW-11. Two pumping tests were successfully completed at PW-2 and PW-3, which are screened in the CJC aquifer along the eastern and western boundaries of the study area. A step pumping-drawdown test was performed at PW-1, which is screened in the chert aquifer on the plateau, but the well went dry very quickly after pumping up to 1 gpm (3.75 lpm) for 7 minutes. It was determined that a pumping test would not yield viable results at PW-1 and that the chert does not recharge readily. Results of the large-scale pumping tests performed to support the collector well design are summarized in Section 2.4.12.3.3.

Results of the slug and pumping tests are presented in Table 2.4-53 and Table 2.4-54, respectively. The estimated hydraulic conductivity of the Graydon Chert aquifer ranges over four orders of magnitude from 7.05E-3 ft per day to 9.02 ft per day (2.49E-6 cm per sec to 3.18E-3 cm per sec). The estimated hydraulic conductivity of the CJC aquifer ranges over two orders of magnitude from 1.57E-1 ft per day to 3.09 ft per day (5.54E-5 cm per sec to 1.09E-3 cm per sec). The estimated transmissivity of the CJC aquifer averages 2.6 sq ft and 13.8 sq ft per day (sq ft per day) (2.79E-2 sq cm per sec and 1.49E-1 sq cm per sec) at PW-3 and PW-2, respectively. The estimates of transmissivity are based on the length of the screened interval and sand pack of each pumping well and not the entire aquifer. The storativity values average 1.58E-4 and 3.03E-4 at PW-3 and PW-2, respectively. The hydraulic conductivity of the alluvial aquifer along the shoreline could not be estimated from slug tests, because the wells responded too fast to obtain data. The estimated hydraulic conductivity of the upgradient well FMW-5 and the CJC bedrock well beneath the alluvium (FMW-1D) are 16.2 ft per day (5.72E-3 cm per sec) and 5.72E-2 ft per day (2.02E-5 cm per sec), respectively.

The pumping test results confirm that the CJC is a leaky, confined aquifer; the pumping test data followed the Theis Curve but delayed yield was observed as the test proceeded due to leakage from overlying alluvium or recharge from the streams (the tests were performed in the spring when water was flowing in the streams). The relatively low storativity value for the CJC aquifer is consistent with mildly fractured bedrock aquifers where the small size of fractures and lack of interconnectedness limits the amount of water in storage and the amount of water to potentially yield to a well. Given that the pumping of PW-1 was not viable, the attempted pumping test confirms its low-yielding characteristics.

Shelby-tube samples collected from the unconsolidated zone above or within the top of the Graydon Chert and from the vadose zone of the Missouri River alluvial aquifer were submitted for laboratory testing of moisture content (weight of water in the sample divided by the weight of dry solids), moist (wet) unit weight (weight of water and solids divided by the sample volume), specific gravity, total organic content, and vertical hydraulic conductivity. The moisture content, wet unit weight and specific gravity were utilized to estimate the void ratio and porosity of the sample material. These results are listed in Table 2.4-55. Additionally, grain-size analyses were performed for the Shelby tube samples collected above the chert and for separate, washed grab samples collected with depth from the alluvial aquifer. Results are shown in Table 2.4-56. A summary is as follows:

- Unconsolidated zone above and within top of Graydon Chert. The samples consisted of from 71.3% to 96.0% silt and clay; a few samples had approximately 20% fine sand. Moisture content ranges from 16% to 26%, organic content ranges from 1.3% to 2%, and estimated porosity ranges from 32% to 46%. Estimated vertical hydraulic conductivity ranges over four orders of magnitude from 1.2E-5 ft per day to 4.8E-3 ft per day (4.2E-9 cm per sec to 1.7E-6 cm per sec).

- Vadose zone of Missouri River alluvial aquifer. For three Shelby tube samples, the alluvial material consists of 80% to 90% silt and clay while for two Shelby tube samples at FMW-5 and FSB-13, the alluvial material consists of nearly 80% fine sand. This correlates to estimated vertical hydraulic conductivity values of 1.3E-4 ft per day to 2.5E-4 ft per day (4.6E-8 cm per sec to 8.7E-8 cm per sec) for the samples with high silt and clay content and 5.1E-1 ft per day to 6.0E-1 ft per day (1.8E-4 cm per sec to 2.1E-4 cm per sec) for the samples with high sand content.

- Grab samples from Missouri River alluvial aquifer. Although there is variation with depth and across the floodplain, the alluvial aquifer predominantly consists of coarse, medium, and fine-grained sand. There are some intervals at FSB-4 and FMW-1D that contain a higher percentage of coarser materials such as fine gravel and coarse sand in the lower portion of the aquifer. Field personnel noted a boulder field at these locations in the lower portion of the aquifer and air-hammered to fine, gravel-sized fragments. This was also observed in the lower portion across the river at FSB-13 and FSB-14.

Results from soil lab analyses of samples collected for the geotechnical investigation are presented in Section 2.5.

2.4.12.3.3 Ground Water Flow and Travel Time

The following sections present the most probable groundwater flow direction and travel time from the Callaway Plant Unit 2 power block area to nearby surface water features. Based on the evaluation summarized in the above sections, the Graydon Chert and CJC aquifers may be affected by construction and operation of the Callaway Plant Unit 2. Groundwater use associated with Callaway Plant Unit 2 operations is discussed in Section 2.4.12.2.2.7. Accidental release parameters and pathways for liquid effluents in groundwater and surface water are presented in Section 2.4.13.

The ground water seepage velocity is defined as distance over time and is calculated as follows:

Velocity = ((hydraulic gradient) x (hydraulic conductivity)) / (effective porosity)

The travel time is defined as rate of ground water movement for a set distance and is calculated as follows:

Travel Time = (distance) / (velocity)

2.4.12.3.3.1 Graydon Chert Aquifer, Aquitard, and CJC Aquifer

On the plateau, groundwater originates from precipitation recharge and enhanced recharge from shallow ponds. Groundwater flow from the Callaway Plant Unit 2 power block area will travel outward (horizontal) and downward (vertical) according to the gradients and hydraulic conductivities estimated in the previous sections. In reality, for a groundwater flow "particle" that originates in the power block area, the relationship between (relative magnitude of) the horizontal and vertical velocities will determine its flow path as it travels across the plateau, leaves the Graydon Chert aquifer, travels through the aquitard and underlying Cotter-Jefferson City aquifer until it reaches a point of discharge to a surface water drainage or stream.

If a three-dimensional model were developed and was calibrated to represent the three-dimensional flow field, then the travel time from the power block area to downgradient drainages or streams can be estimated. However, in this section, simplified calculations are performed. In many situations, it may be appropriate when vertical flow is considered to be negligible to estimate groundwater flow in the horizontal direction only. However, for the Callaway Site, the vertical flow component is significant and cannot be dismissed. The approach presented here is a simplified approach that, in spite of its limitations to evaluate the three-dimensional flow field, still honors both horizontal and vertical flow components.

First the horizontal and vertical flow velocities are estimated from the power block area outward and downward. At MW-18, near the center of the power block area, the Graydon Chert aquifer is 40 ft (12.2 m) thick. A groundwater particle is assumed to start at the top of the chert aquifer, travel outward and downward according to the estimated groundwater flow velocities. The travel time for the particle to leave the base of the chert aquifer is estimated. Based on this time estimate, the horizontal travel distance is estimated.

Second, it is assumed that once the groundwater particle moves into the aquitard that only downward, vertical flow occurs until the CJC aquifer is reached. The vertical groundwater flow velocity and the travel time through the aquitard (275 ft (83.8 m) thick at the MW-1D well cluster) are estimated.

Finally, horizontal flow velocities through the CJC aquifer from the deep wells along the periphery of the plateau toward CJC wells along stream boundaries are estimated. Travel times are estimated as well.

It is assumed that both horizontal and vertical flow occur in the Graydon Chert aquifer, vertical flow occurs through the aquitard and horizontal flow occurs through the CJC aquifer. There are several key conclusions from the field investigation and use of the aquifers and creeks that support why these assumptions are appropriate and conservative:

- Callaway Plant Unit 2 is located in the area of the topographic high of the plateau and the highest groundwater elevation was measured at the MW-18 well, which is located in the central portion of the power block area. Radially horizontal and vertically downward hydraulic gradients are both important.

- Drilling conditions and lithologic characteristics of the aquitard were similar in the center and around the periphery of the plateau, which indicates a uniform depositional and weathering history beneath the plateau. Downward vertical hydraulic gradients are relatively uniform in the center and around the periphery of the plateau, which indicates similar recharge rates and hydrogeologic properties of the units beneath the plateau.

- Site reconnaissance of the drainages around the periphery of the plateau indicated that these drainages remain dry except during and after rain events and snow-melt. There was no evidence to suggest that the shallow aquifer is providing significant discharge to these drainages. Given the downward vertical hydraulic gradients, it is likely that any groundwater discharge to a particular drainage is from an area that is fairly localized to the drainage.

- The shallow Graydon Chert aquifer is not used as a water supply; however, the deeper CJC aquifer is utilized by private well users in the area. The major creeks, such as Auxvasse, Mud, and Logan, are not utilized for a public or private drinking water supply, but private users could have incidental contact or use of these creeks. Therefore, the shortest travel time through the aquitard and into the CJC aquifer is estimated (vertical). Then from the CJC aquifer, the shortest travel time to the creeks is estimated (horizontal).

Because the estimates of vertical groundwater flow through the aquitard are performed through the center of the plateau and the estimates of groundwater flow through the CJC aquifer are performed from the periphery of the plateau to downgradient streams, the combined travel time estimates from the top of the aquitard to the downgradient streams are conservative.

Table 2.4-57 provides the data used to calculate groundwater flow velocities, the travel distances, and travel times associated with groundwater moving through the Graydon Chert aquifer, aquitard, and CJC aquifer. A summary of the data are as follows:

- The mean vertical or horizontal hydraulic gradient between well pairs for the May, August, November, and January rounds of water levels.
- The mean horizontal hydraulic conductivity for the Graydon Chert aquifer from slug test results.
- The mean vertical hydraulic conductivity from permeability testing of Shelby-tube samples.
- The mean horizontal hydraulic conductivity of the CJC aquifer from slug tests.
- The vertical hydraulic conductivity for the aquitard is assumed to be 10% of the mean from the Shelby tube samples, or 1.7E-5 feet/day (6.1E-9 cm/sec).
- Porosity of all materials was estimated as 5%. The chert is consolidated but has weathered intervals. The aquitard is expected to have relatively low porosity and any sustained flow is likely through fractures or weathered intervals. The CJC aquifer is expected to have relatively higher porosity (as compared to the aquitard), but again is subject to fracturing and weathering characteristics. It is believed that 5% is conservative. Increases in porosity will result in slower groundwater flow velocities and longer travel times.

Results indicate that the estimated horizontal groundwater flow velocities through the Graydon Chert aquifer from the Unit 2 power block area range from 0.0027 to 0.0094 feet/day (8.2E-4 to 2.9E-3 m/day), and the estimated vertical groundwater flow velocity is 0.0029 feet/day (8.3E-4 m/day). The maximum horizontal travel distance for a groundwater particle that originates in the power block area at MW-18 before it leaves the chert aquifer is 128.3 feet (39.1 m) and the travel time associated with this distance is 37.4 years. This means that groundwater does not move far in the Graydon Chert aquifer from the power block area.

The estimated vertical groundwater flow velocity through the aquitard is 0.00029 feet/day (8.8E-5 m/day), and the associated travel time is 2,573 years. The estimated horizontal groundwater flow velocity through the CJC aquifer ranges from 0.0093 to 0.0534 feet/day (2.8E-3 to 1.6E-2 m/day), and the minimum estimated travel time through the CJC aquifer for the evaluated well pairs is 408 years.

It should be emphasized that this analysis was performed for a groundwater particle that originates in the power block area, and is not representative of groundwater that originates around the periphery of the plateau or along the drainages that run from the periphery of the plateau.

2.4.12.3.3.2 Missouri River Alluvial Aquifer

Horizontal Collector Well Pumping Test Results and Design Yield

As stated previously in Section 2.4.12.3.1.4, two pumping tests were performed in the alluvial aquifer at locations very close to FMW-07 and FMW-11 to investigate whether the aquifer will support the operation of collector wells at a capacity to meet cooling water intake needs for Callaway Units 1 and 2. This effort included the installation of a 12-inch (0.31-m) diameter pumping well (TW-01 at the FMW-07 location and TW-02 at the FMW-11 location) and 9 observation wells at each test location (Burns & McDonnell, 2008a).

The materials identified in samples from the well boreholes were interpreted in the Burns & McDonnell report as follows. Generally, there is a coarsening-downward sequence of inter-bedded layers of fine to coarse sand. The upper 10 feet (3.05 m) of the formation is a mixture of silt, clay and sand, which transitions downward to fine-to-medium grained sand. From approximately 10 to 60 feet (3.05 to 18.29 m) bgs, the formation is primarily sand with some gravel. The lower 40 feet (12.19 m) of the formation is a poorly sorted mixture of sand and gravel with some cobbles. The report states that based on visual observations and geophysical logs, clay layers were not encountered in any test boring at depths greater than 30 feet (9.14 m) bgs. Bedrock underlying the sand and gravel consists of dolomite and was encountered at depths ranging from 95 to 99 feet (28.96 to 31.18 m) bgs. Groundwater elevations were measured prior to the start of pumping activities and averaged approximately 20 feet (6.10 m) bgs, and the saturated thickness of the aquifer is approximately 75 to 80 feet (22.86 to 24.38 m).

An observation well was to be installed into the dolomite beneath the alluvial aquifer at each test location. At the FMW-07 location, the bedrock section of the borehole was left as an open hole during the pumping test, and data from the borehole during the pumping test was inconclusive. Later, the well was completed in a similar manner as the bedrock well at the FMW-11 location; a 20-foot (6.10-m) well screen was installed from approximately 20 to 40 feet (6.10 to 12.19 m) below the top of the bedrock. Slug tests were performed on these wells. The estimated hydraulic conductivity of the bedrock wells was 0.13 ft/day (4.6E-5 cm/sec). This is similar to the value reported at FMW-1D of 0.06 ft/day (2.0E-5 cm/sec).

A step-drawdown test was performed prior to a 72-hour pumping test, and recovery was monitored for 24 hours. Constant pumping rates for TW-01 and TW-02 were 1,595 and 1,906 gpm (6,038 and 7,215 lpm), respectively. Drawdown at the pumping wells was not reported. At a monitoring location approximately 250 feet (76.2 m) inland (furthest from the pumping well), the drawdowns were approximately 1.6 and 1.8 feet (0.49 and 0.55 m), respectively. All pumping test activities took place from November 7 through 17, 2007. Results from the Burns & McDonnell (2008a) report are reproduced in the following table: .

Site	TW-01	TW-02
Transmissivity	450,000 gpd/ft	400,000 gpd/ft
Distance to Line Source of Recharge	1,000 feet	825 feet
Saturated Thickness	78 feet	77 feet
Hydraulic Conductivity	5,770 gpd/ft^2	5,195 gpd/ft^2
Storativity	0.179	0.208

The test results were considered to be favorable and test site TW-01 (at the FMW-07 location) has been chosen as the area where three collector well systems will be constructed with a planned collective yield of approximately 50,000 gpm (189,300 lpm). Recall from Section 2.4.12.2.7, that the anticipated average cooling water intake need for Units 1 and 2 are 16,000 gpm (60,800 lpm) and 24,160 gpm (91,446 lpm), respectively. The design yield for each collector well in million gallons per day (MGD) (million liters per day (MLD)) and gallons per minute (gpm) (liters per minute (lpm)) is as follows: .

	(MGD)	(gpm)	(MLD)	(lpm)
Average Summer	37	26,000	140	97,200
Test Conditions	32	22,000	121	84,000
Average Winter	25	17,000	95	65,700

The report states that the water supply from the collector wells could be 85% river water and 15% aquifer water during most of the year, except during winter months; with cold river water, it is expected that a larger percentage would come from the aquifer; however, no calculations in the report (Burns & McDonnell, 2008a) were provided.

Kansas City Board of Utilities (BPU) System and U.S. Geological Survey (USGS) Studies

Similar collector well systems are operational at other areas along the Missouri River, and one that is of comparable size is operated by the Kansas City Board of Public Utilities (BPU). Two horizontal collector wells in Kansas City were put into operation in early 2000 (HCW-1) and 2006 (HCW-2) to withdraw water from the Missouri River alluvial aquifer. These wells were each designed to supply at least 25 MGD (17,000 gpm) (113.6 MLD (79,000 lpm)), with design criteria selected for 30 MGD (20,800 gpm) (94.6 MLD (65,700 lpm)), (HydroGroup, 1993; Collector Wells International, 2006). These wells are located approximately 1000 feet (304.8 m) apart along the Missouri River where the depth to bedrock ranges from 140 to 150 feet (42.7 to 45.7 m) bgs, the saturated aquifer thickness is estimated to be 124 feet (37.8 m), and the estimated hydraulic conductivity was approximately 825 ft/day (251.5 m/day). The lowest recommended pumping level is approximately 86 feet (26.2 m) below grade or 70 feet (21.3 m) below the top of the aquifer. A quarterly monitoring report for data collected through May 2006 indicates (three months after the second well began operation):

- The highest observed combined rate from both wells was 37.1 MGD (140 MLD).
- The observed groundwater levels were drawn down to approximately 18 ft (5.5 m) at HCW-1 and 7 ft (2.1 m) at HCW-2 below the river level.
- Drawdown at a new monitoring well located approximately 1000 ft (305 m) upgradient of HCW-1 was approximately 7 feet (2.1 m) below the river level.
- The pumping of HCW-2 interfered with HCW-1, but this interference may not indicate a substantial loss in well efficiency.

The U.S. Geological Survey (USGS, 1996) studied and modeled contributing recharge areas of the alluvial aquifer across a study area that included many well fields in the Kansas City area. Transient groundwater flow and particle tracking results indicate that contributing recharge areas extend up-valley, but are smaller and skewed toward the river when the wells are in close proximity to the river. Calibrated horizontal hydraulic conductivities varied widely, but typical values of areas that have similar alluvial sand thickness and characteristics as those cited in the Burns & McDonnell (2008a) report ranged from 328 to 1,640 ft/day (100 to 500 m/day). Sensitivity analyses indicated that the model results were most sensitive to changes in hydraulic conductivity (increases and decreases from the calibrated values) and less sensitive to increases in vertical conductance of the riverbed.

Information and analyses from the comparable system in Kansas City and the USGS modeling study help to provide context for the Burns & McDonnell pumping test results at the Callaway location. Several conclusions can be inferred:

- The estimates of transmissivity and hydraulic conductivity of the Burns & McDonnell test results are similar to the BPU location and are within the range estimated at a comparable area of the USGS modeling study.
- The saturated thickness of the alluvial aquifer at the Callaway location is approximately 45 feet (13.7 m) less than at the BPU location. However, drawdown at the BPU HCW-1 well is only 20 feet (6.1 m) of the approximate 125 feet (38.1 m) of saturated aquifer.
- Based on the observed interference of the two collector wells at the BPU location, there may be interference between the three collector wells at the Callaway location. The BPU wells are approximately 1,000 feet (305 m) apart while the planned distance between collector wells at the Callaway location is approximately 1,500 feet (457 m).
- Based on the current Callaway modeling results, it is anticipated that the contributing recharge area for the Callaway collector wells will extend inland across the floodplain and potentially beneath the Missouri River. These modeling results are similar to the USGS modeling results and BPU monitoring conducted for the BPU well field.

Groundwater Modeling and Assessment of Potential Impact

Based on the analyses presented in 2.4.12.3, there is a hydraulic connection between groundwater in the CJC aquifer, the alluvial aquifer, and the surface water bodies, especially the Missouri River and Auxvasse Creek. Therefore, it was determined that groundwater modeling should be performed to evaluate the anticipated drawdown and contributing recharge areas in the alluvial and CJC aquifers. Also, evaluations are needed to assess potential impact to well users upgradient from the alluvial aquifer and also to assess the capability and impact of the collector well system during a hypothetical 100-year drought condition.

First, a three-dimensional steady-state groundwater flow model was developed across the entire study area shown on Figure 2.4-49. The model includes layers for the Quarternary and glacial material on the plateau, the Graydon Chert aquifer, the aquitard, the CJC aquifer, miscellaneous alluvium along stream valleys, and the Missouri River alluvial aquifer. The model was calibrated to simulate average groundwater elevations, which were estimated from data measured from March 2007 through January 2008. The calibrated model is continuous across the study area, such that the transition from the glacial valley wall to the floodplain is simulated.

Once the model was calibrated, the three collector wells were added to the alluvial aquifer and a simulation was performed with the collector wells pumping at projected pumping rates of 18,000 gpm (68,130 lpm) each. This simulation is termed the baseline simulation. Next, a sensitivity analysis was performed by varying hydraulic conductivity and riverbed conductance, one parameter at a time. For assessment of the 100-year drought condition, surface water boundary conditions were lowered (as discussed below). For each simulation, a parameter or condition was changed, the model was run without the wells pumping, the model-predicted steady-state hydraulic heads were saved back into the model as starting heads, and the model was then run with the wells pumping. This allowed for an evaluation of how each change in parameter values affected drawdown, both in magnitude and areal extent as compared to the baseline simulation. It should be noted that none of the simulations had an impact to areas very far upgradient of the glacial valley wall and therefore, there was no impact to other upstream areas or upper layers of the model. Therefore, the following discussion of the model inputs and subsequent results are presented with a focus on the floodplain area.

The floodplain area of the model was developed with ground surface elevations and bedrock elevations estimated from boring logs. Hydraulic conductivity of the alluvial aquifer was set to 750 ft/day (228.6 m/day), based on estimates from the Burns & McDonnell pumping tests. Horizontal hydraulic conductivity of the CJC aquifer beneath the alluvial aquifer was set to 0.06 ft/day (2.1E-5 cm/sec) based on slug test results. Vertical hydraulic conductivity of the CJC aquifer was calibrated as 0.0012 ft/day (4.5E-3 cm/sec). The Missouri River bed hydraulic conductivity was set to 250 ft/day (76.2 m/day).

For the average groundwater elevation condition, the Missouri River elevations varied from 507 feet (154.5 m) msl at the upstream end of the model to 503 feet (153.3 m) msl at the downstream end of the model. For the 100-year drought, the Missouri River elevations varied from 499 feet (152.1 m) msl at the upstream end of the model to 495 feet (150.9 m) msl at the downstream end of the model. A river surface elevation of 496 feet (151.2 m) msl corresponds to a river flow rate of 9000 cfs (255 cms) that the U.S. Army Corps of Engineers (USACE) will provide (assuming no tributary input) and projections for the winter with ice jam condition at the Callaway surface water intake. A flow rate of less than 9,000 cfs (255 cms) is considered to have a probability of 10% (Burns & McDonnell, 2007). The 495 feet (150.88 m) msl was estimated to be the lowest probable river elevation by performing a linear regression using the median, lower quartile, and lower decile values of 499, 497, and 496 feet (152.1, 151.5, and 151.2 m) msl, respectively, and projecting the regression line to 1%.

Figure 2.4-87 and Figure 2.4-88 show the baseline calibrated groundwater elevations for the non-pumping conditions. Model-predicted drawdown in the alluvial and CJC aquifers during pumping conditions are presented in Figure 2.4-88 and Figure 2.4-89, respectively. The following list summarizes the model simulations and their generalized result. Drawdown was contoured at 2-foot (0.61 m) intervals; only significant changes are reported:

- When the river bed conductivity was increased to 500 feet/day (152.4 m/day) or decreased to 125 feet/day (38.1 m/day), there was no significant change in the drawdown at the pumping wells or the drawdown and contributing recharge area across the alluvial or CJC aquifers.

- When the alluvial aquifer conductivity was increased to 900 feet/day (274 m/day), drawdown at the pumping wells decreased by approximately 2 feet (0.61 m) and there was no significant change in the drawdown in the CJC beneath the pumping wells. The contributing recharge area was broader in the alluvial aquifer and smaller in the CJC aquifer. When the alluvial aquifer conductivity was decreased to 600 feet/day (183 m/day), drawdown did not change significantly in the alluvial aquifer but increased in the bedrock beneath the pumping wells by approximately 2 feet (0.61 m).

- When the CJC aquifer horizontal conductivity was increased to 0.1 feet/day (3.5E-5 cm/sec), there was no significant change. When the CJC horizontal conductivity was decreased to 0.01 feet/day (3.5E-6 cm/sec), the drawdown in the CJC aquifer beneath the pumping wells increased by approximately 4 feet/day (1.22 m/day) and the contributing recharge area increased slightly in size.

- When the hydraulic conductivity of the alluvial aquifer outside of Binggeli Island area was decreased to 250 feet/day (76.2 m/day) or 100 feet/day (30.5 m/day), there was no significant change in the drawdown at the pumping wells or in the CJC aquifer beneath the pumping wells. The contributing recharge areas extended slightly wider across the floodplain but did not extend as far to the valley wall.

- When the river level was decreased to 495 feet (150.9 m) msl (i.e., the 100-year drought condition), there was no significant change in the drawdown near the pumping wells, but the drawdown in the CJC aquifer beneath the pumping wells increased by approximately 2 feet (0.061 m/day). There was no significant change in the contributing recharge areas.

In summary, the model simulations suggest that the groundwater capacity required for Callaway Units 1 and 2 can be met by the proposed collector well system (3 collector wells pumping 50,000 gpm (189,300 lpm)) within the parameter constraints reported from the pumping test results by Burns & McDonnell (2008a). The model simulations suggest that the potential impact to the alluvial and CJC aquifers is minimal. The simulated drawdown and contributing recharge areas of the alluvial aquifer at the Callaway location are similar to the observed drawdown at the BPU well field and estimated contributing recharge areas from the USGS study. There is no anticipated impact to groundwater well users that have been identified in Section 2.4.12.2.

2.4.12.4 Monitoring or Safeguard Requirements

Groundwater monitoring (water level observation) of the Callaway Plant Unit 2 area is currently being implemented through the use of the groundwater monitoring wells wells installed in 2007 for the Callaway Plant Unit 2 site subsurface investigation and through the periodic review of water levels from selected wells in central Missouri that are monitored by the MDNR Groundwater Monitoring Network.

With respect to groundwater monitoring, the existing site Radiological Environmental Monitoring Program (REMP) for Unit 1 (AmerenUE, 2006b; AmerenUE, 2007e) and NRC regulations contain no explicit requirements to routinely monitor groundwater on-site near plant facilities. By design, liquid effluents are not released to groundwater or structures that discharge to groundwater, and as such, there is no expected or intended human exposure pathway associated with groundwater for Callaway Plant Unit 2. However, recent nuclear industry initiatives by the Nuclear Energy Institute, the Electric Power Research Institute and NRC assessments (NRC, 2006) of existing nuclear reactors indicate that guidance documents covering the implementation of NRC regulation 10 CFR 20.1406 (NRC, 2007) relating to groundwater monitoring for both operating and future nuclear reactors is being developed. Groundwater monitoring near plant facilities will provide an early indication if unexpected releases through system leaks or failures have occurred and are impacting the environment beyond expected pathways. Development of these guidance documents concerning groundwater protection is being followed and future requirements will be addressed, as applicable, for inclusion in the Callaway Plant Unit 2 REMP (UniStar, 2007).

Safeguards will be used to minimize the potential of adverse impacts to the groundwater by construction and operation of Callaway Plant Unit 2. These safeguards would include the use of lined containment structures around storage tanks (where appropriate), hazardous materials storage areas, emergency cleanup procedures to capture and remove surface contaminants, and other measures deemed necessary to prevent or minimize adverse impacts to groundwater beneath the Callaway Plant Unit 2 site. No groundwater wells are planned for safety-related purposes.

2.4.12.5 Site Characteristics for Subsurface Hydrostatic Loading and Dewatering

Groundwater conditions relative to the foundation stability of safety-related facilities and plans for the analysis of seepage and piping conditions during construction are discussed in Section 2.5.4.6.

A summary of the groundwater conditions is provided for assessment of hydrostatic loading and de-watering requirements. Across the plateau, the Graydon Chert Formation is considered to be the shallow aquifer. There are localized areas where the overlying material may be included in this aquifer, but on the whole it was found that saturated groundwater is confined within the chert. During the Callaway Plant Unit 2 field investigation, field personnel identified the chert as a moderate water-bearing unit, with the glacial till acting as the confining unit above the chert and the Burlington Limestone acting as the confining unit and top of the aquitard beneath the chert. The Graydon Chert lies unconformably atop the Burlington Limestone and unconformably below the glacial till so its elevation and thickness vary. Across the plateau, the depth of the Graydon Chert ranges from 15 to 39 feet (4.6-11.9 meters (m)) below ground surface (bgs) and averages approximately 27 feet (8.2 m) bgs. Its thickness ranges from 16 to 61 feet (4.9-18.6 m) and averages approximately 38 feet (11.6 m). At the centrally located MW-18 well (beneath the proposed power block area), the depth to the Graydon Chert is 30 feet (9.1 m) bgs and its thickness is 40 feet (12.2 m). The corresponding elevations of the top and bottom of the chert at this location are 810 feet (246.9 m) and 770 feet (234.7 m), respectively.

Due to confined groundwater conditions in the Graydon Chert aquifer, groundwater elevations measured in the monitoring wells rise above the top of the chert to within approximately 7 to 15 feet (2.1-4.6 m) of the ground surface in the central portion of the plateau. Within the power block area at MW-18, the maximum measured groundwater elevation was 832.21 feet (253.66 m) msl. Overall, groundwater elevations did not vary much through the year, typically by less than 1 to 2 feet (0.3-0.6 m) across the central part of the plateau and several feet at the shallow wells around the perimeter of the plateau.

Beneath the shallow aquifer, there is a leaky, confining aquitard. The depth to the top of the aquitard averages 68 feet bgs (20.7 m) across the plateau, and its thickness is approximately 290 feet (88 m) in the central portion of the plateau. Beneath the aquitard is the Cotter-Jefferson City (CJC) aquifer. The depth to the CJC aquifer is approximately 350 feet bgs (107 m) in the central portion of the plateau. Based on the well logs for the three AmerenUE industrial wells, the thickness of the CJC aquifer beneath the plateau is approximately 300 feet (92 m). Regionally, the CJC aquifer is considered to be a minor aquifer and represents the top of the Cambrian-Ordovician aquifer system, which consists of intervals of minor aquifers and major aquifers with intermittent aquitards to depths up to 2,000 feet (610 m) bgs. Groundwater levels for the deeper CJC wells beneath the plateau are also confined such that measured groundwater levels rise approximately 50 feet (15.2 m) above the top of the CJC aquifer to an approximate elevation of between 550 and 560 feet (168-171 m) mean sea level. Although groundwater elevations appear to respond to seasonal changes in precipitation, they vary only by approximately 1 foot (0.3 m).

From the Callaway Plant Unit 1 investigation, it was estimated that the well yield for the chert aquifer is less than 1 gallon per minute (gpm) (3.8 liters per minute (lpm)) and for the CJC aquifer is approximately 5 to 10 gpm (19-38 lpm). Drilling observations and pumping test results for the Callaway Plant Unit 2 investigation confirm these estimates. Two pumping tests were performed successfully in the CJC aquifer, and the relatively low estimates of storativity are consistent with mildly fractured bedrock aquifers where the small size of fractures and low degree of interconnectedness limits the amount of water in storage and the amount of water to potentially yield to a well. A step-drawdown test at a pumping well in the chert aquifer resulted in a dry well after a short period of time, which made the pumping test unviable.

The completed nominal surface grade for the Callaway Plant Unit 2 nuclear island will be 845 feet (257.6 m) msl. The bottom of the nuclear island building foundations will range from 36 to 46 feet (11.0 to 14.0 m) bgs or 809 to 799 feet (246.6 to 243.5 m) msl. The Essential Services Water (ESW) cooling towers and emergency diesel generators will have a nominal surface grade between 843 to 845 feet (257.0 to 257.6 m) msl. The proposed entry elevation of the safety structures is 6 inches to 1 foot (0.152 to 0.305 m) above nominal grade. The existing ground surface elevation at MW-18 in the area of the nuclear island is approximately 840 feet msl. The maximum design depth for construction activities is currently estimated to be 1 foot (0.3 m) beneath the foundation depths, however there could be some trenching or minor excavation up to 5 feet (1.5 m) beneath the bottom of building foundations.

Temporary dewatering will be required for groundwater management during excavation and construction of Callaway Plant Unit 2 foundations. During the Callaway Plant Unit 1 construction, the low yield of the glacial and postglacial soil deposits and older sediments allowed minimal seepage into excavations during construction. The maximum depth of excavations for Unit 1 was below the base of glacial till, extending approximately 15 feet (4.6 m) into the Graydon Chert conglomerate. Although the highest water table in the site area was about 10 to 15 feet (3.0-4.6 m) above the top of the chert conglomerate, neither the postglacial and glacial soils nor the chert conglomerate layer required dewatering (AmerenUE, 2003).

Observations of the groundwater conditions during construction did not reveal any seepage into the excavations through the cohesive materials. Isolated saturated silt lenses at the bottom of the loess and sand lenses in the glacial till did yield seepage when exposed by excavations, but the small seepage did not hinder construction or affect construction quality. Sump pumps located in the excavations were adequate to remove seepage and any runoff occurring after periods of rainfall (AmerenUE, 2003).

Current groundwater conditions are similar to those presented in the Unit 1 FSAR, so it is anticipated that seepage and subsequent control of seepage for Unit 2 construction will be similar to that encountered during Unit 1 construction. Groundwater associated with seepage into the excavations will be controlled through site grading and sump pumps. Water will be diverted to on-site stormwater and sediment control ponds that were constructed for Unit 1 construction purposes.

Temporary dewatering is required for the excavation of the ESW Emergency Makeup System Pump house and the UHS Retention Pond. During the Callaway Plant Unit 1 construction, the completed UHS Retention Pond was constructed above the Graydon Chert unit. Due to the low permeability of the glacial and postglacial materials, it was considered unnecessary to seal the pond side slopes and bottom with an impervious material. The pond side slopes and bottom were inspected during construction. Any sand or silt lenses encountered were removed and replaced with Category I Cohesive Fill. For Unit 2 construction, de-watering and stability control such as a sheetpile cofferdam or equivalent will be designed to aid with the dewatering needs; however, some level of groundwater control is still required to maintain a relatively dry excavation during construction. At a minimum, sumps will be installed to control and/or lower the groundwater level inside the excavation. A construction dewatering specification will be developed to support construction excavations on site.

Disruption of the current Graydon Chert aquifer recharge and discharge areas by plant construction is not a concern. The Graydon Chert aquifer is isolated on the plateau and is not used for public or private well use. The construction area is relatively flat and clear of vegetated areas. Runoff is currently directed toward stormwater and sediment control ponds and during construction, runoff and water from dewatering of excavations will be directed toward these ponds and two additionally planned retention ponds. Due to low-permeability soils, groundwater recharge is minimal, and construction activities are not expected to significantly alter groundwater recharge or discharge. Any locally lowered Graydon Chert aquifer water levels would be expected to eventually recover after the dewatering and other subsurface construction activities are completed.

The U.S. EPR FSAR (Areva, 2007) requires that the maximum post-construction groundwater elevation to be at least 3.3 feet (1.0 m) below grade for the nuclear island. Based on the final grade of the nuclear island (845 feet msl), groundwater for the existing conditions is well below grade at 810 feet (246.9 m) msl for the saturated chert with hydraulic head of approximately 832 feet (253.6 m) msl.

The constructed configuration of Callaway Plant Unit 2 is not expected to greatly alter the Graydon Chert aquifer. However, a groundwater flow model was utilized to evaluate the potential impact of reduced recharge due to the presence of structures and controlled run-off from the power-block area toward the stormwater and sediment control ponds. This analysis allows for the projection of post-construction groundwater levels below the nuclear island. By reducing recharge from 3 inches/year (7.6 cm/year) to 2 inches/year (5.1 cm/year) across the Unit 2 area of construction and structures, groundwater elevations are projected to decline by less than 1 foot (0.3 m). Assuming that the highest measured groundwater elevation is 832 feet (253.6 m) msl, the altered maximum groundwater elevation is projected nearer to 831 feet (253.3 m) msl. However, to be conservative, the highest measured groundwater elevation is utilized to estimate a maximum of approximately 33 feet (10.0 m) of groundwater induced hydrostatic head loadings (799 to 809 feet (243.5 to 246.6 m) msl is the range of foundation depth elevations of safety-related structures) as the design basis for the subsurface portions of all safety-related structures.

A permanent groundwater dewatering system will not be needed for the Callaway Plant Unit 2 facility. Groundwater elevations will continue to be monitored, and any observed deviations in groundwater elevations potentially impacting the current design bases will be accounted for to design a construction dewatering system, if necessary.

2.4.12.6 References

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2.4.13 PATHWAYS OF LIQUID EFFLUENTS IN GROUND AND SURFACE WATERS

The U.S. EPR FSAR includes the following COL Item in Section 2.4.13:

> A COL Applicant that references the U.S. EPR design certification will provide site-specific information on the ability of the ground water and surface water environment to delay, disperse, dilute or concentrate accidental radioactive liquid effluent releases, regarding the

effects that such releases might have on existing and known future uses of ground water and surface water resources.

This COL Item is addressed as follows:

Sections 2.4.13.1 through 2.4.13.3 are added as a supplement to the U.S. EPR FSAR.

2.4.13.1 Ground Water

This section provides a conservative analysis of a postulated, accidental liquid release of effluents to the ground water associated with the operation of {Callaway Plant Unit 2}. The accident scenario is described, and the conceptual model used to evaluate radionuclide transport is presented, along with potential pathways of contamination to water users. The radionuclide concentrations that a water user might be exposed to are compared against the regulatory limits.

2.4.13.1.1 Accident Scenario

This section describes the ability of ground water and surface water systems to delay, disperse, or dilute a liquid effluent if accidentally released from the site. The U.S. EPR General Arrangement Drawings were reviewed to determine which component in each of the main areas of the nuclear island outside the reactor building could contain the maximum radionuclide concentration/volume. This review also determined that the proposed design includes no buildings, facilities, or tanks containing radionuclides outside of the nuclear island. Components were evaluated based on their respective volumes and whether they could contain reactor coolant activity. Except for the Reactor Building, there is no secondary containment in the nuclear island compartments/buildings. The tanks and components that are designed to contain or process radioactive liquids are within the nuclear island. These components include:

- Reactor Coolant Storage Tanks (total of six, each 4,061 ft^3 (115 m^3)) in the Nuclear Auxiliary Building
- Liquid Waste Storage Tanks (total of five, each approximately 495 ft^3 (14.0 m^3)) in the Radioactive Waste Building
- Volume Control Tank (350 ft^3 (9.9 m^3)) in the Fuel Building
- LHSI Heat Exchanger (total of four, each 33 ft^3 (0.93 m^3)) in the Safeguards Building

As defined by NUREG-0800, Standard Review Plan 2.4.13 (NRC, 2007a), the source term is determined from a postulated release from a single tank or pipe rupture outside of the containment. The postulated source of the liquid effluent would be a tank rupture in a Reactor Coolant Storage Tank in the Nuclear Auxiliary Building, because these tanks contain the largest volume of reactor coolant water. An instantaneous release from a tank would discharge the contents faster than from a pipe rupture that is connected to the tank and based on the piping configuration discharge more contents to the environment. The piping configuration may cause more contents to be held up in the tank by the nozzle locations and pipe routing than a tank failure. Therefore, modeling a tank failure will result in a more conservative analysis.

The inventory of radionuclides in reactor coolant water, and their analyzed activities in the Reactor Coolant Storage Tanks are shown on Table 2.4-58 (half-life values provided are consistent with values provided in references NRC, 1992 and ICRP, 1983). The reactor coolant activity levels represent the maximum activity levels without radioactive decay based on a 0.25% defective fuel rate, as shown on Table 2.4-58. Reactor coolant activity level values used in this evaluation represent the maximum (most conservative) value observed in two reactor coolant analyses. The 0.25% defective fuel rate was selected to be consistent with the fuel failure rate prescribed by the U.S. EPR FSAR. This fuel failure rate is two times the failure rate prescribed by Branch Technical Position 11-6 (0.12%) (NRC, 2007b) and provides a conservative bounding estimate of the radionuclide inventory and associated activity levels in the postulated release.

2.4.13.1.2 Ground Water Pathway

The ground water pathway evaluation includes the components of advection, decay, and retardation. The advective component is discussed in Section 2.4.12.3. A radionuclide assumed to be undergoing purely advective transport travels at the same velocity as ground water. This approach is conservative because advective flow does not account for hydrodynamic dispersion, which would normally dilute radionuclide concentrations in ground water through the processes of molecular diffusion and mechanical dispersion. For conservatism, the effects of hydrodynamic dispersion were not considered.

Radionuclides in ground water flow systems are subject to radioactive decay, the rate of which depends on the half-life of the radionuclide. Table 2.4-58 includes the half-lives of the radionuclides of concern.

Retardation considers chemical interactions between dissolved constituents in the ground water and the aquifer matrix. Contaminants that react with the aquifer matrix are retarded relative to the ground water velocity. Reactions with the aquifer matrix include cation/anion exchange, complexation, oxidation-reduction reactions, and surface sorption.

2.4.13.1.3 Conceptual Model

This section describes the conceptual model used to evaluate an accidental release of liquid effluent to ground water, or to surface water via the ground water pathway. The conceptual model of the site ground water system is based on information presented in Section 2.4.12. The key elements and assumptions embodied in the conceptual model are described below.

As previously indicated, a Reactor Coolant Storage Tank with a capacity of 4,061 ft^3 (115 m^3) is assumed to be the source of the release. The tank is located within the Nuclear Auxiliary Building, which has a building slab top depth of approximately {31.5 feet (9.60 m) below grade, at an elevation of approximately 813.5 feet (248.0 m) above mean sea level (msl); the final surface grade has been established as 845 feet msl (257.6 m)}. The Reactor Coolant Storage Tank is postulated to rupture, and 80% of its liquid volume (3,248.8 ft^3 (92.0 m^3)) is assumed to be released in accordance with Branch Technical Position 11-6 (NRC, 2007b). Flow from the tank rupture is postulated to flood the building and migrate past the building containment structure and sump collection system and enter the subsurface at the top of the building slab at an elevation of approximately {813.5 feet (248.0 m) msl}. Since this elevation is approximately {3.5 feet (1.1 m) above the top of the primary water bearing unit of concern (Graydon Chert aquifer) and there is a downward hydraulic gradient}, vertical downward flow ensues. A pathway is created that would allow the entire 3,248.8 ft^3 (92.0 m^3) to enter the ground water system instantaneously. This assumption is very conservative because it requires failure of the containment systems and sump pumps and it ignores the travel time required for the vertical migration through the {glacial till or post-construction back-fill above the Graydon Chert}.

{With the postulated instantaneous release of the contents of the Reactor Coolant Storage Tank, radionuclides would enter the Graydon Chert aquifer, which has an approximate thickness of 40 feet (12.2 m) from 770 to 810 feet (234.7 to 246.9 m) msl at the MW-18 monitoring well location in the area of the Unit 2 Nuclear Auxiliary Building. From the Nuclear Auxiliary Building release point, groundwater in the Graydon Chert aquifer flows radially outward and downward through the Graydon Chert into the underlying aquitard, flows vertically downward through the aquitard and enters the CJC aquifer, and then flows west toward Auxvasse Creek and southwest toward Mud Creek (refer to Figure 2.4-92). Analyses of the flow directions, hydraulic gradients, and groundwater flow velocities are provided in Section 2.4.12.3. In Section 2.4.12.3, travel times were estimated for 1) a groundwater particle starting at the top of the Graydon Chert aquifer in the power block area traveling horizontally outward and vertically downward and entering the aquitard; 2) a groundwater particle traveling vertically downward through the aquitard in the center of the plateau; and 3) a groundwater particle traveling from the periphery of the plateau to a potential discharge location along Auxvasse Creek or along Mud Creek. Several radial directions of flow were considered both in the Graydon Chert aquifer and in the CJC aquifer. The resulting travel times are shown on Table 2.4-57 and are summarized as follows:

- The estimated travel time for a groundwater particle at the top of the Graydon Chert in the power block area to flow outward and downward and to enter the aquitard is 37.4 years (13,651 days).
- The estimated travel time for a groundwater particle to travel downward through the aquitard and enter the CJC aquifer beneath the plateau is 2573 years (939,145 days).
- The estimated travel time for a groundwater particle to flow through the CJC aquifer from the western periphery of the plateau to the PW-2 well location along Auxvasse Creek was 579 years (211,335 days). The estimated travel time for a groundwater particle to flow through the CJC aquifer from the southern periphery of the plateau to the MW-16 well location along Mud Creek is 408 years (148,920 days). These were the shortest two travel times estimated for potential groundwater discharge to local streams.

In this section, the postulated accidental release scenario assumes the release immediately enters the Graydon Chert aquifer and travels along a flow path that leaves the Graydon Chert aquifer, flows vertically downward through the aquitard to the CJC aquifer, and then remains in this aquifer as it flows toward the projected discharge locations (both the Auxvasse Creek at the PW-2 well location and Mud Creek at the MW-16 well location are considered). Groundwater has the potential to discharge at these locations and would enter the creeks and flow toward the Missouri River. Refer to Figure 2.4-68 through Figure 2.4-71 for potentiometric surface contours of the seasonal groundwater flow through the CJC aquifer and groundwater discharge to surface water drainages. The PW-2 well location is paired with the surface water monitoring location SG-A3 along Auxvasse Creek. The MW-16 well location is located between the surface monitoring locations SG-M1 and SG-M2 located along Mud Creek.

Groundwater users have been identified in Section 2.4.12.2. Some of these users have wells that draw water from the CJC aquifer, so it is important to characterize potential radionuclide concentrations that leave the aquitard and enter this aquifer. Surface water users have been identified in Section 2.4.1.2. These users draw water from the Missouri River. Specific users of the Auxvasse and Mud Creeks have not been identified. However, radionuclide concentrations predicted for Auxvasse and Mud Creeks will be further diluted as the flow enters the Missouri

River, and therefore, the predicted concentrations are conservative with regard to surface water users on the Missouri River. Surface water release points are described in Section 11.2.3.}

2.4.13.1.4 Analysis of Accidental Releases to Ground Water

The analysis of accidental release of liquid effluents to ground water was accomplished in two steps. The first step was to screen the listing of source term radionuclides in Table 2.4-58, assuming only advective transport and radioactive decay. Radioactive decay data were taken from Table E.1 of NUREG/CR-5512, Vol. 1 (NRC, 1992). Radioactive decay data for some of the shorter-lived radionuclides were taken from International Commission on Radiological Protection (ICRP) Publication 38 (ICRP, 1983). This step allows the screening out of radionuclides that decay to activities below a level of concern before reaching the discharge {points identified at Auxvasse Creek and Mud Creek}. Those radionuclides that remain above activity levels of concern are evaluated considering the added effect of retardation. This analysis accounts for the parent radionuclides expected to be present in the Reactor Coolant Storage Tank plus progeny radionuclides that would be generated during subsequent ground water transport. The analysis considered all progeny in the decay chain sequences that are important for dosimetric purposes. ICRP Publication 38 (ICRP, 1983) was used to identify the progeny for which the decay chain sequences can be truncated. For several of the radionuclides expected to be present in the Reactor Coolant Storage Tank, consideration of up to three members of the decay chain was required. The derivation of the equations governing the transport of the parent and progeny radionuclides follows.

One-dimensional radionuclide transport along a ground water pathway is governed by the advection-dispersion-reaction equation (Javandel, 1984), which is given as:

$$R\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - v\frac{\partial C}{\partial x} - \lambda RC \qquad \text{(Eq. 2.4.13-1)}$$

where:

C = radionuclide concentration
R = retardation factor
D = coefficient of longitudinal hydrodynamic dispersion
n = average linear ground water velocity
λ = radioactive decay constant
t = ground water travel time
x = travel distance

The retardation factor is determined from (Equation 6 of Javendal et al., 1984):

$$R = 1 + \frac{\rho_b K_d}{n_e} \qquad \text{(Eq. 2.4.13-2)}$$

where:

ρ_b = bulk density (g/cm^3)

K_d = distribution coefficient (cm^3/g or mL/g)

n_e = effective porosity (unitless)

The average linear ground water velocity (v) is determined using Darcy's law:

$$v = -\frac{K}{n_e}\frac{dh}{dx} \qquad \text{(Eq. 2.4.13-3)}$$

where:

K = hydraulic conductivity

dh/dx = hydraulic gradient

n_e as previously defined

The radioactive decay constant (λ) can be written as:

$$\lambda = \frac{\ln 2}{t_{1/2}} \qquad \text{(Eq. 2.4.13-4)}$$

where:

$t_{1/2}$ = radionuclide half-life

A method of characteristics approach can be used on Equation 2.4.13-1 to determine the material derivative of concentration:

$$\frac{dC}{dt} = \frac{\partial C}{\partial t} + \frac{dx}{dt}\frac{\partial C}{\partial x} \qquad \text{(Eq. 2.4.13-5)}$$

Conservatively neglecting the coefficient of longitudinal hydrodynamic dispersion, the characteristic equations for Equation 2.4.13-1 can be expressed as follows:

$$\frac{dC}{dt} = -\lambda C \qquad \text{(Eq. 2.4.13-6)}$$

$$\frac{dx}{dt} = \frac{v}{R} \qquad \text{(Eq. 2.4.13-7)}$$

The solutions of the system of equations comprising Equations 2.4.13-6 and 2.4.13-7 can be obtained by integration to yield the characteristic curves of Equation 2.4.13-1. For transport of a parent radionuclide, the equations representing the characteristic curves are:

$$C_{P1} = C_{P0}\exp(-\lambda_1 t) \qquad \text{(Eq. 2.4.13-8)}$$

$$t = R_1\frac{L}{v} \qquad \text{(Eq. 2.4.13-9)}$$

where:

C_{P1} = parent radionuclide concentration at time t

C_{P0} = initial bounding parent concentration (Table 2.4-59)

λ_1 = radioactive decay constant for parent from Equation 2.4.13-4

t = travel time from source to receptor

R_1 = retardation factor for parent radionuclide

L = flow path length from source to receptor

v = average linear ground water velocity

Similar relationships exist for progeny radionuclides. For the first progeny in the decay chain, the advection-dispersion-reaction equation is:

$$R_2 \frac{\partial C_2}{\partial t} = D\frac{\partial^2 C_2}{\partial x^2} - v\frac{\partial C_2}{\partial x} + d_{12}\lambda_1 R_1 C_1 - \lambda_2 R_2 C_2 \qquad \text{(Eq. 2.4.13-10)}$$

where:

subscript 2 denotes properties/concentration of first progeny

d_{12} = fraction of parent radionuclide transitions that result in production of progeny

The characteristic equations for Equation 2.4.13-10, conservatively neglecting the coefficient of longitudinal hydrodynamic dispersion, can be derived as:

$$\frac{dC_2}{dt} = d_{12}\lambda_1^{'} C_1 - \lambda_2 C_2 \qquad \text{(Eq. 2.4.13-11)}$$

$$\frac{dx}{dt} = \frac{v}{R_2} \qquad \text{(Eq. 2.4.13-12)}$$

where:

$$\lambda_1^{'} = \lambda_1 \frac{R_1}{R_2}$$

Recognizing that Equation 2.4.13-11 is formally similar to Equation B.43 in NUREG/CR-5512 (NRC, 1992), these equations can be integrated to yield:

$$C_2 = K_1 \exp(-\lambda_1^{'} t) + K_2 \exp(-\lambda_2 t) \qquad \text{(Eq. 2.4.13-13)}$$

$$t = R_2 \frac{L}{v} \qquad \text{(Eq. 2.4.13-14)}$$

for which:

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$$K_1 = \frac{d_{12}\lambda_2 C_{P0}}{\lambda_2 - \lambda_1^{'}}$$

$$K_2 = C_{20} - \frac{d_{12}\lambda_2 C_{P0}}{\lambda_2 - \lambda_1^{'}}$$

The advection-dispersion-reaction equation for the second progeny in the decay chain is:

$$R_3 \frac{\partial C_3}{\partial t} = D\frac{\partial^2 C_3}{\partial x^2} - v\frac{\partial C_3}{\partial x} + d_{13}\lambda_1 R_1 C_1 + d_{23}\lambda_2 R_2 C_2 - \lambda_3 R_3 C_3 \quad \text{(Eq. 2.4.13-15)}$$

where:

subscript 3 denotes properties/concentration of second progeny radionuclide

d_{13} = fraction of parent radionuclide transitions that result in production of second progeny

d_{23} = fraction of first progeny transitions that result in production of second progeny

The characteristic equations for Equation 2.4.13-15, conservatively neglecting the coefficient of longitudinal hydrodynamic dispersion, can be derived as:

$$\frac{dC_3}{dt} = d_{13}\lambda_1^{'} C_1 + d_{23}\lambda_2^{'} C_2 - \lambda_3 C_3 \quad \text{(Eq. 2.4.13-16)}$$

$$\frac{dx}{dt} = \frac{v}{R_3} \quad \text{(Eq. 2.4.13-17)}$$

where:

$$\lambda_1^{'} = \lambda_1 \frac{R_1}{R_3}$$

$$\lambda_2^{'} = \lambda_2 \frac{R_2}{R_3}$$

Considering the formal similarity of Equation 2.4.13-16 to Equation B.54 in NUREG/CR-5512 (NRC, 1992), Equations 2.4.13-16 and 2.4.13-17 can be integrated to yield:

$$C_3 = K_1 \exp(-\lambda_1^{'} t) + K_2 \exp(-\lambda_2^{'} t) + K_3 \exp(-\lambda_3 t) \quad \text{(Eq. 2.4.13-18)}$$

$$t = R_3 \frac{L}{v} \quad \text{(Eq. 2.4.13-19)}$$

for which:

$$K_1 = \frac{d_{13}\lambda_3 C_{P0}}{\lambda_3 - \lambda_1^{'}} + \frac{d_{23}\lambda_2^{'} d_{12}\lambda_3 C_{P0}}{\left(\lambda_3 - \lambda_1^{'}\right)\left(\lambda_2^{'} - \lambda_1^{'}\right)}$$

$$K_2 = \frac{d_{23}\lambda_3 C_{20}}{\lambda_3 - \lambda_2^{'}} - \frac{d_{23}\lambda_2^{'} d_{12}\lambda_3 C_{10}}{\left(\lambda_3 - \lambda_2^{'}\right)\left(\lambda_2^{'} - \lambda_1^{'}\right)}$$

$$K_3 = C_{30} - \frac{d_{13}\lambda_3 C_{P0}}{\lambda_3 - \lambda_1^{'}} - \frac{d_{23}\lambda_3 C_{20}}{\lambda_3 - \lambda_2^{'}} + \frac{d_{23}\lambda_2^{'} d_{12}\lambda_3 C_{10}}{\left(\lambda_3 - \lambda_1^{'}\right)\left(\lambda_3 - \lambda_2^{'}\right)}$$

To estimate the radionuclide concentrations in ground water, Equations 2.4.13-8, 2.4.13-13, and 2.4.13-18 were applied as appropriate along the ground water transport pathway originating at the Nuclear Auxiliary Building at {Callaway Plant Unit 2}. The analysis was performed as described below.

2.4.13.1.4.1 Transport Considering Advection and Radioactive Decay Only

{The analysis considered a groundwater flow pathway from the Nuclear Auxiliary Building at the top of the Graydon Chert to the projected discharge points at Auxvasse and Mud Creeks. The cumulative travel times identified in Section 2.4.13.1.3 were utilized in Equations 2.4.13-8, 2.4.13-13, and 2.4.13-18 for each of the four points of interest: 1) as groundwater leaves the Graydon Chert aquifer and enters the aquitard, 2) as groundwater leaves the aquitard and enters the CJC aquifer, 3) as groundwater leaves the CJC aquifer and potentially discharges to the Auxvasse Creek location, and 4) as groundwater leaves the CJC aquifer and potentially discharges to the Mud Creek location. These estimated travel times are considered to be conservative because:

- The geometric mean of hydraulic conductivity (0.112 ft per day (3.95E-5 cm per sec)) from all wells screened in the shallow Graydon Chert aquifer was utilized to estimate the horizontal groundwater flow velocity through the chert (refer to Table 2.4-53 for slug test results), and this value is larger than the estimate of hydraulic conductivity at the MW-18 monitoring well within the Callaway Plant Unit 2 power block area (the estimated value of hydraulic conductivity was 0.0284 ft per day (1.00E-5 cm per sec)).

- Because the estimates of vertical groundwater flow through the aquitard are performed through the center of the plateau and the estimates of groundwater flow through the CJC aquifer are performed from the periphery of the plateau to downgradient streams, the combined travel time estimates from the top of the aquitard to the downgradient streams are conservative.

The calculated radionuclide activities for each of the four points of interest were compared with the 10 CFR, Part 20, Appendix B, Table 2, Effluent Concentration Limits (ECLs) (CFR, 2007). The ratio of the groundwater activity concentration to the ECL was used as the screening indicator. Ratios that were greater than or equal to 0.01 (greater than or equal to one percent of the ECL) were retained for further evaluation using retardation. Most of the estimated radionuclide concentrations given in these tables have concentrations less than one percent of their respective ECLs and are eliminated from further consideration as their concentrations would be well below their regulatory limits. The equation inputs are provided in Table 2.4-59 and the results are summarized in Table 2.4-60. The results indicate that the radionuclides H-3, Co-60, Sr-90, Y-90, I-129, Cs-134, Cs-137, and Pu-239 exceed one percent of the ECL as groundwater leaves the Graydon Chert aquifer. As groundwater leaves the aquitard and enters the CJC aquifer beneath the plateau, I-129 and Pu-239 exceed one percent of the ECL. As groundwater reaches the two locations along Mud Creek and Auxvasse Creek, I-129 and Pu-239 are the only radionuclides that exceed one percent of the ECL.}

2.4.13.1.4.2 Transport Considering Advection, Radioactive Decay, and Retardation

The radionuclides of concern identified by the radioactive decay screening analysis were further evaluated considering retardation in addition to radioactive decay. Distribution coefficients for these elements were assigned using both literature based and site-specific laboratory derived values.

Site-specific distribution coefficients (K_d) were used for Mn, Fe, Co, Zn, Sr, Ru, Cs, and Ce. These values were based on the laboratory K_d analysis of {5 soil samples obtained from above and within the Graydon Chert aquifer at the Callaway Plant Unit 2 site}. ASTM D 4646-03, Standard Test Method for 24-h Batch-Type Measurement of Contaminant Sorption by Soils and Sediments (ASTM, 2003), was used to determine laboratory K_d values using site ground water. Soil samples were spiked with radioactive (Mn, Co, Zn, Sr, Cs, and Ce) and non-radioactive (Fe and Ru) isotopes for the analytes of concern. Follow on analyses were performed using gamma pulse height analysis for the radioactive isotopes and either inductively-coupled plasma emission spectroscopy (Fe) or inductively-coupled plasma mass spectrometry (Ru) for the non-radioactive isotopes. For each of these analytes, the lowest measured K_d value was used in the transport analysis to ensure conservatism (Table 2.4-62). Distribution coefficients for H and I were taken to be zero, because these elements are not expected to interact with the aquifer matrix based on their chemical characteristics.

Distribution coefficients for Y, Np, and Pu were taken from published values summarized in Attachment C, Table 3.9.1 of NUREG/CR-6697 (NRC, 2000). The K_d values from the reference are assumed to be lognormally distributed, and, for conservatism, the selected K_d values were taken as the 10th percentile in the data distribution. In the case of Y, no literature data are available from which to estimate a K_d value. Instead, adsorption characteristics for Y were assumed to be similar to that of Sc, as these two elements lie adjacent in the periodic table. The approach of using the 10^{th} percentile values for Y, Np, and Pu is expected to be conservative. {A comparison of the site-specific K_d values against their associated 10^{th} percentile literature values indicates that latter values are more conservative for most of the elements that were laboratory tested.

The predicted activities of the radionuclides considering the combined effects of advection, decay, and retardation using conservative travel times identified for groundwater leaving the chert, groundwater leaving the aquitard, and groundwater arriving at the two identified discharge locations along Auxvasse and Mud Creeks. Equation inputs and results are summarized on Table 2.4-62 and Table 2.4-63, respectively. From this evaluation, it is concluded that H-3, Y-90, I-129, and Pu-239 exceed one percent of the ECL as groundwater leaves the Graydon Chert aquifer. As groundwater leaves the aquitard and enters the CJC aquifer, I-129 exceeds one percent of the ECL. As groundwater reaches the two locations along Mud Creek and Auxvasse Creek, I-129 is the only radionuclide that exceeds one percent of the ECL.}

2.4.13.1.4.3 Transport Considering Advection, Radioactive Decay, Retardation, and Dilution

{The radionuclides discharging with the groundwater to Auxvasse Creek or Mud Creek would mix with uncontaminated stream water in the creeks, leading to further reduction of activity levels due to dilution. The groundwater discharge rate itself is a function of the Darcy velocity and the assumed volume and dimensions of the resulting contaminant slug. In this evaluation, the Darcy velocity was calculated to be 2.67E-3 ft per day (8.13E-4 m per day) at the Auxvasse Creek location and 2.37E-3 ft per day (7.22E-4 m per day) at the Mud Creek location. These were estimated with a hydraulic conductivity value of 0.771 ft per day (0.235 m per day) and a hydraulic gradient of 0.00346 ft per ft and 0.00308 ft per ft for Auxvasse Creek and Mud Creek locations, respectively. These values are based on the hydrogeologic characteristics of the CJC aquifer that were described previously in Section 2.4.12.3 with results summarized on Table 2.4-57. The volume of the liquid release has been assumed to be 3249 ft^3 (92.0 m^3), which represents 80% of the 4061 ft^3 (115 m^3) capacity of one Reactor Coolant Storage Tank. Considering the effective porosity of the CJC aquifer to be 0.05, the volume of the saturated material that would be occupied by the release is:

$$V_{CJC} = \frac{V_{release}}{n_e} = \frac{3249}{0.05} = 64,980 \text{ ft}^3 \ (1,840 \text{ m}^3)$$

The shape of the resulting contaminant slug is assumed to be square in plan view and extend vertically throughout the entire saturated thickness of the CJC aquifer. Using 25 ft (7.6 m) as a representative saturated thickness of the CJC aquifer, the slug would have an area of approximately 2600 ft^2 (242 m^2) in plan view and a width of approximately 51 ft (15.5 m). The cross-sectional area of the contaminant slug normal to the groundwater flow direction would therefore be:

$$A = 25 \text{ ft x } 51 \text{ ft} = 1,275 \text{ ft}^2 \ (118.5 \text{ m}^2)$$

The total flow, Q_A, through this area from the CJC aquifer to Auxvasse Creek and Mud Creek is the product of the cross-sectional area and the Darcy velocity:

$$Q_{CJC\text{-}Aux} = (1,275 \text{ ft}^2) \text{ x } (2.67\text{E-3 ft/day})$$

$$= 3.4 \text{ ft}^3\text{/day } (0.096 \text{ m}^3\text{/day})$$

$$= 3.9\text{E-5 ft}^3\text{/sec } (1.1\text{E-6m}^3\text{/sec})$$

$$Q_{CJC\text{-}Mud} = (1,275 \text{ ft}^2) \text{ x } (2.37\text{E-3 ft/day})$$

$$= 3.0 \text{ ft}^3\text{/day } (0.085 \text{ m}^3\text{/day}$$

$$= 3.5\text{E-5 ft}^3\text{/sec } (1.0\text{E-6 m}^3\text{/sec})$$

This is the flow rate at which a slug of groundwater hypothetically contaminated with radionuclides would flow to Auxvasse Creek and Mud Creek at the identified discharge locations.

The surface water flow rates were estimated in Auxvasse and Mud Creeks seasonally at specific cross-sections as previously identified in Section 2.4.12. Refer to Figure 2.4-68 through Figure 2.4-71 for surface water monitoring locations and their measured surface water elevations for four seasonal rounds. Refer to Table 2.4-50 for the estimated width, depth, velocity, and flow rate at each location. Overall, there is a large variation in estimated flow rates in the creeks. Auxvasse Creek locations are flowing throughout the year; however, Mud and Logan Creeks are dry through the summer and to early fall and in some cases until January. Based on the estimated surface water flow rates at SG-A3 for Auxvasse Creek and SG-M1 and SG-M2 for Mud Creek, a flow rate Q_{Aux} = 2.0 ft^3/sec (0.057 m^3/sec) is assumed for Auxvasse Creek, and a flow rate of Q_{Mud} = 1.0 ft^3/sec (0.028 m^3/sec) is assumed for Mud Creek. The corresponding dilution factors would be equal to:

$$Q_{CJC\text{-}Aux}/Q_{Aux} = (3.9\text{E-}5\ \text{ft}^3/\text{sec}) / (2.0\ \text{ft}^3/\text{sec}) = 2.0\text{E-}5$$

$$Q_{CJC\text{-}Mud}/Q_{Mud} = (3.5\text{E-}5\ \text{ft}^3/\text{sec}) / (1.0\ \text{ft}^3/\text{sec}) = 3.5\text{E-}5$$

This dilution factor is applied to the I-129 activity levels reported in Table 2.4-63 for groundwater that flows to the Auxvasse and Mud Creek discharge locations. Table 2.4-64 summarizes the resulting activity levels, which would represent the diluted activity levels in the surface water at these two locations. No radionuclides exceed one percent of the ECL.}

2.4.13.1.5 Compliance with 10 CFR Part 20

{The groundwater pathway from the Callaway Plant Unit 2 tank rupture into the Graydon Chert aquifer, through the aquitard and into the CJC aquifer, and through the CJC aquifer to two potential discharge locations along Auxvasse and Mud Creeks has been evaluated. The radionuclide transport analysis presented indicates that all radionuclides accidentally released to the groundwater are individually below their ECL prior to leaving the aquitard and entering the CJC aquifer (and hence, prior to being discharged from the CJC aquifer to Auxvasse and Mud Creeks). 10 CFR Part 20, Appendix B, Table 2 imposes additional requirements when the identity and activities of each radionuclide in a mixture are known. In this case, the sum of the ratios representing the radionuclide activity level present in the mixture divided by the ECL activities otherwise established in Appendix B for the specified radionuclides not in a mixture may not exceed "1" (i.e., "unity"). The sum of fractions approach has been applied to the radionuclide concentrations conservatively estimated above. Results are summarized in Table 2.4-65. The sum of the mixture ratios is 0.249 for groundwater leaving the aquitard and entering the CJC aquifer and 0.248 for groundwater that potentially discharges to Auxvasse and Mud Creeks. These values are below unity; therefore, it is concluded that an accidental liquid release of effluents to groundwater would not exceed 10 CFR Part 20 limits. The radionuclide mixture ratios used in this analysis represent the calculated value observed for each radionuclide for the advection/decay calculation. Retardation and dilution would decrease the predicted concentrations and the resulting sum of the mixture ratios further.**}**

{Prior to reaching the Missouri River, potential discharge of radionuclides into Auxvasse or Mud Creek would be further diluted downstream by increases in surface water discharge from tributary input and additional discharge of uncontaminated groundwater. However, this dilution is ignored, as part of the conservative approach followed in this section. In accordance with Branch Technical Position 11-6, the evaluation should consider the impacts of the postulated tank failure on the nearest potable water supply in an unrestricted area. "Supply" is defined as a well or surface water intake that is used as a water source for direct human consumption or indirectly through animals, crops, or food processing (NRC, 2007b). The closest well user is identified in Section 2.4.12.2; it is an irrigation well that draws water from the CJC aquifer. Specific water users along Auxvasse and Mud Creeks have not been identified.

However, the shortest travel times for groundwater that originates at Callaway Plant Unit 2 and flows through the Graydon Chert aquifer, flows through the aquitard and into the CJC aquifer, flows through the CJC aquifer to discharge locations identified in Auxvasse and Mud Creeks have been utilized in these analyses. Therefore, the predicted concentrations at Auxvasse and Mud Creeks represent the maximum concentrations that are expected at a surface water discharge point.}

2.4.13.2 Surface Water Pathway

2.4.13.2.1 Direct Releases to Surface Waters

{As described in Section 2.4.13.1.1, all Callaway Plant Unit 2 facilities containing radionuclide inventories are located in the nuclear island. For the Nuclear Auxiliary and Radioactive Waste Buildings, the depth of the top of the basemat is approximately 31.5 ft (9.60 m) below grade. Assuming liquid releases from postulated Reactor Coolant Storage Tank and/or Liquid Waste Storage Tank ruptures would flood the lowest levels of the Nuclear Auxiliary and Radioactive Waste Buildings, respectively. It is unlikely that a release could reach the ground surface and be capable of impacting surface water.

The concrete floor supporting the Volume Control Tank in the Fuel Building is at grade level. However, the room containing this tank is centrally located in the interior of the Fuel Building, and the tank is entirely surrounded by concrete walls. There are no doors providing entry to this room and access is only possible via a ladder through the top of the room. Therefore, a postulated release from the Volume Control Tank will not leave the Fuel Building, reach the ground surface, and impact surface water.

Two heat exchangers in each of the three Safeguards Buildings are located at grade level. One Safeguards Building (Building 2/3) houses its grade level heat exchangers within double wall concrete containment, and has no exterior doors leading into the building at grade level. The remaining Safeguards buildings (Buildings 1 and 4) do not have double wall containment, and grade level exterior entry doors are present. However, these doorways are designed with six inch concrete thresholds and the doors are watertight to a flood depth of one meter. Therefore, it is unlikely that a release from the grade level Heat Exchangers in the Safeguards Buildings will reach the ground surface and impact surface water.

Because there are no outdoor tanks that could release radioactive effluent, no accident scenario could result in the release of effluent directly to the surface water from outdoor tanks.}

2.4.13.3 References

{**ASTM, 2003.** Standard Test Method for 24-h Batch-Type Measurement of Contaminant Sorption by Soils and Sediments, ASTM D 4646-03, American Society for Testing and Materials, November 2003.

CFR, 2007. Title 10, Code of Federal Regulation, Part 20, Appendix B, Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations, Concentrations for Release to Sewerage, 2007.

ICRP, 1983. Radionuclide Transformations – Energy and Intensity Emissions, International Commission on Radiation Protection, ICRP Publication 38, 11-13, ICRP 1983, Pergamon Press, 1983.

Javandel, 1984. Groundwater Transport: Handbook of Mathematical Models, Water Resources Monograph 10, American Geophysical Union, I. Javandel, C. Doughty, and C. Tsang, 1984.

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NRC, 2007a. Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters, NUREG-0800, Standard Review Plan, Section 2.4.13, Revision 3, Nuclear Regulatory Commission, March 2007.

NRC, 2007b. Postulated Radioactive Releases due to Liquid-Containing Tank Failures, Branch Technical Position 11-6, NUREG-0800, Standard Review Plan, Nuclear Regulatory Commission, March, 2007.}

2.4.14 TECHNICAL SPECIFICATION AND EMERGENCY OPERATION REQUIREMENTS

The U.S. EPR FSAR includes the following COL Item in Section 2.4.14:

> A COL applicant that references the U.S. EPR design certification will describe any emergency measures required to implement flood protection in safety-related facilities and to verify that there is an adequate water supply for shutdown purposes.

This COL Item is addressed as follows:

{References to elevation values in this section are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), unless stated otherwise.}

Sections 2.4.14.1 and 2.4.14.2 are added as a supplement to the U.S. EPR FSAR.

2.4.14.1 Need for Technical Specifications and Emergency Operations Requirements

{The preceding subsections of Section 2.4 provide an in-depth evaluation of the site's hydrologic acceptability for locating Callaway Plant Unit 2. The information provided below concludes that there is no need for emergency protective measures designed to minimize the impact of hydrology-related events on safety-related facilities. Therefore, the requirements of 10 CFR 50.36 (CFR, 2007a), 10 CFR Part 50, Appendix A, General Design Criteria 2 (CFR, 2007b), 10 CFR Part 100 (CFR, 2007c), and10 CFR 52.79 (CFR, 2007d) are met with respect to determining the acceptability of the site.}

Sections 2.4.1 through 2.4.11 present a comprehensive discussion of the potential for flooding and low water at the site, including details of each potential cause and the resulting effects.

{The Callaway Plant Unit 2 design plant grade elevation for safety related facilities are located above the design basis flood level, as stated in Section 2.4.2 and above the Probable Maximum Flood (PMF) elevation from local streams, as stated in Section 2.4.3.

The Callaway Plant Unit 2 site is approximately located at Missouri River Mile 115 (185 km) on a plateau at plant grade elevation El. 845 ft (258 m) msl. At the site, the Missouri River 100-yr floodplain is approximately El. 533.4 ft (162.6 m) msl (NOAA, 2007). Thus, the Callaway Plant

Unit 2 site is approximately 311.6 ft (95.0 m) above the Missouri River 100-year floodplain and protection of the safety-related facilities from floods from the Missouri River is not necessary.

The results of the analysis in Section 2.4.3 indicate a probable maximum flood (PMF) water surface elevation of 697 ft (212 m) for Logan Creek and 590.6 ft (180 m) for Mud Creek and 707 ft (215 m) for Auxvasse Creek. Thus, the Callaway Plant Unit 2 site nuclear island safety related structures are minimum of 149.0 ft (45.4 m) above the Logan Creek PMF and 255.4 ft (77.8 m) above the Mud Creek PMF and about 139.0 ft (42.4 m) above the Auxvasse Creek PMF. As a result, the plant site is dry with respect to major flooding on the Auxvasse Creek, Logan Creek and Mud Creek.

Because of the location of the Callaway Plant Unit 2 site relative to the nearest coast and the elevation of the plant site relative to the Missouri River, tsunami and storm surge and seiche flooding considerations are not applicable for this site.

Section 2.4.2 evaluations conclude that flooding in the power block area of safety related Structures, Systems, and Components (SSCs) due to local intense precipitation, or local Probable Maximum Precipitation (PMP), will be prevented by the site drainage features engineered and constructed for that purpose.

The U.S. EPR FSAR requires that the maximum post-construction groundwater elevation to be at least 3.3 ft (1.0 m) below grade for the nuclear island. Based on the final grade of the nuclear island (845 ft (258 m)), groundwater for the existing conditions is well below grade at 810 ft (247 m) for the saturated chert with hydraulic head at approximately 832 ft (254 m).

Callaway Plant Unit 2 is designed such that no actions need be captured in Technical Specifications or Emergency Operating Procedures to protect the facility from flooding or interruption of water supply for shutdown and cooldown purposes.

Additionally, as described in U.S. EPR FSAR Section 9.2.5 for the Essential Service Water System (ESWS) cooling tower basins, measures will be taken to ensure that the basins underneath the cooling tower cells have a minimum of 72 hours water supply without the need for any makeup water during a Design Basis Accident (DBA). Any makeup water to the basin needed beyond the 72 hour, post-DBA period will be supplied from the Callaway Plant Unit 2 ESWEMS Pond.

The low flow conditions discussed in Section 2.4.11 and 2.4.12 in the Missouri River do not influence the dependability of the ESWEMS Pond. Following the first 72 hours of an accident and assuming minimum required initial level, the pond is designed to provide a minimum of 27 days water supply without makeup during the worst 30 days of evaporation.

Seventy-two (72) hours of cooling water inventory in the ESWS cooling tower basin is sufficient for shutdown and cooldown, should an event require plant shutdown, and operation of the ESW Emergency Makeup System is therefore not required for achieving cold shutdown. The minimum 72 hour water inventory in the ESWS cooling tower basin and additional details of ESWS operation are discussed in U.S. EPR FSAR Section 9.2.5.

The worst case low water event does not pose a potential of interrupting the supply of cooling water as discussed in Section 2.4.12. There are no other uses of water drawn from the Callaway Plant Unit 2 ESWEMS Pond, such as fire water or system charging requirements. There are no other interdependent safety-related water supply systems to the ESWS, such as reservoirs or cooling lakes. There is no potential of blockage of the safety-related ESWS intake due to ice or channel diversions as discussed in Sections 2.4.7 and 2.4.8. Other potential low water conditions are also evaluated and accounted for in the establishment of the design low water level, as discussed in Section 2.4.11 and 2.4.12.

Accordingly, no plant specific technical specifications or emergency protective measures are required to minimize the effect of hydrology-related events on safety-related facilities.}

2.4.14.2 References

{**CFR, 2007a**. Title 10, Code of Federal Regulations, Part 50.36, Technical Specifications, 2007.

CFR, 2007b. Title 10, Code of Federal Regulations, Part 50, Appendix A, General Design Criteria for Nuclear Power Plants, Criteria 2, Design Bases for Protection Against Natural Phenomena, 2007.

CFR, 2007c. Title 10, Code of Federal Regulations, Part 100, Reactor Site Criteria, 2007.

CFR, 2007d. Title 10, Code of Federal Regulations, Part 52.79 (a)(1)(iii), Contents of applications; technical information in final safety analysis report, 2008.

NOAA, 2007. Advanced Hydrologic Prediction Service, National Weather Service, Website: http://www.crh.noaa.gov/ahps2/hydrograph.php?wfo=lsx&gage=cmsm7&view=1,1,1,1,1,1,1,1 &toggles=10,7,8,2,9,15,6&type=0, Date accessed: September 18, 2007.}

Table 2.4-1— {Monthly Streamflow for Hermann, MO USGS Station No. 06934500, (1957 through 2006)}

(Page 1 of 2)

	Discharge, cubic feet per second											
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1957										46,830	33,610	34,430
1958	24,150	32,120	103,800	73,240	73,990	71,640	179,800	127,200	76,310	52,770	43,620	24,530
1959	25,120	58,860	71,550	72,320	95,020	77,380	59,770	55,200	49,690	96,820	37,970	32,180
1960	52,950	49,020	67,740	213,500	139,000	79,970	75,720	52,670	52,690	41,400	44,580	28,970
1961	22,340	29,710	107,000	124,500	196,600	78,950	80,490	55,280	137,700	80,410	144,300	45,110
1962	46,980	121,600	132,300	104,100	60,130	107,900	75,650	51,030	55,490	60,150	43,450	24,710
1963	17,350	25,620	69,170	45,800	75,080	52,660	45,250	40,760	37,800	36,680	38,780	17,060
1964	18,130	19,250	22,810	80,920	63,250	121,000	59,690	41,070	52,240	38,170	43,770	24,730
1965	43,740	37,940	99,460	137,300	61,870	111,400	147,100	56,540	159,500	84,050	54,990	44,980
1966	44,250	64,740	56,710	77,600	71,100	73,250	52,940	50,630	43,750	41,620	42,270	27,660
1967	21,570	27,480	29,910	83,480	66,590	228,800	118,900	57,520	52,460	73,050	84,520	65,110
1968	33,740	62,470	51,330	81,930	79,480	69,590	59,450	83,270	49,890	62,390	76,420	66,380
1969	69,980	94,530	109,000	175,800	126,100	140,100	195,200	78,510	95,790	140,700	76,030	47,840
1970	31,050	41,850	55,050	119,400	137,400	137,800	53,890	59,640	109,000	99,890	78,980	50,520
1971	50,860	84,590	108,400	64,920	89,330	106,300	76,630	60,600	58,170	60,120	74,050	86,050
1972	47,780	39,320	60,610	81,510	116,400	71,540	63,350	70,380	85,200	68,060	134,000	66,550
1973	129,000	135,300	267,500	333,400	192,100	113,400	92,290	72,910	84,410	221,900	127,600	127,400
1974	114,700	115,600	129,100	87,050	143,800	132,600	55,880	53,650	64,250	51,460	104,400	54,780
1975	58,920	103,100	108,300	124,000	88,110	112,500	82,570	80,750	92,730	79,590	81,530	68,900
1976	40,190	49,540	80,480	101,100	103,800	70,000	59,470	47,250	43,760	48,190	45,640	36,060
1977	21,560	34,150	42,840	50,660	53,720	83,470	77,150	58,670	128,400	93,350	125,100	47,200
1978	32,830	26,710	169,800	173,200	145,400	88,500	90,990	79,900	89,050	67,760	77,620	54,110
1979	32,390	67,340	192,800	158,500	116,600	94,390	99,200	70,260	63,340	50,900	70,920	54,960
1980	41,550	49,360	73,320	124,500	58,970	83,450	48,860	49,910	50,700	45,260	47,030	40,750
1981	26,230	30,030	30,910	51,390	97,480	117,900	153,300	89,730	54,830	52,730	59,750	49,080
1982	37,450	136,800	111,200	76,770	124,400	223,500	135,000	100,100	103,400	72,680	80,840	178,900
1983	77,940	90,670	119,100	233,600	204,200	156,000	109,300	63,470	56,770	61,360	103,100	84,000
1984	50,600	92,710	169,500	248,400	205,500	206,700	164,100	71,990	67,410	78,200	111,300	85,940
1985	96,820	124,400	171,700	122,800	106,400	152,700	71,770	81,990	68,530	156,000	152,700	116,300
1986	61,030	91,410	88,880	107,300	155,500	99,990	132,400	76,070	107,100	286,700	149,700	133,100
1987	71,280	80,110	146,800	177,800	123,600	105,900	99,330	77,300	72,110	53,730	63,930	98,760
1988	67,450	75,410	84,420	105,800	64,740	46,150	44,010	42,790	45,280	46,660	47,280	37,250
1989	36,850	39,120	52,970	57,540	47,710	57,020	48,900	56,410	97,110	44,860	34,260	21,740

Table 2.4-1— {Monthly Streamflow for Hermann, MO USGS Station No. 06934500, (1957 through 2006)}

(Page 2 of 2)

	Discharge, cubic feet per second											
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1990	31,010	48,730	95,370	89,980	183,600	183,500	89,710	74,700	45,450	45,560	29,400	30,970
1991	48,930	48,920	42,310	80,810	115,900	92,640	52,840	39,540	40,720	40,810	35,130	44,960
1992	39,350	50,860	62,680	100,000	62,210	59,600	119,100	109,000	80,980	61,050	118,200	146,000
1993	108,000	96,640	149,200	197,800	194,900	176,000	376,300	306,600	243,500	169,000	127,900	91,390
1994	62,380	86,920	107,000	173,200	174,000	127,300	85,750	57,140	56,260	49,160	82,220	64,080
1995	67,750	66,510	63,900	109,400	313,000	282,300	178,000	118,900	83,030	79,190	85,280	58,130
1996	44,370	52,840	58,710	82,620	194,500	199,600	132,300	110,400	92,020	97,000	135,500	100,200
1997	61,600	126,600	146,700	193,800	154,800	155,800	107,700	90,260	91,420	93,950	96,170	103,000
1998	89,850	91,360	148,400	189,300	111,000	158,400	130,900	100,600	91,140	173,000	174,800	106,800
1999	77,160	124,000	107,100	172,200	220,400	172,800	147,200	83,940	69,700	66,650	63,820	57,860
2000	49,210	46,860	54,730	51,160	54,600	75,500	70,330	56,840	45,940	46,940	47,800	30,040
2001	32,830	84,590	123,700	118,700	116,400	206,200	97,450	61,240	59,410	57,830	44,680	43,600
2002	34,880	54,450	44,960	65,810	184,500	100,800	47,810	44,480	41,610	42,670	40,360	28,910
2003	25,540	29,000	38,130	47,170	81,730	65,030	53,390	37,920	50,850	38,500	44,660	48,240
2004	51,040	38,740	103,700	70,600	94,400	107,200	87,790	72,820	62,070	42,640	70,610	65,000
2005	119,500	102,700	47,200	65,800	73,500	128,000	56,580	57,680	55,420	49,250	26,790	28,190
2006	30,100	30,540	34,460	50,960	72,360	48,250	40,970	42,660	44,790			
Mean	**51,400**	**67,600**	**94,100**	**117,000**	**120,000**	**119,000**	**97,600**	**73,000**	**74,700**	**76,500**	**76,700**	**61,700**

Table 2.4-2—{Mean Daily Streamflow for Hermann, MO USGS Station No. 06934500, (1957 through 2006)}

	Discharge, cubic feet per second											
Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	59,100	62,200	79,400	110,000	119,000	122,000	109,000	92,100	68,400	79,300	70,800	71,400
2	56,400	62,700	77,400	113,000	121,000	123,000	110,000	90,100	68,300	79,300	77,000	72,500
3	53,200	64,000	77,700	116,000	117,000	121,000	110,000	86,900	69,100	78,900	83,000	75,300
4	55,200	65,200	81,100	118,000	114,000	119,000	110,000	84,900	69,500	78,200	86,500	74,200
5	59,200	64,100	85,700	118,000	114,000	119,000	107,000	84,500	68,200	78,900	86,400	72,200
6	58,900	62,600	88,200	122,000	116,000	119,000	105,000	82,500	67,900	81,000	83,300	70,900
7	55,300	61,100	89,700	121,000	118,000	122,000	106,000	79,600	66,700	80,200	80,500	69,800
8	52,100	60,000	88,900	116,000	123,000	119,000	104,000	77,300	65,800	79,200	77,900	68,800
9	50,400	59,600	89,900	111,000	128,000	119,000	103,000	74,800	66,700	77,900	74,300	66,700
10	48,200	62,700	88,900	109,000	128,000	120,000	101,000	73,300	68,400	78,600	72,800	64,700
11	46,900	62,800	88,400	111,000	126,000	118,000	97,500	72,900	68,500	80,400	71,900	64,800
12	44,300	61,300	87,400	118,000	123,000	117,000	96,200	72,500	67,300	81,800	71,400	63,100
13	44,000	61,100	87,600	119,000	121,000	117,000	97,400	72,600	66,800	84,400	71,100	60,700
14	45,200	62,000	89,900	119,000	121,000	119,000	97,400	70,300	70,300	85,100	73,200	58,500
15	45,400	62,100	93,100	121,000	123,000	123,000	98,300	71,800	74,900	84,500	74,700	58,300
16	45,000	61,600	95,800	121,000	125,000	123,000	98,300	71,700	77,100	83,000	75,400	59,600
17	45,600	61,700	97,100	119,000	126,000	123,000	93,400	70,600	79,100	81,100	76,600	60,300
18	46,600	62,800	97,600	117,000	129,000	125,000	90,300	69,400	77,100	79,000	78,100	58,800
19	49,600	63,700	96,100	117,000	128,000	122,000	90,000	68,400	77,200	77,200	78,700	57,400
20	50,800	65,900	96,700	118,000	123,000	118,000	89,300	67,100	77,400	77,000	79,300	57,300
21	51,400	68,500	101,000	119,000	117,000	115,000	90,000	65,700	75,500	75,400	80,100	58,000
22	52,500	74,200	102,000	120,000	113,000	117,000	92,100	64,600	75,200	72,900	79,700	57,500
23	52,400	81,400	100,000	121,000	112,000	118,000	95,600	64,100	78,400	70,300	79,100	56,000
24	52,900	83,300	98,500	123,000	114,000	116,000	96,700	63,800	82,500	68,300	77,100	54,200
25	51,700	84,400	99,100	123,000	114,000	116,000	93,000	64,900	85,600	68,600	75,100	54,400
26	50,000	83,700	100,000	118,000	116,000	118,000	89,400	65,600	87,500	69,800	74,100	52,700
27	51,200	83,900	103,000	111,000	118,000	116,000	90,000	66,700	88,800	69,700	75,100	52,000
28	51,500	82,400	105,000	110,000	119,000	113,000	90,700	69,200	86,100	69,200	74,100	54,800
29	51,900	55,100	110,000	113,000	120,000	111,000	90,100	69,600	84,500	67,700	72,800	54,900
30	56,400		113,000	116,000	119,000	109,000	91,200	68,600	81,700	66,800	70,400	55,900
31	61,100		110,000		119,000		92,700	67,800		67,100		57,200

FSAR: Section 2.4

Table 2.4-3—{Maximum Daily Streamflow for Hermann, MO USGS Station No. 06934500, (1957 through 2006)}

	Discharge, cubic feet per second											
Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	239,000	177,000	271,000	386,000	321,000	386,000	330,000	716,000	160,000	394,000	182,000	177,000
2	238,000	157,000	229,000	389,000	374,000	379,000	300,000	655,000	207,000	353,000	203,000	211,000
3	193,000	189,000	210,000	397,000	382,000	367,000	314,000	584,000	210,000	374,000	248,000	300,000
4	155,000	231,000	185,000	402,000	336,000	334,000	322,000	512,000	179,000	435,000	245,000	354,000
5	206,000	232,000	248,000	403,000	265,000	311,000	326,000	457,000	170,000	519,000	274,000	334,000
6	261,000	212,000	274,000	394,000	276,000	303,000	309,000	415,000	167,000	519,000	285,000	355,000
7	240,000	191,000	289,000	367,000	294,000	337,000	402,000	383,000	176,000	456,000	269,000	373,000
8	200,000	182,000	307,000	348,000	323,000	346,000	418,000	365,000	162,000	414,000	240,000	325,000
9	167,000	170,000	299,000	336,000	385,000	339,000	408,000	350,000	150,000	384,000	208,000	260,000
10	148,000	161,000	296,000	313,000	401,000	314,000	365,000	337,000	155,000	354,000	204,000	218,000
11	128,000	152,000	343,000	281,000	382,000	299,000	343,000	328,000	181,000	315,000	208,000	201,000
12	116,000	151,000	350,000	376,000	369,000	301,000	331,000	328,000	207,000	272,000	214,000	202,000
13	159,000	152,000	333,000	437,000	324,000	303,000	332,000	371,000	207,000	346,000	218,000	166,000
14	194,000	150,000	333,000	413,000	345,000	301,000	347,000	318,000	204,000	353,000	205,000	140,000
15	179,000	184,000	338,000	365,000	332,000	292,000	435,000	300,000	266,000	338,000	211,000	161,000
16	156,000	192,000	337,000	315,000	315,000	281,000	492,000	290,000	268,000	298,000	222,000	268,000
17	132,000	181,000	315,000	297,000	366,000	271,000	416,000	275,000	274,000	310,000	239,000	285,000
18	109,000	166,000	299,000	313,000	465,000	267,000	375,000	250,000	271,000	318,000	244,000	273,000
19	164,000	167,000	277,000	323,000	523,000	276,000	357,000	220,000	246,000	316,000	302,000	254,000
20	213,000	198,000	260,000	333,000	486,000	278,000	347,000	197,000	234,000	311,000	322,000	234,000
21	210,000	220,000	269,000	338,000	386,000	288,000	337,000	186,000	239,000	295,000	314,000	210,000
22	221,000	252,000	260,000	381,000	358,000	291,000	330,000	181,000	240,000	271,000	277,000	180,000
23	221,000	294,000	275,000	463,000	350,000	300,000	337,000	184,000	324,000	230,000	295,000	156,000
24	209,000	384,000	268,000	489,000	355,000	310,000	325,000	193,000	363,000	184,000	288,000	149,000
25	185,000	405,000	329,000	449,000	375,000	322,000	347,000	185,000	375,000	181,000	259,000	162,000
26	178,000	394,000	340,000	407,000	377,000	331,000	376,000	173,000	419,000	190,000	227,000	155,000
27	238,000	375,000	332,000	376,000	373,000	343,000	386,000	165,000	432,000	208,000	197,000	148,000
28	244,000	334,000	349,000	345,000	384,000	367,000	427,000	164,000	435,000	223,000	177,000	180,000
29	221,000	105,000	368,000	289,000	396,000	367,000	511,000	153,000	465,000	218,000	172,000	167,000
30	203,000		368,000	294,000	392,000	356,000	636,000	159,000	442,000	203,000	166,000	166,000
31	197,000		364,000		390,000		739,000	152,000		189,000		170,000

Table 2.4-4—{Minimum Daily Streamflow for Hermann, MO USGS Station No. 06934500, (1957 through 2006)}

	Discharge, cubic feet per second											
Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	15,400	13,400	17,400	36,500	42,000	44,600	41,000	38,600	37,200	36,300	28,800	23,300
2	17,600	13,200	17,400	35,700	41,500	44,600	40,500	38,200	37,000	35,800	28,800	23,200
3	17,200	12,800	17,200	35,700	41,000	43,700	40,600	38,600	37,800	36,000	28,400	23,100
4	16,300	14,000	16,700	36,200	40,500	43,700	39,900	37,500	37,900	36,000	28,100	23,000
5	15,000	15,000	16,900	37,700	40,000	45,200	40,400	35,800	39,600	36,000	27,600	22,300
6	12,800	13,600	17,200	38,600	39,600	47,200	44,700	35,200	39,400	36,000	28,600	22,500
7	17,200	14,400	17,400	40,700	39,700	46,600	41,400	35,600	39,400	36,000	28,000	22,400
8	14,800	15,700	17,800	43,200	41,300	44,400	39,900	35,500	38,300	35,200	26,500	21,000
9	19,100	17,000	20,100	41,500	45,800	43,500	38,700	35,000	37,800	35,200	25,900	19,400
10	18,300	17,400	23,600	39,800	44,700	43,500	37,600	34,900	37,400	35,500	25,500	19,200
11	17,600	17,800	24,700	39,800	43,000	46,000	37,500	35,100	36,200	35,700	25,300	19,200
12	13,400	18,700	27,900	40,400	41,800	46,000	37,000	35,600	35,400	35,400	25,000	19,200
13	13,000	20,100	26,900	40,700	41,000	42,200	38,600	37,000	34,900	35,700	24,700	19,200
14	14,000	19,700	24,500	40,700	40,300	38,900	41,600	37,500	34,900	36,700	23,900	20,500
15	14,400	19,700	23,600	40,400	39,200	39,500	42,300	38,000	36,600	36,800	23,700	17,900
16	13,700	19,900	22,200	39,300	38,100	40,100	42,200	38,900	36,300	36,000	23,800	16,200
17	11,000	16,000	20,800	39,700	38,000	40,400	42,800	38,100	36,300	35,700	23,500	16,700
18	10,000	15,000	19,700	40,000	38,300	40,400	43,500	37,500	36,000	35,700	25,400	9,620
19	9,500	19,700	19,200	41,000	38,600	42,500	43,600	36,900	35,800	35,700	25,300	9,430
20	9,000	19,700	19,400	40,600	39,300	41,500	42,800	36,000	35,800	36,000	24,900	7,580
21	10,000	19,700	21,300	41,300	41,900	40,100	43,200	35,500	36,300	35,000	23,900	6,720
22	11,000	19,900	22,200	41,300	41,300	39,800	41,000	38,600	38,600	33,400	23,500	6,550
23	8,000	19,900	22,200	41,900	41,600	40,700	39,700	38,600	37,100	32,800	23,000	6,210
24	7,530	19,400	22,200	40,700	41,600	42,400	38,100	35,500	36,000	32,000	21,600	7,760
25	10,000	19,000	21,700	39,500	38,000	41,300	37,700	33,000	36,500	31,900	21,400	8,670
26	11,400	19,400	22,000	38,900	38,000	42,200	38,400	33,500	36,500	31,500	23,000	8,300
27	13,000	19,700	22,400	39,800	42,200	41,600	37,900	34,600	36,000	34,100	23,800	9,430
28	14,000	18,500	26,700	41,900	46,400	41,400	37,000	37,300	37,400	32,000	23,900	10,200
29	11,000	17,600	35,700	43,000	44,100	41,400	36,400	36,900	38,000	30,600	23,800	11,800
30	11,500		38,700	42,500	42,900	41,200	36,400	34,900	37,700	29,700	23,500	13,100
31	11,000		38,600		45,000		38,500	34,000		29,100		15,600

Table 2.4-5—{Monthly Streamflow for Boonville, MO, USGS Station No. 06909000, (1957 through 2007)}

(Page 1 of 2)

	Discharge, cubic feet per second											
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1957										46,740	29,710	26,130
1958	18,490	24,920	57,750	50,150	57,810	58,200	129,100	87,670	62,550	47,300	36,780	18,080
1959	17,010	38,190	54,640	62,350	84,420	69,480	54,410	51,710	50,150	69,080	29,280	24,220
1960	41,110	35,770	50,120	181,400	99,790	75,300	71,700	50,440	49,140	38,870	38,650	20,220
1961	18,230	27,910	87,660	82,780	88,810	70,310	66,340	47,420	109,000	68,800	108,800	31,200
1962	34,210	96,750	93,130	86,240	56,310	97,260	71,930	48,270	50,360	49,670	39,890	21,870
1963	14,770	23,200	56,200	40,440	56,210	47,010	42,340	38,380	37,540	36,890	36,820	13,840
1964	16,110	17,620	19,460	55,210	50,870	92,590	51,200	38,570	50,930	36,280	40,520	21,020
1965	36,090	31,040	82,080	94,300	56,420	82,930	129,200	49,460	113,900	67,650	51,410	39,150
1966	31,270	41,140	41,610	48,820	50,050	66,000	44,950	46,920	40,120	40,080	40,920	23,290
1967	18,090	20,530	27,830	70,490	46,210	199,100	81,000	49,590	49,520	64,650	56,790	34,090
1968	25,680	36,310	33,620	62,110	52,460	49,120	52,050	67,900	43,130	53,720	52,120	36,130
1969	33,500	53,560	83,690	135,300	101,800	104,700	143,600	68,530	78,080	84,170	59,770	38,790
1970	25,020	35,530	43,830	73,840	81,220	93,470	48,680	55,410	88,760	75,090	63,050	44,270
1971	29,020	67,050	85,710	56,790	82,180	94,650	71,110	55,550	52,400	56,040	67,660	58,190
1972	31,580	33,130	50,420	60,150	91,170	66,770	61,550	65,580	77,600	62,300	88,680	49,800
1973	90,150	101,000	183,900	212,700	138,600	87,920	81,180	65,310	81,250	187,800	103,900	85,160
1974	79,490	80,700	72,200	65,310	118,900	97,080	49,220	45,980	45,000	44,590	58,020	34,580
1975	34,820	45,850	57,570	85,940	66,990	96,320	73,650	70,160	76,270	69,850	73,090	54,300
1976	32,640	41,750	57,490	81,570	80,260	61,000	50,250	44,740	41,910	43,660	42,590	32,910
1977	21,060	28,510	35,010	45,340	49,900	63,690	49,060	56,960	116,900	81,440	95,820	38,300
1978	28,980	24,550	123,200	132,600	109,500	76,420	85,890	72,250	82,780	64,790	75,160	49,520
1979	25,650	45,040	173,100	121,500	91,850	80,260	83,040	65,340	55,280	48,920	67,100	47,410
1980	36,290	38,110	54,750	98,940	54,190	73,390	43,480	48,260	48,570	44,420	45,830	37,240
1981	24,090	26,000	28,190	46,490	69,590	71,100	95,720	63,330	48,690	47,370	46,520	35,690
1982	29,060	106,300	84,160	64,800	118,900	175,000	105,500	82,360	82,780	66,400	71,860	106,200
1983	57,360	78,350	111,500	181,700	129,900	105,500	97,550	57,860	54,760	56,290	74,030	54,630
1984	43,420	73,090	107,000	175,400	163,700	201,100	137,200	68,460	63,230	68,890	85,640	66,770
1985	53,780	86,380	90,560	61,250	76,260	73,500	52,070	67,000	60,850	131,400	93,220	48,900
1986	45,120	52,920	72,440	86,670	138,900	83,850	119,500	72,260	103,400	180,600	91,700	93,460
1987	56,020	51,400	108,400	139,900	115,000	92,330	88,580	74,200	67,550	51,330	54,670	60,200
1988	34,930	48,400	49,170	56,580	48,150	41,990	41,560	38,830	42,160	42,970	36,280	24,190
1989	22,570	24,740	31,250	39,060	40,770	44,680	42,980	41,850	83,720	40,120	27,960	22,150

Table 2.4-5—{Monthly Streamflow for Boonville, MO, USGS Station No. 06909000, (1957 through 2007)}

(Page 2 of 2)

	Discharge, cubic feet per second											
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1990	26,120	29,690	49,900	45,920	107,300	112,800	65,450	61,240	38,310	37,890	24,600	20,240
1991	26,370	35,070	34,650	67,820	88,240	79,850	46,270	36,570	36,730	37,120	25,570	30,660
1992	30,580	36,060	50,920	78,980	51,840	50,260	96,300	86,550	69,820	51,800	77,730	91,760
1993	53,500	68,040	123,800	161,900	161,500	134,000	375,200	213,600	165,900	99,490	70,960	58,740
1994	43,370	59,190	78,840	88,740	90,340	79,500	72,300	50,880	47,180	46,000	51,110	41,750
1995	38,030	42,990	51,270	81,980	234,700	189,400	120,800	91,510	74,310	74,180	76,800	54,320
1996	37,070	49,330	52,050	63,620	149,700	172,100	113,100	97,900	80,070	81,680	95,560	70,800
1997	45,680	96,010	96,110	162,300	137,600	111,100	95,440	83,450	82,860	89,530	93,110	84,300
1998	60,240	73,510	98,200	141,400	85,080	130,600	106,300	82,040	74,200	121,000	139,100	81,790
1999	54,750	76,380	75,180	147,100	171,400	135,900	122,700	82,460	69,390	60,970	60,130	48,810
2000	39,980	35,600	41,130	45,810	48,900	67,230	59,700	46,920	42,300	44,270	46,500	28,320
2001	30,980	64,680	104,000	98,090	110,600	166,800	74,770	50,590	56,820	49,070	42,700	33,600
2002	28,530	33,820	32,530	51,700	110,000	58,850	37,530	37,900	37,290	41,400	37,990	25,740
2003	22,590	25,190	28,460	39,370	61,990	53,430	49,360	33,550	43,020	35,630	38,250	32,800
2004	27,420	28,470	64,240	44,680	68,700	96,330	76,120	63,050	54,550	38,560	40,890	32,630
2005	45,360	56,680	31,640	53,180	67,210	102,100	46,670	48,600	41,040	42,850	24,280	26,670
2006	27,960	26,640	29,440	47,770	52,850	42,240	37,000	41,630	42,550	32,680	22,610	27,420
2007	29,380	40,070	67,090	79,580	183,600	98,990	54,570	58,120	48,170			
Mean	**35,500**	**48,300**	**68,300**	**87,100**	**93,000**	**93,500**	**81,300**	**62,500**	**64,300**	**63,000**	**59,000**	**43,600**

Table 2.4-6—{Mean Daily Streamflow for Boonville, MO, USGS Station No. 06909000, (1957 through 2007)}

	Discharge, cubic feet per second											
Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	40,500	40,900	57,300	85,000	86,900	99,200	89,400	77,100	60,600	66,800	61,600	52,100
2	38,600	41,800	58,100	87,900	86,300	98,200	88,700	73,200	60,400	66,600	66,300	53,400
3	37,300	42,000	58,700	89,500	83,500	95,800	88,400	69,700	60,900	65,100	69,400	52,500
4	37,700	41,900	60,400	90,600	81,900	93,000	87,300	69,500	59,800	64,700	69,000	50,700
5	38,200	42,700	63,400	93,100	83,300	92,800	86,900	68,600	58,900	65,500	66,400	50,100
6	37,000	42,100	66,200	93,200	84,000	93,200	86,300	66,900	57,700	67,100	63,300	50,300
7	35,700	41,600	66,000	89,300	88,000	92,200	84,500	64,800	57,400	66,500	60,600	50,000
8	34,600	41,600	64,600	84,700	97,200	93,500	84,200	63,000	58,400	65,000	57,900	49,800
9	33,700	42,000	63,500	82,100	101,000	95,000	82,200	62,800	59,800	65,200	55,800	48,700
10	32,400	43,300	61,500	81,500	101,000	94,300	79,800	63,500	60,800	65,500	55,500	47,200
11	31,600	43,500	60,200	84,600	99,900	92,900	80,200	63,600	59,300	66,200	56,100	46,500
12	30,600	43,900	59,800	87,400	98,200	92,500	83,100	63,500	58,700	68,100	55,900	44,700
13	30,700	44,200	61,200	88,100	97,400	94,000	83,800	62,200	59,100	70,000	56,300	42,200
14	31,200	45,200	64,300	89,300	98,000	97,000	84,300	62,700	63,600	70,300	57,200	40,700
15	31,900	45,300	67,100	88,600	98,900	98,800	83,400	63,000	67,500	68,600	57,700	42,100
16	32,400	45,000	69,800	88,700	97,900	98,600	79,800	61,400	68,500	65,800	58,400	43,600
17	32,700	45,400	70,000	88,400	96,600	99,300	77,800	60,500	67,600	63,600	58,700	42,700
18	33,900	45,800	69,100	88,100	97,100	96,600	75,900	59,800	65,500	62,500	58,600	41,000
19	35,900	47,000	69,300	87,300	97,700	92,900	73,700	58,500	65,000	63,300	59,600	40,100
20	36,000	49,300	72,200	86,600	95,000	90,200	74,100	58,200	64,500	62,600	60,000	40,200
21	35,600	53,200	74,900	87,,800	93,000	91,300	77,100	57,200	64,500	60,400	60,900	40,300
22	36,100	57,100	73,900	89,200	90,500	92,100	91,300	56,600	65,700	58,100	61,400	39,400
23	36,800	60,300	70,700	89,800	89,500	91,200	81,600	56,000	68,100	56,700	59,900	38,100
24	36,600	61,300	69,600	89,900	88,700	90,500	78,000	56,500	71,200	57,600	58,300	37,100
25	35,600	62,400	71,100	87,300	88,400	92,000	75,100	56,600	73,500	59,100	56,200	37,400
26	35,700	62,200	74,000	83,200	90,200	92,500	75,800	57,200	74,600	58,700	55,600	37,900
27	35,700	60,600	75,900	80,300	92,900	90,200	78,000	59,900	71,500	57,800	54,800	37,900
28	36,400	59,300	80,100	80,800	94,300	88,800	79,600	61,400	70,000	57,100	54,400	37,600
29	38,000	41,600	82,400	85,000	93,900	88,100	81,200	61,000	67,900	56,400	53,200	38,300
30	39,600		81,100	86,300	93,200	87,400	79,900	60,100	66,700	55,800	52,000	39,200
31	41,100		82,300		96,900		78,700	61,100		57,500		41,200

Table 2.4-7—{Maximum Daily Streamflow for Boonville, MO, USGS Station No. 06909000, 1957 through 2007)}

	Discharge, cubic feet per second											
Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	150,000	138,000	149,000	288,000	225,000	275,000	247,000	603,000	169,000	267,000	134,000	115,000
2	130,000	121,000	142,000	302,000	238,000	269,000	242,000	479,000	163,000	292,000	195,000	128,000
3	112,000	186,000	136,000	315,000	248,000	251,000	256,000	387,000	154,000	313,000	219,000	158,000
4	92,300	190,000	174,000	324,000	239,000	231,000	275,000	340,000	149,000	325,000	249,000	150,000
5	95,600	174,000	220,000	329,000	214,000	213,000	282,000	311,000	148,000	326,000	255,000	153,000
6	93,000	159,000	228,000	327,000	242,000	245,000	273,000	289,000	151,000	298,000	233,000	189,000
7	106,000	150,000	195,000	314,000	230,000	277,000	283,000	269,000	141,000	283,000	201,000	193,000
8	106,000	134,000	203,000	297,000	245,000	294,000	303,000	249,000	129,000	273,000	167,000	179,000
9	95,200	110,000	200,000	270,000	303,000	275,000	312,000	230,000	123,000	243,000	151,000	168,000
10	84,300	113,000	189,000	241,000	330,000	246,000	301,000	212,000	172,000	204,000	158,000	156,000
11	72,800	106,000	208,000	225,000	338,000	270,000	318,000	197,000	214,000	224,000	176,000	142,000
12	63,900	100,000	219,000	234,000	338,000	276,000	375,000	204,000	218,000	269,000	185,000	120,000
13	60,800	97,400	224,000	274,000	339,000	279,000	400,000	211,000	180,000	277,000	173,000	97,400
14	75,000	105,000	223,000	277,000	337,000	267,000	458,000	214,000	222,000	262,000	154,000	86,300
15	92,200	128,000	223,000	257,000	320,000	252,000	439,000	206,000	266,000	268,000	147,000	193,000
16	91,600	118,000	219,000	235,000	286,000	250,000	405,000	190,000	264,000	276,000	182,000	238,000
17	100,000	127,000	208,000	248,000	279,000	256,000	383,000	171,000	242,000	277,000	174,000	237,000
18	97,000	122,000	191,000	262,000	314,000	260,000	353,000	154,000	205,000	281,000	179,000	212,000
19	181,000	130,000	194,000	249,000	354,000	255,000	328,000	142,000	177,000	266,000	161,000	184,000
20	167,000	153,000	195,000	228,000	353,000	253,000	315,000	134,000	149,000	250,000	180,000	162,000
21	148,000	203,000	216,000	292,000	333,000	262,000	304,000	131,000	157,000	224,000	163,000	131,000
22	151,000	230,000	214,000	320,000	300,000	267,000	305,000	135,000	215,000	182,000	191,000	108,000
23	143,000	249,000	217,000	313,000	269,000	269,000	314,000	143,000	246,000	143,000	195,000	89,600
24	138,000	284,000	234,000	300,000	265,000	273,000	321,000	144,000	258,000	125,000	190,000	76,500
25	133,000	280,000	249,000	274,000	272,000	273,000	340,000	139,000	244,000	146,000	158,000	79,800
26	165,000	248,000	256,000	241,000	278,000	269,000	393,000	135,000	263,000	151,000	139,000	95,800
27	170,000	207,000	269,000	194,000	291,000	258,000	487,000	131,000	277,000	175,000	126,000	90,300
28	152,000	167,000	270,000	213,000	296,000	252,000	606,000	152,000	280,000	170,000	113,000	88,700
29	140,000	75,400	260,000	248,000	296,000	241,000	706,000	156,000	273,000	157,000	120,000	126,000
30	133,000		247,000	260,000	293,000	228,000	721,000	151,000	259,000	141,000	111,000	130,000
31	164,000		265,000		289,000		662,000	140,000		131,000		140,000

Table 2.4-8—{Minimum Daily Streamflow for Boonville, MO, USGS Station No. 06909000, (1957 through 2007)}

	Discharge, cubic feet per second											
Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	14,000	10,500	15,300	26,800	39,200	40,800	37,100	33,700	35,400	35,100	26,300	22,200
2	12,800	10,000	15,300	30,400	40,600	39,800	38,400	34,400	35,000	35,000	25,500	21,700
3	12,600	9,150	15,100	33,800	40,900	39,800	37,800	33,500	35,100	35,400	24,200	20,600
4	15,000	9,300	15,100	34,200	39,500	41,000	39,600	32,800	36,500	35,400	23,400	19,200
5	14,500	9,900	15,300	33,500	39,200	43,000	39,700	32,200	36,100	35,000	23,000	18,800
6	8,340	11,100	15,500	33,200	38,800	40,100	38,500	31,700	35,800	34,900	22,600	18,800
7	8,200	11,400	16,000	33,300	38,400	38,700	38,000	31,500	33,800	34,900	22,500	18,400
8	8,200	13,400	16,900	33,800	38,200	40,000	36,600	31,200	32,900	34,900	22,400	17,800
9	8,340	17,000	17,300	34,700	37,800	39,800	36,000	31,300	32,900	34,500	22,100	17,100
10	9,390	15,900	18,700	34,900	37,400	38,500	35,500	31,600	33,700	34,400	21,300	16,900
11	10,300	14,900	19,100	35,500	37,400	38,000	35,300	32,700	34,500	34,600	20,600	16,900
12	10,500	13,800	18,500	36,300	37,300	39,000	36,000	34,100	34,600	34,800	20,000	15,600
13	11,000	15,600	17,300	35,000	36,900	36,500	36,700	34,000	34,800	34,900	19,500	12,400
14	12,500	14,200	17,100	36,000	36,400	37,600	38,700	33,000	34,700	35,100	19,400	12,400
15	12,300	13,000	16,400	35,200	35,900	38,400	37,000	33,200	34,900	35,200	19,000	11,000
16	10,000	12,400	16,000	35,200	36,100	38,100	37,800	33,800	35,800	35,000	18,700	10,000
17	8,000	12,400	15,800	35,200	36,300	38,300	38,200	33,400	36,400	34,200	20,000	9,000
18	8,000	11,800	15,800	35,600	36,400	38,200	37,600	33,900	36,100	32,500	21,500	7,200
19	7,000	11,100	16,000	36,500	36,400	38,100	36,600	32,900	36,400	30,500	21,100	6,600
20	6,500	11,300	16,600	36,900	35,300	37,700	36,100	31,600	37,600	28,800	19,800	5,500
21	6,000	12,600	17,100	38,200	34,800	37,600	35,900	30,400	37,000	27,300	18,600	5,000
22	5,500	14,000	18,000	39,100	34,500	37,400	35,600	29,400	36,200	26,200	17,400	5,000
23	6,000	15,400	17,800	39,200	33,400	37,700	35,100	29,100	35,600	25,500	16,600	5,500
24	5,500	16,000	17,300	37,900	33,100	37,300	34,500	30,500	35,600	25,800	16,200	6,000
25	6,000	15,800	17,300	37,400	34,800	38,000	33,700	31,600	35,900	25,500	19,600	6,500
26	9,000	16,200	20,000	37,900	37,800	38,300	33,100	31,200	35,700	24,800	20,200	7,000
27	12,000	16,400	24,500	38,000	37,500	37,800	33,200	30,700	35,200	24,900	20,400	9,000
28	10,000	15,800	24,300	38,100	37,000	37,700	32,900	30,500	35,100	27,300	21,300	11,000
29	9,500	16,200	24,200	37,900	37,800	37,800	33,200	30,500	35,100	27,500	22,400	12,000
30	9,000		26,400	37,800	41,500	37,200	34,800	30,500	35,200	26,900	22,400	13,000
31	10,000		28,000		41,500		34,100	33,200		26,600		14,000

Table 2.4-9—{Details of Harry Truman and Bagnell Dams}

Information	Bagnell Dam	Harry Truman Dam
Dam Name	Bagnell	Harry S. Truman
NID ID	MO30014	MO20725
Longitude (decimal degree)	-92.6248	-93.4017
Latitude (decimal degree)	38.2031	38.2667
County	Miller	Benton
River	Osage	Osage
Owner Name	Ameren UE	USACE
Year Completed	1931	1979
Total Crest Length (ft, top of the dam)	2,543 (775 m)	5,964 (1,818 m)
Dam Height (to the nearest ft)	148 (45 m)	126 (38 m)
Maximum Discharge at Normal max Pool (cfs)	Not available	Not available
Maximum Storage (ac-ft)	1,893,670 (2.34 E+9 m^3)	3,999,300 (4.93E+9 m^3)
Surface Area (acres)	55,000 (86 mi^2)	55,600 (87 mi^2)
Drainage Area (mi^2)	14,000 (36,260 Km^2)	11,500 (29,785 Km^2)
Down Stream Hazard Potential	Hazard Class 1	Hazard Class 1
Regulated Agency	FERC	FERC
Spillway Type	Controlled	Controlled
Spillway Width (to the nearest ft)	520 (159 m)	190 (58 m)

Source: **MWH, 2004** and **USACE, 2008**

Table 2.4-10— {Permitted Surface Water Withdrawals in Callaway & Osage Counties}

Owner	County	Waterbody Name	Waterbody Type	Water Pumped, gal/yr	Water Pumped, m3/yr	Purpose
AmerenUE	Callaway	MISSOURI RIVER @ MILE 115.4	RIVER	8.04E+09	3.04E+07	Power
ATKINSON, FRED	Callaway	ATKINSON-GUTHRIE LAKE	IMPOUNDMENT	6.00E+07	2.27E+05	Irrigation
ATKINSON, TERRY	Callaway	LAKE	IMPOUNDMENT	8.64E+07	3.27E+05	Irrigation
CENTRAL ELEC. POWER CO-OP	Osage	MISSOURI RIVER @ MILE 117.1	RIVER	2.49E+10*	9.41E+07*	Power
SAMSON, VINCENT A.	Osage	BIG LOOSE CREEK	CREEK	6.00E+06	2.27E+04	Irrigation

*Water pumped is returned to Missouri River after passing through condenser.
Source: **MDNR, 2007c**

Table 2.4-11— {Callaway Plant Unit 1 Cooling Tower Blowdown Discharge Permit No. MO-0098001}

Monthly Average (MGD)													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Yearly Average
2004	4.47	2.70	4.82	7.02	6.12	5.03	4.87	3.36	5.55	4.90	4.83	4.82	4.87
2005	4.32	4.55	4.60	4.57	4.97	6.37	5.96	7.65	4.97	0.23	3.25	5.49	4.74
2006	4.81	4.31	4.82	5.81	2.21	4.83	6.66	5.88	n.a	4.70	5.62	4.98	4.97*
2007	5.05	5.21	7.01	3.73	2.40	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A

Monthly Average (m3/day)													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Yearly Average
2004	1.7E+04	1.0E+04	1.8E+04	2.7E+04	2.3E+04	1.9E+04	1.8E+04	1.3E+04	2.1E+04	1.9E+04	1.8E+04	1.8E+04	1.8E+04
2005	1.6E+04	1.7E+04	1.7E+04	1.7E+04	1.9E+04	2.4E+04	2.3E+04	2.9E+04	1.9E+04	8.7E+02	1.2E+04	2.1E+04	1.8E+04
2006	1.8E+04	1.6E+04	1.8E+04	2.2E+04	8.4E+03	1.8E+04	2.5E+04	2.2E+04	n.a	1.8E+04	2.1E+04	1.9E+04	1.9E+04*
2007	1.9E+04	2.0E+04	2.7E+04	1.4E+04	9.1E+03	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A

Note: N.A= not available

*Monthly yearly average based on 11-month period, since September data was not available.

Source: MDNR, 2007d

Table 2.4-12— {Probable Maximum Precipitation (PMP) Depths}

Area (mi^2)	6-hr	12-hr	24-hr	48-hr	72-hr
10	27.5	33.0	34.8	38.6	40.0
200	20.0	24.5	26.0	29.5	31.0
1,000	14.8	18.5	20.5	23.5	25.5
5,000	8.9	12.2	14.2	17.5	19.0
10,000	7.0	9.7	11.8	14.9	16.5
20,000	5.2	7.7	9.5	12.6	14.0

Source: **NOAA, 1978.**

Table 2.4-13—{Sub-Basin Drainage Areas for Callaway Plant Unit 2 (Site Drainage)}

Hydrologic Element/Sub-Basin	Drainage Area (ft^2)	Drainage Area (acres)
Switchyard	632,627.6	14.523
Sub-Line Area/Parking Lot	766,716.5	17.601
Nuclear Island	1,515,452.4	34.790
ESWEMS Retention Pond	294,497.7	6.761
ESWEMS Spillway Area	422,642.5	9.702

Table 2.4-14—{HEC-HMS Sub-Basin Site PMP Peak Discharges for Callaway Plant Unit 2 (Site Drainage)}

Hydrologic Element/Sub-basin	Drainage Area (ft^2)	Peak Discharge (cfs)	Runoff Volume (in)
Switchyard	632,627.6	284.6	39.87
Sub-line Area/Parking Lot	766,716.5	344.9	39.87
Nuclear Island	1,515,452.4	682.8	39.87
ESWEMS Retention Pond	294,497.7	132.8	39.87
ESWEMS Spillway Area	422,642.5	189.6	39.87

Table 2.4-15—{Safety-Related Facility Entrance Elevation Summary}

Safety-Related Facility	Entrance Elevation (ft)	PMP Peak Water Elevation (ft)	Freeboard (ft)
Nuclear Island[1]	846.00	844.80	1.20
ESW Cooling Tower Structures	846.00	844.80	1.20
Emergency Power Generator Building	846.00	844.80	1.20
ESWEMS Building	840.50	839.66	0.84

[1] Includes Reactor, Fuel and Safeguards Buildings.

Table 2.4-16—{Approximate Length and Average Gradient of Creeks Located near Callaway Plant Unit 2}

#	Creek Name	Sub-Watershed Name	Length ft (m)	Average Slope %
1	Cow Creek	Auxvasse Creek Watershed	48,448 (14,767)	0.63
2	Logan Creek	Auxvasse Creek Watershed	56,811 (17,316)	0.27
3	Mud Creek	Auxvasse Creek Watershed	26,319 (8,022)	1.19
4	Auxvasse Creek	Auxvasse Creek Watershed	276,973 (84,421)	0.14

Note: Lengths represent the entire length of each creek. Slopes were estimated based on upstream and downstream elevations.

Table 2.4-17—{Auxvasse Creek Sub-Basin Delineation}

Sub-Basin	Drainage Area (mi^2)	USGS Watersheds [1]
Crows Fork 1	3.78	SUB-70001
Crows Fork 2	11.92	
Dyers Branch	6.25	
Dunlap Creek	3.99	
Houfs Branch	3.37	
Maddox Branch	7.88	
McKinney Creek	6.27	
Richland Creek	23.10	
Big Hollow	5.50	SUB-70002
Dark Hollow	1.44	
Smith Branch	4.69	
Stinson Creek 1	19.68	
Stinson Creek 2	1.87	
Stinson Creek 3	6.73	
Youngs Creek	6.86	
Auxvasse Creek 1	9.61	SUB-80001
Auxvasse Creek 2	7.10	
Auxvasse Creek 3	9.13	
Bynum Creek	24.07	
Fourmille Branch	9.74	
Leeper Branch	4.06	
Lick Branch	4.82	
Auxvasse Creek	12.52	SUB-80002
Harrison Branch 1	6.70	
Harrison Branch 2	2.97	
Harrison Branch 3	6.71	
Yates Branch	4.99	
Auxvasse Creek 1	14.42	SUB-80003
Auxvasse Creek 2	3.84	
Auxvasse Creek 3	5.64	
Auxvasse Creek 4	2.41	
Auxvasse Creek 5	3.36	
Booth Branch	4.78	
Cows Creek 1	6.25	
Cows Creek 2	6.70	
Craghead Branch	4.37	
Pinch Creek 1	1.40	
Pinch Creek 2	4.08	
Auxvasse Creek 1	5.58	SUB-80004
Auxvasse Creek 2	6.02	
Auxvasse Creek 3	1.63	
Blue Creek	4.55	
Halls Creek	7.04	
Logan Creek 1	18.57	
Logan Creek 2	1.79	
Mud Creek	7.37	

[1] The 14-digit Hydrologic Unit Code (HUC) used to identify each USGS watershed was simplified as follows: 10300102270001 (“70001”); 10300102270002 (“70002”); 10300102280001 (“80001”); 10300102280002 (“80002”); 10300102280003 (“80003”); 10300102280004 (“80004”).

Table 2.4-18—{Reservoirs within Auxvasse Creek Watershed}
(Page 1 of 2)

Name	Year Completed	ID Number	Lake Area (acres)	USGS Watershed [1]
Bass Lake Dam	1980	MO12213	30.0	SUB-80003
Brush Lake Dam	Not available	MO12218	3.0	
Canyon Lake Upper Dam	1973	MO10432	13.0	
Hrin Lake Dam	1959	MO10739	17.0	
Knittel Dam #2	1973	MO11314	9.0	
Knittel Lake Dam	1947	MO10030	8.0	
Knittel Lake Dam #3	1972	MO12214	15.0	
Konrad Dam	1973	MO11421	8.0	
Lake Lahweeno Dam	1972	MO31276	42.0	
Lake Thunderbird Lower Dam	1968	MO11426	20.0	
Lake Thunderbird Upper Dam	1967	MO10988	19.0	
Leisure Lake Dam East	1800	MO11438	7.0	
Leisure Lake Dam South	1800	MO11439	7.0	
Leisure Lake Dam West	1960	MO10740	10.0	
Leisure Lake Main Dam	1960	MO10874	46.0	
Lost Canyon Lakes Dam Sec 26 East	1800	MO11425	2.0	
Lost Canyon Lakes Dam Sec 26 West	1800	MO11424	3.0	
Lost Canyon Lakes Dam Sec 25 Upper	1800	MO11423	2.0	
Lower Canyon Lake Dam	1973	MO31274	40.0	
Meyer Dam	1965	MO10873	24.0	
Mirts Lake Dam	1955	MO11420	4.0	
Muckler & Sielfleisch Lake Dam	1967	MO10737	17.0	
Shrand Lake Dam	Not available	MO12217	3.0	
Sielfleisch Dam	1980	MO12101	55.0	
Sullivan Lake Dam	1977	MO31279	9.0	
Winfield Investment Lake Dam	1800	MO11422	6.0	
Winfield Lake Dam	Not available	MO12219	3.0	
Wright Lake Dam	1958	MO30657	10.0	
Woods Dam North	1973	MO10900	13.0	SUB-80002
Woods Dam South	1971	MO10915	25.0	
Atkinson Lake Dam	1976	MO11193	12.0	SUB-70001
Atkinson Lake Dam	1800	MO11528	6.0	
Backer Lake Dam	1976	MO11194	9.0	
Borman Lake Dam	1976	MO11527	25.0	
Dolnick Lake Dam	1960	MO10856	11.0	
Glover Spring Lake Dam	1954	MO10736	35.0	
Guthrie Lake Dam	1976	MO10990	24.0	
Harbison-Walker Refractory Lake Dam	1960	MO10885	10.0	
Herring Lake Dam	1957	MO11419	3.0	
Lawrence Dam	1967	MO11418	7.0	
Lee Sualts	1960	MO30947	7.0	
McCredie Experiment Station	1940	MO10882	16.0	
Phillips Lake Dam	1800	MO11440	6.0	
Renner Dam	1974	MO11195	12.0	

Table 2.4-18—{Reservoirs within Auxvasse Creek Watershed}

(Page 2 of 2)

Name	Year Completed	ID Number	Lake Area (acres)	USGS Watershed [1]
Baker Lake Dam	1965	MO10910	16.0	SUB-80001
Lamers Lake Dam	1973	MO10902	20.0	
Lehenbaur Lake Dam Sect 35	1974	MO10912	45.0	
Lehenbaur Lake Dam Sect 28	1969	MO10745	10.0	
Lehenbaur Lake Dam Sect 25	1977	MO11162	37.1	
Offutt Dam	1971	MO10174	16.0	
Vanderkamp Lake Dam	1976	MO11049	24.0	
Hauck Lake Dam	1974	MO10989	6.0	SUB-70002
Junior Lake Dam	1960	MO11526	18.0	
Lac Piete Dam	1967	MO10886	3.0	
Reed Lake Dam	1946	MO10854	10.0	
Richardson Lake Dam	1963	MO10877	15.0	
Vernon Echelmeier Dam	1979	MO50054	1.0	

Source: MDNR, 2007.

[1] The 14-digit Hydrologic Unit Code (HUC) used to identify each USGS watershed was simplified as follows: 10300102270001 (“70001”); 10300102270002 (“70002”); 10300102280001 (“80001”); 10300102280002 (“80002”); 10300102280003 (“80003”); 10300102280004 (“80004”).

Table 2.4-19—{Reservoirs Simulated in HEC-HMS Model}

Name	ID Number	Lake Area (acres)	Dam Height (ft)	Volume[1] (acre-ft)	USGS Watershed[2]
Lamers Lake Dam	MO10902	20	28	186.7	80001
Vanderkamp Lake Dam	MO11049	24	24	192.0	80001
Guthrie Lake Dam	MO10990	24	26	208.0	70001
Woods Dam South	MO10915	25	32	266.7	80002
Meyer Dam	MO10873	24	37	296.0	80003
Lehenbaur Lake Dam Sect 35	MO10912	45	20	300.0	80001
Lake Thunderbird Upper Dam	MO10988	19	49	310.3	80003
Bass Lake Dam	MO12213	30	33	330.0	80003
Glover Spring Lake Dam	MO10736	35	33	385.0	70001
Lake Thunderbird Lower Dam	MO11426	20	68	453.3	80003
Lehenbaur Lake Dam Sect 25	MO11162	37.1	45	556.5	80001
Lake Lahweeno Dam	MO31276	42	46	644.0	80003
Lower Canyon Lake Dam	MO31274	40	58	773.3	80003
Leisure Lake Main Dam	MO10874	46	58	889.3	80003
Sielfleisch Dam	MO12101	55	49	898.3	80003

Source: MDNR, 2007.

(1) The water storage volume was calculated as 1/3 of the lake area multiplied by the dam height.

(2) The 14-digit Hydrologic Unit Code (HUC) used to identify each USGS watershed was simplified as follows: 10300102270001 (“70001”); 10300102270002 (“70002”); 10300102280001 (“80001”); 10300102280002 (“80002”); 10300102280003 (“80003”); 10300102280004 (“80004”).

FSAR: Section 2.4

Table 2.4-20—{PMP Peak Flow Rates for Auxvasse Creek Watershed}

(Page 1 of 3)

Hydrologic Element	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak[1]	Volume (in)
70001-Junction1	41.10	54,469.8	44:15	25.4
70001-Junction2	56.83	74,192.6	44:00	25.4
70001-MO10736	5.70	23,304.8	40:45	25.8
70001-MO10990	0.48	8,224.4	39:45	26.9
70001-Rch-Crows fork 1	41.10	54,309.2	44:45	25.4
70001-Rch-Crows fork 2	56.83	73,096.8	45:00	25.4
70001-Rch-Dyers Branch	6.25	10,505.3	44:30	25.4
70001-Rch-MckInney Creek	0.48	3,548.2	41:15	26.5
70001-Sub-Crows Fork 1	3.78	8,057.8	42:00	25.4
70001-Sub-Crows Fork 2	11.92	13,687.9	45:15	25.4
70001-Sub-Dunlap Creek	3.99	10,177.7	41:15	25.4
70001-Sub-Dyers Branch	6.25	10,588.4	43:30	25.4
70001-Sub-Houfs Branch	3.37	6,442.1	42:45	25.4
70001-Sub-Maddox Branch	7.88	10,930.6	45:00	25.4
70001-Sub-McKinney Creek	6.27	10,915.7	43:15	25.4
70001-Sub-MO10736	1.71	6,487.8	40:00	25.5
70001-Sub-MO10990	0.48	1,716.8	39:45	25.6
70001-Sub-Richland Creek	23.10	29,787.3	45:45	25.4
70002-Junction 1	24.37	25,529.7	45:30	25.5
70002-Junction 2	39.92	45,845.7	43:45	25.5
70002-Rch-Stinson Creek 2	24.37	25,498.7	46:00	25.5
70002-Rch-Stinson Creek 3	39.92	45,672.2	44:30	25.5
70002-Sub-Big Hollow	5.50	11,349.3	42:30	25.5
70002-Sub-Dark Hollow	1.44	4,506.2	40:30	25.5
70002-Sub-Smith Branch	4.69	8,486.5	43:00	25.5
70002-Sub-Stinson Creek 1	19.68	21,113.9	47:15	25.5
70002-Sub-Stinson Creek 2	1.87	3,675.2	42:15	25.5
70002-Sub-Stinson Creek 3	6.73	11,171.1	43:15	25.5
70002-Sub-Youngs Creek	6.74	10,063.1	44:30	25.5
80001-80002 Common Junction	74.16	77,784.8	44:00	25.9
80001-Junction 1	24.17	31,243.6	44:00	25.9
80001-Junction 2	40.96	69,211.5	41:30	26.1
80001-MO10902	0.56	8,142.4	39:45	27.5
80001-MO10912	0.86	11,990.3	40:00	29.6
80001-MO11049	0.47	6,430.4	39:30	27.4
80001-MO11162	3.74	25,855.4	41:30	27.1
80001-Rch-Auxvasse Creek 2	24.17	31,089.4	44:30	25.9
80001-Rch-Auxvasse Creek 3	40.96	55,408.1	43:30	26.1
80001-Rch-Leeper Branch	0.47	3,207.7	41:15	26.4
80001-Sub-Auxvasse Creek 1	9.61	13,317.8	43:45	25.9
80001-Sub-Auxvasse Creek 2	7.10	13,110.4	42:00	25.9
80001-Sub-Auxvasse Creek 3	9.13	13,337.8	43:45	25.9
80001-Sub-Bynum Creek	24.07	18,093.1	27:30	25.7
80001-Sub-Fourmille Branch	9.74	11,815.9	45:00	25.9
80001-Sub-Leeper Branch	4.06	7,569.8	42:30	25.9
80001-Sub-Lick Branch	4.82	7,169.2	42:45	25.9
80001-Sub-MO10902	0.56	2,386.5	39:30	26
80001-Sub-MO10912	0.86	2,968.2	39:45	26.1

Table 2.4-20—{PMP Peak Flow Rates for Auxvasse Creek Watershed}
(Page 2 of 3)

Hydrologic Element	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak[1]	Volume (in)
80001-Sub-MO11049	0.47	2,127.9	39:30	26.1
80001-Sub-MO11162	3.74	8,049.3	41:15	25.9
80002-80003 Common Junction	108.22	127,842.4	43:30	25.9
80002-Junction 1	6.87	16,967.8	41:00	26
80002-Junction 2	14.83	25,940.7	41:45	25.9
80002-MO10915	0.17	9,261.6	41:00	35.7
80002-Rch-Auxvasse Creek	74.16	77,273.4	44:30	25.9
80002-Rch-Harrison Branch 2	6.87	10,753.9	41:30	26
80002-Rch-Harrison Branch 3	14.83	25,434.4	42:30	25.9
80002-Sub-Auxvasse Creek	12.52	17,852.5	43:15	25.8
80002-Sub-Harrison Branch 1	6.70	10,406.8	42:45	25.8
80002-Sub-Harrison Branch 2	2.97	5,783.6	41:30	25.8
80002-Sub-Harrison Branch 3	6.71	13,209.1	42:00	25.8
80002-Sub-MO10915	0.17	753.7	39:30	26.4
80002-Sub-Yates Branch	4.99	9,862.4	42:15	25.8
80003-8000-70002-70001 CmnJn	288.47	285,681.1	45:45	25.4
80003-Junction 1	123.69	125,757.7	45:30	25.6
80003-Junction 2	1.92	16,521.0	39:45	25.9
80003-Junction 3	133.53	131,929.5	45:45	25.5
80003-Junction 4	8.09	64,934.0	40:00	26
80003-Junction 5	156.82	145,574.6	46:15	25.4
80003-Junction 6	169.71	151,204.3	46:30	25.4
80003-MO10873	0.52	13,617.8	39:45	29.5
80003-MO10874	1.05	42,923.5	39:45	34
80003-MO10988	0.99	21,740.7	39:45	32.4
80003-MO11426	1.33	46,636.9	39:45	40.8
80003-MO12101	0.66	29,473.8	40:00	36
80003-MO12213	0.79	8,672.8	39:45	24.1
80003-MO31274	2.86	43,204.5	40:45	27.9
80003-MO31276	1.18	28,257.9	40:00	28.2
80003-Rch-Auxvasse Creek 1	108.22	114,992.1	45:30	25.6
80003-Rch-Auxvasse Creek 2	123.69	124,763.5	46:00	25.5
80003-Rch-Auxvasse Creek 3	133.53	128,638.8	46:45	25.4
80003-Rch-Auxvasse Creek 4	156.82	143,887.5	46:45	25.3
80003-Rch-Auxvasse Creek 5	169.71	150,931.5	46:45	25.4
80003-Rch-Cows Creek 2	14.79	43,467.9	40:30	25.3
80003-Rch-Pinch Creek 2	1.92	8,678.4	40:30	25.9
80003-Sub-Auxvasse Creek 1	14.42	11,146.8	47:00	24.3
80003-Sub-Auxvasse Creek 2	3.84	5,542.9	42:15	24.5
80003-Sub-Auxvasse Creek 3	5.64	6,329.7	43:30	24.5
80003-Sub-Auxvasse Creek 4	2.41	3,166.6	42:45	24.5
80003-Sub-Auxvasse Creek 5	3.36	6,819.7	41:00	24.5
80003-Sub-Booth Branch	4.78	10,298.2	42:15	24.5
80003-Sub-Cow Creek 1	6.25	12,923.2	42:15	24.5
80003-Sub-Cow Creek 2	6.70	13,135.7	42:15	24.5
80003-Sub-Craghead Branch	4.37	8,961.6	42:30	24.5
80003-Sub-MO10873	0.52	1,835.3	39:45	24.8
80003-Sub-MO10874	1.05	4,555.1	39:30	24.8

Table 2.4-20—{PMP Peak Flow Rates for Auxvasse Creek Watershed}

(Page 3 of 3)

Hydrologic Element	Drainage Area (mi^2)	Peak Discharge (cfs)	Time of Peak[1]	Volume (in)
80003-Sub-MO10988	0.99	3,700.2	40:00	24.6
80003-Sub-MO11426	0.34	1,711.0	39:15	24.9
80003-Sub-MO12101	0.66	2,431.7	39:45	25
80003-Sub-MO12213	0.79	3,028.4	39:45	24.7
80003-Sub-MO31274	2.86	7,698.9	40:45	24.6
80003-Sub-MO31276	0.39	1,912.1	39:15	25.2
80003-Sub-Pinch Creek 1	1.40	3,945.1	40:45	24.5
80003-Sub-Pinch Creek 2	4.08	8,448.0	41:45	24.5
80004-Junction 1	301.09	288,514.7	46:00	25.3
80004-Junction 2	311.66	284,185.6	46:45	25.1
80004-Junction 3	313.29	283,830.7	47:15	25
80004-Junction 4	25.94	39,589.2	42:30	24.1
80004-Junction 5	27.73	41,020.5	43:45	24.1
80004-Rch-Auxvasse Creek 1	288.47	284,218.0	46:00	25.3
80004-Rch-Auxvasse Creek 2	301.09	278,500.0	47:00	25.1
80004-Rch-Auxvasse Creek 3	311.66	282,706.4	47:15	25
80004-Rch-Logan Creek 2	25.94	38,712.1	43:45	24.1
80004-Sub-Auxvasse Creek 1	5.58	14,927.3	41:15	24.1
80004-Sub-Auxvasse Creek 2	6.02	5,136.6	43:45	24
80004-Sub-Auxvasse Creek 3	1.63	2,291.5	41:45	24.1
80004-Sub-Blue Creek	4.55	10,901.1	41:30	24.1
80004-Sub-Halls Creek	7.04	17,150.0	41:30	24.1
80004-Sub-Logan Creek 1	18.57	28,681.8	44:15	24.1
80004-Sub-Logan Creek 2	1.79	2,541.1	42:15	24.1
80004-Sub-Mud Creek	7.37	17,816.8	41:30	24.1

[1]Time to peak is measured from the start of the 72-hr synthetic Probable Maximum Precipitation Event.

Table 2.4-21— {Auxvasse Creek PMF Flow Rates and Water Surface Elevations}

Cross Section	River Station	Discharge cfs	Water Surface Elevation (msl) ft
Auxvasse Creek	**37193**	**124,767**	**704.33**
	20817	124,767	620.32
	10824	128,639	587.49
	7957	284,218	577.26
	84	282,706	533.04
Logan Creek	**11782**	**28,682**	**677.30**
	7849	28,682	595.62
	4573	28,682	554.67
	3585	28,682	551.33
	33	28,682	550.78
Mud Creek	**4522**	**17,817**	**577.57**
	3867	17,817	561.65
	2447	17,817	551.00
	1093	17,817	550.85
	266	17,817	550.82
Cow Creek	**2056**	**118,769**	**578.57**
	1388	118,769	578.53
	98	118,769	578.21

Table 2.4-22—{Dams within 10-miles (16 Km) Radius of Callaway Plant Unit 2}

Name	Year Completed	Height (ft)	Drainage Area (acres)	Lake Area (acres)
Bass Lake Dam	1980	33.0	528.0	30.0
Canyon Lake Upper Dam	1973	25.0	1,300.0	13.0
Glover Spring Lake Dam	1954	33.0	3,700.0	35.0
Lake Lahweeno Dam	1972	46.0	760.0	42.0
Lake Thunderbird Lower Dam	1968	68.0	916.0	20.0
Lake Thunderbird Upper Dam	1967	49.0	643.0	19.0
Leisure Lake Dam East	1800	25.0	49.0	7.0
Leisure Lake Dam South	1800	28.0	110.0	7.0
Leisure Lake Dam West	1960	30.0	170.0	10.0
Leisure Lake Main Dam	1960	58.0	690.0	46.0
Lower Canyon Lake Dam	1973	58.0	1,792.0	40.0
Muckler & Sielfleisch Lake Dam	1967	31.0	180.0	17.0
Sielfleisch Dam	1980	49.0	450.0	55.0
Name	**Year Completed**	**Height (m)**	**Drainage Area (Km^2)**	**Lake Area (Km^2)**
Bass Lake Dam	1980	10.1	2.1	0.12
Canyon Lake Upper Dam	1973	7.6	5.3	0.05
Glover Spring Lake Dam	1954	10.1	15.0	0.14
Lake Lahweeno Dam	1972	14.0	3.1	0.17
Lake Thunderbird Lower Dam	1968	20.7	3.7	0.08
Lake Thunderbird Upper Dam	1967	14.9	2.6	0.08
Leisure Lake Dam East	1800	7.6	0.2	0.03
Leisure Lake Dam South	1800	8.5	0.4	0.03
Leisure Lake Dam West	1960	9.1	0.7	0.04
Leisure Lake Main Dam	1960	17.7	2.8	0.19
Lower Canyon Lake Dam	1973	17.7	7.3	0.16
Muckler & Sielfleisch Lake Dam	1967	9.4	0.7	0.07
Sielfleisch Dam	1980	14.9	1.8	0.22

Source: **MODNR, 2007**. Missouri Dam Report by County.

Table 2.4-23—{Details of Harry Truman and Bagnell Dams}

Information	Bagnell Dam	Harry Truman Dam
Dam Name	Bagnell	Harry Truman
NID ID	MO30014	MO20725
Longitude (decimal degree)	-92.6254	-93.4016
Latitude (decimal degree)	38.2036	38.2646
County	Miller	Benton
River	Osage	Osage
Owner Name	Ameren UE	USACE
Year Completed	1931	1979
Total Crest Length (ft, top of the dam)	2,543 (775 m)	5,000 or 7,500 (15,524 or 2,286 m)
Dam Height (to the nearest ft)	148 (45 m)	126 (38 m)
Maximum Discharge at Normal max Pool (cfs)	150,000 (4,248 m^3/s)	65,200 (1,846 m^3/s)
Maximum Storage (ac-ft)	1,893,670 (2.34 E+9 m^3)	6,310,000 (7.78E+9 m^3)
Surface Area (acres)	55,040 (86 mi^2)	55,600 (87 mi^2)
Drainage Area (mi^2)	14,000 (36,260 Km^2)	11,500 (29,785 Km^2)
Down Stream Hazard Potential	Hazard Class 1	Hazard Class 1
Regulated Agency	FERC	FERC
Spillway Type	Controlled	Controlled
Spillway Width (to the nearest ft)	520 (159 m)	Not available

Table 2.4-24—{Bagnell Dam Break Analysis at Missouri River Mile 110.7}

Scenario	Flood Arrival Time (hr)	Peak Flood Time (hr)	Peak Elevation (ft)	Peak Flow (cfs)	Stage Increase (ft)
During PMF-Overtop With Failure	42.0	213.4	544.6	525,813	15.1
Sunny Day 160-ft (49-m) Wide Breach	19.5	43.8	541.8	405,074	12.29

Scenario	Flood Arrival Time (hr)	Peak Flood Time (hr)	Peak Elevation (m)	Peak Flow (m^3/s)	Stage Increase (m)
During PMF-Overtop With Failure	42.0	213.4	166.0	14,889	4.6
Sunny Day 160-ft (49-m) Wide Breach	19.5	43.8	165.1	11,470	3.7

Source: **AmerenUE, 2006**. Emergency Action Plan: Osage Project No. 459.

Table 2.4-25—{Harry Truman Dam Break Analysis at Missouri River Mile 118}

Scenario	Flood Arrival Time (hr)	Peak Flood Time (hr)	Peak Elevation (ft)
Spill Design Flood Without Dam Failure	90.0	212.5	527.0
Spill Design Flood With Dam Failure	90.0	137.5	544.5

Scenario	Flood Arrival Time (hr)	Peak Flood Time (hr)	Peak Elevation (m)
Spill Design Flood Without Dam Failure	90.0	212.5	160.6
Spill Design Flood With Dam Failure	90.0	137.5	166.0

Source: **USACE, 1999**. Emergency Action Plan, Volume II: Harry S. Truman Lake, Operation and Maintenance Manual.

Table 2.4-26—{Costliest Hurricanes to Strike the U.S. Mainland from 1900-2006}

Name	States Affected	Year	Category
Ernesto	FL, NC, VA	2006	tropical storm
Katrina	FL, LA, MS	2005	3
Wilma	FL	2005	3
Rita	LA,TX	2005	3
Dennis	FL	2005	3
Charley	FL	2004	4
Ivan	AL,FL	2004	3
Frances	FL	2004	2
Jeanne	FL	2004	3
Isabel	Mid Atlantic	2003	2
Lili	SC/LA	2002	1
Allison	TX	2001	tropical storm
Floyd	Mid Atlantic & North East U.S.	1999	2
Georges	FL,MS,AL	1998	2
Erin	FL	1998	2
Frances	TX	1998	tropical storm
Fran	NC	1996	3
Opal	FL,AL	1995	3
Alberto	FL,GA,AL	1994	tropical storm
Andrew	FL, LA	1992	5
Bob	NC, North East U.S.	1991	2
Hugo	SC	1989	4
Allison	TX	1989	tropical storm
Bonnie	NC,VA	1988	2
Juan	LA	1985	1
Elena	MS,AL,FL	1985	3
Gloria	Eastern U.S.	1985	3
Alicia	TX	1983	3
Frederic	AL,MS	1979	3
Agnes	FL, North East U.S.	1972	1
Camille	MS,LA,VA	1969	5
Betsy	FL,LA	1965	3
Diane	Northeast U.S.	1955	1

Source: National Weather Services (NWS, 2007)
Notes:
Category 1: 74-95 mph;
Category 2: 96-110 mph;
Category 3: 111-130 mph;
Category 4: 131-155 mph;
Category 5: >155 mph;

Table 2.4-27—{Historical Tsunamis Affecting the East Coast of the U.S. and Canada}

Date			Tsunami Cause				Tsunami Source Location				Max Water Height (meter) Above Sea Level
Year	Mo	Day	Val[1]	Code[2]	Earthquake Mag	Volcano	Country	Name	Latitude	Longitude	
1755	11	1	4	1	*		PORTUGAL	LISBON	36	-11	30
1811	12	16	3	1	8.5		USA	AR: NE - NEW MADRID EARTHQUAKES	35.6	-90.4	
1811	12	16	3	1	8		USA	AR: NE - NEW MADRID EARTHQUAKES	35.6	-90.4	
1812	1	23	3	1	8.4		USA	NEW MADRID, MO	36.3	-89.6	
1812	2	7	3	1	8.8		USA	NEW MADRID, MO	36.5	-89.6	
1848	9	24	3	8			CANADA	FISHING SHIPS HARBOUR, NEWFOUNDLAND	52.616	-55.766	
1864	6	27	3	1	*		CANADA	SW AVALON PENINSULA, NEWFOUNDLAND	46.5	-53.7	
1886	9	1	4	1	7.7		USA	CHARLESTON, SC	32.9	-80	
1895	9	1	3	1	4.3		USA	HIGH BRIDGE, NJ	40.667	-74.883	
1918	10	11	4	1	7.3		USA TERRITORY	PUERTO RICO: MONA PASSAGE	18.5	-67.5	6.1
1929	11	18	4	3	7.4		CANADA	GRAND BANKS, NEWFOUNDLAND	44.69	-56	7
1946	8	4	4	1	8.1		DOMINICAN REPUBLIC	NORTHEASTERN COAST	19.3	-68.9	5
1946	8	8	4	1	7.9		DOMINICAN REPUBLIC	NORTHEASTERN COAST	19.71	-69.51	0.6
1964	5	19	3	8			USA	LONG ISLAND, NY	40.8	73.1	0.28
2004	12	26	4	1	9		INDONESIA	OFF W. COAST OF SUMATRA	3.295	95.982	50.9

Notes:

1 4 = definite tsunami
3 = probable tsunami
2 = questionable tsunami
1 = very doubtful tsunami
0 = erroneous entry

2 0 = Unknown
1 = Earthquake
2 = Questionable Earthquake
3 = Earthquake and Landslide
4 = Volcano and Earthquake
5 = Volcano, Earthquake, and Landslide
6 = Volcano
7 = Volcano and Landslide
8 = Landslide
9 = Meteorological
10 = Explosion
11 = Astronomical Tide

Source: NOAA, 2006 Historical Tsunami Record, http://www.ngdc.noaa.gov/seg/hazard/tsu_db.shtml, Date accessed: September, 2007

Table 2.4-28—{Historical Tsunamis Affecting the Gulf of Mexico}

Date			Tsunami Cause				Tsunami Source Location				Max Water Height (meter) Above Sea Level
Year	Mo	Day	Val[1]	Code[2]	Earthquake Mag	Volcano	Country	Name	Latitude	Longitude	
1918	10	24	4	1	*		USA TERRITORY	PUERTO RICO	18.5	-67.5	
1964	3	28	4	3	9.2		USA	PRINCE WILLIAM SOUND, AK	61.1	-147.5	67.1

Notes:

1 4 = definite tsunami
3 = probable tsunami
2 = questionable tsunami
1 = very doubtful tsunami
0 = erroneous entry

2 0 = Unknown
1 = Earthquake
2 = Questionable Earthquake
3 = Earthquake and Landslide
4 = Volcano and Earthquake
5 = Volcano, Earthquake, and Landslide
6 = Volcano
7 = Volcano and Landslide
8 = Landslide
9 = Meteorological
10 = Explosion
11 = Astronomical Tide

Source:
NOAA,2006 Historical Tsunami Record, http://www.ngdc.noaa.gov/seg/hazard/tsu_db.shtml, Date accessed: September, 2007.

Table 2.4-29—{Historical Tsunamis Affecting U.S.A. Territories in the Pacific Basin}

(Page 1 of 3)

Date			Tsunami Cause				Tsunami Source Location				Max Water Height (meter) Above Sea Level
Year	Mo	Day	Val[1]	Code[2]	Earthquake Mag	Volcano	Country	Name	Latitude	Longitude	
1837	11	7	4	3	8.5		CHILE	S. CHILE	-42.5	-74	6
1849	1	24	3	1	7.5		USA TERRITORY	GUAM, MARIANA ISLANDS	14	143.3	6.1
1892	5	16	4	1	7.5		USA TERRITORY	GUAM, MARIANA ISLANDS	14	143.3	
1909	12	9	4	1	8		USA TERRITORY	GUAM, MARIANA ISLANDS	12.5	145	
1917	6	26	4	1	8.3		SAMOA	SAMOA ISLANDS	-15.5	-173	12.2
1922	11	11	4	1	8.5		CHILE	N. CHILE	-28.5	-70	9
1946	4	1	4	1	8.1		USA	UNIMAK ISLAND, AK	53.32	-163.19	35.05
1948	9	8	4	1	7.8		TONGA	TONGA TRENCH	-21	-174	2
1952	3	4	4	1	8.1		JAPAN	SE. HOKKAIDO ISLAND	42.15	143.85	6.5
1952	3	17	4	1	4.5		USA	HAWAII	19.1	-155	1
1952	3	19	4	1	7.7		PHILIPPINES	E. OF MINDANO, PHILIPPINES	9.4	125.1	0.33
1952	11	4	4	1	9		RUSSIA	KAMCHATKA	52.75	159.5	18
1953	9	14	4	3	6.8		FIJI	FIJI ISLANDS	-18.2	178.3	3
1957	3	9	4	1	9.1		USA	ANDREANOF ISLANDS, AK	51.292	-175.629	22.8
1958	11	6	4	1	8.3		RUSSIA	S. KURIL ISLANDS	44.53	148.54	5
1960	5	22	4	1	9.5	Vol	CHILE	CENTRAL CHILE	-39.5	-74.5	25
1963	2	13	4	1	7.3		TAIWAN	E. TAIWAN-RYUKYU ISLANDS	24.4	122.1	0.2
1963	10	13	4	1	8.5		RUSSIA	S. KURIL ISLANDS	44.81	149.54	4.5
1963	10	20	4	1	6.7		RUSSIA	S. KURIL ISLANDS	44.1	150.1	15
1964	3	28	4	3	9.2		USA	PRINCE WILLIAM SOUND, AK	61.1	-147.5	67.1
1965	2	4	4	1	8.7		USA	RAT ISLANDS, ALEUTIAN ISLANDS, AK	51.29	178.55	10.7
1965	8	11	4	1	7		VANUATU	VANUATU ISLANDS	-15.8	167.2	7
1966	10	17	4	1	8.1		PERU	CENTRAL PERU	-10.7	-78.8	3
1966	12	28	4	1	7.8		CHILE	N. CHILE	-25.5	-70.7	0.42
1966	12	31	4	1	7.5		SOLOMON ISLANDS	SANTA CRUZ ISLANDS	-11.8	166.5	2.03
1967	1	1	4	1	8.1		SOLOMON ISLANDS	SOLOMON ISLANDS	-11.8	166.5	2
1968	4	1	4	1	7.5		JAPAN	SEIKAIDO	32.3	132.5	3
1968	5	16	4	1	8.2		JAPAN	OFF EAST COAST OF HONSHU ISLAND	40.8	143.2	6
1968	8	1	4	1	7.3		PHILIPPINES	E. LUZON ISLAND	16.5	122.2	0.3
1969	8	11	4	1	8.2		RUSSIA	S. KURIL ISLANDS	43.6	147.9	5
1969	11	22	4	1	7.7		RUSSIA	KAMCHATKA	57.7	163.6	15
1971	7	14	4	1	7.9		PAPUA NEW GUINEA	BISMARCK SEA	-5.5	153.9	6

Table 2.4-29—{Historical Tsunamis Affecting U.S.A. Territories in the Pacific Basin}

(Page 2 of 3)

Date			Tsunami Cause				Tsunami Source Location				Max Water Height (meter) Above Sea Level
Year	Mo	Day	Val[1]	Code[2]	Earthquake Mag	Volcano	Country	Name	Latitude	Longitude	
1971	7	26	4	1	7.9		PAPUA NEW GUINEA	BISMARCK SEA	-4.9	153.2	3
1973	1	30	4	1	7.5		MEXICO	S. MEXICO	18.48	-103	1.13
1973	6	17	4	1	7.7		JAPAN	HOKKAIDO ISLAND	43.2	145.8	4.5
1974	10	3	4	1	8.1		PERU	CENTRAL PERU	-12.27	-77.79	0.92
1975	6	10	4	1	7		RUSSIA	S. KURIL ISLANDS	43.024	147.734	5.5
1975	10	31	4	1	7.2		PHILIPPINES	PHILIPPINE TRENCH	12.54	125.993	4
1975	11	29	4	3	7.1	Vol	USA	HAWAII	19.334	-155.024	14.3
1975	12	26	4	1	7.8		SAMOA	SAMOA ISLANDS	-16.265	-172.467	0.75
1977	4	2	4	1	7.6		SAMOA	SAMOA ISLANDS	-16.7	-172.1	0.08
1977	6	22	4	1	7.2		TONGA	TONGA TRENCH	-22.878	-175.9	0.4
1979	3	14	4	1	7.6		MEXICO	S. MEXICO	17.813	-101.276	1.3
1981	9	1	4	1	7.7		SAMOA	SAMOA ISLANDS	-14.96	-173.085	1
1982	12	19	4	1	7.5		NEW ZEALAND	KERMADEC ISLANDS	-24.133	-175.864	0.2
1985	9	19	4	1	8		MEXICO	MEXICO	18.19	-102.533	3
1986	5	7	4	1	8		USA	ANDREANOF ISLANDS, AK	51.52	-174.776	1.4
1986	10	20	4	1	7.8		NEW ZEALAND	KERMADEC ISLANDS	-28.117	-176.367	0.22
1987	10	6	4	1	7.3		TONGA	TONGA ISLANDS	-17.94	-172.225	0.25
1990	4	5	4	1	7.5		USA TERRITORY	MARIANA TRENCH, N. MARIANA ISLANDS	15.125	147.596	0.6
1993	8	8	4	1	7.8		USA TERRITORY	GUAM, MARIANA ISLANDS	12.982	144.801	2.13
1994	10	4	4	1	8.3		RUSSIA	S. KURIL ISLANDS	43.773	147.321	10.4
1995	4	7	4	1	7.4		SAMOA	SAMOA ISLANDS	-15.199	-173.529	0.09
1995	5	16	4	1	7.7		NEW CALEDONIA	LOYALTY ISLANDS	-23.008	169.9	0.5
1995	7	30	4	1	8		CHILE	N. CHILE	-23.34	-70.294	3
1995	9	14	3	1	7.4		MEXICO	MEXICO	16.779	-98.597	0.4
1995	10	9	4	1	8		MEXICO	MEXICO	19.055	-104.205	11
1995	12	3	4	1	7.9		RUSSIA	S. KURIL ISLANDS	44.663	149.3	1.1
1996	6	10	4	1	7.9		USA	ANDREANOF ISLANDS, AK	51.564	-177.632	0.51
1999	11	26	4	1	7.5		VANUATU	VANUATU ISLANDS	-16.423	168.214	6
2001	6	23	4	1	8.4		PERU	S. PERU	-16.265	-73.641	7
2004	12	26	4	1	9		INDONESIA	OFF W. COAST OF SUMATRA	3.295	95.982	50.9
2006	5	3	4	1	8		TONGA	TONGA	-20.187	-174.123	0.27
2006	9	28	4	1	6.9		SAMOA	SAMOA ISLANDS	-16.592	-172.033	0.08

Table 2.4-29—{Historical Tsunamis Affecting U.S.A. Territories in the Pacific Basin}

(Page 3 of 3)

Date			Tsunami Cause				Tsunami Source Location				Max Water Height (meter) Above Sea Level
Year	Mo	Day	Val[1]	Code[2]	Earthquake Mag	Volcano	Country	Name	Latitude	Longitude	
2006	11	15	4	1	8.3		RUSSIA	S. KURIL ISLANDS	46.592	153.266	0.88
2007	1	13	4	1	8.1		RUSSIA	S. KURIL ISLANDS	46.243	154.524	0.32
2007	4	1	4	1	8.1		SOLOMON ISLANDS	SOLOMON ISLANDS	-8.46	157.044	3.5
2007	8	15	4	1	8		PERU	S. PERU	-13.386	-76.603	0.37

Notes:

1 4 = definite tsunami
3 = probable tsunami
2 = questionable tsunami
1 = very doubtful tsunami
0 = erroneous entry

2 0 = Unknown
1 = Earthquake
2 = Questionable Earthquake
3 = Earthquake and Landslide
4 = Volcano and Earthquake
5 = Volcano, Earthquake, and Landslide
6 = Volcano
7 = Volcano and Landslide
8 = Landslide
9 = Meteorological
10 = Explosion
11 = Astronomical Tide

Source:
NOAA,2006 Historical Tsunami Record, http://www.ngdc.noaa.gov/seg/hazard/tsu_db.shtml, Date accessed: September, 2007.

Table 2.4-30—{Estimated Monthly Average Ice Thickness, Missouri River 1970-2006}

Month	AFDD (°F)	Ice Thickness (in)	Ice Thickness (cm)
January	228	2.25	5.71
February	175	1.98	5.03
December	142	1.76	4.47
Average	182	2.00	5.07

Note 1: Estimated values based on **NOAA, 2007a; NOAA, 2007b; USEPA, 2007.**
Note 2: 1996 year was not included in the analysis.

Table 2.4-31—{Estimated Monthly Average Ice Thickness, ESW Emergency Makeup Retention Pond 1970-2006}

Month	AFDD (°F)	Ice Thickness (in)	Ice Thickness (cm)
January	228	10.51	26.70
February	175	9.24	23.47
December	142	8.22	20.88
Average	182	9.32	23.68

Note 1: Estimated values based on **NOAA, 2007a; NOAA, 2007b; USEPA, 2007.**
Note 2: 1996 year was not included in the analysis.

FSAR: Section 2.4

Table 2.4-32— {10 mi^2 Probable Maximum Precipitation Depths at the ESWEMS}

Duration (hrs)	All Season PMP (in)	All Season PMP (cm)
6	27.5	69.9
12	33.0	83.8
24	34.8	88.4
48	38.6	98.0
72	40.0	101.6

Source: USACE, 1978

Table 2.4-33—{Data Input for Wave Runup Calculations}

Scenario	Wind Velocity U (mph)	Effective Fetch F_e (mi)	Wind Tide Fetch F (mi)	Average Depth D (ft)	Wind Setup S (ft)
Fastest Annual Wind	63	0.1297	0.2593	20.26	0.04
2-year Wind Event	50	0.1297	0.2593	20.26	0.02
10-year Wind Event	65	0.1297	0.2593	20.26	0.04
25-year Wind Event	71	0.1297	0.2593	20.26	0.05
50-year Wind Event	72	0.1297	0.2593	20.26	0.05
100-year Wind Event	85	0.1297	0.2593	20.26	0.07
1,000-year Wind Event	118	0.1297	0.2593	20.26	0.13

Scenario	Wind Velocity U (km/hr)	Effective Fetch F_e (km)	Wind Tide Fetch F (km)	Average Depth D (m)	Wind Setup S (cm)
Fastest Annual Wind	101	0.2087	0.4172	6.18	1.22
2-year Wind Event	80	0.2087	0.4172	6.18	0.61
10-year Wind Event	105	0.2087	0.4172	6.18	1.22
25-year Wind Event	114	0.2087	0.4172	6.18	1.52
50-year Wind Event	116	0.2087	0.4172	6.18	1.52
100-year Wind Event	137	0.2087	0.4172	6.18	2.13
1,000-year Wind Event	190	0.2087	0.4172	6.18	3.96

Table 2.4-34—{Wave Runup Results}

Scenario	Wind Setup S (ft)	Wave Runup $R_{u2\%}$ (ft)	Wave Runup Requirement $S+R_{u2\%}$ (ft)
Fastest Annual Wind	0.04	0.78	0.82
2-year Wind Event	0.02	0.61	0.64
10-year Wind Event	0.04	0.81	0.85
25-year Wind Event	0.05	0.89	0.94
50-year Wind Event	0.05	0.91	0.96
100-year Wind Event	0.07	1.09	1.15
1,000-year Wind Event	0.13	1.56	1.69

Scenario	Wind Setup S (m)	Wave Runup $R_{u2\%}$ (m)	Wave Runup Requirement $S+R_{u2\%}$ (m)
Fastest Annual Wind	0.01	0.24	0.25
2-year Wind Event	0.01	0.19	0.20
10-year Wind Event	0.01	0.25	0.26
25-year Wind Event	0.02	0.27	0.29
50-year Wind Event	0.02	0.28	0.29
100-year Wind Event	0.02	0.33	0.35
1,000-year Wind Event	0.04	0.48	0.52

Table 2.4-35—{Fastest Mile Quantities Using Fisher-Tippet Type I (Frechet) Distribution (Interpolated for Callaway County Plant Site)}

Recurrence Interval (years)	Extreme Fastest Mile Wind Speed (mph)	Extreme Fastest Mile Wind Speed (km/h)
2	50	80
10	65	105
25	71	114
50	72	116
100	85	137
1,000	118	190

Source: Thom, 1968

Table 2.4-36—{Extreme Wind Speeds Columbia, Missouri (Periods of Record: 1931-2006)}

Month	Prevailing Direction	Fastest Mile			
		Speed (mph)	Speed (km/h)	Direction	Year
January	S	56	90	NW	1951
February	NW	51	82	NW	1984
March	WNW	59	95	NW	1964
April	S	57	92	NW	1953
May	SSE	58	93	SW	1950
June	SSE	59	95	SW	1985
July	SSE	61	98	NW	1958
August	S	59	95	N	2003
September	SSE	63	101	NW	1952
October	SSE	49	79	NW	1959
November	S	49	79	NW	1955
December	S	58	93	SW	1971
Annual	--	63	101	NW	1952

Source: NOAA, 2007

Table 2.4-37—{Summary of Information of the Stations and Range of Data Used}

Station Name	USGS Station ID	Location		MSL station datum	Period of Record
		Latitude	Longitude	ft (m)	
Hermann, MO	06934500	38°42’35.3”	91°26’18.6”	481.56 (146.78)	1929-2007
Boonville, MO	06909000	38°58’42”	92°45’13”	565.42 (172.34)	1926-2007

Source: USGS, 2007a and USGS, 2007b.

Table 2.4-38—{Annual Minimum Water Levels at Hermann, MO Station}

Date	Annual Min. Water Level (ft)		Annual Min. Water Level (m)	
	Gage Height	MSL	Gage Height	MSL
12/21/1988	1.99	483.55	0.61	147.39
12/25/1989	0.07	481.63	0.02	146.80
11/26/1990	1.75	483.31	0.53	147.31
11/17/1991	1.61	483.17	0.49	147.27
2/11/1992	3.13	484.69	0.95	147.73
12/28/1993	9.29	490.85	2.83	149.61
12/20/1994	5.84	487.40	1.78	148.56
1/13/1995	3.84	485.40	1.17	147.95
1/15/1996	4.25	485.81	1.30	148.07
1/21/1997	6.54	488.10	1.99	148.77
1/27/1998	7.49	489.05	2.28	149.06
12/29/1999	5.40	486.96	1.65	148.43
12/30/2000	1.32	482.88	0.40	147.18
1/1/2001	1.62	483.18	0.49	147.27
12/15/2002	1.27	482.83	0.39	147.17
1/25/2003	0.60	482.16	0.18	146.96
2/17/2004	2.53	484.09	0.77	147.55
12/13/2005	0.33	481.89	0.10	146.88
11/16/2006	0.05	481.61	0.02	146.79
1/23/2007	1.94	483.50	0.59	147.37

Notes: MSL determined based on gage datum of 481.56 ft
Source: USGS, 2007a.

Table 2.4-39—{Annual Minimum Water Levels at Boonville, MO Station}

Date	Annual Min. Water Level (ft)		Annual Min. Water Level (m)	
	Gage Height	MSL	Gage Height	MSL
1/19/1993	7.20	572.62	2.19	174.53
12/14/1994	6.05	571.47	1.84	174.18
1/12/1995	4.40	569.82	1.34	173.68
1/27/1996	4.53	569.95	1.38	173.72
1/17/1997	7.09	572.51	2.16	174.50
1/20/1998	7.81	573.23	2.38	174.72
12/28/1999	7.00	572.42	2.13	174.47
12/21/2000	2.79	568.21	0.85	173.19
1/28/2001	4.03	569.45	1.23	173.57
12/31/2002	2.83	568.25	0.86	173.20
1/25/2003	2.21	567.63	0.67	173.01
1/14/2004	2.33	567.75	0.71	173.05
12/12/2005	2.09	567.51	0.64	172.98
11/23/2006	2.01	567.43	0.61	172.95
1/22/2007	1.77	567.19	0.54	172.88

Notes: MSL determined based on gage datum of 565.42 ft
Source: USGS, 2007b.

FSAR: Section 2.4

Table 2.4-40— {Annual Low Flow Statistics for Hermann (1929-2007) and Boonville (1926-2007) Stations}

Gage Station	$Q_{1,10}$ [cfs]	$Q_{1,30}$ [cfs]	$Q_{7,10}$ [cfs]	$Q_{30,10}$ [cfs]	Mean [cfs]	Median [cfs]	Harmonic Mean [cfs]
Boonville	9,035	5,719	10,861	15,898	62,480	47,800	39,919
Hermann	12,189	7,997	14,572	19,175	79,890	59,600	50,825
Callaway Site (using Boonville gage)	9,348	5,917	11,237	16,448	-	-	-
Callaway Site (using Hermann gage)	12,073	7,921	14,435	18,993	-	-	-

Notes:

Callaway Site statistics were interpolated based on USGS gauging stations at Missouri River Mile 115.

$Q_{1,10}$ flow is the mean stream flow over 1 day which, on a statistical basis, can be expected to occur once every 10 years.

$Q_{7,10}$ flow is the mean stream flow over 7 consecutive days which, on a statistical basis, can be expected to occur once every 10 years.

$Q_{30,10}$ flow is the mean stream flow over 30 consecutive days which, on a statistical basis, can be expected to occur once every 10 years.

$Q_{1,30}$ flow is the mean stream flow over 1 day which, on a statistical basis, can be expected to occur once every 30 years.

FSAR: Section 2.4

Table 2.4-41—{Listing of U.S. Environmental Protection Agency (US EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community Water Systems in Callaway and Osage Counties, Missouri}

(Page 1 of 3)

County	Type	System Name	System ID	Population Served	Primary Water Source	Status	Date Closed
Callaway	Community	AUXVASSE	MO3010039	1135	Groundwater	Active	N/A
Callaway	Community	CALLAWAY #2 WATER DISTRICT	MO3024085	13500	Groundwater	Active	N/A
Callaway	Community	CALLAWAY CO PWSD #1	MO3024084	8350	Groundwater	Active	N/A
Callaway	Community	FULTON	MO3010296	12128	Groundwater	Active	N/A
Callaway	Community	FULTON STATE HOSPITAL	MO3069004	2005	Groundwater	Active	N/A
Callaway	Community	HATTON HILLS MHP	MO3041238	25	Groundwater	Active	N/A
Callaway	Community	JEFFERSON CITY - NORTH	MO3010146	95	Groundwater	Active	N/A
Callaway	Community	KINGDOM CITY	MO3010424	162	Groundwater	Active	N/A
Callaway	Community	MOKANE WATER CO-OP	MO3010535	186	Groundwater	Active	N/A
Callaway	Community	NEW BLOOMFIELD	MO3010563	560	Groundwater	Active	N/A
Callaway	Community	NEW CHRISTIAN LIFE FELLOWSHIP	MO3048994	87	Groundwater	Active	N/A
Callaway	Community	RIVERVIEW NURSING CENTER	MO3069003	60	Groundwater	Active	N/A
Callaway	Community	SCOTCHMAN PLACE	MO3048263	67	Groundwater	Active	N/A
Callaway	Community	COUNTRY MANOR	MO3069077	35	Groundwater	Closed	12/1/1985
Callaway	Community	MC DONALD MHP	MO3048262	130	Groundwater	Closed	2/1/1984
Callaway	Community	REFORM MOBILE RENTALS	MO3048260	100	Groundwater	Closed	11/1/1984
Callaway	Community	RENZ FARM	MO3069002	320	Groundwater	Closed	8/1/1993
Callaway	Community	SALMONS TRAILER COURT	MO3040740	30	Groundwater	Closed	9/1/1996
Callaway	Community	TOWER MHP	MO3048261	115	Groundwater	Closed	4/1/2005
Callaway	Non-Transient Non-Community	AMEREN U.E.-CALLAWAY PLT	MO3182219	860	Groundwater	Active	N/A
Callaway	Non-Transient Non-Community	SOUTH CALLAWAY CO R-II SCHOOLS	MO3171252	760	Groundwater	Active	N/A
Callaway	Non-Transient Non-Community	HATTEN MCCREDIE R-1 ELEM	MO3171127	255	Groundwater	Closed	7/1/1984
Callaway	Non-Transient Non-Community	KINGDOM CITY SINCLAIR	MO3181315	25	Groundwater	Closed	1/1/1988
Callaway	Non-Transient Non-Community	MERIAL LIMITED	MO3181380	29	Groundwater	Closed	10/1/1998
Callaway	Non-Transient Non-Community	NORTH CALLAWAY R-I SR. HIGH	MO3171251	400	Groundwater	Closed	7/1/1995

Table 2.4-41—{Listing of U.S. Environmental Protection Agency (US EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community Water Systems in Callaway and Osage Counties, Missouri}
(Page 2 of 3)

County	Type	System Name	System ID	Population Served	Primary Water Source	Status	Date Closed
Callaway	Non-Transient Non-Community	WILLIAMSBURG R-1 ELEM SCHOOL	MO3171128	210	Groundwater	Closed	4/1/1984
Callaway	Transient Non-Community	CROOKED CREEK CAMPGROUND	MO3240054	40	Groundwater	Active	N/A
Callaway	Transient Non-Community	WILDWOOD LOT OWNERS ASSOCIATION	MO3242162	100	Groundwater	Active	N/A
Callaway	Transient Non-Community	EBENEZER BAPTIST CHURCH	MO3270305	25	Groundwater	Closed	7/1/1991
Callaway	Transient Non-Community	FOREST'S STANDARD SERV	MO3232044	200	Groundwater	Closed	12/1/1991
Callaway	Transient Non-Community	FRONTIER MOTEL	MO3190681	60	Groundwater	Closed	12/1/1991
Callaway	Transient Non-Community	KINGDOM CITY SERVICES INC	MO3210680	800	Groundwater	Closed	11/15/2006
Callaway	Transient Non-Community	LAY'S MOTEL	MO3191737	25	Groundwater	Closed	12/1/1991
Callaway	Transient Non-Community	MOC 1 TRAVEL PLAZA	MO3290603	50	Groundwater	Closed	1/1/2000
Callaway	Transient Non-Community	OLD AUXVASSE NM PRESBY CHURCH	MO3270503	25	Groundwater	Closed	12/1/1991
Callaway	Transient Non-Community	POPLAR TREE RESTAURANT	MO3211456	500	Groundwater	Closed	12/1/1991
Callaway	Transient Non-Community	PORTLAND BAPTIST CHURCH	MO3270306	25	Groundwater	Closed	7/1/1991
Callaway	Transient Non-Community	RICHLAND BAPTIST CHURCH	MO3271314	25	Groundwater	Closed	7/1/1991
Callaway	Transient Non-Community	SKELLY TRUCK PLAZA	MO3212043	750	Groundwater	Closed	12/1/1991
Callaway	Transient Non-Community	SONNY'S RESTAURANT	MO3211600	300	Groundwater	Closed	12/1/1991
Osage	Community	CHAMOIS	MO3010155	456	Groundwater	Active	N/A
Osage	Community	FRANKENSTEIN	MO3010904	113	Groundwater	Active	N/A
Osage	Community	FREEBURG	MO3010291	850	Groundwater	Active	N/A
Osage	Community	LINN	MO3010470	1220	Groundwater	Active	N/A

Table 2.4-41—{Listing of U.S. Environmental Protection Agency (US EPA) SDWIS Community, Non-Transient Non-Community, and Transient Non-Community Water Systems in Callaway and Osage Counties, Missouri}

(Page 3 of 3)

County	Type	System Name	System ID	Population Served	Primary Water Source	Status	Date Closed
Osage	Community	META	MO3010517	410	Groundwater	Active	N/A
Osage	Community	OSAGE CO PWSD #1	MO3024437	1003	Groundwater	Active	N/A
Osage	Community	OSAGE CO PWSD #2-NORTH	MO3024438	650	Groundwater	Active	N/A
Osage	Community	OSAGE CO PWSD #2-SOUTH	MO3024441	400	Groundwater	Active	N/A
Osage	Community	OSAGE CO PWSD #3	MO3024439	1155	Groundwater	Active	N/A
Osage	Community	OSAGE CO PWSD #4	MO3024440	358	Groundwater	Active	N/A
Osage	Community	LINN MANOR REST HOME	MO3069011	40	Groundwater	Closed	6/1/1991
Osage	Non-Transient Non-Community	DIAMOND PET FOODS	MO3181615	60	Groundwater	Active	N/A
Osage	Non-Transient Non-Community	CENTRAL ELECTRIC POWER COOP	MO3182248	25	Groundwater	Closed	10/1/2004
Osage	Non-Transient Non-Community	LINN MIDDLE ELEM SCHOOL	MO3171204	155	Groundwater	Closed	7/1/1982
Osage	Non-Transient Non-Community	QUAKER WINDOW CO	MO3180620	25	Groundwater	Closed	11/1/1987
Osage	Non-Transient Non-Community	STANDARD MILLING CO	MO3180622	25	Groundwater	Closed	2/1/1988
Osage	Transient Non-Community	MARI-OSA-DELTA	MO3190087	30	Groundwater	Active	N/A
Osage	Transient Non-Community	OSAGE COUNTRY CLUB	MO2202792	60	Groundwater	Active	N/A
Osage	Transient Non-Community	RAINBOW LANES BOWLING	MO3281735	25	Groundwater	Active	N/A
Osage	Transient Non-Community	MFA SERVICE	MO3231465	25	Groundwater	Closed	1/1/1992
Osage	Transient Non-Community	ROY & JOAN'S COUNTRY LOUNGE	MO3211484	25	Groundwater	Closed	1/1/1992
Osage	Transient Non-Community	WILLIBRANDS, INC	MO3231384	50	Groundwater	Closed	2/26/2007

Reference: U.S. Environmental Protection Agency, Safe Drinking Water Information System (SDWIS) Website, http://www.epa.gov/enviro/html/sdwis, Accessed August 29, 2007.

N/A – not applicable.

Table 2.4-42—{Listing of Missouri Department of Natural Resources Public Water Use for Callaway and Osage Counties, Missouri}
(Page 1 of 2)

County	Type	System Name	System ID	# Wells	1st Year	Pop. Served	Service Connections	Supply (MGD)	Consumption (MGD)	Storage (MG)
Callaway	Community	AUXVASSE	MO3010039	3	1913	1,135	454	0.2880	0.0860	0.4000
Callaway	Community	CALLAWAY #2 WATER DISTRICT	MO3024085	10	1973	13,500	4,910	4.5000	1.0280	1.3047
Callaway	Community	CALLAWAY CO PWSD #1	MO3024084	6	1968	8,350	3,600	3.2112	0.8600	2.7500
Callaway	Community	FULTON	MO3010296	6	1937	12,128	4,500	4.3900	1.3000	5.7000
Callaway	Community	FULTON STATE HOSPITAL	MO3069004	2	2005	2,005	2	0.8000	0.2530	0.2500
Callaway	Community	HATTON HILLS MHP	MO3041238	1	2006	25	100	NR	NR	NR
Callaway	Community	JEFFERSON CITY - NORTH	MO3010146	2	1963	95	30	0.3000	0.0230	0.0500
Callaway	Community	KINGDOM CITY	MO3010424	1	1989	162	62	0.5000	0.0820	0.5000
Callaway	Community	MOKANE WATER CO-OP	MO3010535	1	1961	186	105	0.0700	0.0150	0.0370
Callaway	Community	NEW BLOOMFIELD	MO3010563	2	1961	560	264	0.2100	0.0400	0.0500
Callaway	Community	NEW CHRISTIAN LIFE FELLOWSHIP	MO3048994	1	1979	87	25	0.0400	0.0200	0.0006
Callaway	Community	RIVERVIEW NURSING CENTER	MO3069003	1	1978	60	1	0.0700	0.0050	0.0002
Callaway	Community	SCOTCHMAN PLACE	MO3048263	1	1989	67	40	0.0430	0.0096	0.0004
Callaway	Non-Transient Non-Community	AMEREN U.E.-CALLAWAY PLT	MO3182219	3	1976	860	NR	NR	NR	NR
Callaway	Non-Transient Non-Community	SOUTH CALLAWAY CO R-II SCHOOLS	MO3171252	2	1958	760	NR	NR	NR	NR
Callaway	Transient Non-Community	CROOKED CREEK CAMPGROUND	MO3240054	1	1995	40	NR	NR	NR	NR
Callaway	Transient Non-Community	WILDWOOD LOT OWNERS ASSOCIATION	MO3242162	1	1973	100	NR	NR	NR	NR
Osage	Community	CHAMOIS	MO3010155	2	1923	456	243	0.4000	0.0500	0.1500
Osage	Community	FRANKENSTEIN	MO3010904	1	1976	113	45	0.0640	0.0060	0.0010
Osage	Community	FREEBURG	MO3010291	2	1965	850	340	0.3600	0.0650	0.1500
Osage	Community	LINN	MO3010470	4	1937	1,220	629	0.9300	0.2900	0.3000
Osage	Community	META	MO3010517	1	1959	410	133	0.3000	0.0500	0.1000
Osage	Community	OSAGE CO PWSD #1	MO3024437	2	1966	2,150	325	0.3740	0.0700	0.0740
Osage	Community	OSAGE CO PWSD #2-NORTH	MO3024438	2	1969	650	221	0.1080	0.0400	0.0300

Table 2.4-42—{Listing of Missouri Department of Natural Resources Public Water Use for Callaway and Osage Counties, Missouri}
(Page 2 of 2)

County	Type	System Name	System ID	# Wells	1st Year	Pop. Served	Service Connections	Supply (MGD)	Consumption (MGD)	Storage (MG)
Osage	Community	OSAGE CO PWSD #2-SOUTH	MO3024441	2	1969	400	158	0.0790	0.0270	0.0370
Osage	Community	OSAGE CO PWSD #3	MO3024439	1	1975	750	327	0.2300	0.0800	0.0870
Osage	Community	OSAGE CO PWSD #4	MO3024440	2	1974	400	135	0.1000	0.0210	0.0370
Osage	Non-Transient Non-Community	DIAMOND PET FOODS	MO3181615	1	1997	60	NR	NR	NR	NR
Osage	Transient Non-Community	MARI-OSA-DELTA	MO3190087	1	NR	30	NR	NR	NR	NR
Osage	Transient Non-Community	OSAGE COUNTRY CLUB	MO2202792	1	NR	60	NR	NR	NR	NR
Osage	Transient Non-Community	RAINBOW LANES BOWLING	MO3281735	1	1960	25	NR	NR	NR	NR

NR – not reported.

Table 2.4-43—{Listing of Local, Public and Private Groundwater Monitoring Wells for Callaway and Osage Counties, Missouri}

(Page 1 of 6)

Dataset[1]	Twp.	Rge.	Sect.	ID or Ref. Num.	MO#	Type	Distance[2] from site (miles)	Year	Gnd Elev. (ft msl)	Depth bgs (ft)	Casing bgs (ft)	Formation[3]	Yield (gpm)	Remarks[4]
Inside Study Area Boundary – Callaway County														
1	47N	8W	19	00053030	NA	Well	Unknown	NR	NR	395	232	Ls	40	Private
1	47N	8W	19	00357839	NA	Pump	Unknown	NR	NR	NR	NR	NR	NR	Private
1	47N	8W	20	00080777	NA	Well	Unknown	1991	NR	363	238	Ls	30	Private
1	47N	8W	21	00047677	NA	Well	Unknown	1991	NR	450	147	Ls-sh-flint	40	Private
1	47N	8W	21	00080740	NA	Well	Unknown	1992	NR	343	261	Ls/cht	40	Private
1	47N	8W	21	00151442	NA	Well	Unknown	1996	700	410	148	Sh-cht	30	Private
1	47N	8W	23	00395853	NA	Well	Unknown	NR	690	426	240	NR	25	Private
1	47N	7W	19	00116829	NA	Heat Pump	Unknown	NR	NR	NR	NR	NR	NR	Private
1	47N	8W	28	00335855	NA	Well	Unknown	2004	NR	395	80	ls to sh to ls	30	Private
1	47N	8W	29	00335833	NA	Well	Unknown	2004	NR	350	80	Ls-flint	30	Private
1	47N	8W	32	00113586	NA	Heat Pump	Unknown	NR	622	155	NR	NR	NR	Private
1	47N	8W	34	00057084	NA	Reconstruct	Unknown	1994	NR	NR	NR	NR	NR	Thunderbird Lake Assoc.
1	47N	8W	34	00064627	NA	Well	Unknown	1991	NR	150	NR	NR	NR	Private
1	47N	8W	34	00064628	NA	Well	Unknown	1991	730	365	103	Ls	22	Private
1	47N	8W	34	00191092	NA	Well	Unknown	1998	740	450	169	Cotter flint	25	Private
1	46N	7W	5	00077892	NA	Well	Unknown	1992	NR	435	218	Ls-ls/cht	30	Private
1	46N	8W	2	00114869	NA	Abandoned	Unknown	1996	NR	29	NR	NR	NR	AmerenUE (abandoned)
1	46N	8W	2	00211756	NA	Well	Unknown	1998	780	426	210	Ls-ls/flint	35	Private
1	46N	8W	3	00044091	NA	Unknown	Unknown	1989	NR	435	184	Ls – sh – ls/flint	30	Private
1	46N	8W	3	00169520	NA	Well	Unknown	1996	NR	426	164	Ls – ls/flint	30	Private
1	46N	8W	6	00008038	NA	Well	Unknown	NR	NR	210	80	NR	30	Private
1	46N	8W	6	00010329	NA	Pump	Unknown	NR	NR	210	NR	NR	NR	Private
1	46N	8W	7	00007056	NA	Reconstruct	Unknown	1988	NR	375	NR	NR	NR	Private
1	46N	8W	11	00316189	NA	Monitoring	Unknown	NR	834	31	60	NR	NR	AmerenUE
1	46N	7W	7	00164558	NA	Reconstruct	Unknown	1998	NR	NR	NR	NR	NR	Private
1	46N	8W	13	00316191	NA	Monitoring	Unknown	NR	842	42	60	NR	NR	AmerenUE
1	46N	8W	13	00003458	NA	Well	Unknown	1987	NR	377	186	NR	NR	AmerenUE
1	46N	8W	14	00003459	NA	Well	Unknown	1987	NR	402	136	NR	NR	AmerenUE

Table 2.4-43—{Listing of Local, Public and Private Groundwater Monitoring Wells for Callaway and Osage Counties, Missouri}

(Page 2 of 6)

Dataset[1]	Twp.	Rge.	Sect.	ID or Ref. Num.	MO#	Type	Distance[2] from site (miles)	Year	Gnd Elev. (ft msl)	Depth bgs (ft)	Casing bgs (ft)	Formation[3]	Yield (gpm)	Remarks[4]
1	46N	8W	14	00122521	NA	Monitoring	Unknown	1995	NR	29	NR	Grvl – clay	NR	AmerenUE
1	46N	8W	14	00122522	NA	Monitoring	Unknown	1995	NR	28	NR	Sty clay – grvl	NR	AmerenUE
1	46N	8W	14	00122524	NA	Monitoring	Unknown	1995	NR	29	NR	Sty clay – grv	NR	AmerenUE
1	46N	8W	14	00122525	NA	Monitoring	Unknown	1996	NR	30	NR	Ls/grvl	NR	AmerenUE
1	46N	8W	14	00122526	NA	Monitoring	Unknown	1996	NR	28	NR	Ls/grvl	NR	AmerenUE
1	46N	8W	14	00122531	NA	Monitoring	Unknown	1995	NR	27	NR	Sty clay-grvl-clay	NR	AmerenUE
1	46N	8W	14	00131867	NA	Abandoned	Unknown	1995	NR	29	9	NR	NR	AmerenUE (abandoned)
1	46N	8W	14	00131868	NA	Abandoned	Unknown	1996	NR	18	NR	NR	NR	AmerenUE (abandoned)
1	46N	8W	14	00145125	NA	Monitoring	Unknown	NR	NR	25	NR	NR	NR	AmerenUE
1	46N	8W	14	00145126	NA	Monitoring	Unknown	NR	NR	29	NR	NR	NR	AmerenUE
1	46N	8W	14	00275184	NA	Abandoned	Unknown	2002	840	64.4	NR	NR	NR	AmerenUE (abandoned)
1	46N	8W	14	00316190	NA	Monitoring	Unknown	NR	829	35	60	NR	NR	AmerenUE
1	46N	8W	16	00007729	NA	Well	Unknown	1988	NR	390	104	Ls-sh-cotter	30	Private
1	46N	8W	16	00308414	NA	Pump	Unknown	2004	NR	450	NR	NR	NR	Private
1	46N	8W	16	00308468	NA	Well	Unknown	2002	NR	450	106	Ls-rx/flint	30	Private
1	46N	8W	17	00242018	NA	Heat Pump	Unknown	NR	NR	150	NR	Ls	NR	Private
1	46N	8W	19	00000079	NA	Well	Unknown	1987	NR	375	62	Ls-flint	25	Private
1	46N	8W	19	00064288	NA	Well	Unknown	1991	NR	350	126	Sh-rx	30	Private
1	46N	7W	19	00211752	NA	Well	Unknown	1998	680	306	82	Ls-ls/flint	30	Private
1	46N	8W	20	00213227	NA	Well	Unknown	1998	680	NR	426	Ls-ls/sh-ls/flint	40	Private
1	46N	8W	21	00135670	NA	Well	Unknown	1995	700	450	168	Rx/sh-rx/flint	30	Private
1	46N	7W	29	00374270	NA	Pump	Unknown	NR	NR	365	NR	NR	NR	Private
1	46N	7W	29	00402075	NA	Well	Unknown	NR	NR	365	120	NR	40	Private
1	46N	7W	30	00200378	NA	Well	Unknown	1997	720	465	90	Ls-clay-sh-ls	30	Private
1	46N	8W	25	00003452	NA	Well	Unknown	1987	550	301	105	Ls/flint	30	Private
1	46N	8W	27	00006638	NA	Well	Unknown	1988	520	147	82	Ls	20	Private
1	46N	8W	27	00048226	NA	Well	Unknown	1990	NR	170	80	Ls-flint	NR	Private
1	46N	8W	27	00087075	NA	Well	Unknown	1992	600	450	122	Sh-flint	40	Private
1	46N	8W	27	00198973	NA	Well	Unknown	1998	600	386	102	Ls-ls/flint	NR	Private

Table 2.4-43—{Listing of Local, Public and Private Groundwater Monitoring Wells for Callaway and Osage Counties, Missouri}
(Page 3 of 6)

Dataset[1]	Twp.	Rge.	Sect.	ID or Ref. Num.	MO#	Type	Distance[2] from site (miles)	Year	Gnd Elev. (ft msl)	Depth bgs (ft)	Casing bgs (ft)	Formation[3]	Yield (gpm)	Remarks[4]
1	46N	8W	27	00224427	NA	Well	Unknown	1999	NR	306	126	Ls/sh-ls	50	Private
1	46N	8W	28	00228356	NA	Well	Unknown	1999	740	426	123	Ls-ls/flint	40	Private
1	46N	8W	29	00191043	NA	Well	Unknown	1997	NR	510	106	Flint	30	Private
1	46N	7W	31	00134215	NA	Well	Unknown	1994	NR	375	84	Ls-ls/flint	30	Private
1	46N	7W	31	00188914	NA	Reconstruct	Unknown	1999	NR	270	NR	NR	NR	Private
1	46N	7W	32	00001376	NA	Well	Unknown	1987	NR	227	61	Ls	25	Private
1	46N	7W	32	00010425	NA	Well	Unknown	1988	640	247	82	Ls	20	Private
1	46N	7W	32	00081995	NA	Well	Unknown	1991	640	330	82	Ls-ls/cht	50	Private
1	46N	7W	32	00169268	NA	Well	Unknown	1997	NR	190	80	Ls/flint	30	Private
1	46N	7W	32	00273760	NA	Well	Unknown	2002	600	330	82	Ls-sand-ls-ls/flint -pink ls	25	Private
1	45N	8W	6	00018802	NA	Well	Unknown	1996	580	306	102	Ls/flint	35	Private
1	45N	8W	6	00180662	NA	Well	Unknown	1997	BR	450	148	Sh-flint	30	Private
1	45N	8W	7	00019262	NA	Well	Unknown	1996	660	426	102	Ss/flint	NR	Private
1	45N	8W	7	00151208	NA	Well	Unknown	1996	NR	330	82	Ls/flint/ss	25	Private
1	45N	8W	7	00148453	NA	Well	Unknown	1996	NR	270	90	Ls/cht	30	Private
1	46N	8W	33	00308424	NA	Pump	Unknown	NR	NR	430	NR	NR	NR	Private
1	46N	8W	33	00318634	NA	Well	Unknown	NR	NR	430	106	NR	40	Private
1	46N	8W	34	00289232	NA	Pump	Unknown	NR	NR	NR	NR	NR	NR	Private
1	46N	8W	34	00318658	NA	Well	Unknown	NR	NR	450	148	NR	80	Private
1	45N	7W	5	00100248	NA	Unknown	Unknown	1996	510	854	350	Fill/grvl-la-dol-ls/ dol	665	Union Electric Co (AmerenUE)
1	45N	8W	5	00000081	NA	Well	Unknown	1987	NR	250	62	Ls-flint-ls	30	Private
1	45N	8W	1	00000328	NA	Public	Unknown	1987	530	95	75	Med-cse sand & boulders	1002	Central Electric Power
1	45N	8W	1	00274562	NA	Irrigation	Unknown	2005	530	97	78	Med-cse sand	1007	Central Electric Power
1	45N	8W	1	00323237	NA	Abandoned	Unknown	2005	NR	95	75	NR	NR	Central Electric Power
1	45N	8W	10	00239778	NA	Well	Unknown	2000	NR	230	80	Ls/flint	25	Private
1	45N	8W	12	00024151	NA	Well	Unknown	1998	NR	290	82	Ls/flint	30	Private
1	45N	8W	12	00200091	NA	Well	Unknown	1998	600	350	143	Ls/flint	25	Private

Table 2.4-43—{Listing of Local, Public and Private Groundwater Monitoring Wells for Callaway and Osage Counties, Missouri}
(Page 4 of 6)

Dataset[1]	Twp.	Rge.	Sect.	ID or Ref. Num.	MO#	Type	Distance[2] from site (miles)	Year	Gnd Elev. (ft msl)	Depth bgs (ft)	Casing bgs (ft)	Formation[3]	Yield (gpm)	Remarks[4]
1	45N	8W	12	00374281	NA	Pump	Unknown	NR	NR	326	NR	NR	NR	Private
1	45N	7W	8	00242685	NA	Heat Pump	Unknown	NR	NR	180	NR	NR	NR	Private
1	45N	7W	8	00385871	NA	Abandoned	Unknown	NR	NR	12	NR	NR	NR	IBID Co. Inc
2	47N	8W	22	010796	NA	Outcrop	4.5	1949	740	177	NA	Alluvial	NA	No well
2	47N	8W	35	027390	3242162	Non-comm	2.5	1973	782	755	450	CJC-Roub	200	Lost Canyon Estates
2	46N	8W	1	018462	NA	Private	2.0	1959	761	325	38	Cotter	20	Private
2	46N	8W	2	028021	3024085	Non-comm	1.8	1975	795	705	400	CJC-Roub	100	Callaway PWSD#2 W5
2	46N	8W	9	019953	NA	Non-comm	3.1	1961	779	500	225	CJC	15	Church of God
2	46N	8W	11	027975	3182219	Industrial	Site	1976	845	1506	380	CJC-DDR	210	AmerenUE #1
2	46N	8W	12	018459	NA	Private	0.8	1959	830	375	73	Cotter	25	Private
2	46N	8W	13	028347	3182219	Industrial	Site	1980	824	1480	400	CJC-DDR	565	AmerenUE #3
2	46N	8W	14	028076	3182219	Industrial	Site	1977	822	1100	405	CJC-Emin	194	AmerenUE #2
2	46N	8W	28	012615	NA	Private	3.2	1953	795	300	108.5	Cotter	8	Private
2	46N	8W	28	012616	NA	Private	3.2	1953	795	250	27	Cotter	5	Private
2	46N	8W	35	022569	NA	Private	3.2	1964	807	520	170	CJC-Roub	15	Private
2	46N	8W	25	013368	NA	Private	2.6	1955	545	275	22	Cotter	8	Private
2	46N	8W	35	024567	NA	Profile Test	3.7	1966	521	47	NA	Alluvial	NA	No well
2	46N	7W	18	019774	NA	Private	2.1	1961	662	260	37	CJC	10	Private
2	46N	7W	30	020390	NA	Private	2.6	1961	587	205	100	CJC	7	Private
2	45N	8W	3	012619	NA	Private	4.5	1953	534	200	31	Cotter	2	Private
2	45N	8W	2	024508	NA	Profile Test	4.7	1967	525	35	NA	Alluvial	NA	No well
3	47N	8W	35	NR	NA	Private	2.8	NR	NR	NR	NR	NR	NR	Private
3	46N	7W	7	NR	NA	Private	1.7	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	1	NR	NA	Private	2.0	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	2	NR	NA	Private	2.5	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	10	NR	NA	Private	1.9	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	15	NR	NA	Private	1.6	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	15	NR	NA	Private	1.7	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	15	NR	NA	Private	1.6	NR	NR	NR	NR	NR	NR	Private

Table 2.4-43—{Listing of Local, Public and Private Groundwater Monitoring Wells for Callaway and Osage Counties, Missouri}

(Page 5 of 6)

Dataset[1]	Twp.	Rge.	Sect.	ID or Ref. Num.	MO#	Type	Distance[2] from site (miles)	Year	Gnd Elev. (ft msl)	Depth bgs (ft)	Casing bgs (ft)	Formation[3]	Yield (gpm)	Remarks[4]
3	46N	8W	16	NR	NA	Private	1.9	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	25	NR	NA	Private	2.9	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	25	NR	NA	Private	3.1	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	26	NR	NA	Private	2.7	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	27	NR	NA	Private	2.7	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	27	NR	NA	Private	2.8	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	27	NR	NA	Private	2.7	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	27	NR	NA	Private	2.6	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	27	NR	NA	Private	2.4	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	27	NR	NA	Private	2.8	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	27	NR	NA	Private	2.7	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	34	NR	NA	Private	3.2	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	28	NR	NA	Private	2.4	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	34	NR	NA	Private	3.2	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	35	NR	NA	Private	3.4	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	35	NR	NA	Private	3.0	NR	NR	NR	NR	NR	NR	Private
3	46N	7W	18	NR	NA	Private	2.1	NR	NR	NR	NR	NR	NR	Private
3	46N	7W	19	NR	NA	Private	2.2	NR	NR	NR	NR	NR	NR	Private
3	46N	7W	30	NR	NA	Private	3.1	NR	NR	NR	NR	NR	NR	Private
3	46N	7W	31	NR	NA	Private	3.2	NR	NR	NR	NR	NR	NR	Private
3	46N	7W	31	NR	NA	Private	3.2	NR	NR	NR	NR	NR	NR	Private
3	46N	7W	31	NR	NA	Private	4.0	NR	NR	NR	NR	NR	NR	Private
3	46N	7W	31	NR	NA	Private	3.8	NR	NR	NR	NR	NR	NR	Private
3	46N	7W	31	NR	NA	Private	4.0	NR	NR	NR	NR	NR	NR	Private
3	46N	7W	31	NR	NA	Private	4.0	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	36	NR	NA	Private	3.3	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	36	NR	NA	Private	3.2	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	36	NR	NA	Private	3.6	NR	NR	NR	NR	NR	NR	Private
4	46N	8W	12	NR	NR	Private	0.8	NR	NR	NR	NR	NR	NR	Private
4	45N	7W	5	0100248	NR	Industrial	4.6	1996	541	854	350	LS + Dolo	665	AmerenUE (intake)

Table 2.4-43—{Listing of Local, Public and Private Groundwater Monitoring Wells for Callaway and Osage Counties, Missouri}

(Page 6 of 6)

Dataset[1]	Twp.	Rge.	Sect.	ID or Ref. Num.	MO#	Type	Distance[2] from site (miles)	Year	Gnd Elev. (ft msl)	Depth bgs (ft)	Casing bgs (ft)	Formation[3]	Yield (gpm)	Remarks[4]
4	45N	7W	5	NR	NR	Industrial	4.6	1988	NR	103	4	NR	300	AmerenUE (intake)
	Outside Study Area Boundary – Callaway County													
2	47N	7W	31	013024	NA	Private	3.5	1954	801	330	100	Cotter	10	Private
2	45N	8W	5	019153	NA	Private	5.9	1960	669	340	NR	Roub	NR	Private
2	45N	8W	6	022026	NA	Private	6.2	1963	654	342	32	CJC	NR	Private
2	45N	8W	6	022019	NA	Private	6.4	NR	NR	NR	NR	NR	NR	Private
2	45N	8W	7	018964	NA	Private	6.9	1960	540	200	76	Cotter	35	Private
3	46N	7W	6	NR	NA	Private	2.3	NR	NR	NR	NR	NR	NR	Private
3	46N	7W	6	NR	NA	Private	2.4	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	1	NR	NA	Private	2.1	NR	NR	NR	NR	NR	NR	Private
3	46N	8W	1	NR	NA	Private	2.1	NR	NR	NR	NR	NR	NR	Private
3	46N	7W	19	NR	NA	Private	2.5	NR	NR	NR	NR	NR	NR	Private
3	46N	7W	30	NR	NA	Private	3.1	NR	NR	NR	NR	NR	NR	Private
	Outside Study Area Boundary – Osage County													
2	45N	8W	12	019910	3010155	Comm	6.2	1961	567	705	354	Cotter-Eminence	1200	Chamois W2
2	45N	8W	12	013591	NA	Private	6.5	1955	685	220	NR	NR	NR	Private

[1]Dataset Codes:
1 – MDNR Well Search for Callaway County, written response to request for information, dated November 20, 2007 (Township-Range-Section was only location information given for wells);
2 – MDNR, DGLS database;
3 – Callaway Plant 2006 Land Use Census Report;
4 – AmerenUE Confirmed Well Locations.
[2]Wells within the Callaway Site Boundary are labeled as "Site."
[3]Formation name reported from well log or material description from database (material abbreviations are not decipherable).
[4]Property Owner – Private wells were from the MDNR DGLS database and/or identified directly with the current property owner and reported in the Callaway Plant 2006 Land Use Census Report. Private well owner names are withheld.
NA – not applicable.
NR – not reported.

Table 2.4-44—{Listing of MDNR Monitoring Well Network}

(Page 1 of 4)

County	Station Name	Legal Location			Well Elevation (feet, msl)	Well Depth (feet)	Casing Depth (feet)	Screen Length (feet)	Formations Open Below Casing Depth (uppermost-lowermost)	Aquifer(s) Penetrated	Date Installed
		Sec.	Twn.	Rng.							
Audrain	**Mexico**	**32**	**51N**	**8W**	**815**	**610**	**382**	**NA**	**Devonian – St. Peters (e)**	**Cambrian-Ordovician aquifer**	**9/7/2000**
Barry	Butterfield Spfld. Plateau aquifer	36	24N	28W	1,505	304	85	NA	Reeds Spring-Pierson	Springfield Plateau aquifer	6/18/2007
Barry	Butterfield Ozark aquifer	36	24N	28W	1,505	803	357	NA	Cotter-Roubidoux	Ozark aquifer	6/18/2007
Barry	Cassville	29	23N	27W	1,326	1,200	300	NA	Cotter – Gasconade	Ozark aquifer	1/5/2001
Barry	Monett Well No. 10	6	25N	27W	1,288	1,475	500	NA	Cotter – Derby-Doerun	Ozark aquifer	5/17/2006
Barton	Asbury Spfld. Plateau aquifer	7	30N	33W	925	404	145	NA	Warsaw-Pierson	Springfield Plateau aquifer	NR
Barton	Asbury Ozark aquifer	7	30N	33W	925	657	483	NA	Cotter-Jefferson City	Ozark aquifer	NR
Barton	Golden City	26	31N	29W	1,060	893	400	NA	Jefferson City – Gasconade	Ozark aquifer	2/28/1996
Barton	Lamar	30	35N	30W	980	981	575	NA	Cotter – Gasconade	Ozark aquifer	6/17/1958
Benton	Cole Camp	35	43N	21W	1,045	510	60	NA	Jefferson City-Eminence	Ozark aquifer	4/19/2007
Benton	Warsaw	4	40N	22W	747	1,406	210	NA	Gasconade – Lamotte	Ozark and St. Francois aquifers	7/20/1979
Benton	Lost Valley Hatchery	4	40N	22W	723	151	80	NA	Roubidoux Formation	Ozark aquifer	7/9/2007
Bollinger	Duck Creek	32	28N	9E	346	75	70.5	4.5	Quaternary alluvium	Southeast Lowlands alluvial aquifer	11/1/1956
Boone	**Columbia**	**16**	**48N**	**13W**	**640**	**1,353**	**661**	**NA**	**Roubidoux – Derby-Doerun**	**Cambrian-Ordovician aquifer**	**12/28/2000**
Buchanan	St. Joseph	31	57N	35W	821	75	71	4	Quaternary alluvium	Missouri River alluvial aquifer	5/14/1957
Buchanan	Lewis and Clark	33	55N	37W	787	83	NR	NR	Quaternary alluvium	Missouri River alluvial aquifer	3/30/2001
Butler	Qulin	36	23N	7E	315	81	76	5	Quaternary alluvium	Southeast Lowlands alluvial aquifer	9/22/2000
Callaway	**Jefferson City**	**10**	**44N**	**11W**	**558.3**	**95**	**91**	**4**	**Quaternary alluvium**	**Missouri River alluvial aquifer**	**4/20/1956**
Camden	Ozark Fisheries	30	37N	14W	815	910	NR	NA	NR – Derby-Doerun	Ozark aquifer	9/22/2001
Camden	Camdenton	25	38N	17W	1,042	1,100	435	NA	Eminence – Derby-Doerun	Ozark aquifer	11/4/2000
Cape Girardeau	Delta	8	29N	12E	338	75	70.5	4.5	Quaternary Alluvium	Southeast Lowlands alluvial aquifer	11/1/1956
Cape Girardeau	Jackson	28	32N	13E	600	1,800	450	NA	Plattin-Powell/Smithville	Ozark aquifer	8/24/2007
Carroll	Carrollton	5	52N	23W	672	71	56	15	Quaternary Alluvium	Missouri River alluvial aquifer	11/7/2006
Carter	Big Spring	6	26N	1E	470	56	NR	NA	Eminence (e)	Ozark aquifer	4/19/1971
Christian	Billings	10	27N	24W	1,364	804	303	NA	Cotter-Roubidoux	Ozark aquifer	9/25/2007
Christian	Ozark	35	27N	21W	1,300	688	327	NA	Cotter – Jefferson City (e)	Ozark aquifer	8/31/2000
Clark	Wayland	29	65N	6W	540	150e	NR	NR	Pleistocene glacial drift	Drift-filled preglacial channel aquifer	10/8/1974

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Table 2.4-44—{Listing of MDNR Monitoring Well Network}
(Page 2 of 4)

County	Station Name	Legal Location			Well Elevation (feet, msl)	Well Depth (feet)	Casing Depth (feet)	Screen Length (feet)	Formations Open Below Casing Depth (uppermost-lowermost)	Aquifer(s) Penetrated	Date Installed
		Sec.	Twn.	Rng.							
Cooper	Arrow Rock	12	49N	19W	700	230	NR	NA	Burlington – Chouteau (e)	Springfield Plateau aquifer	3/29/1962
Cooper	Blackwater	34	49N	19W	620	70	59	10	Quaternary alluvium	Blackwater River alluvial aquifer	5/17/2007
Crawford	Bourbon	33	40N	3W	962	625	375	NA	Eminence-Potosi	Ozark aquifer	6/12/2007
Daviess	Jameson	18	60N	27W	860	92	89	5	Pleistocene glacial drift	Drift-filled preglacial channel aquifer	4/30/1996
Daviess	Coffey	18	61N	27W	906	NR	NR	NR	Pleistocene glacial drift	Drift-filled preglacial channel aquifer	9/29/2000
Dunklin	Malden	34	22N	10E	287	108	104	4	Quaternary alluvium	Southeast Lowlands alluvial aquifer	8/8/1956
Franklin	New Haven	36	45N	3W	519	1,075	216	NA	Jefferson City-Potosi	Ozark aquifer	9/20/2007
Franklin	St. Clair	26	42N	1W	739	255	80	NA	Roubidoux – Gasconade	Ozark aquifer	4/28/1956
Franklin	Sullivan	17	40N	2W	985	810	440	NA	Eminence -Derby	Ozark aquifer	3/13/2007
Gasconade	**Drake**	**22**	**43N**	**5W**	**865**	**400**	**222**	**NA**	**Jefferson City – Roubidoux (e)**	**Ozark aquifer**	**8/23/2000**
Greene	Springfield	4	29N	21W	1,375	565	252	NA	Cotter – Jefferson City (e)	Ozark aquifer	8/25/2000
Greene	McDaniel Lake	25	30N	22W	1,157.60	1,404	302	NA	Jefferson City – Derby-Doerun	Ozark aquifer	6/13/2001
Greene	Valley Water Mills (shallow)	5	29N	21W	1,220	63	100	NA	Elsey-Pierson	Springfield Plateau aquifer	3/22/2007
Greene	Valley Water Mills (deep)	5	29N	21W	1,220	168	600	NA	Cotter-Roubidoux	Ozark aquifer	3/22/2007
Greene	Valley Park	4	28N	21W	1,295	685	403	NA	Jefferson City – Roubidoux	Ozark aquifer	7/26/2006
Grundy	Spickard	20	63N	25W	790	140	136	4	Pleistocene glacial drift	Drift-filled preglacial channel aquifer	11/15/1973
Henry	Urich	3	42N	28W	770	246	70	NA	Cherokee group	Pennsylvanian Cherokee Sand	10/1/2001
Hickory	Pomme de Terre	12	36N	22W	890	298	178	NA	Jefferson City-Roubidoux	Ozark aquifer	4/18/2007
Howell	West Plains	18	24N	8W	1,107	1,605	796	NA	Gunter – Potosi	Ozark aquifer	11/22/2000
Iron	Bixby	1	34N	2W	1,380	640	120	NA	Eminence – Potosi (e)	Ozark aquifer	1/1/1988
Iron	Viburnum Trend #2	11	34N	2W	1,420	310	120	NA	Eminence-Potosi	Ozark aquifer	5/30/2007
Jasper	Atlas Powder	36	28N	32W	970	1,747	375	NA	Cotter – Reagan	Ozark and St. Francois aquifers	2/8/1956
Jasper	Carthage	2	28N	31W	963	1,825	498	NA	Jefferson City – Precambrian	Ozark and St. Francois aquifers	11/6/2003
Jefferson	S. Jefferson Co.	22	38N	5E	780	NR	NR	NA	NR	Ozark aquifer	8/8/2000
Jefferson	De Soto	22	39N	4E	790	1,500	NR	NA	NR – Bonneterre (e)	Ozark and St. Francois aquifers	11/18/1960
Jefferson	Festus	6	40N	6E	450	1,084	425	NA	Roubidoux – Potosi (e)	Ozark aquifer	11/21/2001
Johnson	Warrensburg	30	46N	25W	770	1,001	410	NA	Jefferson City – Gasconade (e)	Ozark aquifer	6/28/2001
Johnson	Knob Noster	22	46N	24W	806	840	293	NA	Cotter-Gasconade	Ozark aquifer	NR
Laclede	Lebanon	24	34N	16W	1,320	405	210	NA	Gasconade (e)	Ozark aquifer	8/17/2000

Table 2.4-44—{Listing of MDNR Monitoring Well Network}
(Page 3 of 4)

County	Station Name	Legal Location			Well Elevation (feet, msl)	Well Depth (feet)	Casing Depth (feet)	Screen Length (feet)	Formations Open Below Casing Depth (uppermost-lowermost)	Aquifer(s) Penetrated	Date Installed
		Sec.	Twn.	Rng.							
Lawrence	Aurora	24	26N	26W	1,460	1,425	725	NA	Jefferson City – Eminence (e)	Ozark aquifer	7/2/1988
Lawrence	Mt. Vernon Spfld. Plateau aquifer	36	28N	27W	1,215	204	126	NA	Elsey-Pierson	Springfield Plateau aquifer	5/10/2007
Lawrence	Mt. Vernon Ozark aquifer	36	28N	27W	1,215	252	624	NA	Cotter-Jefferson City	Ozark aquifer	5/10/2007
Lawrence	Pierce City	21	26N	28W	1,205	1,160	409	NA	Cotter-Gasconade	Ozark aquifer	1/9/2007
Lincoln	Troy (2, deep)	27	49N	1W	642	1,470	440	NA	Kimmswick – Gasconade	Cambrian-Ordovician aquifer	5/20/2000
Lincoln	Troy (1, shallow)	26	49N	1W	533	813	400	NA	Kimmswick – St. Peter	Cambrian-Ordovician aquifer	4/15/1980
Livingston	Fountain Grove	6	56N	21w	672	65	45	20	Pleistocene glacial drift	Drift-filled preglacial channel	10/27/2000
McDonald	Noel	22	21N	33W	830	850	99	NA	Cotter – Roubidoux	Ozark aquifer	5/2/1962
McDonald	Longview	18	23N	30W	1,289.60	346	44	NA	Burlington – Compton	Springfield Plateau aquifer	1/3/1956
Madison	Fredericktown	20	33N	7E	857.2	590	187	NA	Bonneterre – Lamotte	St. Francois aquifer	11/18/1958
Marion	Hannibal	10	58N	5W	484	85	81	4	Quaternary alluvium	Mississippi River alluvial aquifer	5/28/1957
Mississippi	East Prairie	29	25N	16E	307	118	114	4	Quaternary alluvium	Southeast Lowlands alluvial aquifer	11/1/1956
Montgomery	**New Florence**	**23**	**48N**	**5W**	**877**	**1,030**	**323**	**NA**	**Joachim – Roubidoux**	**Cambrian-Ordovician aquifer**	**5/29/1981**
Newton	Joplin	28	27N	33W	900	1,505	500	NA	Jefferson City – Potosi (e)	Ozark aquifer	11/5/2003
Newton	Neosho Spfld. Plateau aquifer	18	24N	31W	1,265	344	105	NA	Burlington-Reeds Spring	Springfield Plateau aquifer	7/17/2007
Newton	Neosho Ozark aquifer	18	24N	31W	1,265	696	460	NA	Cotter-Jefferson City	Ozark aquifer	7/17/2007
Nodaway	Hopkins	2	66N	35W	1,045	28	24	4	Quaternary	One Hundred and Two River alluv.	5/2/2007
Osage	**Linn**	**17**	**43N**	**8W**	**941**	**1,080**	**427**	**NA**	**Gasconade - Derby-Doerun**	**Ozark aquifer**	**12/1/2005**
Ozark	Theodosia	19	22N	15W	710	264	215	NA	Jefferson City	Ozark aquifer	12/1/2000
Pemiscot	Caruthersville	16	18N	13E	270	1,388	1,306	85	Wilcox	Wilcox aquifer	8/30/2007
Pemiscot	Steele	36	17N	11E	260	131	127	4	Quaternary alluvium	Southeast Lowlands alluvial aquifer	8/22/1956
Perry	National Lead	34	34N	8E	992	1,526	NR	NA	NR – Lamotte (e)	Ozark (?) and St. Francois aquifers	7/18/1960
Pettis	Dresden	26	46N	22W	820	NR	NR	NA	NR – Cotter (e)	Springfield Plateau/Ozark aquifers	8/30/1996
Pettis	Dresden School	21	46N	22W	836	456	202	NA	Cotter – Jefferson City (e)	Ozark aquifer	8/18/2000
Pettis	Sedalia	34	47N	22W	824	1,410	432	NA	Jefferson City – Davis	Ozark aquifer	11/12/1973
Phelps	Ramada Inn	10	37N	8W	974	650	420	NA	Gunter – Eminence	Ozark aquifer	1/2/1968
Phelps	Mo. Cons. Dept.	3	37N	8W	1,192	450	212	NA	Jefferson City – Gasconade	Ozark aquifer	9/8/1980

Table 2.4-44—{Listing of MDNR Monitoring Well Network}

(Page 4 of 4)

County	Station Name	Legal Location			Well Elevation (feet, msl)	Well Depth (feet)	Casing Depth (feet)	Screen Length (feet)	Formations Open Below Casing Depth (uppermost-lowermost)	Aquifer(s) Penetrated	Date Installed
		Sec.	Twn.	Rng.							
Phelps	Rolla Indust. Park	29	38N	7W	1,189	800	400	NA	Gasconade – Eminence	Ozark aquifer	4/30/1975
Pike	Clarksville	16	53N	1E	459	650	144	NA	Kimmswick-Cotter	Cambrian-Ordovician aquifer	9/25/2007
Polk	Halfway	5	33N	21W	1,114	200	43	NA	Jefferson City – Cotter	Ozark aquifer	3/5/1956
Reynolds	Viburnum Trend #5	25	33N	2W	1,160	170	126	NA	Eminence	Ozark aquifer	5/30/2007
Reynolds	Viburnum Trend #6	12	32N	2W	1,150	250	210	NA	Eminence	Ozark aquifer	6/7/2007
Ripley	Naylor	3	22N	4E	303	65	61	4	Quaternary alluvium	Southeast Lowlands alluvial aquifer	8/8/1956
St. Charles	Wentzville	24	47N	2E	608	1,337	380	NA	Kimmswick – Roubidoux	Cambrian-Ordovician aquifer	5/13/1980
St. Clair	Osceola	22	38N	26W	877	875	20	NA	Pennsylvanian - Eminence	Ozark aquifer	11/12/1958
St. Francois	Farmington	12	35N	5E	890	325	80	NA	Bonneterre – Lamotte (e)	St. Francois aquifer	1/20/2001
St. Louis	Eureka	35	44N	3E	615	820	300	NA	Cotter – Gasconade	Ozark aquifer	10/14/2000
St. Louis	Columbia Bottoms	18	47N	8E	432.5	104	100	4	Quaternary alluvium	Mississippi River alluvial aquifer	6/24/1957
Schuyler	Vandike Farms	29	66N	14W	935	27	27	27	Pleistocene glacial drift, rock walled	Glacial drift aquifer	7/21/1980
Scott	Sikeston	21	26N	14E	312	136	131.5	4.5	Quaternary alluvium	Southeast Lowlands alluvial aquifer	11/1/1956
Shannon	Akers	24	31N	6W	865	425	NR	NA	Eminence – Potosi (e)	Ozark aquifer	11/15/1971
Shelby	Shelbina	32	57N	10W	770	82	62	20	Pleistocene glacial drift	Drift-filled preglacial channel	9/8/2000
Stone	Silver Dollar City	29	23N	22W	1,102	910	250	NA	Cotter-Gasconade	Ozark aquifer	3/7/2007
Taney	Cooper Creek	7	22N	21W	840	1,400	380	NA	Roubidoux – Derby-Doerun	Ozark aquifer	4/22/1996
Taney	Branson	32	23N	21W	845	1,002	393	NA	Roubidoux – Gasconade	Ozark aquifer	11/17/1993
Texas	Fairview	17	30N	11W	1,467	481	50	NA	Cotter – Roubidoux	Ozark aquifer	2/27/1956
Washington	Potosi	11	37N	2E	930	1,100	555	NA	Bonneterre – Lamotte	St. Francois aquifer	7/26/1988
Webster	Marshfield		30N	18W	1,485	1,315	362	NA	Roubidoux - Potosi	Ozark aquifer	6/22/2005
Worth	Sheridan	23	66N	33W	955	41	31	10	Pleistocene Glacial Drift	Glacial Drift aquifer	12/2/2004
Wright	Norwood	13	28N	14W	1,519	1,221	450	NA	Roubidoux - Eminence	Ozark aquifer	4/27/2005

NA – not applicable
e – estimated
NR – Not reported (no data available)

Table 2.4-45—{Callaway Plant Unit 2 Monitoring Well Construction Details}

(Page 1 of 2)

Well ID	Northing State Plane[1] (ft)	Easting State Plane[1] (ft)	Ground Surface Elevation[2] (ft msl)	Top of Casing Elevaton[2] (ft msl)	Boring Depth (ft Bgs)	Screen Diameter/ Slot Size (in)	Screen Interval Top (ft bgs)	Screen Interval Bottom (ft bgs)	Screen Interval Elevation Top (ft msl)	Screen Interval Elevation Bottom (ft msl)	Hydrogeologic Unit
Plateau Shallow Wells											
PW-1	1067801.65	1845747.19	845.4	848.01	50.0	4/0.010	30.0	50.0	815.4	795.4	Glacial/Graydon Chert
MW-2S	1076444.82	1846189.87	781.1	783.77	35.0	2/0.010	15.0	35.0	766.1	746.1	Alluv/Glacial/ Graydon Chert
MW-3S	1068236.86	1850889.85	824.7	827.32	60.0	4/0.010	35.0	55.0	789.7	769.7	Graydon Chert
MW-5S	1066063.58	1839748.89	821.5	824.19	52.0	2/0.010	32.0	52.0	789.5	769.5	Graydon Chert
MW-6S	1071137.82	1840344.23	834.5	837.14	50.0	2/0.010	30.0	50.0	804.5	784.5	Glacial/Graydon Chert
MW-8	1069314.02	1845853.56	842.5	844.81	62.0	2/0.010	42.0	62.0	800.5	780.5	Graydon Chert
MW-9	1067031.11	1846943.76	833.7	836.28	45.0	2/0.010	25.0	45.0	808.7	788.7	Graydon Chert
MW-10	1065231.21	1845930.93	845.3	848.02	52.0	2/0.010	30.0	50.0	815.3	795.3	Graydon Chert
MW-11	1067242.14	1843435.83	854.5	856.91	80.0	2/0.010	47.0	67.0	807.5	787.5	Graydon Chert
MW-12	1068338.49	1843101.33	851.5	853.91	60.0	2/0.010	35.0	55.0	816.5	796.5	Graydon Chert
MW-18	1068101.78	1844187.77	839.9	842.35	70.0	2/0.010	25.0	45.0	814.9	794.9	Glacial/Graydon Chert
Plateau Intermediate Well											
MW-1I	1067776.08	1845723.45	844.6	847.25	400.0	4/0.010	167.0	182.0	677.6	662.6	Cotter-Jefferson City Confining Unit (Aquitard)
Plateau Deep Cotter-Jefferson City Wells											
MW-1D	1067745.62	1845729.23	844.1	846.66	380.0	4/0.010	345.0	375.0	499.1	469.1	Cotter-Jefferson City
MW-2D	1076453.63	1846204.02	780.9	783.44	290.0	4/0.010	270.0	290.0	510.9	490.9	Cotter-Jefferson City
MW-3D	1068262.36	1850885.26	824.2	826.86	350.0	4/0.010	325.0	350.0	499.2	474.2	Cotter-Jefferson City
MW-4D	1058085.89	1843973.82	817.6	820.24	370.0	4/0.010	345.0	370.0	472.6	447.6	Cotter-Jefferson City
MW-5D	1066050.55	1839738.72	821.7	824.44	350.0	4/0.010	330.0	350.0	491.7	471.7	Cotter-Jefferson City
MW-6D	1071109.51	1840342.79	834.3	836.79	360.0	4/0.010	334.0	359.0	500.3	475.3	Cotter-Jefferson City
MW-7D	1085262.95	1821950.45	780.3	782.74	340.0	4/0.010	315.0	340.0	465.3	440.3	Cotter-Jefferson City
Study Boundary Cotter-Jefferson City Wells											
MW-13	1087151.31	1837276.03	554.6	554.31	48.0	2/0.010	28.0	48.0	526.6	506.6	Cotter-Jefferson City
MW-14	1073323.07	1826004.31	566.5	568.69	75.0	2/0.010	52.0	72.0	514.5	494.5	Cotter-Jefferson City
MW-15	1046106.89	1833429.15	540.6	540.30	117.0	2/0.010	94.0	114.0	446.6	426.6	Cotter-Jefferson City
MW-16	1052711.25	1839372.03	547.3	549.97	41.0	2/0.010	21.0	41.0	526.3	506.3	Cotter-Jefferson City
MW-17	1049043.77	1845199.81	556.0	558.49	45.0	2/0.010	25.0	45.0	531.0	511.0	Cotter-Jefferson City

Table 2.4-45—{Callaway Plant Unit 2 Monitoring Well Construction Details}

(Page 2 of 2)

Well ID	Northing State Plane[1] (ft)	Easting State Plane[1] (ft)	Ground Surface Elevation[2] (ft msl)	Top of Casing Elevaton[2] (ft msl)	Boring Depth (ft Bgs)	Screen Diameter/ Slot Size (in)	Screen Interval Top (ft bgs)	Screen Interval Bottom (ft bgs)	Screen Interval Elevation Top (ft msl)	Screen Interval Elevation Bottom (ft msl)	Hydrogeologic Unit
PW-2	1065502.13	1828469.86	532.5	535.42	75.0	4/0.010	55.0	75.0	477.5	457.5	Cotter-Jefferson City
PZ-2,1	1065508.35	1828483.50	532.8	532.39	75.0	2/0.010	55.0	75.0	477.8	457.8	Cotter-Jefferson City
PZ-2,2	1065508.02	1828455.75	532.2	531.86	75.0	2/0.010	55.0	75.0	477.2	457.2	Cotter-Jefferson City
PZ-2,3	1065486.33	1828470.37	532.8	532.46	75.0	2/0.010	55.0	75.0	477.8	457.8	Cotter-Jefferson City
PW-3	1061781.07	1855490.04	569.8	572.17	52.0	4/0.010	32.0	52.0	537.8	517.8	Cotter-Jefferson City
PZ-3,1	1061771.77	1855477.26	569.6	569.35	52.0	2/0.010	32.0	52.0	537.6	517.6	Cotter-Jefferson City
PZ-3,2	1061795.91	1855490.12	569.8	569.48	52.0	2/0.010	32.0	52.0	537.8	517.8	Cotter-Jefferson City
PZ-3,3	1061775.66	1855503.58	570.4	570.05	52.0	2/0.010	32.0	52.0	538.4	518.4	Cotter-Jefferson City
Missouri River Alluvial Wells											
FMW-1D	1038992.76	1837942.63	525.2	524.94	135.0	2/0.010	114.0	134.0	411.2	391.2	Cotter-Jefferson City
FMW-1S	1038995.53	1837956.06	525.3	524.93	65.4	2/0.010	45.0	65.0	480.3	460.3	Alluvium
FMW-5	1047388.10	1851772.50	525.0	528.13	54.0	2/0.010	33.5	48.5	491.5	476.5	Alluvium
FMW-6	1040481.32	1851066.54	525.2	524.63	106.0	2/0.010	81.5	101.5	443.7	423.7	Alluvium
FMW-7	1039841.12	1849706.88	526.1	525.80	98.5	2/0.010	78.5	98.5	447.6	427.6	Alluvium
FMW-8	1039529.50	1848383.31	524.4	523.98	99.0	2/0.010	77.0	97.0	447.4	427.4	Alluvium
FMW-9	1039620.36	1846762.66	525.4	524.84	97.0	2/0.010	75.0	95.0	450.4	430.4	Alluvium
FMW-10	1039680.35	1845265.75	525.9	525.60	99.0	2/0.010	77.0	97.0	448.9	428.9	Alluvium
FMW-11	1039136.45	1839487.41	530.8	530.42	95.3	2/0.010	75.0	95.0	455.8	435.8	Alluvium
FMW-12	1045810.79	1857168.19	520.3	522.72	104.0	2/0.010	81.5	101.5	438.8	418.8	Alluvium
Missouri River Alluvial Borings											
FSB-2	1043787.02	1836579.86	527.4	NA	NA	NA	NA	NA	NA	NA	Alluvium
FSB-3	1039453.66	1840680.39	524.3	NA	NA	NA	NA	NA	NA	NA	Alluvium
FSB-4	1045261.95	1843189.48	526.1	NA	NA	NA	NA	NA	NA	NA	Alluvium
FSB-13	1036766.57	1841334.31	527.0	NA	NA	NA	NA	NA	NA	NA	Alluvium
FSB-14	1039565.20	1853906.80	525.4	NA	NA	NA	NA	NA	NA	NA	Alluvium

(1) Horizontal Datum NAD83 State Plane feet
(2) Vertical Datum NAD88 feet FMW-1D is screened in the bedrock beneath the alluvial aquifer.

Table 2.4-46—{Callaway Plant Unit 2 Formation Depths and Thicknesses }

(page 1 of 5)

Well I.D.	Ground Surface Elevation (ft msl)	Depth to Top of Loess/ Misc. Fill (ft bgs)	Elevation Top of Loess/ Misc. Fill (ft msl)	Thickness of Loess/ Misc. Fill (ft)	Depth to Top of Accretion Gley (ft bgs)	Elevation Top of Accretion Gley (ft msl)	Thickness of Accretion Gley (ft)	Depth to Top of Glacial Till (ft bgs)	Elevation Top of Glacial Till (ft msl)	Thickness of Glacial Till (ft)	Depth to Top of Graydon Chert (ft bgs)	Elevation Top of Graydon Chert (ft msl)	Thickness of Graydon Chert (ft)
Plateau Wells													
PW-1, MW-1I/D	844	0	844	10	NP	NP	NP	10	834	26	36	808	24
MW-2S/D	781	0	781	32	32	749	3	NP	NP	NP	35	746	45
MW-3S/D	824	0	824	27	27	797	6	NP	NP	NP	33	791	42
MW-4D	818	0	818	10	NP	NP	NP	10	808	29	39	779	16
MW-5S/D	822	0	822	3	NP	NP	NP	3	819	12	15	807	61
MW-6S/D	834	0	834	5	5	829	12	17	817	16	33	802	33
MW-7D	780	0	780	15	NP	NP	NP	15	765	5	20	760	58
MW-8	843	0	843	9	NP	NP	NP	9	834	11	20	823	42
MW-9	834	0	834	1	NP	NP	NP	1	833	19	20	814	25
MW-10	845	0	845	14	NP	NP	NP	14	831	9	23	822	27
MW-11	855	0	855	2	NP	NP	NP	2	853	20	22	833	45
MW-12	852	0	852	4	NP	NP	NP	4	848	20	23	829	37
MW-18	840	0	840	4	NP	NP	NP	4	836	26	30	810	40

Table 2.4-46—{Callaway Plant Unit 2 Formation Depths and Thicknesses}

(page 2 of 5)

Well I.D.	Elevation Ground Surface (ft msl)	Depth to Top of Burlington Limestone (ft bgs)	Elevation Top of Burlington Limestone (ft msl)	Thickness of Burlington Limestone (ft)	Depth to Top of Bushburg Sandstone (ft bgs)	Elevation Top of Bushburg Sandstone (ft msl)	Thickness of Bushburg Sandstone (ft)	Depth to Top of Snyder Cr. Limestone (ft bgs)	Elevation Top of Snyder Cr. Limestone (ft msl)	Thickness of Snyder Cr. Limestone (ft)	Depth to Top of Callaway Lime-stone (ft bgs)	Elevation Top of Callaway Lime-stone (ft msl)	Thickness of Callaway Lime-stone (ft)
MW-1I/D	844	60	784	6	NP	NP	NP	66	778	12	78	766	71
MW-2S/D	781	80	701	25	NP	NP	NP	105	676	29	134	647	21
MW-3S/D	824	75	749	15	90	734	5	95	729	10	105	719	30
MW-4D	818	55	763	20	75	743	5	80	738	35	115	703	45
MW-5S/D	822	75	747	25	100	722	10	110	712	30	140	682	20
MW-6S/D	834	65	769	45	NP	NP	NP	110	724	25	135	699	35
MW-7D	780	78	702	37	NP	NP	NP	115	665	30	145	635	40

Table 2.4-46—{Callaway Plant Unit 2 Formation Depths and Thicknesses}

(page 3 of 5)

Well I.D.	Elevation Ground Surface (ft msl)	Depth to Top of CJC (Upper) Dolomitic Limestone (ft bgs)	Elevation Top of CJC (Upper) Dolomitic Limestone (ft msl)	Thickness of CJC (Upper) Dolomitic Limestone (ft)	Depth to Top of CJC (Lower) Dolomitic Limestone (ft bgs)	Elevation Top of CJC (Lower) Dolomitic Limestone (ft msl)	Thickness Penetrated of CJC (Lower) Dolomitic Limestone (ft)
MW-1I/D	844	149	695	200	349	495	51
MW-2S/D	781	155	626	105	260	521	30
MW-3S/D	824	135	689	190	325	499	25
MW-4D	818	160	658	185	345	473	20
MW-5S/D	822	160	662	170	330	492	20
MW-6S/D	834	160	674	174	334	500	25
MW-7D	780	185	595	130	315	465	25

Table 2.4-46— {Callaway Plant Unit 2 Formation Depths and Thicknesses}
(page 4 of 5)

Well ID	Elevation Ground Surface (ft msl)	Depth to Top of Alluvium (ft bgs)	Elevation Top of Alluvium (ft bgs)	Thickness of Alluvium (ft)	Depth to Top of CJC Dolomitic Limestone (ft bgs)	Elevation Top of CJC Dolomitic Limestone (ft msl)	Thickness Penetrated of CJC Dolomotic Limestone (ft)
Study Boundary Cotter-Jefferson City Wells							
MW-13	555	0	555	21	21	534	27
MW-14	567	0	567	44	44	523	31
MW-15	541	0	541	89	89	452	28
MW-16	547	0	547	9	9	538	32
MW-17	556	0	556	20	20	536	25
PW-2	533	0	533	42	42	491	33
PW-3	570	0	570	10	10	560	42

Table 2.4-46— {Callaway Plant Unit 2 Formation Depths and Thicknesses}

(page 5 of 5)

Well ID	Elevation Ground Surface (ft msl)	Depth to Top of CJC (Lower) Dolomitic Limestone (ft bgs)	Elevation Top of CJC (Lower) Dolomotic Limestone (ft msl)
Missouri River Alluvial Wells			
FMW-1D	525	94	431
FMW-1S	525	94	431
FSB-2	527	85	443
FSB-3	524	100	424
FSB-4	526	96	430
FMW-5	525	50	475
FMW-6	525	101	424
FMW-7	526	99	427
FMW-8	524	96	428
FMW-9	525	96	430
FMW-10	526	97	429
FMW-11	531	91	440
FMW-12	520	104	416
FSB-13	530	97	433
FSB-14	525	100	425

NP – unit is not present at this location.

Table 2.4-47—{Callaway Plant Unit 2 Monitoring Well Water Level Depths and Elevations}

(Page 1 of 2)

Well ID	Top of Casing[a]	Depth to Water							Water Level Elevation						
		March 26, 2007	April 19, 2007	April 26, 2007	May 7, 2007	May 13, 2007	June 5, 2007	June 26 - 28 2007[b]	March 26, 2007	April 19, 2007	April 26, 2007	May 7, 2007	May 13, 2007	June 5, 2007	June 26 - 28 2007[b]
	(ft msl)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)
Plateau Shallow Wells															
PW-1	848.01	18.16	NR	18.08	18.15	18.19	18.31	18.30	829.85	NR	829.93	829.86	829.82	829.70	829.71
MW-2S	783.77	13.02	NR	11.79	11.61	11.82	11.95	[3]12.62	770.75	NR	771.98	772.16	771.95	771.82	771.15
MW-3S	827.32	27.38	NR	20.41	21.61	20.82	19.90	22.84	799.94	NR	806.91	805.71	806.50	807.42	804.48
MW-5S	824.19	31.69	NR	29.91	29.82	29.86	29.34	[3]30.24	792.50	NR	794.28	794.37	794.33	794.85	793.95
MW-6S	837.14	21.61	NR	21.87	21.91	21.94	21.67	[3]22.15	815.53	NR	815.27	815.23	815.20	815.47	814.99
MW-8	844.81	15.87	NR	15.58	15.62	15.68	15.88	15.68	828.94	NR	829.23	829.19	829.13	828.93	829.13
MW-9	836.28	9.14	NR	8.88	8.94	8.93	8.49	[3]8.74	827.14	NR	827.40	827.34	827.35	827.79	827.54
MW-10	848.02	24.37	NR	24.03	24.06	24.12	24.56	24.26	823.65	NR	823.99	823.96	823.90	823.32	823.76
MW-11	856.91	65.58	NR	69.48	69.60	69.61	69.60	69.68	791.33	NR	787.43	787.31	787.30	787.31	787.23
MW-12	853.91	27.17	NR	26.78	26.85	26.87	26.41	[3]26.66	826.74	NR	827.13	827.06	827.04	827.50	827.25
MW-18	842.35	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plateau Intermediate Well															
MW-1I	847.25	182.82	NR	183.01	183.08	183.10	183.17	183.20	664.43	NR	664.24	664.17	664.15	664.08	664.05
Plateau Cotter-Jefferson City Wells															
MW-1D	846.66	293.18	NR	293.11	293.02	293.08	293.60	[3]292.78	553.48	NR	553.55	553.64	553.58	553.06	553.88
MW-2D	783.44	230.32	NR	230.02	230.20	230.49	229.78	230.26	553.12	NR	553.42	553.24	552.95	553.66	553.18
MW-3D	826.86	273.41	NR	273.28	273.29	273.36	272.85	[3]273.15	553.45	NR	553.58	553.57	553.50	554.01	553.71
MW-4D	820.24	266.62	NR	266.50	266.41	266.56	266.08	266.68	553.62	NR	553.74	553.83	553.68	554.16	553.56
MW-5D	824.44	268.04	NR	267.80	267.98	268.11	267.70	268.10	556.40	NR	556.64	556.46	556.33	556.74	556.34
MW-6D	836.79	283.28	NR	283.06	283.11	283.27	282.10	283.02	553.51	NR	553.73	553.68	553.52	554.69	553.77
MW-7D	782.74	227.65	NR	227.47	227.55	227.70	227.48	228.02	555.09	NR	555.27	555.19	555.04	555.26	554.72
Study Boundary Cotter-Jefferson City Wells															
MW-13	554.31	9.19	NR	8.02	8.72	9.54	10.51	[3]10.81	545.12	NR	546.29				
MW-14	568.69	44.61	NR	43.02	44.04	[1]39.91	44.80	[3]46.51	524.08	NR	525.67				
MW-15	540.29	25.23	NR	23.89	22.84	[1]19.12	19.53	21.07	515.06	NR	516.40				

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Table 2.4-47—{Callaway Plant Unit 2 Monitoring Well Water Level Depths and Elevations}

(Page 2 of 2)

Well ID	Top of Casing[a]	Depth to Water							Water Level Elevation						
		March 26, 2007	April 19, 2007	April 26, 2007	May 7, 2007	May 13, 2007	June 5, 2007	June 26 - 28 2007[b]	March 26, 2007	April 19, 2007	April 26, 2007	May 7, 2007	May 13, 2007	June 5, 2007	June 26 - 28 2007[b]
	(ft msl)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)
MW-16	549.97	18.59	NR	17.11	17.11	18.77	19.95	20.67	531.38	NR	532.86				
MW-17	558.49	24.75	NR	22.59	18.22	20.73	28.22	31.45	533.74	NR	535.90				
PW-2	535.42	NA	18.66	16.62	17.27	[1]7.08	14.41	19.59	NA	516.76	518.80				
PZ-2,1	532.39	NA	15.12	13.34	13.95	[1] 3.57	11.32	NR	NA	517.27	519.05				
PZ-2,2	531.86	NA	15.61	13.09	13.70	[1] 4.03	10.83	NR	NA	516.25	518.77				
PZ-2,3	532.46	NA	15.69	13.68	14.33	[1] 3.99	11.32	NR	NA	516.77	518.78				
PW-3	572.17	NA	10.40	9.56	9.81	[2]10.64	10.94	11.70	NA	561.77	562.61				
PZ-3,1	569.35	NA	7.67	6.91	7.17	[2] 8.02	8.28	NR	NA	561.68	562.44				
PZ-3,2	569.48	NA	8.25	7.43	7.64	[2] 8.50	8.77	NR	NA	561.23	562.05				
PZ-3,3	570.05	NA	7.66	6.82	7.06	[2] 7.90	8.17	NR	NA	562.39	563.23				
Missouri River Alluvial Wells															
FMW-1D	524.94	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA		
FMW-1S	524.93	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA		
FMW-5	528.13	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA		
FMW-6	524.63	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA		
FMW-7	525.80	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA		
FMW-8	523.98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA		
FMW-9	524.84	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA		
FMW-10	525.60	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA		
FMW-11	530.42	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA		
FMW-12	522.72	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA		

FMW-1D is screened in the bedrock beneath the alluvial aquifer.

Table 2.4-47— {Callaway Plant Unit 2 Monitoring Well Water Level Depths and Elevations}

(Page 1 of 2)

Well ID	Top of Casing [a]	Depth to Water							Water Level Elevation						
		August 12, 2007	August 26-29, 2007[b]	October 3, 2007	November 20, 2007	December 19, 2007	January 9, 2008	February 1, 2008	August 12, 2007	August 26-29, 2007[b]	October 3, 2007	November 20, 2007	December 19, 2007	January 9, 2008	February 1, 2008
	(ft msl)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)
Plateau Shallow Wells															
PW-1	848.01	18.16	18.34	18.33	18.31	18.36	18.16	18.25	829.85	829.67	829.68	829.70	829.65	829.85	829.76
MW-2S	783.77	14.06	14.40	14.99	15.22	14.87	14.54	14.70	769.71	769.37	768.78	768.55	768.90	769.23	769.07
MW-3S	827.32	20.42	20.25	20.75	20.20	20.89	20.55	20.96	806.90	807.07	806.57	807.12	806.43	806.77	806.36
MW-5S	824.19	29.79	29.69	30.42	30.10	30.55	30.67	30.69	794.40	794.50	793.77	794.09	793.64	793.52	793.50
MW-6S	837.14	23.12	23.24	23.46	23.65	23.69	23.81	23.92	814.02	813.90	813.68	813.49	813.45	813.33	813.22
MW-8	844.81	15.58	15.50	15.88	15.94	16.43	16.49	16.68	829.23	829.31	828.93	828.87	828.38	828.32	828.13
MW-9	836.28	8.62	8.65	8.78	8.50	9.10	9.19	9.35	827.66	827.63	827.50	827.78	827.18	827.09	826.93
MW-10	848.02	24.28	24.36	24.25	24.29	24.49	24.65	24.62	823.74	823.66	823.77	823.73	823.53	823.37	823.40
MW-11	856.91	69.68	NR	69.70	69.71	69.72	69.72	69.71	787.23	NR	787.21	787.20	787.19	787.19	787.20
MW-12	853.91	26.79	26.79	26.93	27.78	27.08	27.18	27.20	827.12	827.12	826.98	826.13	826.83	826.73	826.71
MW-18	842.35	[b]10.82	10.46	10.14	10.86	11.50	11.76	12.06	831.53	831.89	832.21	831.49	830.85	830.59	830.29
Plateau Intermediate Well															
MW-1I	847.25	183.41	183.48	183.57	183.70	183.79	183.14	183.88	663.84	663.77	663.68	663.55	663.46	664.11	663.37
Plateau Cotter-Jefferson City Wells															
MW-1D	846.66	293.36	293.74	294.12	294.29	293.29	293.26	293.04	553.30	552.92	552.54	552.37	553.37	553.40	553.62
MW-2D	783.44	230.18	230.84	231.12	231.37	231.28	230.91	230.78	553.26	552.60	552.32	552.07	552.16	552.53	552.66
MW-3D	826.86	273.64	273.71	274.22	274.46	274.41	274.13	273.91	553.22	553.15	552.64	552.40	552.45	552.73	552.95
MW-4D	820.24	267.10	267.31	267.72	268.06	267.76	267.31	267.22	553.14	552.93	552.52	552.18	552.48	552.93	553.02
MW-5D	824.44	268.70	268.98	NR	269.50	269.8	269.41	269.32	555.74	555.46	NR	554.94	554.64	555.03	555.12
MW-6D	836.79	283.51	283.68	283.97	284.23	284.19	283.96	283.78	553.28	553.11	552.82	552.56	552.60	552.83	553.01
MW-7D	782.74	228.51	228.51	228.54	228.78	228.94	229.04	229.21	554.23	554.23	554.20	553.96	553.80	553.70	553.53
Study Boundary Cotter-Jefferson City Wells															
MW-13	554.31	11.04	11.10	11.06	10.93	10.78	9.73	10.90	543.27	543.21	543.25	543.38	543.53	544.58	543.41
MW-14	568.69	47.66	47.74	47.92	47.91	47.54	46.20	47.49	521.03	520.95	520.77	520.78	521.15	522.49	521.20
MW-15	540.29	23.47	24.03	25.42	25.59	26.21	25.97	25.97	516.82	516.26	514.87	514.70	514.08	514.32	514.32
MW-16	549.97	21.42	20.65	21.28	20.96	19.42	16.5	19.95	528.55	529.32	528.69	529.01	530.55	533.47	530.02
MW-17	558.49	33.82	34.34	35.64	36.40	36.27	35.62	36.09	524.67	524.15	522.85	522.09	522.22	522.87	522.40
PW-2	535.42	20.23	20.53	20.21	20.09	20.09	18.06	19.88	515.19	514.89	515.21	515.33	515.33	517.36	515.54
PZ-2,1	532.39	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
PZ-2,2	531.86	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

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Table 2.4-47— {Callaway Plant Unit 2 Monitoring Well Water Level Depths and Elevations}

(Page 2 of 2)

Well ID	Top of Casing [a]	Depth to Water							Water Level Elevation						
		August 12, 2007	August 26-29, 2007[b]	October 3, 2007	November 20, 2007	December 19, 2007	January 9, 2008	February 1, 2008	August 12, 2007	August 26-29, 2007[b]	October 3, 2007	November 20, 2007	December 19, 2007	January 9, 2008	February 1, 2008
	(ft msl)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)
PZ-2,3	532.46	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
PW-3	572.17	12.85	13.03	12.73	12.76	11.11	9.84	11.42	559.32	559.14	559.44	559.41	561.06	562.33	560.75
PZ-3,1	569.35	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
PZ-3,2	569.48	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
PZ-3,3	570.05	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Missouri River Alluvial Wells															
FMW-1D	524.94	[4]15.88	16.40	17.77	18.36		16.79					506.58	501.34	508.15	505.79
FMW-1S	524.93	[4]15.81	16.58	18.08	18.94		16.23					505.99	507.17	508.70	505.97
FMW-5	528.13	[4]18.34	18.51	19.44	19.80		20.17					508.33	507.99	507.96	507.26
FMW-6	524.63	[4]17.48	17.98	19.75	20.36		19.35					504.27	505.33	505.28	503.96
FMW-7	525.80	[4]18.64	19.23	20.00	21.73		19.98					504.07	505.61	505.82	503.89
FMW-8	523.98	[4]16.82	17.41	19.16	19.77		18.56					504.21	505.54	505.42	504.03
FMW-9	524.84	[4]16.39	17.06	18.98	19.44		19.12					505.40	505.98	505.72	504.73
FMW-10	525.60	[4]16.83	17.46	19.26	20.23		19.42					505.37	506.39	506.18	505.09
FMW-11	530.42	[4]21.62	22.39	23.89	24.55		22.09					505.87	506.79	508.33	505.77
FMW-12	522.72	[4]17.15	17.68	19.22	19.82		18.25					502.90	504.02	504.47	502.52

NA - not applicable; well was not constructed.
NR - not recorded.
[a]vertical datum NAD88 feet
[b]measured in conjunction with water quality sampling – recorded on water quality sampling form.
[1]effected by flood stage of Auxvasse Creek.
[2]not fully recovered from pump test - 5/9 - 5/10
[3]gauged during week prior in conjunction with water quality sampling.
[4]gauged 8/22/07 in conjunction with water quality sampling.
[5]gauged 8/24/07

Table 2.4-48— {Callaway Plant Unit 2 Groundwater Water Quality Data}

(Page 1 of 3)

Location	Date	pH	S.Cond (mS/cm)	Turbidity (NTU)[1]	DO (mg/L)[1,2]	Temp. (Celsius)	ORP (mV)	Salinity (ppt)	TDS (gm/l)[2]
Plateau Shallow Wells									
PW-1	6/26/07	7.13	0.788	1514.3	1.98	18.03	150.1	0.39	0.511
	8/26/07	7.11	0.988	42.4	4.64	21.38	60.4	0.49	0.642
	11/13/07	6.94	0.929	81.4	3.78	16.34	69.5	0.46	0.604
	01/13/08	7.22	0.944	482.6	0.88	11.17	-9.3	0.47	0.614
MW-2S	6/27/07	7.00	0.851	652.0	1.42	20.00	150.2	0.42	0.553
	8/27/07	7.02	0.96	199.2	3.25	18.27	115.9	0.47	0.623
	11/16/07	6.97	0.913	36.8	3.59	17.71	57.5	0.45	0.584
	01/10/08	6.99	0.898	114.3	3.43	14.05	56.1	0.45	0.504
MW-3S	6/27/07	7.20	0.780	1469.2	3.85	15.88	74.0	0.38	0.507
	8/27/07	7.24	0.852	868.0	6.94	16.48	74.2	0.42	0.553
	11/18/07	7.06	0.800	10.0	4.12	14.29	29.2	0.39	0.520
	01/11/08	7.12	0.772	5.8	7.50	13.47	53.1	0.38	0.502
MW-5S	6/19/07	7.03	0.879	44.7	3.58	19.68	174.2	0.83	0.571
	8/28/07	7.22	1.822	210.0	9.19	17.76	78.4	0.93	1.183
	11/18/07	6.93	1.799	15.5	10.48	15.37	56.5	0.92	1.170
	01/11/08	6.95	1.754	14.9	8.75	13.91	53.5	0.89	1.139
MW-6S	6/19/07	7.31	0.926	1525.6	4.01	18.05	191.2	0.46	0.601
	8/28/07	7.24	1.019	644.6	6.92	20.99	76.9	0.50	0.661
	11/16/07	7.18	1.054	64.6	8.45	15.70	29.3	0.53	0.686
	01/11/08	7.12	1.028	64.1	7.97	14.12	43.8	0.51	0.668
MW-8	6/26/07	7.05	0.906	1527.3	2.47	18.21	150.0	0.45	0.588
	8/26/07	7.09	0.954	1136.9	5.76	17.80	118.3	0.47	0.620
	11/13/07	6.93	0.923	16.6	4.50	16.56	84.1	0.46	0.599
	01/13/08	7.06	0.900	19.2	4.87	13.64	45.2	0.45	0.585
MW-9	6/19/07	7.04	0.703	0.8	3.18	17.94	197.4	0.34	0.458
	8/26/07	7.02	0.755	8.5	8.52	18.33	113.3	0.37	0.491
	11/13/07	6.85	0.719	21.9	8.54	16.78	95.1	0.35	0.468
	01/13/08	7.07	0.715	6.2	7.07	12.94	33.4	0.35	0.465
MW-10	6/26/07	7.03	0.792	1454.6	2.14	17.86	151.8	0.39	0.514
	8/28/07	7.15	0.873	65.4	7.39	18.26	75.8	0.43	0.576
	11/18/07	6.90	0.807	20.3	6.31	17.44	42.2	0.40	0.525
	01/13/08	6.97	0.797	11.7	6.81	13.66	48.5	0.39	0.518
MW-12	6/19/07	7.27	0.538	1.9	3.69	21.74	191.10	0.26	0.365
	8/27/07	7.14	1.067	207.1	9.97	16.41	78.1	0.53	0.693
	11/13/07	6.92	0.981	40.2	7.53	15.49	75.7	0.49	0.638
	01/11/08	7.04	0.971	14.4	7.85	14.52	48.6	0.48	0.631
MW-18	8/26/07	7.15	0.952	211.3	7.43	18.03	84.3	0.47	0.618
	11/13/07	6.97	0.892	5.5	4.70	17.62	78.1	0.44	0.580
	01/13/08	7.13	0.890	39.0	5.45	11.95	35.4	0.44	0.577
Plateau Deep Wells									
MW-1D	6/17/07	7.04	0.705	-44.7	-0.03	20.97	12.6	0.34	0.458
	8/29/07	7.48	0.833	15.4	1.25	16.22	16.3	0.41	0.541
	11/13/07	7.24	0.772	9.2	3.45	14.84	-109.4	0.38	0.502
	01/13/08	7.37	0.774	5.1	1.66	13.99	-87.8	0.38	0.503

Table 2.4-48— {Callaway Plant Unit 2 Groundwater Water Quality Data}

(Page 2 of 3)

Location	Date	pH	S.Cond (mS/cm)	Turbidity (NTU)[1]	DO (mg/L)[1,2]	Temp. (Celsius)	ORP (mV)	Salinity (ppt)	TDS (gm/l)[2]
MW-2D	6/27/07	7.21	0.928	-28.2	-0.12	18.97	-211.3	0.48	0.612
	8/27/07	7.25	1.075	14.2	-0.18	18.44	-184.1	0.53	0.698
	11/18/07	7.13	0.928	2.0	0.08	18.42	-18.8	0.46	0.603
	01/10/08	7.22	0.949	0.0	0.0	16.89	-8.9	0.47	0.617
MW-3D	6/27/07	7.37	0.564	-34.8	-0.10	19.24	-152.6	0.27	0.366
	8/27/07	7.36	0.601	-0.4	-0.16	19.11	14.1	0.29	0.391
	11/18/07	7.22	0.548	3.0	0.62	16.47	-61.5	0.27	0.357
	01/11/08	7.25	0.548	0.0	0.01	17.88	-24.1	0.27	0.356
MW-4D	6/28/07	7.21	0.667	-38.3	-0.08	18.57	-232.5	0.32	0.433
	8/28/07	7.25	0.727	2.9	-0.01	18.34	-91.5	0.36	0.472
	11/18/07	7.11	0.678	7.9	0.82	18.13	-35.2	0.33	0.441
	01/11/08	7.18	0.678	0.0	0.05	18.20	20.0	0.33	0.440
MW-5D	6/28/07	7.24	0.305	-40.1	-0.03	19.88	-188.3	0.15	0.198
	8/28/07	7.27	0.619	1.0	0.30	21.54	-11.7	0.30	0.403
	11/18/07	7.13	0.578	10.2	0.69	20.83	-66.5	0.28	0.376
	01/11/08	7.16	0.572	0.0	0.04	18.27	-11.1	0.28	0.372
MW-6D	6/28/07	7.03	0.826	-37.1	-0.06	19.29	-79.5	0.41	0.537
	8/29/07	7.28	0.824	7.7	3.88	16.11	82.6	0.41	0.536
	11/15/07	7.18	0.790	3.8	3.46	14.43	26.1	0.39	0.514
	01/11/08	6.97	0.827	0.0	0.02	18.90	-46.4	0.41	0.538
MW-7D	6/27/07	7.15	0.812	-40.2	0.0	17.65	-137.3	0.40	0.528
	8/27/07	7.18	0.941	2.9	-0.19	17.79	-153.0	0.47	0.612
	11/14/07	7.02	0.890	1.8	0.39	18.61	-44.6	0.44	0.578
	01/10/08	7.11	0.878	0.0	0.0	16.46	-45.0	0.43	0.571
Study Boundary Rock Wells									
MW-13	6/19/07	7.15	0.789	643.5	0.29	15.49	44.2	0.39	0.513
	8/27/07	7.17	0.861	0.7	-0.23	17.97	-2.2	0.42	0.559
	11/16/07	7.15	0.798	10.6	0.02	15.34	-21.5	0.39	0.519
	01/10/08	7.10	0.805	0.0	0.0	15.37	-32.7	0.40	0.523
MW-14	6/19/07	7.19	0.724	-25.8	0.85	16.55	131.0	0.36	0.471
	8/27/07	7.21	0.788	3.3	1.83	18.49	44.5	0.39	0.512
	11/14/07	7.15	0.738	11.2	0.28	15.99	5.5	0.36	0.479
	01/10/08	7.14	0.730	1.4	0.0	14.35	-13.2	0.36	0.474
MW-15	6/26/07	7.18	0.675	175.5	-0.14	16.87	-306.2	0.33	0.438
	8/29/07	7.28	0.780	3.7	-0.04	17.90	-252.8	0.38	0.507
	11/18/07	7.12	0.718	6.7	0.43	15.19	-138.1	0.35	0.466
	01/13/08	7.17	0.713	3.3	0.06	13.88	-115.1	0.35	0.463
MW-16	6/26/07	7.09	0.689	2.3	-0.15	15.73	33.8	0.34	0.448
	8/28/07	7.17	0.749	4.1	-0.25	16.71	-49.6	0.37	0.487
	11/18/07	6.92	0.698	0.6	0.02	14.84	-22.2	0.34	0.454
	01/13/08	7.05	0.682	0.0	0.01	13.84	5.6	0.33	0.443
MW-17	6/26/07	6.91	0.896	-18.8	0.78	17.25	156.6	0.44	0.582
	8/28/07	6.99	0.974	7.3	1.99	17.66	72.5	0.48	0.633
	11/18/07	6.85	0.902	1000.1	2.34	15.19	-10.9	0.45	0.586
	01/13/08	6.90	0.890	59.1	1.80	13.83	18.9	0.44	0.579

Table 2.4-48— {Callaway Plant Unit 2 Groundwater Water Quality Data}

(Page 3 of 3)

Location	Date	pH	S.Cond (mS/cm)	Turbidity (NTU)[1]	DO (mg/L)[1,2]	Temp. (Celsius)	ORP (mV)	Salinity (ppt)	TDS (gm/l)[2]
PW-2	6/28/07	7.33	0.620	38.7	-0.12	15.64	-117.2	0.30	0.403
	8/28/07	7.33	0.668	-1.4	-0.28	16.36	-37.8	0.33	0.442
	11/18/07	7.19	0.621	0.0	0.81	13.52	-45.6	0.30	0.404
	01/12/08	7.23	0.616	0.0	0.0	13.10	-30.3	0.30	0.401
PW-3	6/26/07	7.21	0.595	-9.0	0.36	16.68	71.8	0.29	0.387
	8/28/07	7.29	0.643	7.1	0.59	16.92	32.5	0.31	0.418
	11/18/07	7.11	0.600	0.0	0.08	14.41	-20.5	0.29	0.390
	01/11/08	7.20	0.597	0.0	1.11	15.43	-13.1	0.29	0.388
Missouri River Alluvial Wells									
FMW-1D	8/22/07	7.39	0.711	-29.4	0.27	20.07	39.3	0.35	0.462
	11/17/07	7.37	0.678	0.0	0.16	14.33	-157.0	0.33	0.441
	01/12/08	7.40	0.669	0.0	0.07	15.10	-129.3	0.33	0.434
FMW-1S	8/22/07	6.99	0.778	-35.1	-0.22	19.74	-146.0	0.38	0.506
	11/17/07	6.92	0.748	0.0	0.0	15.09	-136.1	0.37	0.486
	01/12/08	6.94	0.738	0.0	0.0	15.04	-142.0	0.36	0.480
FMW-5	8/22/07	7.10	0.946	-40.8	-0.18	18.78	-182.7	0.47	0.615
	11/17/07	7.05	0.894	0.0	0.0	16.13	-170.2	0.44	0.581
	01/12/08	7.03	0.889	0.0	0.04	15.64	-168.0	0.44	0.578
FMW-6	8/22/07	6.96	0.955	-37.3	-0.26	21.00	-130.5	0.47	0.620
	11/17/07	6.93	0.902	0.0	0.78	17.33	-135.1	0.45	0.586
	01/12/08	6.95	0.905	0.0	0.03	15.24	-144.1	0.45	0.589
FMW-7	8/22/07	6.95	1.014	-24.8	-0.22	22.54	-139.9	0.50	0.659
	11/17/07	6.92	0.962	0.0	0.07	16.86	-139.9	0.48	0.626
	01/12/08	6.94	0.964	0.0	0.07	15.01	-142.4	0.48	0.627
FMW-8	8/22/07	6.96	1.063	-32.5	-0.21	21.66	-147.5	0.53	0.691
	11/17/07	6.93	1.08	0.0	0.0	16.57	-148.3	0.50	0.655
	01/12/08	6.94	1.019	0.0	0.02	15.35	-152.6	0.51	0.663
FMW-9	8/22/07	6.97	0.938	-36.8	0.18	22.56	-162.5	0.46	0.603
	11/17/07	6.95	0.847	0.0	0.0	16.55	-148.5	0.42	0.551
	01/12/08	6.95	0.851	0.0	0.01	15.44	-151.5	0.42	0.553
FMW-10	8/22/07	6.96	0.872	-38.3	-0.02	23.05	-142.7	0.43	0.567
	11/17/07	6.94	0.834	0.0	0.03	16.04	-140.3	0.41	0.542
	01/12/08	6.94	0.835	0.0	0.0	15.37	-150.6	0.41	0.543
FMW-11	8/22/07	7.01	0.709	-25.4	0.14	21.38	-122.9	0.35	0.461
	11/17/07	6.94	0.718	0.0	0.61	16.05	-124.1	0.35	0.466
	01/12/08	6.94	0.757	0.0	0.0	14.49	-126.9	0.37	0.492
FMW-12	8/22/07	6.99	0.886	-45.1	-0.22	21.14	-160.5	0.44	0.576
	11/17/07	6.97	0.858	0.0	1.62	14.59	-135.9	0.42	0.558
	01/12/08	6.99	0.859	0.0	0.06	14.85	-163.1	0.42	0.558

[1]Small negative turbidity and DO values indicate near zero and values are within the calibration tolerance. In subsequent rounds these values were recorded as 0.0 on the field form.

[2]Units for DO reported as (mg/L) are summarized as (ppm) in the text. Units for TDS reported as (gm/L) are summarized as (ppt) in the text.

FMW-1D is screened in the bedrock beneath the alluvial aquifer.

Table 2.4-49—{Callaway Plant Unit 2 Surface Water Gauge Elevations}

(Page 1 of 2)

Gauge Location ID	Northing[1]	Easting[1]	Reference Elevation[2]	Measured Value[3]					Water Level Elevation[3]				
				March 4, 2007	May 7, 2007	May 11, 2007	June 3, 2007	August 12, 2007	March 4, 2007	May 7, 2007	May 11, 2007	June 3, 2007	August 12, 2007
	(ft)	(ft)	(ft msl)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)
Stream Gauges – Auxvasse Creek													
SG-A1	1087234.88	1836873.30	568.65	25.50	25.70	25.20	26.22	26.66	543.15	542.95	543.45	542.43	541.99
SG-A2	1073436.78	1825657.45	565.03	43.50	43.39	35.27	43.95	43.93	521.53	521.64	529.76	521.08	521.10
SG-A3	1066250.69	1828527.05	559.83	43.10	43.90	33.70	38.73	43.38	516.73	515.93	526.13	521.10	516.45
SG-A4	1047515.99	1828074.57	538.15	23.40	20.10	9.80	19.65	27.08	514.75	518.05	528.35	518.50	511.07
SG-A5	1043774.56	1832214.10	536.60	18.20	14.75	7.25	5.42	22.68	518.40	521.85	529.35	531.18	513.92
Stream Gauges – Logan Creek													
SG-L1	1061636.17	1855466.49	571.97	10.80	11.00	NR	12.84	DRY	561.17	560.97	NR	559.13	DRY
SG-L2	1047720.06	1845224.58	531.35	15.60	14.40	NR	14.65	DRY	515.75	516.95	NR	516.70	DRY
SG-L3	1048138.31	1852818.23	525.82	20.20	13.55	NR	11.84	DRY	505.62	512.27	NR	513.98	DRY
SG-L4	1047749.17	1856430.12	543.82	36.70	29.85	NR	27.31	34.32	507.12	513.97	NR	516.51	509.50
Stream Gauges - Mud Creek													
SG-M1	1054407.67	1838934.36	553.71	11.30	11.00	NR	13.24	DRY	542.41	542.71	NR	540.47	DRY
SG-M2	1049152.44	1841555.34	525.88	9.00	9.37	NR	9.30	DRY	516.88	516.51	NR	516.58	DRY
SG-M3	1047717.12	1842259.33	530.19	13.80	13.50	NR	13.59	DRY	516.39	516.69	NR	516.60	DRY
SG-M4	1047510.92	1844557.31	531.76	22.50	18.69	NR	17.43	DRY	509.26	513.07	NR	514.33	DRY
SG-M5	1047416.53	1845138.56	521.86	13.60	8.69	NR	5.21	DRY	508.26	513.17	NR	516.65	DRY
Stream Gauges – Logan Camp Branch													
SG-LB1	1046622.84	1837832.04	531.49	6.10	6.49	NR	9.92	DRY	525.39	525.00	NR	521.57	DRY
SG-LB2	1047479.45	1841901.15	519.56	DRY	DRY	NR	3.25	DRY	DRY	DRY	NR	516.31	DRY
Pond Gauges													
PG-1	1068834.92	1853480.09	796.48	NA	2.10	NR	1.90	NR	NA	791.92	NR	791.72	NR
PG-2	1069782.92	1849411.34	798.97	NA	1.40	NR	0.78	NR	NA	793.71	NR	793.09	NR
PG-3	1069816.48	1846920.44	828.97	NA	2.95	NR	2.86	NR	NA	825.26	NR	825.17	NR
PG-4	1071117.38	1845705.70	827.61	NA	1.79	NR	1.82	NR	NA	822.74	NR	822.77	NR
PG-5	1070083.38	1844331.41	827.97	NA	2.53	NR	2.69	NR	NA	823.84	NR	824.00	NR

Table 2.4-49—{Callaway Plant Unit 2 Surface Water Gauge Elevations}

(Page 2 of 2)

Gauge Location ID	Northing[1]	Easting[1]	Reference Elevation[2]	Measured Value[3]					Water Level Elevation[3]				
				March 4, 2007	May 7, 2007	May 11, 2007	June 3, 2007	August 12, 2007	March 4, 2007	May 7, 2007	May 11, 2007	June 3, 2007	August 12, 2007
	(ft)	(ft)	(ft msl)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)
PG-6	1066292.04	1841261.07	838.56	NA	2.29	NR	2.38	NR	NA	834.19	NR	834.28	NR
PG-7	1064701.63	1842159.33	817.98	NA	2.20	NR	NR	NR	NA	813.52	NR	NR	NR
PG-9	1064480.81	1845349.41	824.27	NA	2.48	NR	2.40	NR	NA	820.09	NR	820.01	NR
PG-10	1067417.76	1845707.88	836.22	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lake Gauges													
LG-1	1081814.27	1837486.20	683.20	NA	2.75	NR	2.48	NR	NA	679.29	NR	679.02	NR
LG-2	1085165.81	1842458.86	659.19	NA	2.59	NR	3.30	NR	NA	655.12	NR	655.83	NR
LG-3	1081881.43	1846080.95	691.47	NA	3.30	NR	3.04	NR	NA	688.11	NR	687.85	NR

Table 2.4-49— {Callaway Plant Unit 2 Surface Water Gauge Elevations}

(Page 1 of 2)

Gauge Location ID	Northing[1]	Easting[1]	Reference Elevation[2]	Measured Value[3]					Water Level Elevation[3]				
				August 23, 2007	October 4, 2007	November 17, 2007	December 20, 2007	January 9, 2008	August 23, 2007	October 4, 2007	November 17,2007	December 20, 2007	January 9, 2008
	(ft)	(ft)	(ft msl)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)
Stream Gauges – Auxvasse Creek													
SG-A1	1087234.88	1836873.30	568.65	26.85	26.78	26.76	26.43	20.00	541.80	541.87	541.89	542.22	548.65
SG-A2	1073436.78	1825657.45	565.03	45.35	45.31	45.17	44.63	37.60	519.68	519.72	519.86	520.40	527.43
SG-A3	1066250.69	1828527.05	559.83	43.83	47.28	43.65	43.48	36.50	516.00	512.55	516.18	516.35	523.33
SG-A4	1047515.99	1828074.57	538.15	NR	32.64	32.91	32.56	26.75	NR	505.51	505.24	505.59	511.40
SG-A5	1043774.56	1832214.10	536.60	24.34	30.16	30.40	29.11	26.55	512.26	506.44	506.20	507.49	510.05
Stream Gauges – Logan Creek													
SG-L1	1061636.17	1855466.49	571.97	NR	DRY	DRY	13.05	10.37	NR	DRY	DRY	558.92	561.60
SG-L2	1047720.06	1845224.58	531.35	NR	23.52	23.32	23.23	20.82	NR	507.83	508.03	508.12	510.53
SG-L3	1048138.31	1852818.23	525.82	NR	20.02	25.10	22.87	17.60	NR	505.80	500.72	502.95	508.22
SG-L4	1047749.17	1856430.12	543.82	NR	38.16	37.73	38.38	36.16	NR	505.66	506.09	505.44	507.66
Stream Gauges - Mud Creek													
SG-M1	1054407.67	1838934.36	553.71	DRY	DRY	DRY	13.39	13.10	DRY	DRY	DRY	540.32	540.61
SG-M2	1049152.44	1841555.34	525.88	NR	DRY	DRY	9.52	8.81	NR	DRY	DRY	516.36	517.07
SG-M3	1047717.12	1842259.33	530.19	NR	18.70	18.22	18.52	17.05	NR	511.49	511.97	511.67	513.14
SG-M4	1047510.92	1844557.31	531.76	NR	23.14	25.26	25.03	21.13	NR	508.62	506.50	506.73	510.63
SG-M5	1047416.53	1845138.56	521.86	DRY	DRY	14.23	14.13	11.47	DRY	DRY	507.63	507.73	510.39
Stream Gauges – Logan Camp Branch													
SG-LB1	1046622.84	1837832.04	531.49	NR	DRY	DRY	10.91	9.40	NR	DRY	DRY	520.58	522.09
SG-LB2	1047479.45	1841901.15	519.56	DRY	DRY	DRY	DRY	3.99	DRY	DRY	DRY	DRY	515.57
Pond Gauges													
PG-1	1068834.92	1853480.09	796.48	0.88	0.58	0.38	0.74	1.25	790.70	790.40	790.20	790.56	791.07
PG-2	1069782.92	1849411.34	798.97	0.20	3.20	3.36	4.24	4.30	792.51	795.51	795.67	796.55	796.61
PG-3	1069816.48	1846920.44	828.97	2.04	1.84	1.62	NR	NR	824.35	824.15	823.93	NR	NR
PG-4	1071117.38	1845705.70	827.61	0.89	0.56	0.38	1.08	2.04	821.84	821.51	821.33	822.03	822.99
PG-5	1070083.38	1844331.41	827.97	2.08	2.28	2.42	2.82	2.90	823.39	823.59	823.73	824.13	824.21

Table 2.4-49— {Callaway Plant Unit 2 Surface Water Gauge Elevations}

(Page 2 of 2)

Gauge Location ID	Northing[1]	Easting[1]	Reference Elevation[2]	Measured Value[3]					Water Level Elevation[3]				
				August 23, 2007	October 4, 2007	November 17, 2007	December 20, 2007	January 9, 2008	August 23, 2007	October 4, 2007	November 17,2007	December 20, 2007	January 9, 2008
	(ft)	(ft)	(ft msl)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)
PG-6	1066292.04	1841261.07	838.56	1.98	1.76	1.62	1.94	2.19	833.88	833.66	833.52	833.84	834.03
PG-7	1064701.63	1842159.33	817.98	1.60	1.44	1.38	1.30	2.64	812.92	812.76	812.70	812.62	813.96
PG-9	1064480.81	1845349.41	824.27	2.56	2.58	0.56	2.56	2.68	820.17	820.19	818.17	820.17	820.29
PG-10	1067417.76	1845707.88	836.22	0.60	0.65	0.68	1.24	NR	830.16	830.21	830.24	830.80	NR
Lake Gauges													
LG-1	1081814.27	1837486.20	683.20	1.76	2.08	1.98	2.36	3.54	678.30	678.62	678.52	678.90	680.08
LG-2	1085165.81	1842458.86	659.19	1.66	1.39	1.24	1.60	NR	654.19	653.92	653.77	654.13	NR
LG-3	1081881.43	1846080.95	691.47	1.81	1.57	1.52	2.14	3.66	686.62	686.38	686.33	686.95	688.47

Table 2.4-49— {Callaway Plant Unit 2 Surface Water Gauge Elevations}

(Page 1 of 2)

Gauge Location ID	Northing[1]	Easting[1]	Reference Elevation[2]	Measured Value[3]					Water Level Elevation[3]				
				February 2, 2008					February 2, 2008				
	(ft)	(ft)	(ft msl)	(ft)					(ft msl)				
Stream Gauges – Auxvasse Creek													
SG-A1	1087234.88	1836873.30	568.65	26.18					542.47				
SG-A2	1073436.78	1825657.45	565.03	45.96					519.07				
SG-A3	1066250.69	1828527.05	559.83	43.66					516.17				
SG-A4	1047515.99	1828074.57	538.15	32.37					505.78				
SG-A5	1043774.56	1832214.10	536.60	30.28					506.32				
Stream Gauges – Logan Creek													
SG-L1	1061636.17	1855466.49	571.97	13.02					558.95				
SG-L2	1047720.06	1845224.58	531.35	23.31					508.04				
SG-L3	1048138.31	1852818.23	525.82	23.10					502.72				
SG-L4	1047749.17	1856430.12	543.82	38.76					505.06				
Stream Gauges - Mud Creek													
SG-M1	1054407.67	1838934.36	553.71	DRY					DRY				
SG-M2	1049152.44	1841555.34	525.88	9.59					516.29				
SG-M3	1047717.12	1842259.33	530.19	17.62					512.57				
SG-M4	1047510.92	1844557.31	531.76	25.25					506.51				
SG-M5	1047416.53	1845138.56	521.86	14.19					507.67				
Stream Gauges – Logan Camp Branch													
SG-LB1	1046622.84	1837832.04	531.49	7.09					524.40				
SG-LB2	1047479.45	1841901.15	519.56	DRY					DRY				
Pond Gauges													
PG-1	1068834.92	1853480.09	796.48	1.31					791.13				
PG-2	1069782.92	1849411.34	798.97	4.24					796.55				
PG-3	1069816.48	1846920.44	828.97	2.28					824.59				
PG-4	1071117.38	1845705.70	827.61	2.06					823.01				
PG-5	1070083.38	1844331.41	827.97	2.76					824.07				
PG-6	1066292.04	1841261.07	838.56	2.16					834.06				

Table 2.4-49— {Callaway Plant Unit 2 Surface Water Gauge Elevations}

(Page 2 of 2)

Gauge Location ID	Northing[1]	Easting[1]	Reference Elevation[2]	Measured Value[3]					Water Level Elevation[3]				
				February 2, 2008					February 2, 2008				
	(ft)	(ft)	(ft msl)	(ft)					(ft msl)				
PG-7	1064701.63	1842159.33	817.98	2.27					813.59				
PG-9	1064480.81	1845349.41	824.27	2.52					820.13				
PG-10	1067417.76	1845707.88	836.22	NR					NR				
Lake Gauges													
LG-1	1081814.27	1837486.20	683.20	3.34					679.88				
LG-2	1085165.81	1842458.86	659.19	2.84					655.37				
LG-3	1081881.43	1846080.95	691.47	2.84					687.65				

1 - Horizontal Datum NAD83 State Plane feet
2 - Vertical Datum NAD88 feet
3 - Measured value for streams with designated prefix "SG" is depth to water below surveyed bridge reference point. Water level elevation for streams is the reference elevation minus the measured value. Measured value for ponds and lakes with designated prefix "PG" or "LG" is the water level above 0.0 mark on the staff gauge. Water level elevation for ponds and lakes is the reference elevation (top of staff gauge) minus 6.66 feet (distance from top of staff gauge to 0.0 mark) plus the measured value above the 0.0 mark.
NA – not applicable; staff gauge not installed.
NR – not reported

Table 2.4-50—{Callaway Plant Unit 2 Estimated Average Flow Rates, Velocities and Depths of Streams}

(Page 1 of 2)

Location	Date	Total Width (ft)	Avg. Depth (ft)	Avg. Mean Velocity (ft/sec)	Total Discharge (ft^3/sec)
SG-A1	6/14/2007	91.0	2.03	0.015	2.80
	8/12/2007	84.0	1.74	0.011	1.55
	11/18/2007	90.0	1.85	0.042	7.07
	1/12/2008	96.0	2.21	0.139	29.7
SG-A2	6/14/2007	105.0	1.48	0.023	3.53
	8/12/2007	75.0	1.70	0.005	0.67
	11/18/2007	105.0	1.01	0.041	4.37
	1/12/2008	102.0	1.73	0.203	35.8
SG-A3	6/15/2007	140.0	1.53	0.015	3.13
	8/12/2007	130.0	0.76	0.024	2.41
	11/18/2007	138.0	0.70	0.050	4.87
	1/12/2008	149.0	1.38	0.440	90.5
SG-A4	6/15/2007	160.0	7.76	0.018	22.0
	8/12/2007	150.0	5.48	0.057	46.9
	11/18/2007	9.0	1.10	0.422	4.18
	1/12/2008	136.0	2.87	0.204	79.8
SG-A5	6/29/2007	170.0	8.92	0.020	30.0
	8/12/2007	170.0	8.86	0.065	98.1
	11/18/2007	140.0	2.26	0.049	15.5
	1/12/2008	172.0	6.14	0.062	65.8
SG-L1	1/10/2008	41.50	0.26	0.456	4.96
SG-L2	5/24/2007	60.0	5.02	0.035	10.7
	6/15/2007	52.0	3.69	0.030	5.74
	8/12/2007	Standing Water - No Flow			
	11/17/2007	16.50	0.72	0.045	0.53
	1/10/2008	24.0	0.75	0.339	6.07
SG-L3	5/24/2007	78.0	7.54	0.023	13.4
	6/14/2007	76.0	5.85	0.027	12.1
	8/12/2007	Pooled Water - No Flow			
	11/17/2007	39.0	1.16	0.046	2.07
	1/10/2008	46.0	1.37	0.094	5.87
SG-L4	6/29/2007	80.0	4.31	0.069	23.9
	8/12/2007	Standing Water - No Flow			
	11/17/2007	54.0	1.38	0.050	3.74
	1/10/2008	60.0	1.51	0.091	8.28
SG-M1	1/11/2008	14.0	0.25	0.342	1.20
SG-M2	1/11/2008	14.0	0.18	0.376	0.96
SG-M3	5/23/2007	21.0	3.16	0.024	1.59
	6/14/2007	13.5	2.09	0.011	0.30
	8/12/2007	Pooled Water - No Flow			
	11/16/2007	14.0	1.24	0.020	0.34
	1/11/2008	14.3	1.41	0.196	3.93

Table 2.4-50—{Callaway Plant Unit 2 Estimated Average Flow Rates, Velocities and Depths of Streams}
(Page 2 of 2)

Location	Date	Total Width (ft)	Avg. Depth (ft)	Avg. Mean Velocity (ft/sec)	Total Discharge (ft^3/sec)
SG-M4	5/23/2007	38.0	4.46	0.016	2.76
	6/14/2007	36.0	3.71	0.013	1.72
	8/12/2007	Pooled Water – No Flow			
	11/16/2007	9.0	0.61	0.024	0.13
	1/11/2008	13.0	0.59	0.165	1.27
SG-M5	5/21/2007	30.0	6.67	0.053	10.7
	6/14/2007	31.0	4.30	0.019	2.47
	8/12/2007	Pooled Water - No Flow			
	11/16/2007	9.6	0.86	0.216	1.78
	1/11/2008	11.0	1.29	0.170	2.41
SG-LB1	1/10/2008	8.0	1.56	0.030	0.37

Table 2.4-51—{Callaway Plant Unit 2 Surface Water Quality Data}

(Page 1 of 3)

Location	Date	pH	S.Cond (mS/cm)	Turbidity (NTU)[1]	DO (mg/L)[2]	Temp. (Celsius)	ORP (mV)	Salinity (ppt)	TDS (gm/l)[2]
Stream Sampling Locations									
SG-A1	6/12/07	7.87	0.402	74.6	3.78	29.14	NR	0.19	0.261
	6/30/07	7.72	0.250	41.3	3.30	22.05	217.9	0.12	0.162
	8/24/07	7.51	0.486	1.5	3.79	27.98	312.2	0.23	0.316
	11/15/07	7.98	0.615	5.0	8.23	7.86	3.5	0.30	0.399
	01/09/08	8.11	0.183	160.1	10.96	7.06	210.9	0.09	0.119
SG-A2	6/12/07	7.68	0.401	80.3	4.10	27.47	NR	0.19	0.261
	6/30/07	7.82	0.263	46.6	3.31	22.54	215.2	0.12	0.171
	8/24/07	7.74	0.495	7.0	5.42	26.38	239.2	0.24	0.322
	11/14/07	7.78	0.417	7.3	6.14	12.01	-1.0	0.20	0.271
	01/09/08	8.16	0.183	238.3	10.60	7.11	242.1	0.09	0.119
SG-A3	6/12/07	7.68	0.505	92.9	3.40	23.79	NR	0.24	0.328
	6/30/07	7.91	0.346	2.2	3.34	22.64	216.8	0.16	0.225
	8/24/07	7.99	0.877	6.2	6.31	26.14	228.1	0.43	0.570
	11/15/07	8.07	1.018	9.8	11.89	10.42	88.0	0.51	0.662
	01/09/08	8.15	0.218	195.8	11.0	7.23	133.4	0.10	0.142
SG-A5	6/12/07	7.69	0.515	82.4	3.73	26.75	NR	0.25	0.335
	6/30/07	7.69	0.575	-31.6	1.86	25.84	230.1	0.28	0.374
	8/24/07	7.94	0.675	3.3	6.38	29.19	225	0.33	0.439
	11/15/07	7.93	0.894	18.3	9.58	10.75	69.9	0.44	0.581
	01/09/08	8.13	0.223	199.8	10.61	7.40	126.3	0.11	0.145
SG-L1	6/12/07	8.16	0.415	74.4	4.84	30.51	NR	0.20	0.269
	6/30/07	8.13	0.389	-38.6	4.07	22.75	210.6	0.19	0.253
	8/24/07	DRY							
	11/15/07	DRY							
	01/09/08	7.95	0.333	8.3	11.33	7.11	164.6	0.16	0.216
SG-L2	6/12/07	7.17	0.510	82.2	3.53	26.18	NR	0.25	0.337
	6/30/07	7.52	0.609	-13.9	2.24	22.23	234.3	0.30	0.396
	8/24/07	DRY							
	11/15/07	7.62	0.659	12.4	2.80	8.24	-5.3	0.32	0.429
	01/09/08	7.93	0.353	17.9	10.94	6.24	144.2	0.17	0.229
SG-L3	6/12/07	8.08	0.508	87.2	4.76	26.61	NR	0.24	0.330
	6/30/07	7.86	0.609	6.8	2.37	25.26	221.2	0.29	0.396
	8/24/07	DRY							
	11/15/07	7.44	0.692	12.6	2.41	9.10	-34.9	0.34	0.450
	01/09/08	8.09	0.359	34.4	11.04	6.07	123.9	0.17	0.234
SG-M1	6/12/07	DRY							
	6/30/07	7.48	0.938	-38.4	3.30	19.19	182.5	0.46	0.610
	8/24/07	DRY							
	11/15/07	DRY							
	01/09/08	7.98	0.514	11.4	11.83	6.54	135.4	0.25	0.334
SG-M5	6/12/07	7.87	0.529	84.8	4.04	25.36	NR	0.25	0.344
	6/30/07	7.57	0.601	-14.1	2.71	22.62	237.6	0.29	0.390
	8/24/07	DRY							
	11/15/07	7.38	0.630	33.2	2.77	10.54	-41.9	0.31	0.410
	01/09/08	8.06	0.485	18.7	11.86	6.88	184.8	0.23	0.315

Table 2.4-51—{Callaway Plant Unit 2 Surface Water Quality Data}

(Page 2 of 3)

Location	Date	pH	S.Cond (mS/cm)	Turbidity (NTU)[1]	DO (mg/L)[2]	Temp. (Celsius)	ORP (mV)	Salinity (ppt)	TDS (gm/l)[2]
SG-LB1	6/12/07	8.00	0.591	103.1	2.12	21.34	NR	0.29	0.384
	6/30/07	DRY							
	8/24/07	DRY							
	11/15/07	DRY							
	01/09/08	8.07	0.426	0.1	11.18	6.52	132.0	0.21	0.277
Pond Sampling Locations									
PG-1	6/12/07	7.45	0.136	-33.2	4.11	29.16	47.7	0.06	0.089
	8/23/07	7.20	0.170	179.8	6.13	31.76	115	0.08	0.111
	11/14/07	8.25	0.171	6.0	10.30	12.14	35.3	0.08	0.111
	01/09/08	8.29	0.159	6.3	12.12	7.86	180.7	0.08	0.103
PG-2	6/12/07	8.94	0.343	-28.1	5.66	32.00	140.5	0.16	0.223
	8/23/07	8.88	0.500	12.5	12.71	31.51	119.5	0.24	0.325
	11/14/07	8.80	0.463	10.2	11.85	12.60	60.2	0.22	0.301
	01/09/08	8.39	0.380	165.8	12.32	9.48	167.8	0.18	0.247
PG-3	6/12/07	8.30	0.554	-39.5	4.00	28.48	166.2	0.27	0.360
	8/23/07	8.34	0.532	2.8	9.26	29.70	160.0	0.25	0.345
	11/14/07	8.18	0.484	5.3	10.10	11.67	77.6	0.23	0.315
	01/09/08	8.21	0.482	10.2	11.65	7.75	171.1	0.23	0.313
PG-4	6/12/07	9.89	0.195	-39.2	6.08	28.89	79.9	0.09	0.127
	8/23/07	9.97	0.201	2.2	11.71	29.86	43.0	0.09	0.131
	11/14/07	9.47	0.183	12.3	11.42	12.31	23.2	0.09	0.119
	01/09/08	8.22	0.285	10.9	10.36	8.36	193.2	0.14	0.185
PG-5	6/13/07	7.88	0.446	-13.1	3.97	30.26	132.0	0.21	0.290
	8/23/07	9.38	0.367	26.1	19.01	31.96	121.2	0.17	0.239
	11/14/07	9.37	0.34	13.1	11.832	13.18	36.0	0.16	0.221
	01/09/08	8.17	0.436	46.5	9.04	8.30	166.5	0.21	0.284
PG-6	6/12/07	8.68	0.476	-15.4	4.50	29.37	137.4	0.23	0.309
	8/23/07	8.57	0.627	11.2	10.01	30.25	173.0	0.30	0.408
	11/15/07	8.18	0.647	13.2	10.38	10.17	84.7	0.32	0.420
	01/09/08	8.23	0.620	8.3	11.52	8.10	150.9	0.30	0.403
PG-7	6/13/07	DNS - Stormy Weather							
	6/30/07	DNS - Newly Erected Electric Fence							
	8/23/07	8.11	0.994	38.4	8.36	31.11	181.6	0.48	0.646
	11/15/07	8.28	0.995	22.4	10.32	9.55	50.2	0.49	0.646
	01/09/08	8.23	1.078	24.5	11.33	8.31	144.2	0.54	0.701
PG-9	6/13/07	8.74	1.738	-30.4	4.57	30.43	165.2	0.87	1.129
	8/23/07	9.67	1.027	4.1	18.65	31.28	146.7	0.50	0.668
	11/15/07	9.65	0.560	16.5	12.65	10.01	59.5	0.27	0.364
	01/09/08	8.47	1.476	58.6	12.53	7.91	135.0	0.74	0.960
PG-10	6/12/07	DNS							
	8/24/07	8.09	0.563	0.7	1.15	26.55	225.1	0.27	0.366
	11/13/07	8.70	0.419	18.6	11.39	14.33	-12.3	0.20	0.272
	01/09/08	8.22	0.533	10.5	11.84	6.43	169.4	0.26	0.346
Lake Sampling Locations									

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Table 2.4-51—{Callaway Plant Unit 2 Surface Water Quality Data}

(Page 3 of 3)

Location	Date	pH	S.Cond (mS/cm)	Turbidity (NTU)[1]	DO (mg/L)[2]	Temp. (Celsius)	ORP (mV)	Salinity (ppt)	TDS (gm/l)[2]
LG-1	6/13/07	8.46	0.200	-41.9	3.99	28.22	175.5	0.09	0.130
	6/30/07	8.13	0.389	-38.6	4.07	22.75	210.6	0.19	0.253
	8/23/07	8.47	0.233	-0.5	8.75	30.11	210.5	0.11	0.152
	11/14/07	7.92	0.215	3.8	7.28	12.38	98.6	0.10	0.140
	01/09/08	8.12	0.160	5.6	9.98	4.36	228.1	0.08	0.104
LG-2	6/13/07	8.34	0.189	-43.9	3.87	27.76	196.0	0.09	0.123
	6/30/07	7.52	0.609	-13.9	2.24	22.23	234.3	0.30	0.396
	8/23/07	8.45	0.205	-0.9	8.46	29.86	113.1	0.10	0.133
	11/14/07	7.80	0.203	3.3	6.95	11.67	96.1	0.10	0.132
	01/09/08	7.89	0.205	1.0	10.47	4.31	230.1	0.10	0.134
LG-3	6/13/07	8.70	0.212	-38.0	4.23	28.61	156.3	0.10	0.138
	6/30/07	7.86	0.609	6.8	2.37	25.26	221.2	0.29	0.396
	8/23/07	8.52	0.260	2.6	9.59	30.22	166.4	0.12	0.169
	11/14/07	7.72	0.270	6.1	8.00	11.49	102.9	0.13	0.175
	01/09/08	8.04	0.242	23.3	11.01	6.24	211.4	0.12	0.157

[1]Small negative turbidity values indicate near zero and values are within the calibration tolerance. In subsequent rounds these values were recorded as 0.0 on the field form.

[2]Units for DO reported as (mg/L) are summarized as (ppm) in the text. Units for TDS reported as (gm/L) are summarized as (ppt) in the text.

NR – not reported.

DNS – did not sample.

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Table 2.4-52—{Callaway Plant Unit 2 Aquifer Hydraulic Gradients}

Well Pair	General GW Flow Direction	May, 2007	August, 2007	November, 2007	January, 2008	Arithmetic Average[2]
Graydon Chert Aquifer – Central Area of Plateau – Horizontal Gradients						
MW-18/MW-12	WNW	0.00280[1]	0.00429	0.00482	0.00347	0.00419
MW-18/MW-10	SSE	0.00242[1]	0.00245	0.00231	0.00215	0.00230
PW-1/MW-9	ESE	0.00177	0.00143	0.00135	0.00194	0.00162
MW-18/MW-8	NNE	0.00180[1]	0.00125	0.00127	0.00110	0.00121
Graydon Chert Aquifer – Periphery of Plateau – Horizontal Gradients						
MW-12/MW-6S	NW	0.00301	0.00336	0.00322	0.00341	0.00325
MW-12/MW-5S	SW	0.00807	0.00805	0.00791	0.00820	0.00806
PW-1/MW-3S	E	0.00468	0.00438	0.00438	0.00447	0.00448
MW-8/MW-2S	NNE	0.00799	0.00840	0.00845	0.00828	0.00837
CJC Aquifer – Horizontal Gradients						
MW-2D/MW-13	NNW	0.00055	0.00067	0.00062	0.00057	0.00060
MW-6D/MW-14	WNW	0.00200	0.00222	0.00219	0.00209	0.00212
MW-5D/PW-2	W	0.00340	0.00360	0.00351	0.00334	0.00348
MW-4D/MW-16	SSW	0.00296	0.00334	0.00327	0.00275	0.00312
MW-16/MW-15	SW	0.00173	0.00147	0.00161	0.00216	0.00174
Graydon Chert/CJC Aquifers – Vertical Gradients						
PW-1/MW-1D	Downward	0.860	0.861	0.863	0.861	0.861
MW-2S/MW-2D	Downward	0.855	0.846	0.845	0.846	0.848
MW-3S/MW-3D	Downward	0.834	0.867	0.870	0.868	0.866
MW-5S/MW-5D	Downward	0.813	0.816	0.817	0.814	0.815
MW-6S/MW-6D	Downward	0.850	0.847	0.848	0.846	0.848

[1]No reading was available at MW-18 for the May, 2007 round. Hydraulic gradients were estimated from the 830 foot mean sea level (msl) potentiometric surface contour in the area of MW-18 to the downgradient well. These estimates were not included in the arithmetic average. [2]Arithmethic average is calculated from four rounds, except in cases described in note 1.

Table 2.4-53—{Callaway Plant Unit 2 Monitoring Well Slug Test Results}

Well ID	Kh (ft/sec)	Kh (cm/sec)	Kh (ft/day)
Plateau Shallow Wells			
PW-1	8.17E-07	2.49E-05	7.06E-02
MW-2S	1.90E-06	5.79E-05	1.64E-01
MW-3S	1.04E-04	3.18E-03	9.02E+00
MW-5S	6.69E-07	2.04E-05	5.78E-02
MW-6S	8.16E-08	2.49E-06	7.05E-03
MW-8	2.56E-06	7.80E-05	2.21E-01
MW-9	4.94E-06	1.51E-04	4.27E-01
MW-10	1.50E-06	4.59E-05	1.30E-01
MW-11	NT	NT	NT
MW-12	2.37E-07	7.23E-06	2.05E-02
MW-18	3.29E-07	1.00E-05	2.84E-02
Geometric Mean	1.30E-06	3.95E-05	1.12E-01
Plateau Intermediate Well			
MW-1I	NT	NT	NT
Plateau Cotter-Jefferson City Wells			
MW-1D	6.96E-06	2.12E-04	6.01E-01
MW-2D	1.35E-05	4.13E-04	1.17E+00
MW-3D	9.93E-06	3.03E-04	8.58E-01
MW-4D	4.04E-06	1.23E-04	3.49E-01
MW-5D	3.65E-06	1.11E-04	3.15E-01
MW-6D	3.58E-05	1.09E-03	3.09E+00
MW-7D	9.12E-06	2.78E-04	7.88E-01
Geometric Mean	8.92E-06	2.72E-04	7.71E-01
Study Boundary Cotter-Jefferson City Wells			
MW-13	4.36E-06	1.33E-04	3.77E-01
MW-14	4.53E-06	1.38E-04	3.91E-01
MW-15	4.65E-06	1.42E-04	4.02E-01
MW-16	1.82E-06	5.54E-05	1.57E-01
MW-17	4.09E-06	1.25E-04	3.53E-01
PW-2	7.82E-06	2.38E-04	6.76E-01
PW-3	2.36E-06	7.20E-05	2.04E-01
Geometric Mean	3.85E-06	1.17E-04	3.33E-01
Missouri River Alluvial Wells			
FMW-1D	6.62E-07	2.02E-05	5.72E-02[1]
FMW-1S	TF	TF	TF
FMW-5	1.88E-04	5.72E-03	1.62E+01
FMW-6	TF	TF	TF
FMW-7	TF	TF	TF
FMW-8	TF	TF	TF
FMW-9	TF	TF	TF
FMW-10	TF	TF	TF
FMW-11	TF	TF	TF
FMW-12	TF	TF	TF

NT – not tested
TF – recovery was too fast to estimate hydraulic conductivity
[1]FMW-1D is screened in the bedrock beneath the alluvial aquifer.

Table 2.4-54—{Callaway Plant Unit 2 Pumping Test Results}

Well ID	T (ft^2/day)	T (cm^2/sec)	Kh (ft/day)	Kh (cm/sec)	S
Pumping Test PW-2					
PZ-2-1	13.2	1.42E-01	5.30E-01	1.87E-04	2.89E-04
PZ-2-2	15.4	1.66E-01	6.17E-01	2.18E-04	3.19E-04
PZ-2-3	13.0	1.40E-01	5.19E-01	1.83E-04	3.01E-04
Geometric Mean	13.8	1.49E-01	5.54E-01	1.95E-04	3.03E-04
Pumping Test PW-3					
PZ-3-1	2.58	2.77E-02	1.03E-01	3.63E-05	1.83E-04
PZ-3-2	2.48	2.67E-02	9.93E-02	3.50E-05	1.44E-04
PZ-3-3	2.74	2.95E-02	1.10E-01	3.88E-05	1.49E-04
Geometric Mean	2.60	2.79E-02	1.04E-01	3.67E-05	1.58E-04

Note: Transmissivity was assumed over the screened interval plus the sandpack above the well. It is not representative of the entire thickness of the CJC aquifer.

Table 2.4-55—{Callaway Plant Unit 2 Aquifer Unit Geotechnical Parameters}

				Geotechnical Laboratory Analyses					Calculated Values	
Boring Location	Sample Number	Sample Depth	Origin	Moisture Content[1]	Moist Unit Weight[2] (lb/ft^3)	Specific Gravity	Total Organic Content (%)	Vertical Hydraulic Conductivity (cm/sec)	Void Ratio	Porosity (%)
Plateau Shallow Unconsolidated Materials										
PW-1	ST-1	15-17	Till	0.198	122.7	2.567	1.4	1.2E-07	0.56	36.1
MW-2S	ST-1	15-16.3	Loess	0.164	133.5	2.615	1.4	7.1E-08	0.42	29.7
MW-5S	ST-1	10-12	Till	0.188	130.3	2.590	1.7	6.1E-07	0.47	32.1
MW-6S	ST-1	15-17	Gley	0.212	129.3	2.529	1.3	1.1E-07	0.48	32.4
MW-8	ST-1	15-17	Till	0.264	121.8	2.876	2.0	6.0E-09	0.86	46.3
MW-8	ST-2	20-22	Chert	0.208	128.7	2.562	1.3	6.8E-08	0.50	33.4
MW-9	ST-1	15-17	Till	0.222	131.1	2.527	1.4	4.2E-09	0.47	32.0
MW-10	ST-1	15-17	Till	0.258	126.7	2.524	1.3	1.7E-06	0.56	36.1
MW-11	ST-1	15-17	Till	0.183	126.0	2.516	1.6	6.9E-09	0.47	32.2
			Mean =	0.211	127.8	2.590	1.5	6.1E-08	0.53	34.8
Missouri River Alluvium										
FMW-5	S-5	10-12	Alluvium	0.12	103.0	2.53	0.67	2.1E-04	0.72	41.7
FMW-8	S-5	10-12	Alluvium	0.48	106.0	2.61	1.56	4.6E-08	1.27	56.1
FMW-8	S-6	14-15.5	Alluvium	0.38	110.0	2.52	1.42	7.6E-08	0.97	49.3
FMW-12	S-3	10-12	Alluvium	0.37	110.0	2.56	2.35	8.7E-08	0.99	49.7
FSB-13	S-3	10-12.5	Alluvium	0.03	98.0	2.59	0.27	1.8E-04	0.70	41.1
			Mean =	0.27	105.4	2.56	1.25	1.6E-06	0.93	47.5

Note:
Moisture Content = Water Content = weight of water in the sample divided by the weight of dry solids.
Moist Unit Weight = Bulk Density = weight of water and solids divided by the sample volume.
Calculations:
Void Ratio = (Specific Gravity (x) Unit Weight of Water (x) (1+ Natural Moisture))/(Moisture Unit Weight) - 1
Unit Weight Water = 62.4 lb/ft^3
Porosity = (Void Ratio)/(1+Void Ratio)
Means are calculated as arithmetic except geometric mean for hydraulic conductivity.

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Table 2.4-56—{Callaway Plant Unit 2 Grain Size Distribution}

Boring Location	Sample Number	Sample Depth	Origin	Grain Size Characteristics: Coarse Gravel (%)	Fine Gravel (%)	Coarse Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)
Plateau Shallow Unconsolidated Materials										
PW-1	ST-1	15-17	Till	0.0	0.0	0.0	2.5	6.3	42.1	49.1
MW-2S	ST-1	15-16.3	Loess	0.0	0.0	0.0	6.4	11.2	33.6	48.8
MW-5S	ST-1	10-12	Till	0.0	0.0	0.0	7.4	19.9	30.9	41.8
MW-6S	ST-1	15-17	Gley	0.0	0.0	0.0	1.2	5.3	45.3	48.2
MW-8	ST-1	15-17	Till	0.0	0.0	0.0	1.2	5.7	37.5	55.6
MW-8	ST-2	20-22	Chert	0.0	0.0	0.0	5.7	23.0	31.3	40.0
MW-9	ST-1	15-17	Till	0.0	0.0	0.0	6.9	17.3	29.0	46.8
MW-10	ST-1	15-17	Till	0.0	0.0	0.0	1.0	4.4	43.1	51.5
MW-11	ST-1	15-17	Till	0.0	0.0	0.0	0.7	3.3	40.8	55.2
Missouri River Alluvium										
FMW-1D	SS-10	45-50	Alluvium	0.0	18.7	50.7	26.7	3.1	0.5	0.3
FMW-1D	SS-11	50-55	Alluvium	0.0	3.7	33.8	56.7	4.7	0.5	0.6
FMW-1D	SS-12	55-60	Alluvium	0.0	4.8	35.1	52.7	5.9	0.8	0.7
FMW-1D	SS-13	60-65	Alluvium	0.0	30.0	47.7	19.3	2.4	0.2	0.4
FMW-1D	SS-16	75-80	Alluvium	0.0	19.0	53.1	26.0	1.2	0.4	0.3
FMW-1D	SS-17	80-85	Alluvium	0.0	13.1	46.4	34.8	3.4	1.2	1.1
FMW-1D	SS-18	85-90	Alluvium	0.0	15.2	54.4	26.5	2.3	0.4	1.2
FMW-1D	SS-19	90-94	Alluvium	0.0	2.1	51.1	39.1	4.7	1.0	2.0
FSB-2	SS-14	65-70	Alluvium	0.0	0.3	22.4	68.0	8.8	0.1	0.4
FSB-2	SS-15	70-75	Alluvium	0.0	0.1	8.3	83.5	7.4	0.2	0.5
FSB-2	SS-16	75-80	Alluvium	0.0	0.2	15.0	71.5	12.4	0.4	0.5
FSB-2	SS-17	80-85	Alluvium	0.0	0.3	24.6	69.8	5.0	< 0.3% silt and clay	
FSB-3	SS-17	80-85	Alluvium	0.0	4.3	45.5	48.2	1.6	< 0.4% silt and clay	
FSB-3	SS-18	85-90	Alluvium	0.0	4.9	24.1	53.1	14.1	2.3	1.5
FSB-3	SS-19	90-95	Alluvium	0.0	2.6	18.7	58.6	18.4	0.8	0.9
FSB-3	SS-20	95-100	Alluvium	0.0	0.1	12.1	81.4	4.6	0.8	1.0
FSB-4	SS-19	80-85	Alluvium	0.0	19.0	48.7	30.7	1.5	< 0.1% silt and clay	
FSB-4	SS-20	86-91	Alluvium	0.0	3.5	42.6	53.0	0.8	< 0.1% silt and clay	
FSB-4	SS-21	91-96	Alluvium	0.0	32.9	46.3	19.1	1.3	< 0.4% silt and clay	
FSB-4	SS-22	96-99.5	Alluvium	0.0	15.3	45.4	34.2	3.8	0.9	0.4
FMW-5	S-3	10-12.5	Alluvium	0.0	0.0	0.0	0.2	79.0	16.7	4.1
FMW-5	SS-9	35-40	Alluvium	0.0	0.0	9.3	26.3	62.5	1.0	0.9
FMW-5	SS-10	40-45	Alluvium	0.0	0.1	1.0	36.9	60.4	0.9	0.7
FMW-5	SS-11	45-49.5	Alluvium	0.0	0.1	6.6	16.9	73.1	1.1	2.2
FMW-8	S-5	10-12	Alluvium	0.0	0.0	0.0	0.3	0.5	61.4	37.8
FMW-8	S-6	14-15.5	Alluvium	0.0	0.0	0.0	0.8	16.0	37.0	46.2
FMW-12	S-3	10-12	Alluvium	0.0	0.0	0.0	0.1	0.1	46.4	53.4
FSB-13	S-3	10.0-12.5	Alluvium	0.0	0.0	0.0	0.1	77.7	18.4	3.8
FSB-13	SS-18	80-85	Alluvium	0.0	4.6	54.9	38.0	2.0	< 0.5% silt and clay	
FSB-13	SS-19	85-90	Alluvium	0.0	2.7	42.8	51.0	3.0	< 0.5% silt and clay	
FSB-13	SS-20	90-95	Alluvium	0.0	12.4	53.2	32.7	1.5	< 0.2% silt and clay	
FSB-13	SS-21	95-99.5	Alluvium	0.0	4.8	52.6	38.6	3.2	0.3	0.5
FSB-14	SS-16	80-85	Alluvium	0.0	0.1	7.7	80.0	11.3	0.6	0.3
FSB-14	SS-17	85-90	Alluvium	0.0	0.2	32.0	60.2	7.3	< 0.3% silt and clay	
FSB-14	SS-18	90-95	Alluvium	0.0	0.6	35.9	55.5	7.6	< 0.4% silt and clay	
FSB-14	SS-19	95-100	Alluvium	0.0	11.1	51.8	32.7	4.1	< 0.3% silt and clay	

Table 2.4-57—{Callaway Plant Unit 2 Groundwater Flow Velocities and Travel Times}

Well Pair	General GW Flow Direction	Average Gradient (ft/ft)	Hydraulic Conductivity[1] (ft/day)	Porosity	Ground-water Velocity (ft/day)	Travel Distance[2] (ft)	Travel Time (years)[3]
Graydon Chert Aquifer – From Callaway Plant Unit 2 – Horizontal Groundwater Flow							
MW-18/MW-12	WNW	0.00419	0.112	0.05	0.0094	128.3	37.4
MW-18/MW-10	SSE	0.00230	0.112	0.05	0.0052	70.5	37.4
PW-1/MW-9	ESE	0.00162	0.112	0.05	0.0036	49.7	37.4
MW-18/MW-8	NNE	0.00121	0.112	0.05	0.0027	37.0	37.4
Graydon Chert Aquifer – From Callaway Plant Unit 2 – Vertical Groundwater Flow							
PW-1/MW-1D	Downward	0.8612	1.7E-4	0.05	0.0029	40	37.4
Aquitard – Vertical Groundwater Flow							
PW-1/MW-1D	Downward	0.8612	1.7E-5	0.05	0.00029	275	2573
Cotter-Jefferson City Aquifer – Horizontal Groundwater Flow							
MW-2D/MW-13	NNW	0.00060	0.771	0.05	0.0093	13,934	4097
MW-6D/MW-14	WNW	0.00212	0.771	0.05	0.0328	14,508	1213
MW-5D/PW-2	W	0.00346	0.771	0.05	0.0534	11,282	579
MW-4D/MW-16	WSW	0.00308	0.771	0.05	0.0475	7,076	408

1 For the Graydon Chert, horizontal hydraulic conductivity is the geometric mean from slug test results and vertical hydraulic conductivity is from geometric mean from permeability tests. For the aquitard, vertical hydraulic conductivity is 10% of value for the Graydon Chert aquifer. For the CJC aquifer, horizontal hydraulic conductivity is the geometric mean from slug test results.

2 Horizontal travel distance in Graydon Chert aquifer is based on travel time of 37.4 years estimated as the time for a groundwater particle at the top of the chert to travel downward and leave the aquifer.

3 Travel time through CJC aquifer is the time to travel from the first well to the second well in the pair.

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Table 2.4-58—{Reactor Coolant Storage Tank Radionuclide Inventory}

Radioisotope	Half-life $t^{1/2}$ (days)	Concentration (μCi/mL)	Radioisotope	Half-life $t^{1/2}$ (days)	Concentration (μCi/mL)
H-3	4.51E+03	1.0E+00	Te-127m	1.09E+02	6.6E-04
Na-24	6.25E-01	3.8E-02	Te-127*	3.90E-01	0.0E+00
Cr-51	2.77E+01	2.1E-03	I-129	5.73E+09	4.6E-08
Mn-54	3.13E+02	1.1E-03	I-130	5.15E-01	5.0E-02
Fe-55	9.86E+02	8.1E-04	Te-129m	3.36E+01	1.9E-03
Fe-59	4.45E+01	2.0E-04	Te-129*	4.83E-02	3.1E-03
Co-58	7.08E+01	3.1E-03	Te-131m	1.25E+00	4.6E-03
Co-60	1.93E+03	3.6E-04	Te-131*	1.74E-02	3.0E-03
Zn-65	2.44E+02	3.4E-04	I-131*	8.04E+00	7.4E-01
Br-83	9.96E-02	3.2E-02	Te-132	3.26E+00	5.0E-02
Kr-83m*	7.63E-02	0.0E+00	I-132*	9.58E-02	3.7E-01
Br-84	2.21E-02	1.7E-02	I-133	8.67E-01	1.3E+00
Br-85	2.01E-03	2.0E-03	Xe-133m*	2.19E+00	0.0E+00
Kr-85*	1.87E-01	0.0E+00	Xe-133*	5.25E+00	0.0E+00
Rb-88	1.24E-02	1.0E+00	Te-134	2.90E-02	6.7E-03
Rb-89	1.06E-02	4.7E-02	I-134*	3.65E-02	2.4E-01
Sr-89*	5.05E+01	6.7E-04	I-135	2.75E-01	7.9E-01
Sr-90	1.06E+04	4.6E-05	Xe-135m*	1.06E-02	0.0E+00
Y-90*	2.67E+00	1.1E-05	Xe-135*	3.79E-01	0.0E+00
Sr-91	3.96E-01	1.1E-03	Cs-134	7.53E+02	4.4E-01
Y-91m*	3.45E-02	5.4E-04	Cs-136	1.31E+01	1.1E-01
Y-91*	5.85E+01	8.6E-05	Cs-137	1.10E+04	1.7E-01
Sr-92	1.13E-01	1.7E-04	Ba-137m*	1.77E-03	1.6E-01
Y-92*	1.48E-01	1.4E-04	Cs-138	2.24E-02	2.3E-01
Y-93	4.21E-01	6.7E-05	Ba-140	1.27E+01	7.1E-04
Zr-95	6.40E+01	9.9E-05	La-140*	1.68E+00	1.9E-04
Nb-95m*	3.61E+00	0.0E+00	Ce-141	3.25E+01	9.7E-05
Nb-95*	3.52E+01	9.9E-05	Ce-143	1.38E+00	8.3E-05
Mo-99	2.75E+00	1.3E-01	Pr-143*	1.36E+01	9.7E-05
Tc-99m*	2.51E-01	5.7E-02	Ce-144	2.84E+02	7.3E-05
Ru-103	3.93E+01	1.1E-04	Pr-144m*	5.07E-03	0.0E+00
Rh-103m	3.90E-02*	9.4E-05	Pr-144*	1.20E-02	7.3E-05
Ru-106	3.68E+02	6.2E-05	W-187	9.96E-01	1.9E-03
Rh-106*	3.45E-04	6.2E-05	Np-239	2.36E+00	1.5E-03
Ag-110m	2.50E+02	1.0E-06	Pu-239*	8.79E+06	0.0E+00
Ag-110*	2.85E-04	0.0E+00			

Note:
* Decay chain progeny

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Table 2.4-59—{Transport Analysis Considering Advection and Radioactive Decay – Equation Inputs}

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Parent Radionuclide	Progeny in Chain	Half-life (days)	d_{12}	d_{13}	d_{23}	Decay Rate ($days^{-1}$)	Reactor Coolant Conc. ($\mu Ci/cm^3$)	K1	K2	K3
H-3		4.51E+03				1.54E-04	1.0E+00			
Na-24		6.25E-01				1.11E+00	3.8E-02			
Cr-51		2.77E+01				2.50E-02	2.1E-03			
Mn-54		3.13E+02				2.21E-03	1.1E-03			
Fe-55		9.86E+02				7.03E-04	8.1E-04			
Fe-59		4.45E+01				1.56E-02	2.0E-04			
Co-58		7.08E+01				9.79E-03	3.1E-03			
Co-60		1.93E+03				3.59E-04	3.6E-04			
Zn-65		2.44E+02				2.84E-03	3.40E-04			
Br-83		9.96E-02				6.96E+00	3.2E-02			
	Kr-83m	7.63E-02	1.0000			9.08E+00	0.0E+00	1.37E-01	-1.37E-01	
Br-84		2.21E-02				3.14E+01	1.7E-02			
Br-85		2.01E-03				3.44E+02	2.0E-03			
	Kr-85	1.87E-01	1.0000			3.71E+00	0.0E+00	-2.18E-05	2.18E-05	
Rb-88		1.24E-02				5.59E+01	1.0E+00			
Rb-89		1.06E-02				6.54E+01	4.7E-02			
	Sr-89	5.05E+01	1.0000			1.37E-02	6.7E-04	-9.87E-06	6.80E-04	
Sr-90		1.06E+04				6.54E-05	4.6E-05			
	Y-90	2.67E+00	1.0000			2.60E-01	1.1E-05	4.60E-05	-3.50E-05	
Sr-91		3.96E-01				1.75E+00	1.1E-03			
	Y-91m	3.45E-02	0.5780			2.01E+01	5.4E-04	6.96E-04	-1.56E-04	
	Y-91	5.85E+01		0.4220	1.0000	1.18E-02	8.6E-05	-7.91E-06	9.23E-08	9.38E-05
Sr-92		1.13E-01				6.14E+00	1.7E-04			
	Y-92	1.48E-01	1.0000			4.68E+00	1.4E-04	-5.47E-04	6.87E-04	
Y-93		4.21E-01				1.65E+00	6.7E-05			
Zr-95		6.40E+01				1.08E-02	9.9E-05			
	Nb-95m	3.61E+00	0.0070			1.92E-01	0.0E+00	7.34E-07	-7.34E-07	
	Nb-95	3.52E+01		0.9930	1.0000	1.97E-02	9.9E-05	2.20E-04	8.39E-08	-1.21E-04
Mo-99		2.75E+00				2.52E-01	1.3E-01			
	Tc-99m	2.51E-01	0.8760			2.76E+00	5.7E-02	1.25E-01	-6.83E-02	
Ru-103		3.93E+01				1.76E-02	1.1E-04			

Table 2.4-59—{Transport Analysis Considering Advection and Radioactive Decay – Equation Inputs}

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Parent Radionuclide	Progeny in Chain	Half-life (days)	d_{12}	d_{13}	d_{23}	Decay Rate ($days^{-1}$)	Reactor Coolant Conc. ($\mu Ci/cm^3$)	K1	K2	K3
	Rh-103m	3.90E-02	0.9970			1.78E+01	9.4E-05	1.10E-04	-1.58E-05	
Ru-106		3.68E+02				1.88E-03	6.2E-05			
	Rh-106	3.45E-04	1.0000			2.01E+03	6.2E-05	6.20E-05	-5.81E-11	
Ag-110m		2.50E+02				2.77E-03	1.0E-06			
	Ag-110	2.85E-04	0.0133			2.43E+03	0.0E+00	1.33E-08	-1.33E-08	
Te-127m		1.09E+02				6.36E-03	6.60E-04			
	Te-127	3.90E-01	0.9760			1.78E+00	0.00E+00	6.46E-04	-6.46E-04	
I-129		5.73E+09				1.21E-10	4.60E-08			
I-130		5.15E-01				1.35E+00	5.00E-02			
Te-129m		3.36E+01				2.06E-02	1.9E-03			
	Te-129	4.83E-02	0.6500			1.44E+01	3.1E-03	1.24E-03	1.86E-03	
Te-131m		1.25E+00				5.55E-01	4.6E-03			
	Te-131	1.74E-02	0.2220			3.98E+01	3.0E-03	1.04E-03	1.96E-03	
	I-131	8.04E+00		0.7780	1.0000	8.62E-02	7.4E-01	-8.49E-04	-4.26E-06	7.41E-01
Te-132		3.26E+00				2.13E-01	5.0E-02			
	I-132	9.58E-02	1.0000			7.24E+00	3.7E-01	5.15E-02	3.18E-01	
I-133		8.67E-01				7.99E-01	1.3E+00			
	Xe-133m	2.19E+00	0.0290			3.17E-01	0.0E+00	-2.47E-02	2.47E-02	
	Xe-133	5.25E+00		0.9710	1.0000	1.32E-01	0.0E+00	-2.45E-01	-1.77E-02	2.63E-01
Te-134		2.90E-02				2.39E+01	6.70E-03			
	I-134	3.65E-02	1.0000			1.90E+01	2.4E-01	-2.59E-02	2.66E-01	
I-135		2.75E-01				2.52E+00	7.9E-01			
	Xe-135m	1.06E-02	0.1540			6.53E+01	0.0E+00	1.27E-01	-1.27E-01	
	Xe-135	3.79E-01		0.8460	1.0000	1.83E+00	0.0E+00	-2.10E+00	3.65E-03	2.10E+00
Cs-134		7.53E+02				9.21E-04	4.4E-01			
Cs-136		1.31E+01				5.29E-02	1.1E-01			
Cs-137		1.10E+04				6.30E-05	1.7E-01			
	Ba-137m	1.77E-03	0.9460			3.91E+02	1.6E-01	1.61E-01	-8.20E-04	
Cs-138		2.24E-02				3.09E+01	2.3E-01			
Ba-140		1.27E+01				5.46E-02	7.1E-04			
	La-140	1.68E+00	1.0000			4.13E-01	1.9E-04	8.18E-04	-6.28E-04	

Table 2.4-59—{Transport Analysis Considering Advection and Radioactive Decay – Equation Inputs}

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Parent Radionuclide	Progeny in Chain	Half-life (days)	d_{12}	d_{13}	d_{23}	Decay Rate ($days^{-1}$)	Reactor Coolant Conc. ($\mu Ci/cm^3$)	K1	K2	K3
Ce-141		3.25E+01				2.13E-02	9.7E-05			
Ce-143		1.38E+00				5.02E-01	8.30E-05			
	Pr-143	1.36E+01	1.0000			5.11E-02	9.70E-05	-9.40E-06	1.06E-04	
Ce-144		2.84E+02				2.44E-03	7.3E-05			
	Pr-144m	5.07E-03	0.0178			1.37E+02	0.0E+00	1.30E-06	-1.30E-06	
	Pr-144	1.20E-02		0.9822	0.9990	5.78E+01	7.3E-05	7.30E-05	9.50E-07	-9.51E-07
W-187		9.96E-01				6.96E-01	1.9E-03			
Np-239		2.36E+00				2.94E-01	1.5E-03			
	Pu-239	8.79E+06	1.0000			7.89E-08	0.0E+00	-4.03E-10	4.03E-10	

Table 2.4-60—{Transport Analysis Considering Advection and Radioactive Decay – Results}

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Parent Radionuclide	Progeny in Chain	ECL (µCi/cm³)	Groundwater Conc. Chert (µCi/cm³)	Groundwater Conc. Aquitard (µCi/cm³)	Groundwater Conc. CJC_Aux (µCi/cm³)	Groundwater Conc. CJC_Mud (µCi/cm³)	Groundwater Conc. Chert / ECL	Groundwater Conc. Aquitard / ECL	Groundwater Conc. CJC_Aux / ECL	Groundwater Conc. CJC_Mud / ECL
H-3		1.00E-03	1.22E-01	1.89E-64	1.38E-78	2.07E-74	1.22E+02	1.89E-61	1.38E-75	2.07E-71
Na-24		5.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr-51		5.00E-04	1.28E-151	0.00E+00	0.00E+00	0.00E+00	2.57E-148	0.00E+00	0.00E+00	0.00E+00
Mn-54		3.00E-05	8.70E-17	0.00E+00	0.00E+00	0.00E+00	2.90E-12	0.00E+00	0.00E+00	0.00E+00
Fe-55		1.00E-04	5.50E-08	1.03E-294	0.00E+00	0.00E+00	5.50E-04	1.03E-290	0.00E+00	0.00E+00
Fe-59		1.00E-05	6.54E-97	0.00E+00	0.00E+00	0.00E+00	6.54E-92	0.00E+00	0.00E+00	0.00E+00
Co-58		2.00E-05	2.82E-61	0.00E+00	0.00E+00	0.00E+00	1.41E-56	0.00E+00	0.00E+00	0.00E+00
Co-60		3.00E-06	2.68E-06	1.01E-152	1.13E-185	6.11E-176	8.93E-01	3.37E-147	3.78E-180	2.04E-170
Zn-65		5.00E-06	4.95E-21	0.00E+00	0.00E+00	0.00E+00	9.89E-16	0.00E+00	0.00E+00	0.00E+00
Br-83		9.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Kr-83m	NA[2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA[2]	NA[2]	NA[2]	NA[2]
Br-84		4.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-85		NA[2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA[2]	NA[2]	NA[2]	NA[2]
	Kr-85	NA[2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA[2]	NA[2]	NA[2]	NA[2]
Rb-88		4.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-89		9.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Sr-89	8.00E-06	4.09E-85	0.00E+00	0.00E+00	0.00E+00	5.11E-80	0.00E+00	0.00E+00	0.00E+00
Sr-90		5.00E-07	1.88E-05	3.99E-32	3.96E-38	2.35E-36	3.77E+01	7.97E-26	7.93E-32	4.70E-30
	Y-90	7.00E-06	1.88E-05	3.99E-32	3.96E-38	2.35E-36	2.69E+00	5.70E-27	5.66E-33	3.36E-31
Sr-91		2.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Y-91m	2.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Y-91	8.00E-06	1.04E-74	0.00E+00	0.00E+00	0.00E+00	1.29E-69	0.00E+00	0.00E+00	0.00E+00
Sr-92		4.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Y-92	4.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-93		2.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr-95		2.00E-05	9.27E-69	0.00E+00	0.00E+00	0.00E+00	4.64E-64	0.00E+00	0.00E+00	0.00E+00
	Nb-95m	3.00E-05	6.88E-71	0.00E+00	0.00E+00	0.00E+00	2.29E-66	0.00E+00	0.00E+00	0.00E+00
	Nb-95	3.00E-05	2.06E-68	0.00E+00	0.00E+00	0.00E+00	6.87E-64	0.00E+00	0.00E+00	0.00E+00
Mo-99		2.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Tc-99m	1.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-103		3.00E-05	5.00E-109	0.00E+00	0.00E+00	0.00E+00	1.67E-104	0.00E+00	0.00E+00	0.00E+00

Table 2.4-60—{Transport Analysis Considering Advection and Radioactive Decay – Results}

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Parent Radionuclide	Progeny in Chain	ECL (µCi/cm³)	Groundwater Conc. Chert (µCi/cm³)	Groundwater Conc. Aquitard (µCi/cm³)	Groundwater Conc. CJC_Aux (µCi/cm³)	Groundwater Conc. CJC_Mud (µCi/cm³)	Groundwater Conc. Chert / ECL	Groundwater Conc. Aquitard / ECL	Groundwater Conc. CJC_Aux / ECL	Groundwater Conc. CJC_Mud / ECL
	Rh-103m	6.00E-03	5.00E-109	0.00E+00	0.00E+00	0.00E+00	8.33E-107	0.00E+00	0.00E+00	0.00E+00
Ru-106		3.00E-06	4.43E-16	0.00E+00	0.00E+00	0.00E+00	1.48E-10	0.00E+00	0.00E+00	0.00E+00
	Rh-106	NA[2]	4.43E-16	0.00E+00	0.00E+00	0.00E+00	NA[2]	NA[2]	NA[2]	NA[2]
Ag-110m		6.00E-06	3.78E-23	0.00E+00	0.00E+00	0.00E+00	6.31E-18	0.00E+00	0.00E+00	0.00E+00
	Ag-110	NA[2]	5.03E-25	0.00E+00	0.00E+00	0.00E+00	NA[2]	NA[2]	NA[2]	NA[2]
Te-127m		9.00E-06	1.30E-41	0.00E+00	0.00E+00	0.00E+00	1.44E-36	0.00E+00	0.00E+00	0.00E+00
	Te-127	1.00E-04	1.27E-41	0.00E+00	0.00E+00	0.00E+00	1.27E-37	0.00E+00	0.00E+00	0.00E+00
I-129		2.00E-07	4.60E-08	4.60E-08	4.60E-08	4.60E-08	2.30E-01	2.30E-01	2.30E-01	2.30E-01
I-130		2.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-129m		7.00E-06	1.41E-125	0.00E+00	0.00E+00	0.00E+00	2.02E-120	0.00E+00	0.00E+00	0.00E+00
	Te-129	4.00E-04	9.23E-126	0.00E+00	0.00E+00	0.00E+00	2.31E-122	0.00E+00	0.00E+00	0.00E+00
Te-131m		8.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Te-131	8.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	I-131	1.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te-132		9.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	I-132	1.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-133		7.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Xe-133m	NA[2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA[2]	NA[2]	NA[2]	NA[2]
	Xe-133	NA[2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA[2]	NA[2]	NA[2]	NA[2]
Te-134		3.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	I-134	4.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-135		3.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Xe-135m	NA[2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA[2]	NA[2]	NA[2]	NA[2]
	Xe-135	NA[2]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA[2]	NA[2]	NA[2]	NA[2]
Cs-134		9.00E-07	1.52E-06	0.00E+00	0.00E+00	0.00E+00	1.69E+00	0.00E+00	0.00E+00	0.00E+00
Cs-136		6.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137		1.00E-06	7.19E-02	1.45E-27	2.39E-33	1.22E-31	7.19E+04	1.45E-21	2.39E-27	1.22E-25
	Ba-137m	NA[2]	6.81E-02	1.37E-27	2.27E-33	1.16E-31	NA[2]	NA[2]	NA[2]	NA[2]
Cs-138		4.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140		8.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	La-140	9.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

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Table 2.4-60—{Transport Analysis Considering Advection and Radioactive Decay – Results}

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Parent Radionuclide	Progeny in Chain	ECL (µCi/cm³)	Groundwater Conc. Chert (µCi/cm³)	Groundwater Conc. Aquitard (µCi/cm³)	Groundwater Conc. CJC_Aux (µCi/cm³)	Groundwater Conc. CJC_Mud (µCi/cm³)	Groundwater Conc. Chert / ECL	Groundwater Conc. Aquitard / ECL	Groundwater Conc. CJC_Aux / ECL	Groundwater Conc. CJC_Mud / ECL
Ce-141		3.00E-05	5.11E-131	0.00E+00	0.00E+00	0.00E+00	1.70E-126	0.00E+00	0.00E+00	0.00E+00
Ce-143		2.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pr-143	2.00E-05	1.19E-307	0.00E+00	0.00E+00	0.00E+00	5.96E-303	0.00E+00	0.00E+00	0.00E+00
Ce-144		3.00E-06	2.50E-19	0.00E+00	0.00E+00	0.00E+00	8.33E-14	0.00E+00	0.00E+00	0.00E+00
	Pr-144m	NA[2]	4.45E-21	0.00E+00	0.00E+00	0.00E+00	NA[2]	NA[2]	NA[2]	NA[2]
	Pr-144	6.00E-04	2.50E-19	0.00E+00	0.00E+00	0.00E+00	4.16E-16	0.00E+00	0.00E+00	0.00E+00
W-187		3.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Np-239		2.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	2.00E-08	4.03E-10	3.74E-10	3.68E-10	3.69E-10	2.01E-02	1.87E-02	1.84E-02	1.85E-02

Notes:

1. Shaded values exceed one percent of the ECL.
2. Maximum Effluent Concentration Limit (ECL) is not available.
3. Results less than 1E-307 are at the limit of Microsoft Excel spreadsheet minimum value and are reported as 0.0E+00.

Table 2.4-61—{Callaway Plant Unit 2 Radionuclide Adsorption (K_d) Values}

Soil	Sample Depth (ft bgs)	Mn		Co		Zn		Sr		Cs		Ce		Fe		Ru	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Mean	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
PW-1	15-17	83.3	2.0	537	118	2610	1500	55.8	0.8	19200	500	4940	220	169	38	1340	120
MW-8	15-17	74.1	3.4	588	210	2810	1150	67.0	0.4	33100	1100	3610	190	795	90	1340	120
MW-8	20-22	59.6	2.4	627	105	1180	970	57.2	1.2	25400	500	3620	190	785	90	1340	120
MW-2S	15-16.3	77.8	3.7	450	59	1280	940	35.3	0.8	44400	3200	3540	180	80	27	805	90
MW-3S	30-33.3	471	222	251	34	106	15	14.9	0.1	5140	10	691	78	195	34	840	90
Minimum Value		74.1		251		106		14.9		5140		691		80		805	

Note: Units of K_d are cm^3/gm.

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Table 2.4-62—{Transport Analysis Considering Advection, Radioactive Decay, and Retardation – Equation Inputs}

Parent Radionuclide	Progeny in Chain	Decay Rate (days^{-1})	d_{12}	K_1	K_2	Initial Conc. (μCi/cm^3)	Kd (cm^3/g)	Retardation Factor
H-3		1.54E-04				1.00E+00	0	1
Co-60		3.59E-04				3.60E-04	251	10292
Sr-90		6.54E-05				4.60E-05	14.9	611.9
	Y-90	2.60E-01	1.0000	1.10E-05	-3.50E-05	1.10E-05	15.1	620.1
I-129		1.21E-10				4.60E-08	0	1
Cs-134		9.21E-04				4.40E-01	5140	210741
Cs-137		6.30E-05				1.70E-01	5140	210741
Np-239		2.94E-01				1.50E-03	0.96	40.36
	Pu-239	7.89E-08	1.0000	0.00E+00	3.47E-08	0.00E+00	84.8	3477.8

Notes:
1) Effective porosity = 0.05
2) Mean bulk density = 127.8 lb/ft^3 = 2.05 g/cm^3
3) The constants K_1 and K_2 are different numbers than those that appear in Table 2.4-59. They have been re-calculated to include retardation.
4) Kd data is from Table 2.4-61 except for Y-90, Np-239, and Pu-239, which were obtained from literature values as referenced in the text.

Table 2.4-63—{Transport Analysis Considering Advection, Radioactive Decay, and Retardation – Results}

Parent Radionuclide	Progeny in Chain	ECL (μCi/cm	Groundwater Conc. Chert (μCi/cm^3)	Groundwater Conc. Aquitard (μCi/cm^3)	Groundwater Conc. CJC_Aux (μCi/cm^3)	Groundwater Conc. CJC_Mud (μCi/cm^3)	Groundwater Conc. Chert / ECL	Groundwater Conc. Aquitard / ECL	Groundwater Conc. CJC_Aux / ECL	Groundwater Conc. CJC_Mud / ECL
H-3		1.00E-03	1.22E-01	1.89E-64	1.38E-78	2.07E-74	1.22E+02	1.89E-61	1.38E-75	2.07E-71
Co-60		3.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90		5.00E-07	2.58E-242	0.00E+00	0.00E+00	0.00E+00	5.17E-236	0.00E+00	0.00E+00	0.00E+00
	Y-90	7.00E-06	4.56E-06	2.17E-32	2.59E-38	1.46E-36	6.51E-01	3.11E-27	3.71E-33	2.08E-31
I-129		2.00E-07	4.60E-08	4.60E-08	4.60E-08	4.60E-08	2.30E-01	2.30E-01	2.30E-01	2.30E-01
Cs-134		9.00E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137		1.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Np-239		2.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	2.00E-08	8.19E-10	9.90E-122	6.47E-147	1.77E-139	4.10E-02	4.95E-114	3.24E-139	8.87E-132

Note: Shaded values exceed one percent of the ECL

Table 2.4-64—{Transport Analysis Considering Advection, Radioactive Decay, Retardation, and Dilution}

Tank-Plume Characteristics			Dilution – Auxvasse Creek			Dilution – Mud Creek		
Tank volume	4061 ft^3	115 m^3	Plume cross-sectional area	1275 ft^2	118.5 m^2	Plume cross-sectional area	1275 ft^2	118.5 m^2
Spill volume	3249 ft^3	92.0 m^3	Darcy velocity	2.67E-3 ft/day	8.13E-4 m/day	Darcy velocity	2.37E-3 ft/day	7.22E-4 m/day
Effective porosity	0.05	0.05	Groundwater discharge rate	3.9E-5 ft^3/sec	1.1 E-6 m^3/sec	Groundwater discharge rate	3.5E-5 ft^3/sec	1.0 E-6 m^3/sec
Plume volume	64,980 ft^3	1840 m^3	Surface water flow rate	2.0 ft^3/sec	0.057 m^3/sec	Surface water flow rate	1.0 ft^3/sec	0.028 m^3/sec
CJC thickness	25 ft	7.6 m	Dilution factor	2.0E-5	N/A	Dilution factor	3.5E-5	N/A
Plume plan-view area	2600 ft^2	242 m^2						

Radionuclide	ECL[1]	Groundwater Concentration[2] CJC_Aux (µCi/cm^3)	Surface Water Concentration[3] Auxvasse Creek (µCi/cm^3)	Surface Water Concentration Auxvasse Creek / ECL	Groundwater Concentration[1] CJC_Mud (µCi/cm^3)	Surface Water Concentration[2] Mud Creek (µCi/cm^3)	Surface Water Concentration Mud Creek / ECL
I-129	2.00E-07	4.6E-8	9.2E-13	4.6E-6	4.6E-8	1.61E-12	8.05E-06

Notes:

1 Values from 10 CFR Part 20, Appendix B, Table 2, Column 2
2 Values from Table 2.4-63
3 Surface water concentration = groundwater concentration * dilution factor

Table 2.4-65—{Compliance with 10 CFR Part 20, Appendix B, Table 2}

(Page 1 of 2)

Parent Radionuclide	Progeny in Chain	Calculated Value Aquitard GW Conc / ECL[1]	Calculated Value CJC_Auxvasse GW Conc / ECL[1]	Calculated Value CJC_Mud GW Conc / ECL[1]
H-3		1.89E-61	1.38E-75	2.07E-71
Na-24		0.00E+00	0.00E+00	0.00E+00
Cr-51		0.00E+00	0.00E+00	0.00E+00
Mn-54		0.00E+00	0.00E+00	0.00E+00
Fe-55		1.03E-290	0.00E+00	0.00E+00
Fe-59		0.00E+00	0.00E+00	0.00E+00
Co-58		0.00E+00	0.00E+00	0.00E+00
Co-60		3.37E-147	3.78E-180	2.04E-170
Zn-65		0.00E+00	0.00E+00	0.00E+00
Br-83		0.00E+00	0.00E+00	0.00E+00
	Kr-83m	NA[2]	NA[2]	NA[2]
Br-84		0.00E+00	0.00E+00	0.00E+00
Br-85		NA[2]	NA[2]	NA[2]
	Kr-85	NA[2]	NA[2]	NA[2]
Rb-88		0.00E+00	0.00E+00	0.00E+00
Rb-89		0.00E+00	0.00E+00	0.00E+00
	Sr-89	0.00E+00	0.00E+00	0.00E+00
Sr-90		7.97E-26	7.93E-32	4.70E-30
	Y-90	5.70E-27	5.66E-33	3.36E-31
Sr-91		0.00E+00	0.00E+00	0.00E+00
	Y-91m	0.00E+00	0.00E+00	0.00E+00
	Y-91	0.00E+00	0.00E+00	0.00E+00
Sr-92		0.00E+00	0.00E+00	0.00E+00
	Y-92	0.00E+00	0.00E+00	0.00E+00
Y-93		0.00E+00	0.00E+00	0.00E+00
Zr-95		0.00E+00	0.00E+00	0.00E+00
	Nb-95m	0.00E+00	0.00E+00	0.00E+00
	Nb-95	0.00E+00	0.00E+00	0.00E+00
Mo-99		0.00E+00	0.00E+00	0.00E+00
	Tc-99m	0.00E+00	0.00E+00	0.00E+00
Ru-103		0.00E+00	0.00E+00	0.00E+00
	Rh-103m	0.00E+00	0.00E+00	0.00E+00
Ru-106		0.00E+00	0.00E+00	0.00E+00
	Rh-106	NA[2]	NA[2]	NA[2]
Ag-110m		0.00E+00	0.00E+00	0.00E+00
	Ag-110	NA[2]	NA[2]	NA[2]
Te-127m		0.00E+00	0.00E+00	0.00E+00
	Te-127	0.00E+00	0.00E+00	0.00E+00
I-129		2.30E-01	2.30E-01	2.30E-01
I-130		0.00E+00	0.00E+00	0.00E+00
Te-129m		0.00E+00	0.00E+00	0.00E+00
	Te-129	0.00E+00	0.00E+00	0.00E+00
Te-131m		0.00E+00	0.00E+00	0.00E+00
	Te-131	0.00E+00	0.00E+00	0.00E+00
	I-131	0.00E+00	0.00E+00	0.00E+00
Te-132		0.00E+00	0.00E+00	0.00E+00
	I-132	0.00E+00	0.00E+00	0.00E+00

Table 2.4-65—{Compliance with 10 CFR Part 20, Appendix B, Table 2}

(Page 2 of 2)

Parent Radionuclide	Progeny in Chain	Calculated Value Aquitard GW Conc / ECL[1]	Calculated Value CJC_Auxvasse GW Conc / ECL[1]	Calculated Value CJC_Mud GW Conc / ECL[1]
I-133		0.00E+00	0.00E+00	0.00E+00
	Xe-133m	NA[2]	NA[2]	NA[2]
	Xe-133	NA[2]	NA[2]	NA[2]
Te-134		0.00E+00	0.00E+00	0.00E+00
	I-134	0.00E+00	0.00E+00	0.00E+00
I-135		0.00E+00	0.00E+00	0.00E+00
	Xe-135m	NA[2]	NA[2]	NA[2]
	Xe-135	NA[2]	NA[2]	NA[2]
Cs-134		0.00E+00	0.00E+00	0.00E+00
Cs-136		0.00E+00	0.00E+00	0.00E+00
Cs-137		1.45E-21	2.39E-27	1.22E-25
	Ba-137m	NA[2]	NA[2]	NA[2]
Cs-138		0.00E+00	0.00E+00	0.00E+00
Ba-140		0.00E+00	0.00E+00	0.00E+00
	La-140	0.00E+00	0.00E+00	0.00E+00
Ce-141		0.00E+00	0.00E+00	0.00E+00
Ce-143		0.00E+00	0.00E+00	0.00E+00
	Pr-143	0.00E+00	0.00E+00	0.00E+00
Ce-144		0.00E+00	0.00E+00	0.00E+00
	Pr-144m	NA[2]	NA[2]	NA[2]
	Pr-144	0.00E+00	0.00E+00	0.00E+00
W-187		0.00E+00	0.00E+00	0.00E+00
Np-239		0.00E+00	0.00E+00	0.00E+00
	Pu-239	1.87E-02	1.84E-02	1.85E-02
SUM		2.49E-01	2.48E-01	2.48E-01

Notes:

1. Calculated values reported are from the advection/decay analysis. Retardation in groundwater and subsequent dilution into streams would reduce concentrations further.
2. ECL is not available.

FSAR: Section 2.4

Figure 2.4-1—{Plant Site Topography}

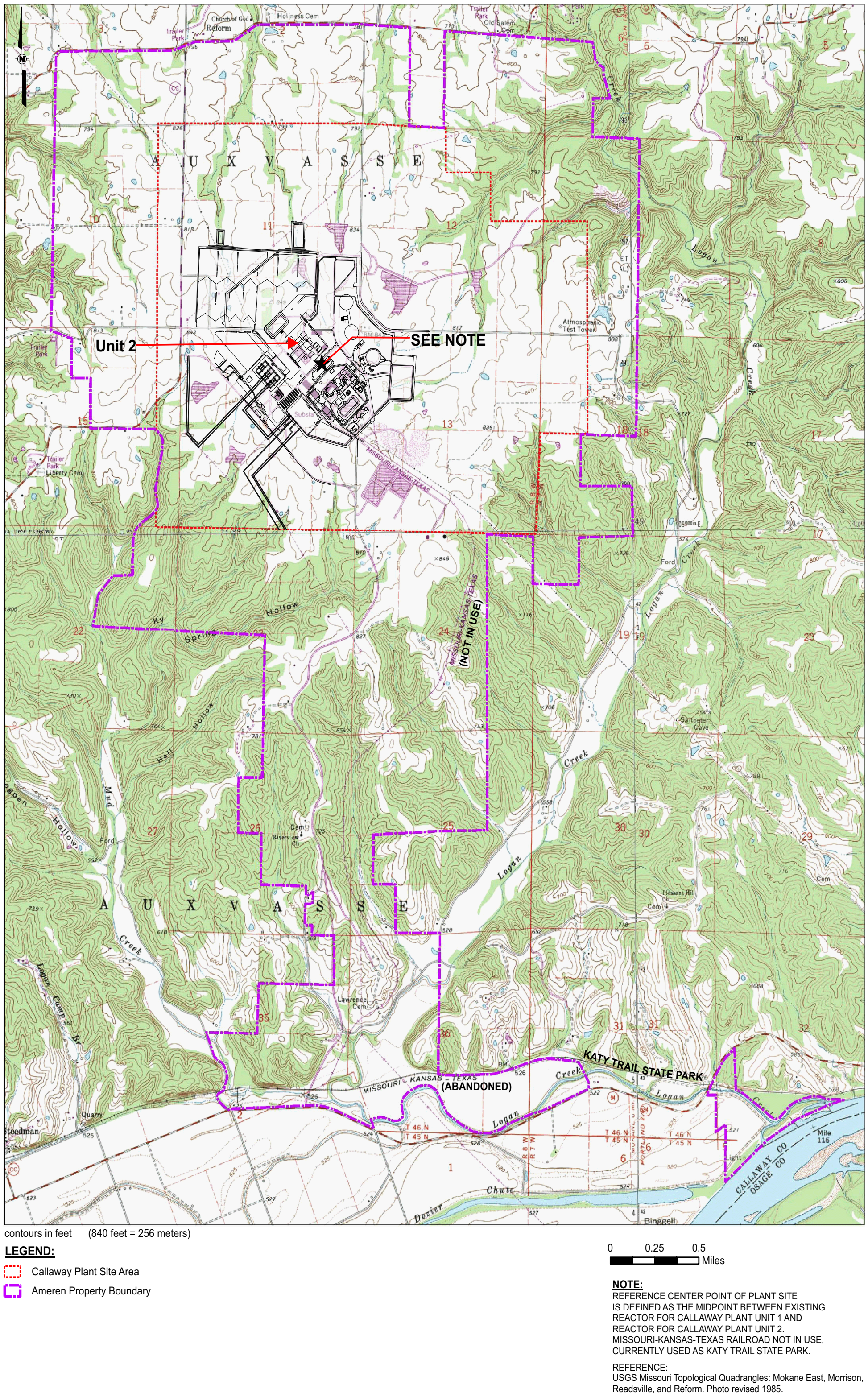
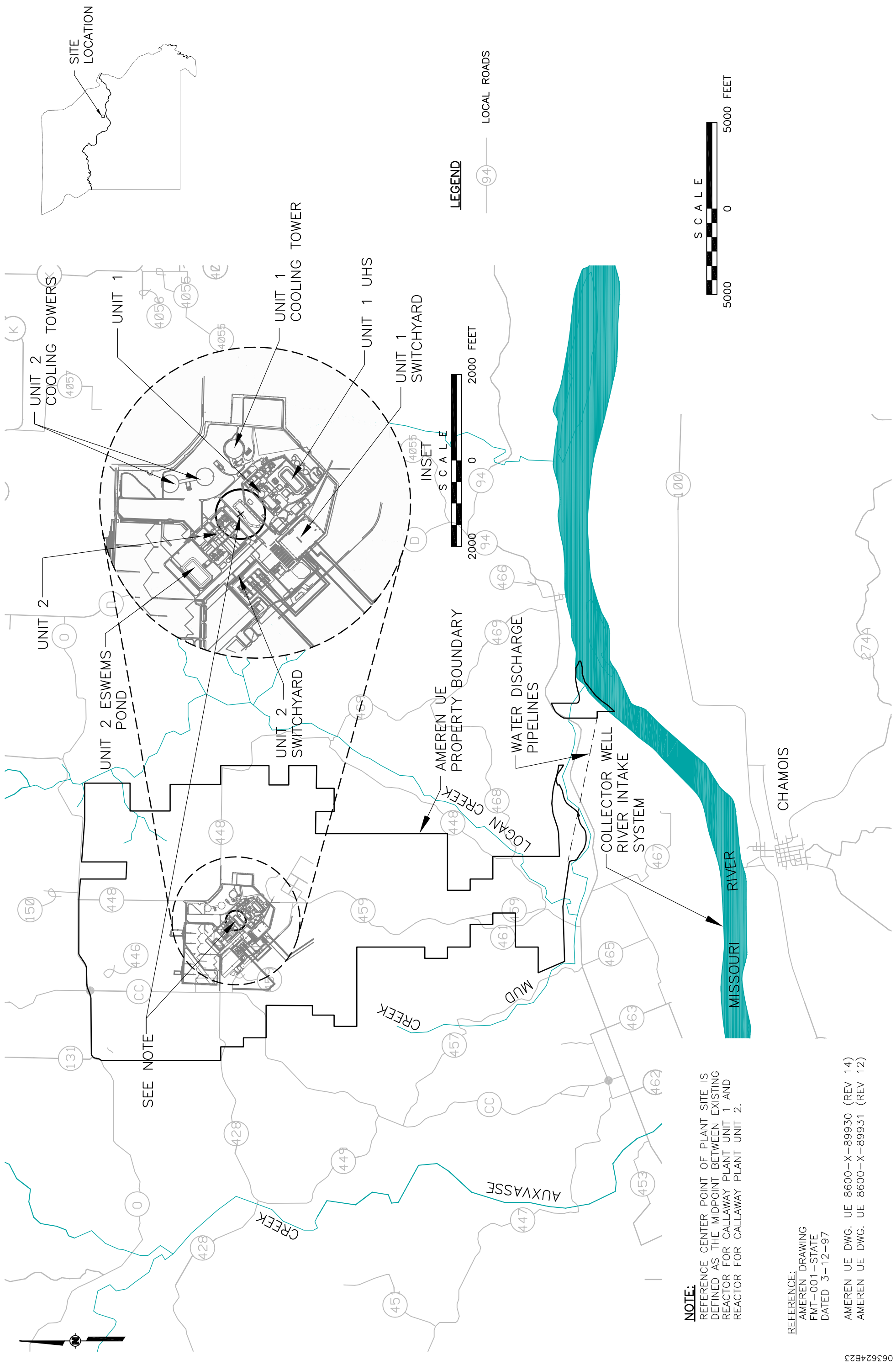
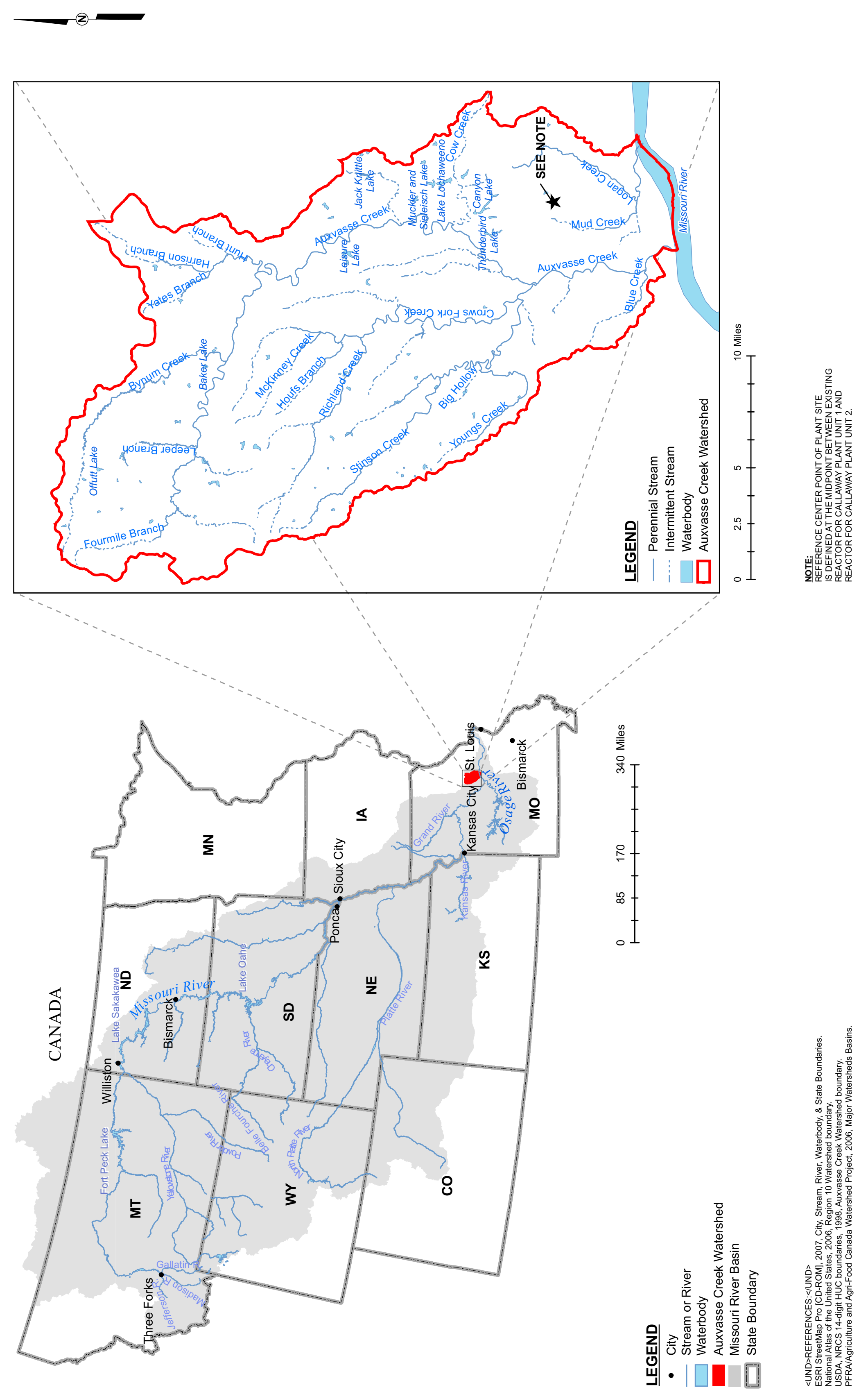


Figure 2.4-2— {Site Utilization Plant Layout}



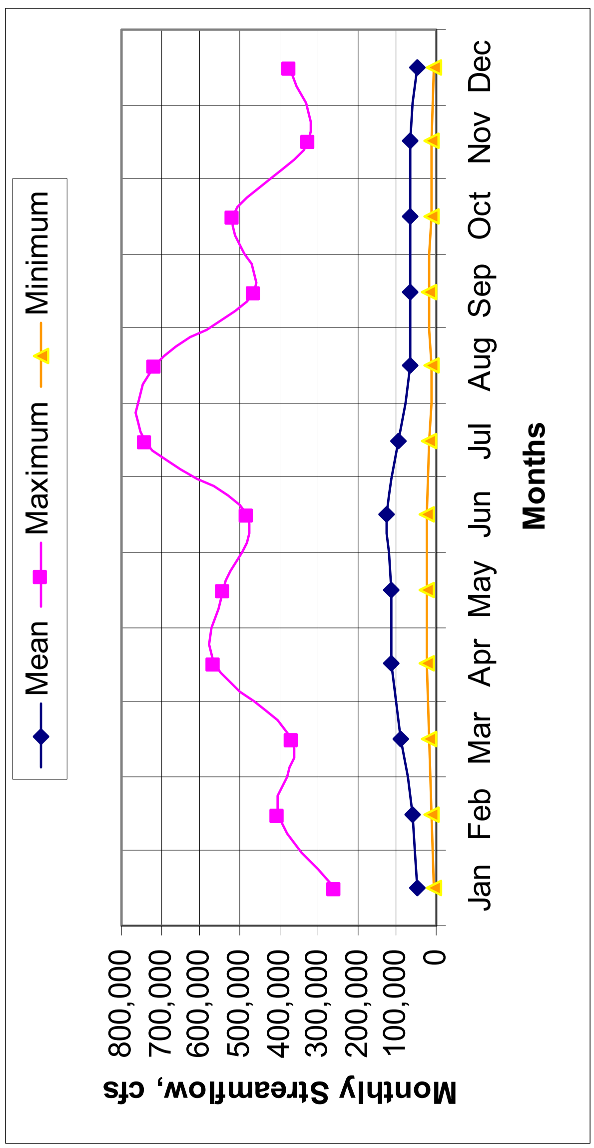
FSAR: Section 2.4

Figure 2.4-3— {Missouri River Basin and Auxvasse Creek Watershed}



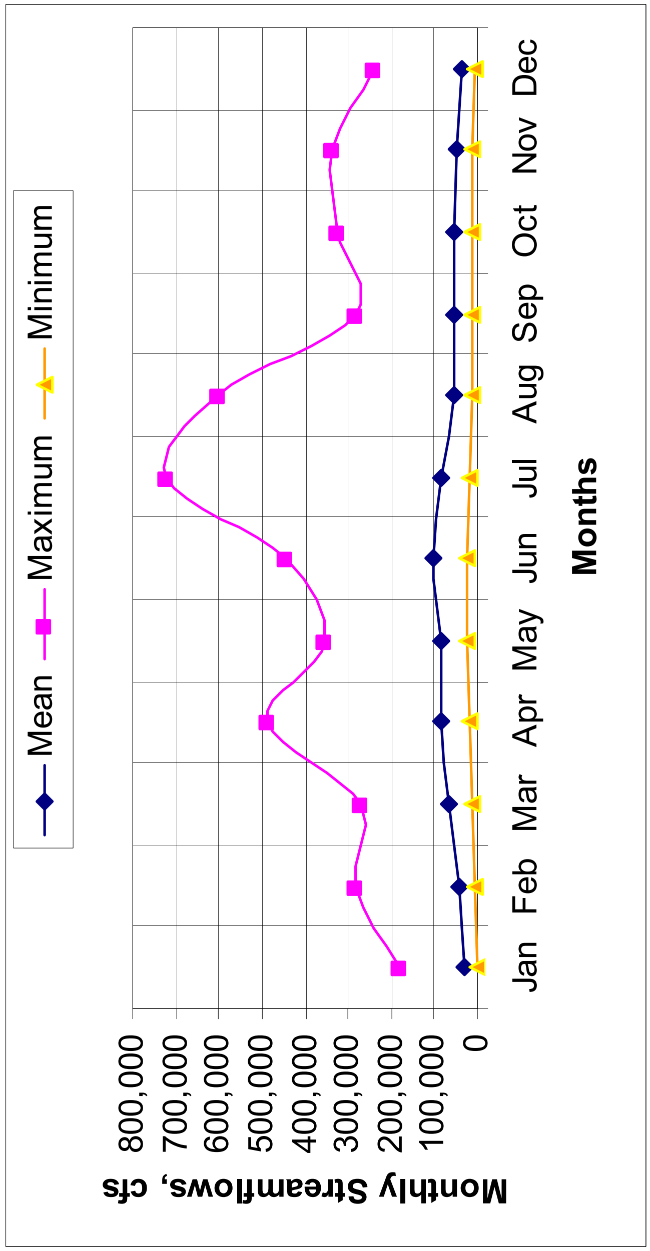
FSAR: Section 2.4

Figure 2.4-4— {Mean, Maximum and Minimum Streamflows for the Hermann, MO USGS 06934500, 1957 through 2006}



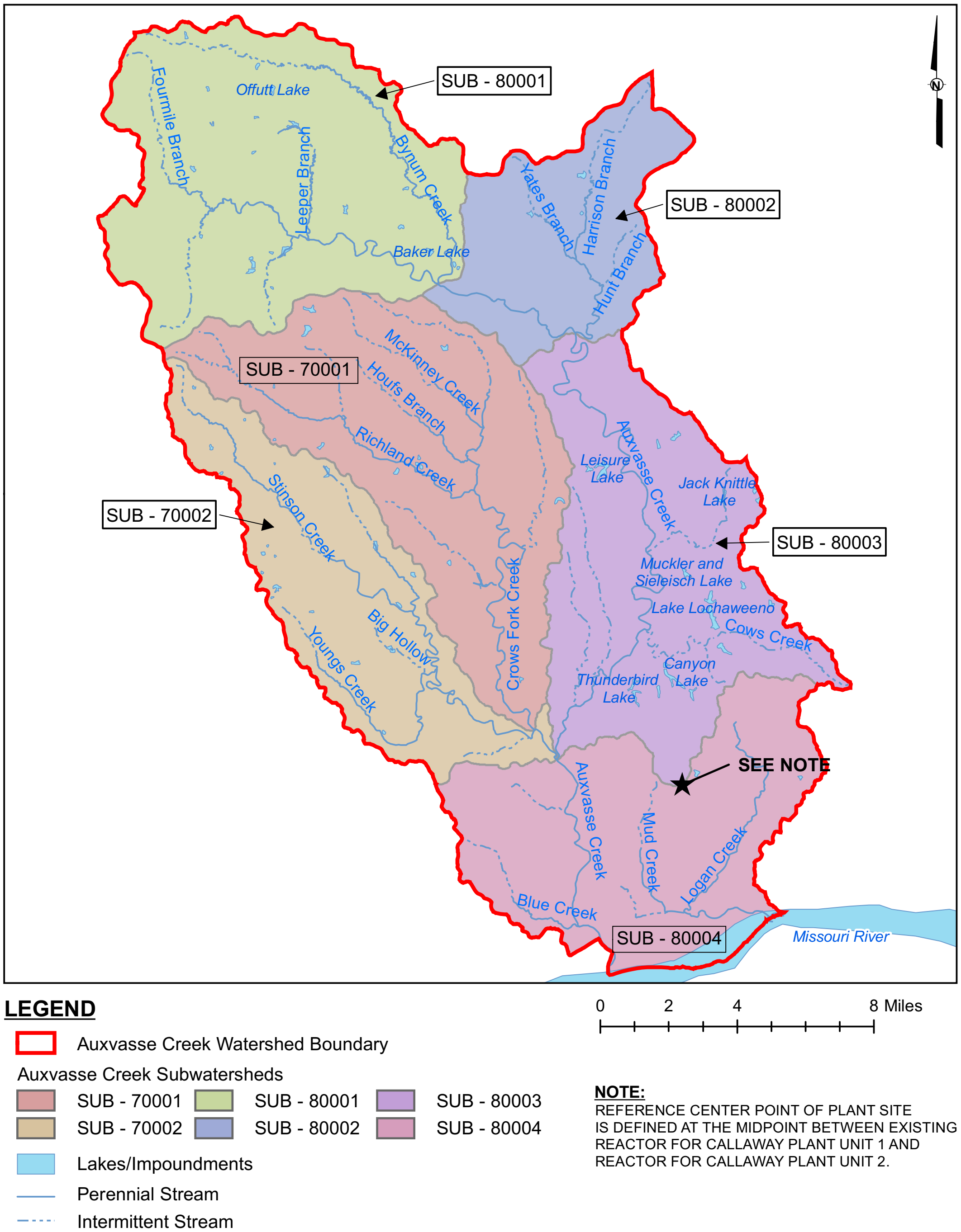
USGS, 2008b. National Water Information System Hermann, MO

Figure 2.4-5—{Mean, Maximum and Minimum Streamflows for the Boonville, MO USGS 06909000, 1957 through 2007}



USGS, 2008a. National Water Information System Boonville, MO

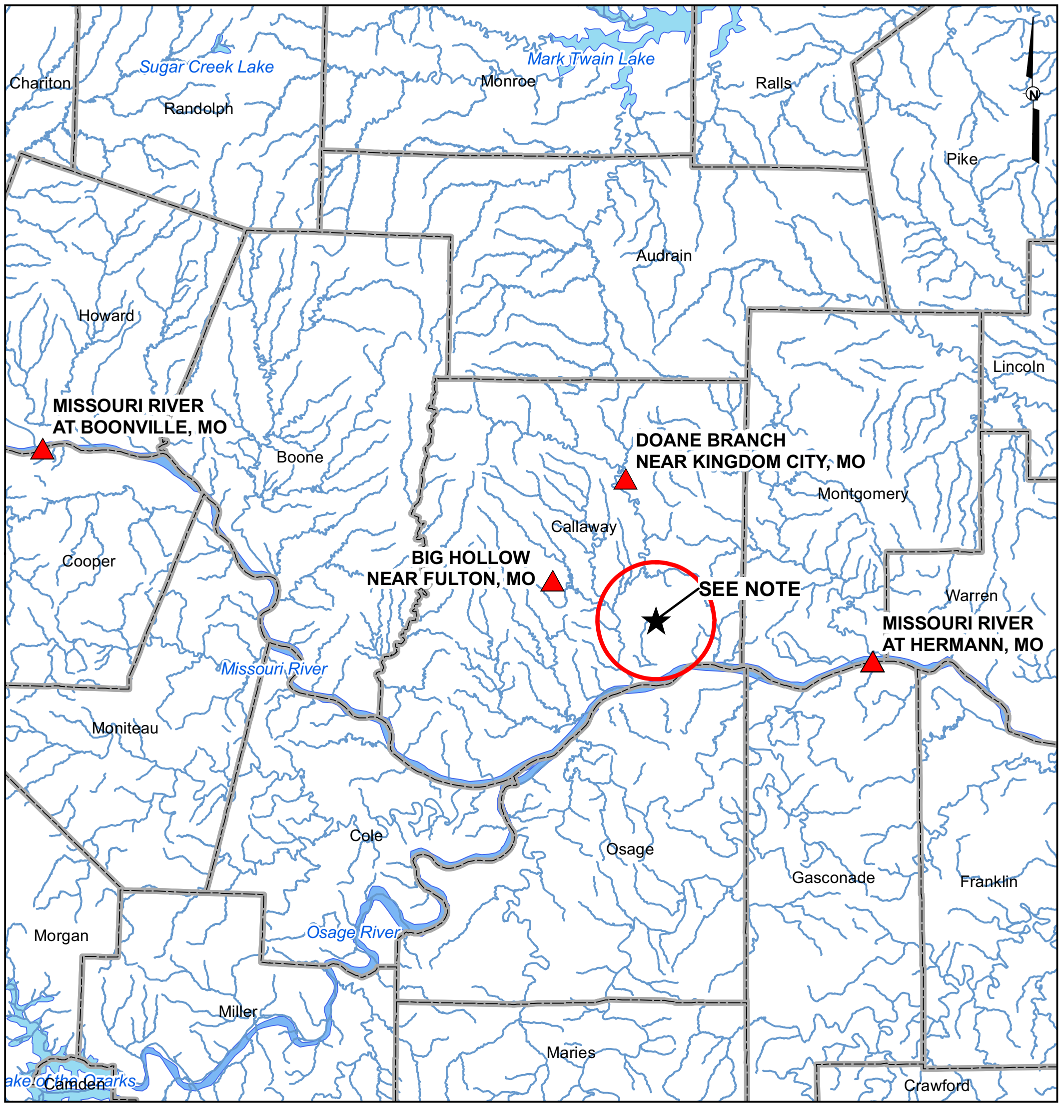
Figure 2.4-6—{Tributaries and Streams within the Auxvasse Creek Watershed}



NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AT THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY PLANT UNIT 1 AND REACTOR FOR CALLAWAY PLANT UNIT 2.

REFERENCE:
ESRI StreetMap Pro [CD-ROM], 2007, Rivers, Streams and Waterbodies.
USDA, NRCS 14-digit HUC boundaries, 1998, Auxvasse Creek Watershed boundary.

Figure 2.4-7—{USGS Gauges Near Callaway Plant Unit 2 Site}



LEGEND

USGS River Gauge

Unit 2 5 Mile (8 Km) Radius

County Boundary

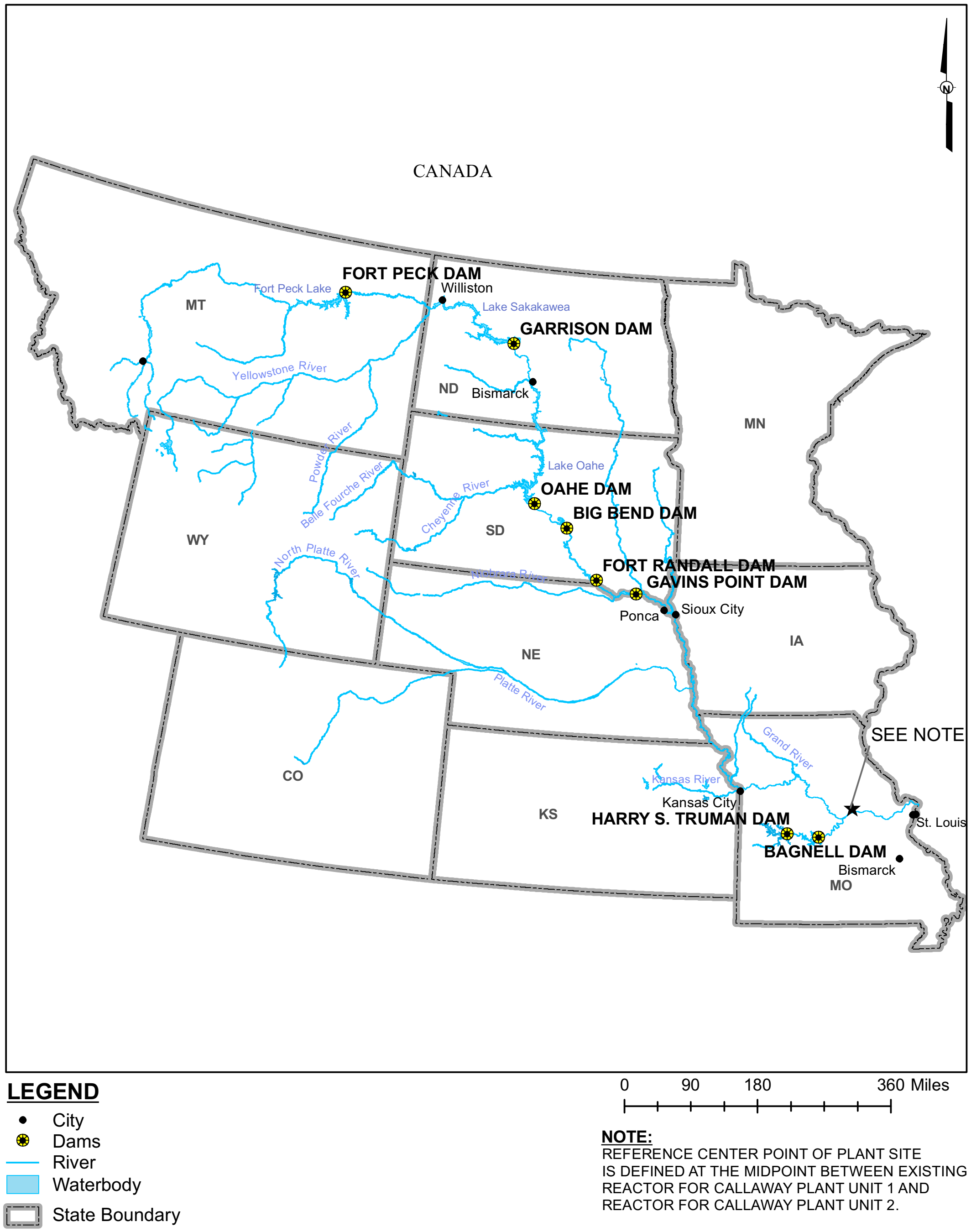
Streams and Rivers

0 6 12 24 Miles

NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AT THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY PLANT UNIT 1 AND REACTOR FOR CALLAWAY PLANT UNIT 2.

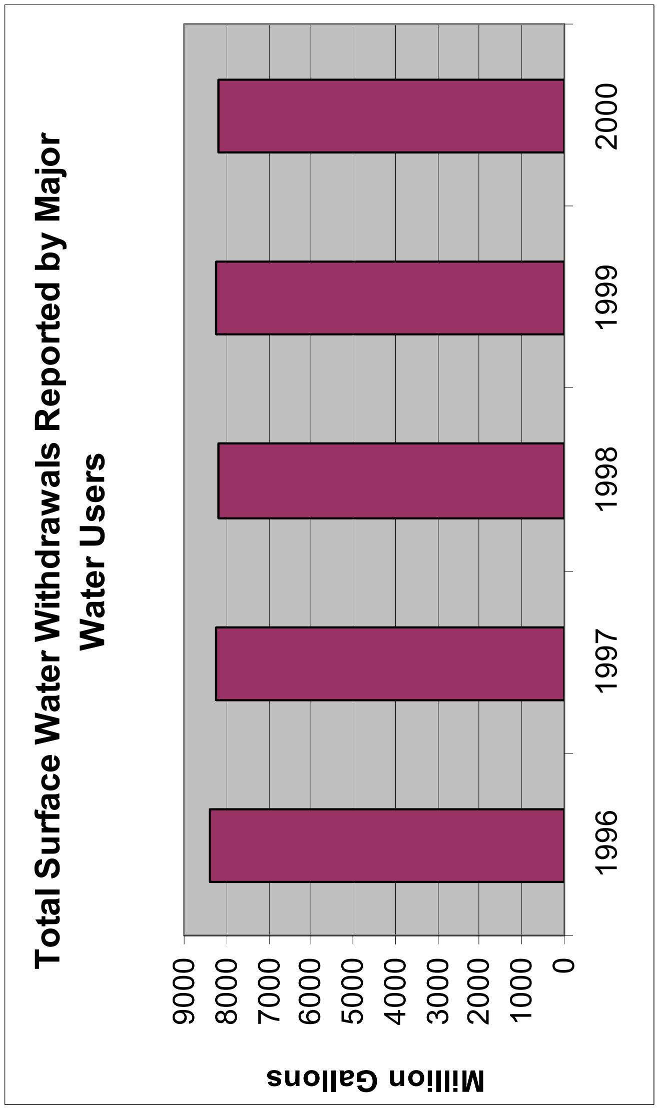
REFERENCE:
ESRI StreetMap Pro [CD-ROM], 2007,
rivers, waterbodies, and county boundaries.
Missouri Spatial Data Information Service
http://www.msdis.missouri.edu

Figure 2.4-8—{Missouri River Main Stem and Osage River Dam System}



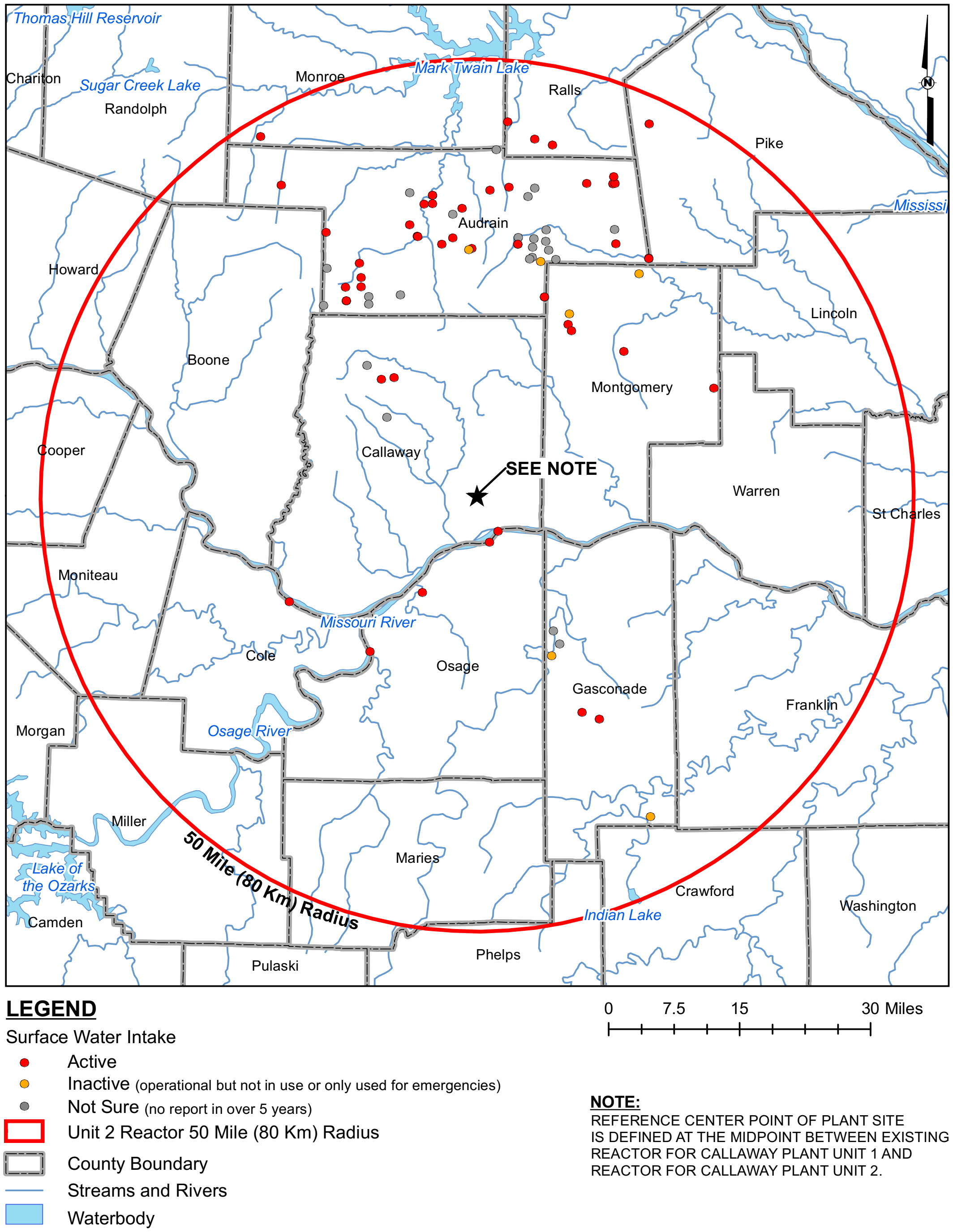
REFERENCES:
ESRI StreetMap Pro [CD-ROM], 2007, City, River & Waterbody, & State Boundaries.
National Atlas of the United States, 2006, Major Dams of the United States.
Watershed boundaries created by theUSDA, NRCS (1998).

Figure 2.4-9—{Callaway County Surface Water Use}



Source: **MDNR, 2003** Major Water Use in Missouri River: 1996-2000, Water Resources Report No. 72

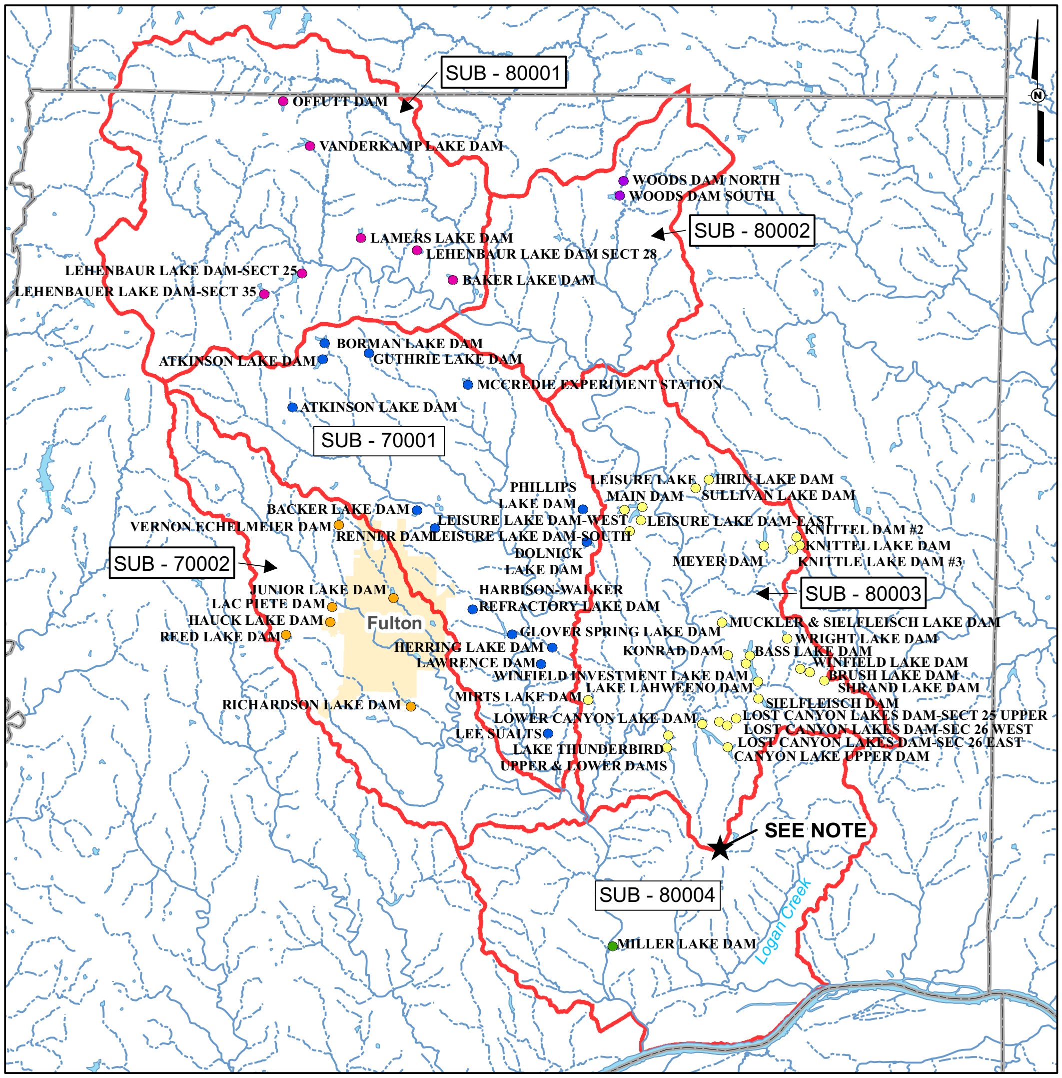
Figure 2.4-10—{Surface Water Intakes 50 Mile (80 Km) Radius}



NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AT THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY PLANT UNIT 1 AND REACTOR FOR CALLAWAY PLANT UNIT 2.

REFERENCE:
ESRI StreetMap Pro [CD-ROM], 2007,rivers, waterbodies, and county boundaries.
Missouri Department of Natural Resources, November 2007,Surface Water Intakes

Figure 2.4-11—{Dams Within Auxvasse Creek Watershed}



LEGEND

Dam by Auxvasse Creek Subwatershed

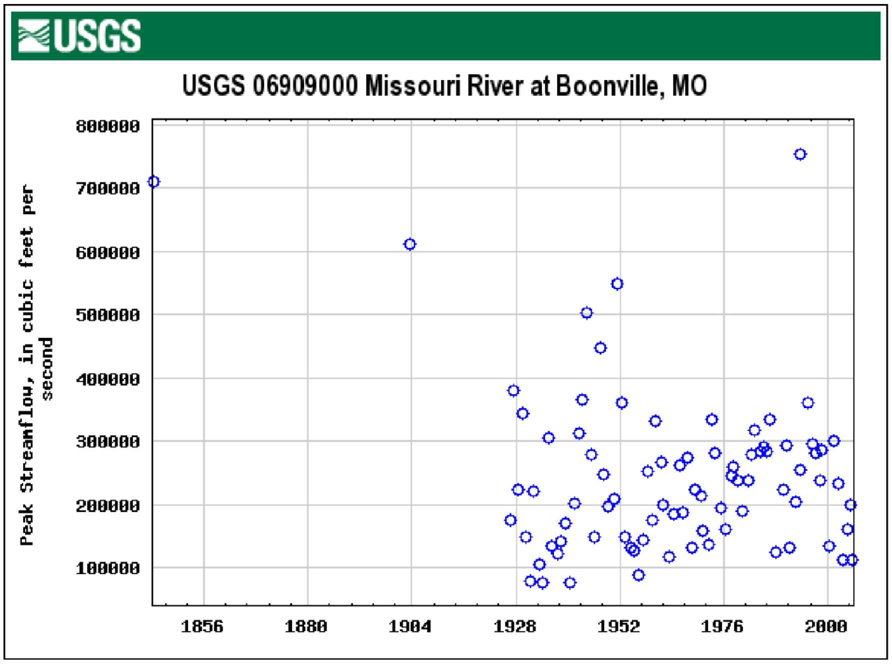
- 70001
- 70002
- 80001
- 80002
- 80003
- 80004
- Stream
- Waterbody
- County Boundary
- Incorporated Area

NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AT THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY PLANT UNIT 1 AND REACTOR FOR CALLAWAY PLANT UNIT 2.

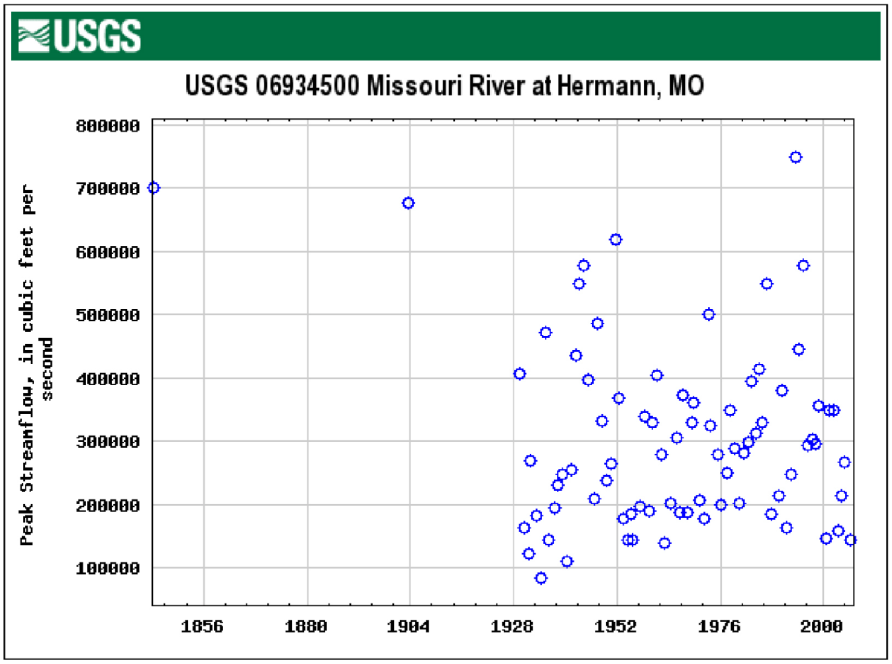
REFERENCE:
ESRI StreetMap Pro [CD-ROM], 2007,
Streams, Waterbody, Incorporated Area, and County Boundary.
MoDNR, Water Resources Center, 2007,
Regulated and Non-Regulated Dams in Missouri.
USDA, NRCS 14-digit HUC boundaries, 1998, Auxvasse Creek Watershed boundary.

FSAR: Section 2.4

Figure 2.4-12—{Peak Streamflow at Boonville and Hermann}



USGS, 2007b. Peak Streamflow USGS 06909000 Missouri River at Boonville, MO



USGS, 2007a. Peak Streamflow USGS 06934500 Missouri River at Hermann

FSAR: Section 2.4

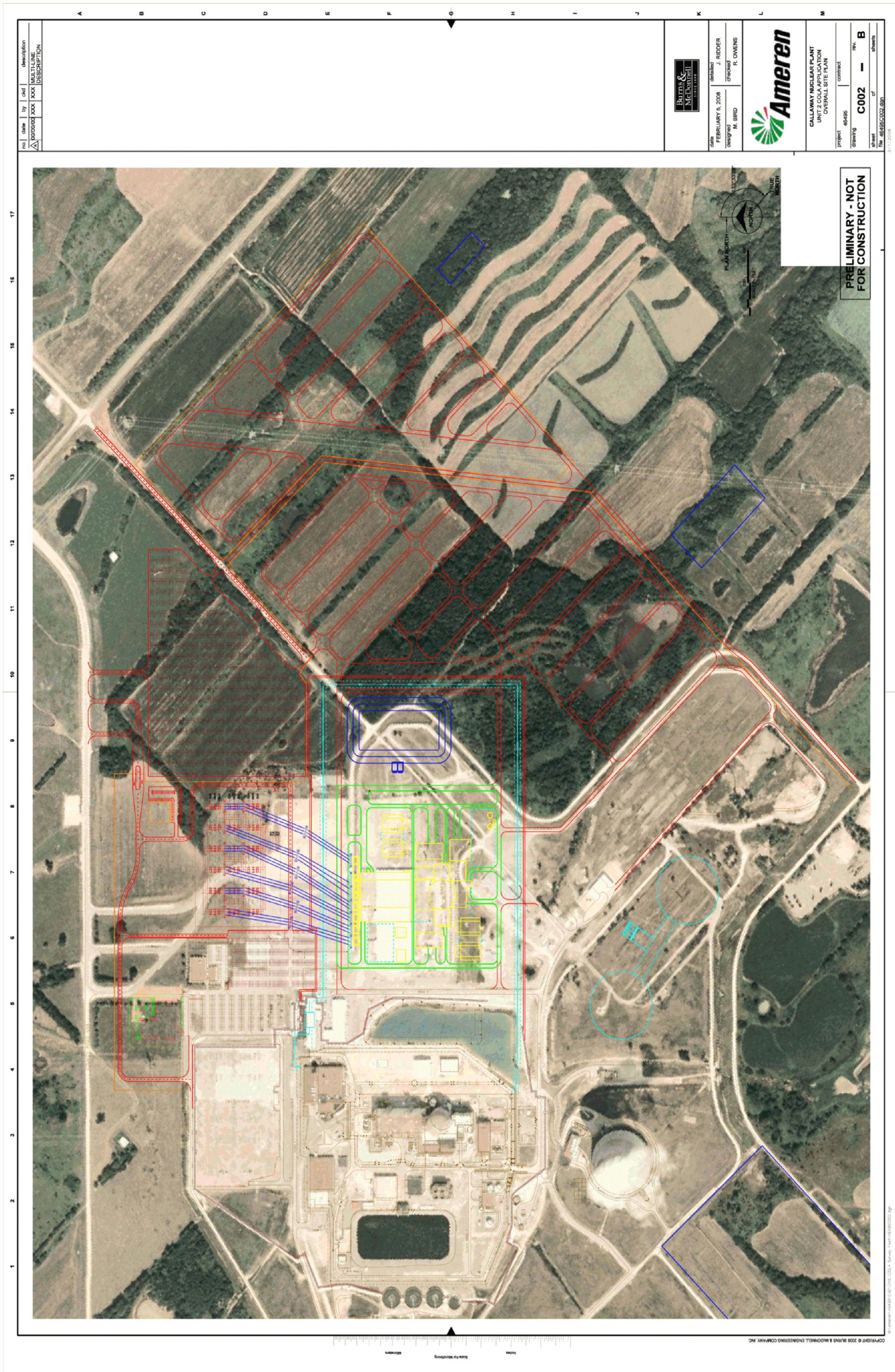


Figure 2.4-13—{Site Layout}

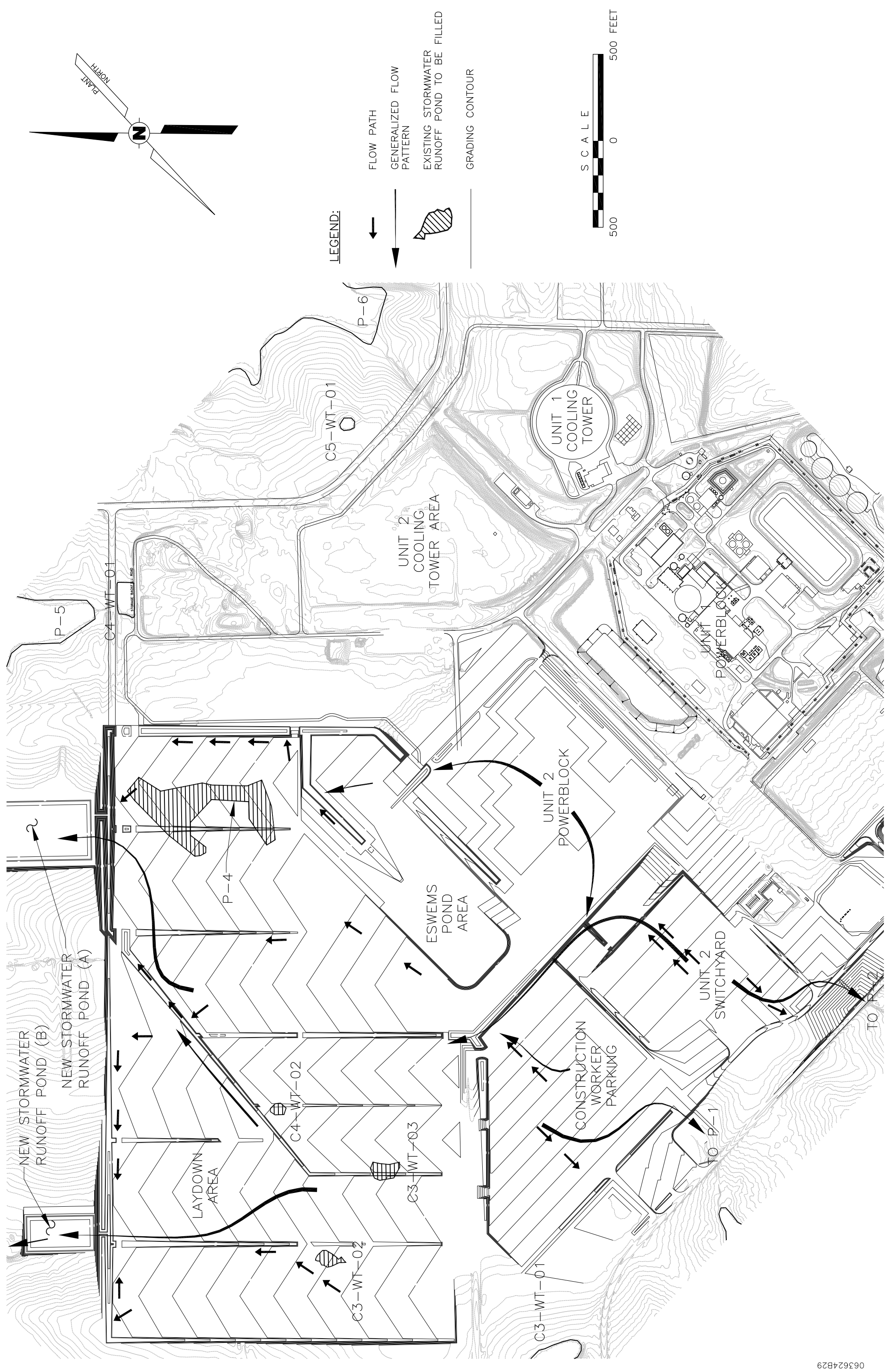


Figure 2.4-14—{Site Grading Plan}

Figure 2.4-15—{Sub-Basin Site Drainage Delineation}

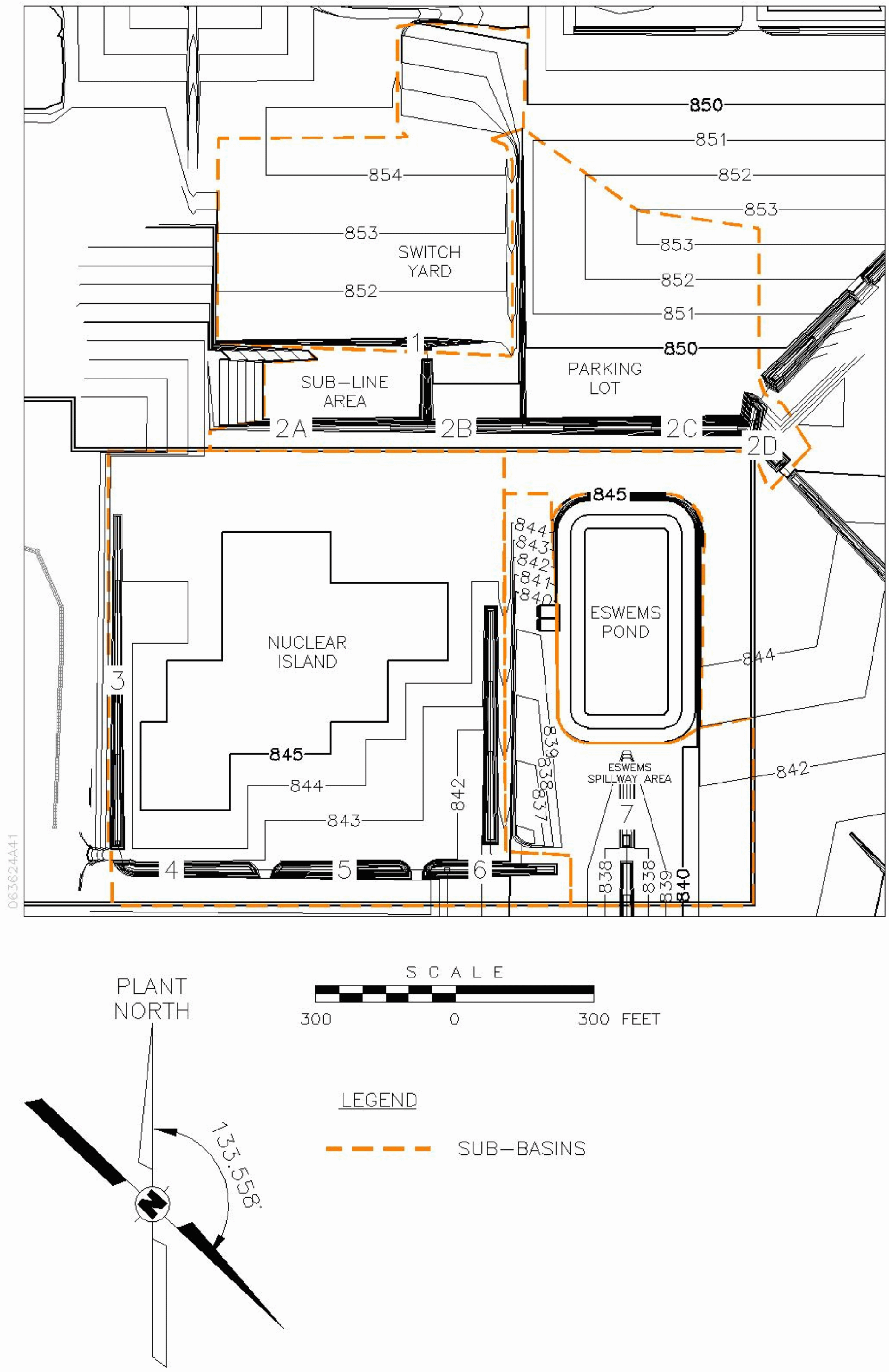
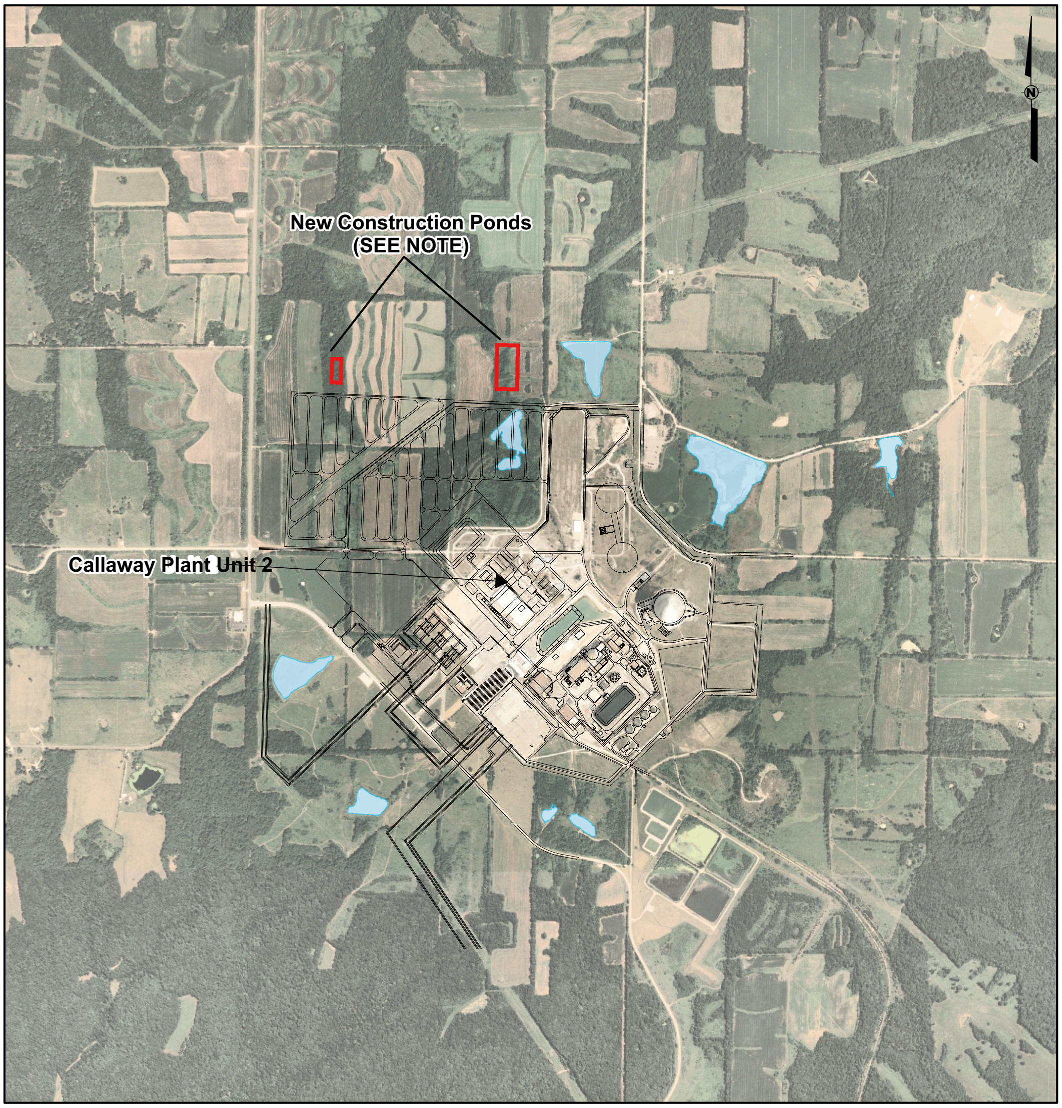


Figure 2.4-16—{HEC-HMS Hydrologic Diagram}

Figure 2.4-17—{Location of Stormwater Runoff Ponds}



LEGEND

Existing Construction Ponds

New Construction Ponds

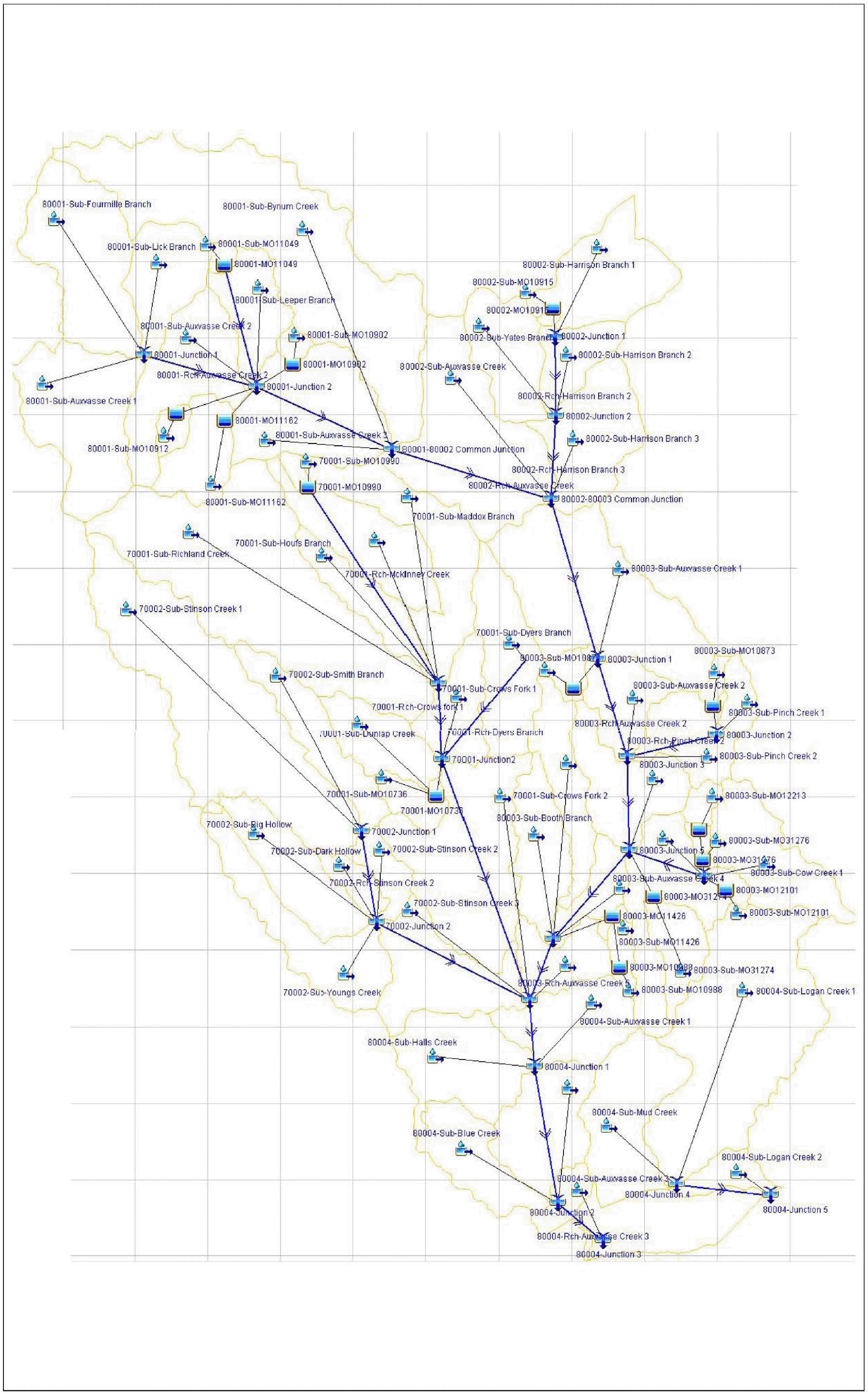
0 1,000 2,000 4,000 Feet

NOTE:
PROPOSED CONSTRUCTION POND LOCATION SUBJECT TO CHANGE.

REFERENCE
2006 Missouri US Department of Agriculture,
National Agriculture Imagery Program Data.
Missouri Spatial Data Information Service (MSDIS) web site
http://www.msdis.missouri.edu/ Accessed September 2007.

Figure 2.4-18—{Auxvasse Creek Watershed Sub-Basins Delineation}

Figure 2.4-19—{HEC-HMS Model Set Up}



FSAR: Section 2.4

Figure 2.4-20—{Sub-Basin 80004 Logan Ck2 Hydrograph}

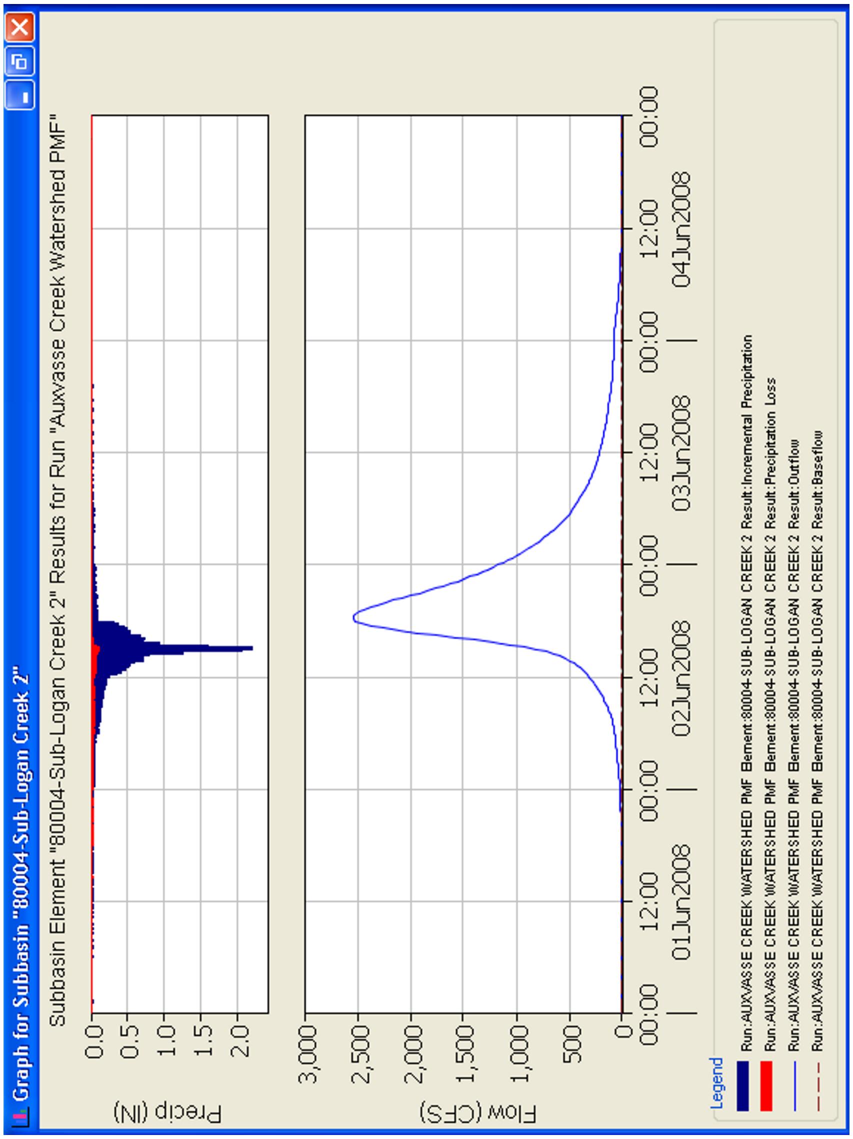
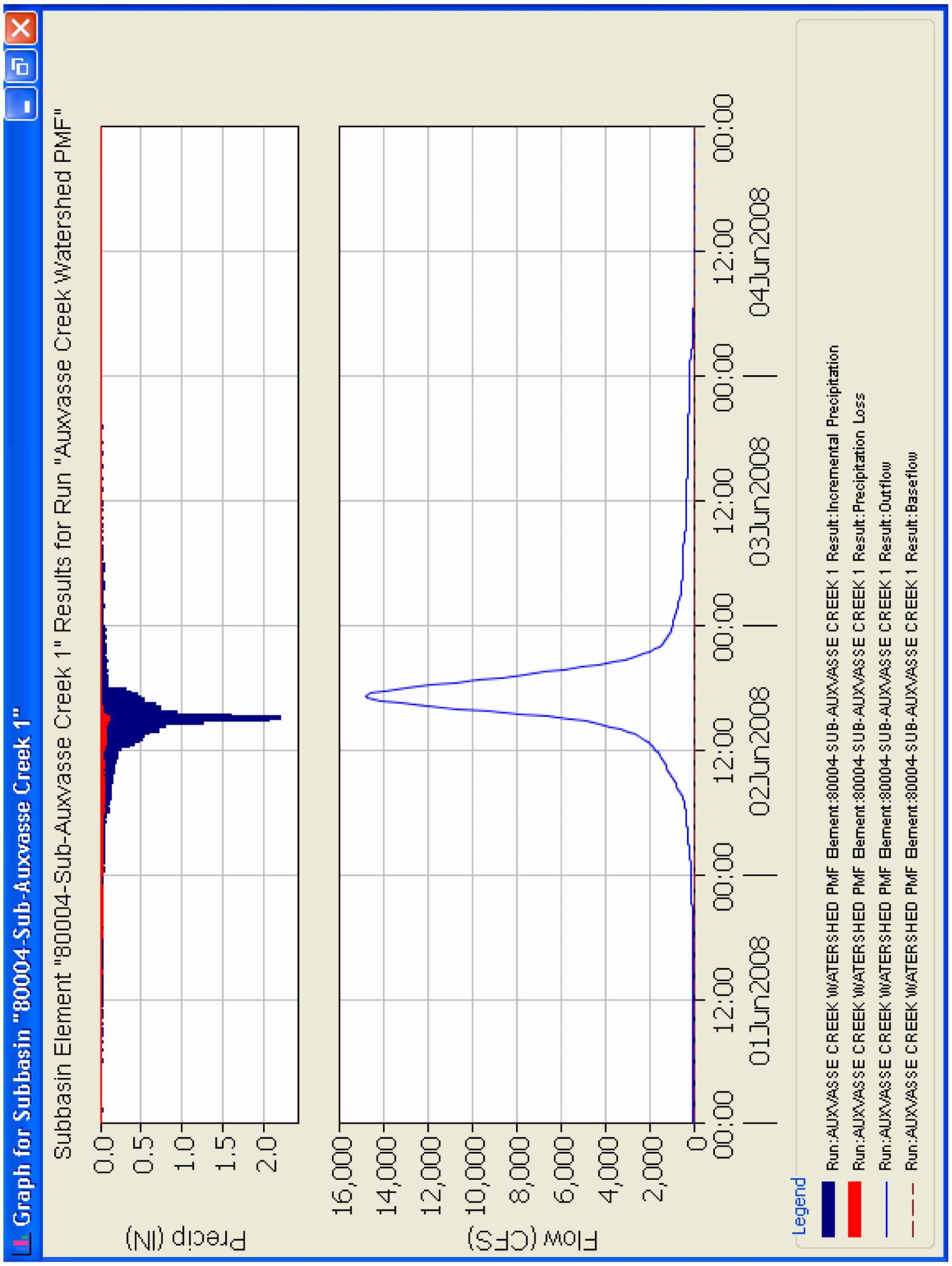


Figure 2.4-21—{Sub-Basin 80004 Auxvasse Ck1 Hydrograph}



FSAR: Section 2.4

Figure 2.4-22—{Sub-Basin 80004 Auxvasse Ck3 Hydrograph}

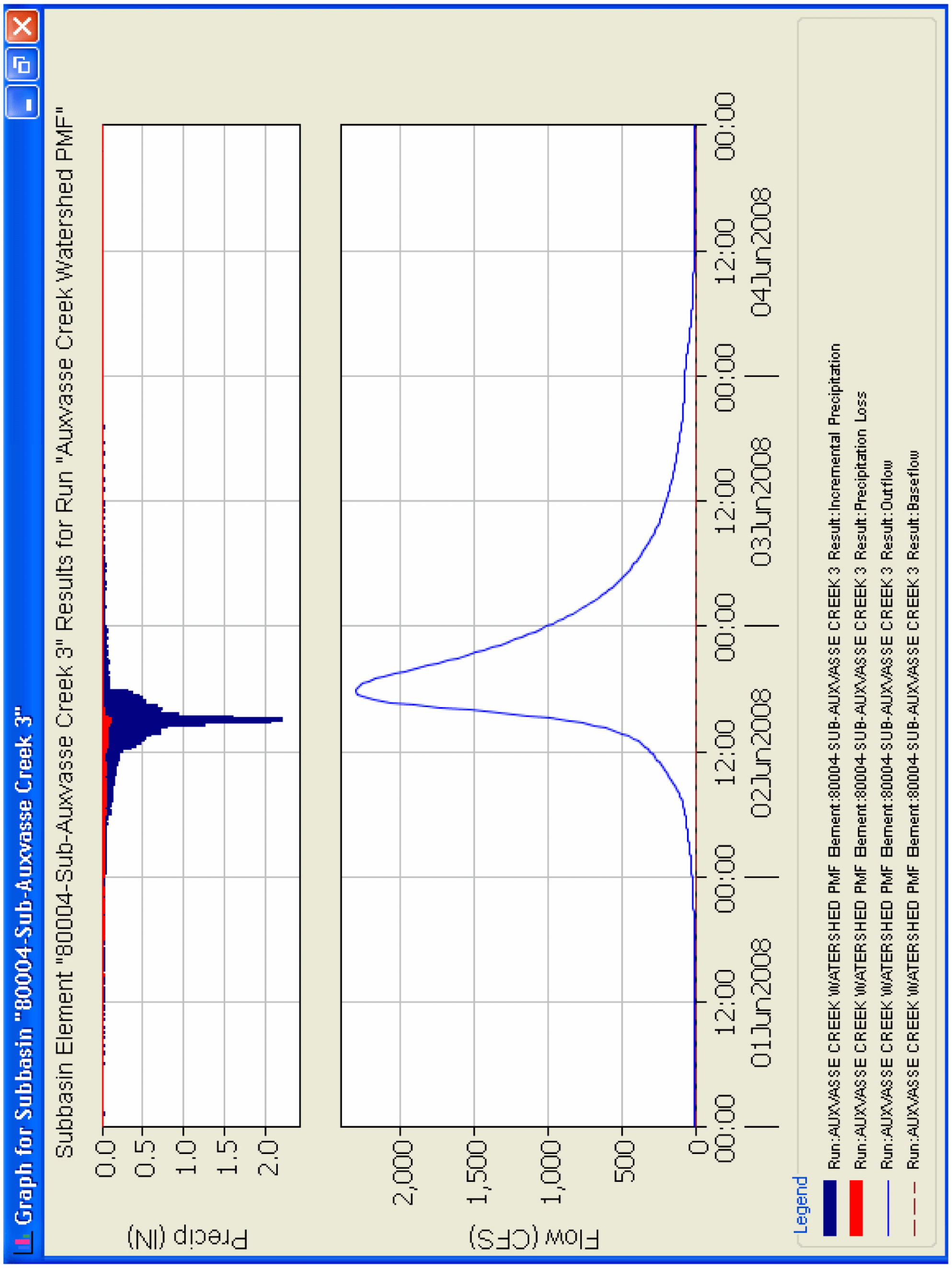
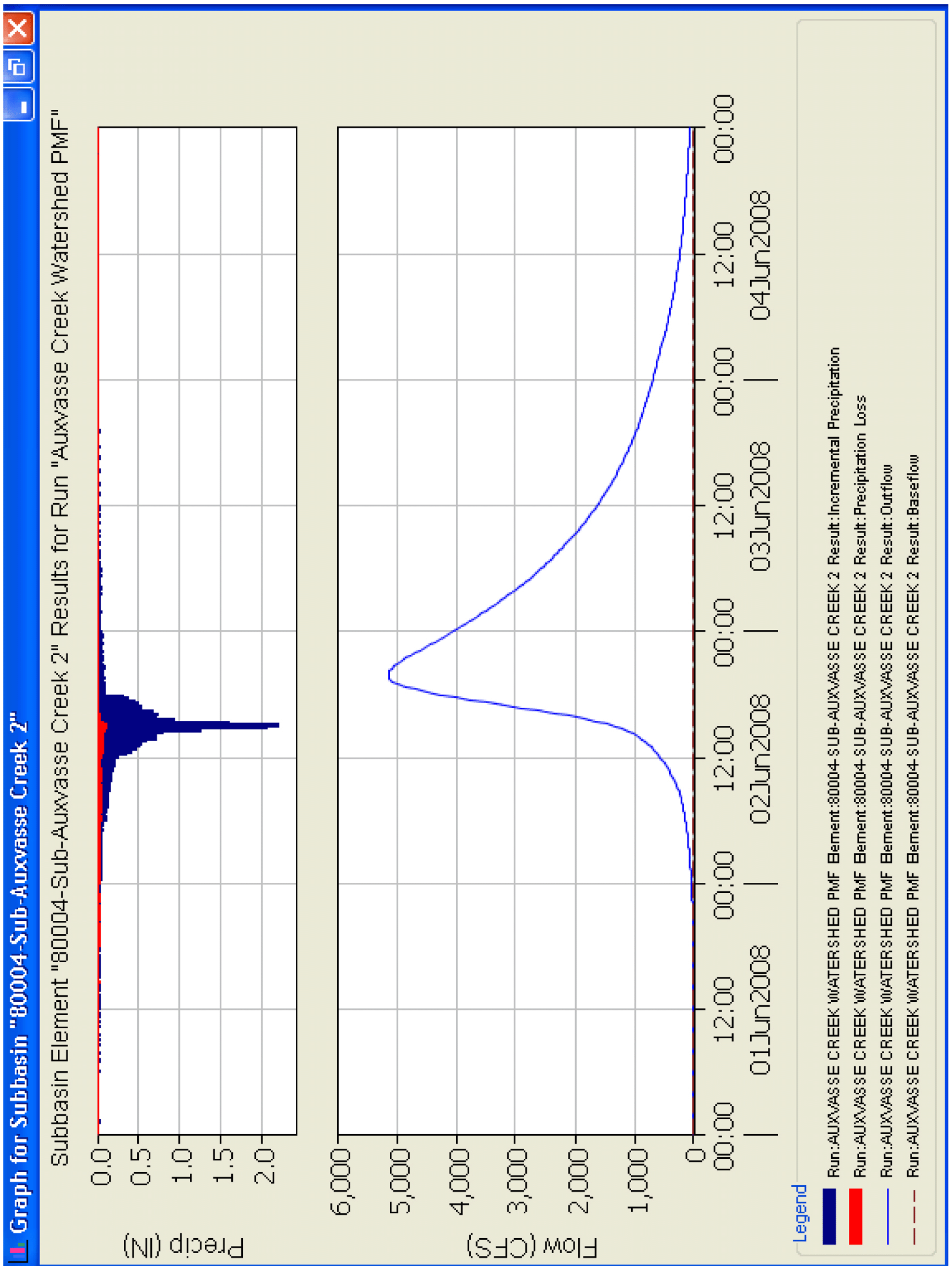
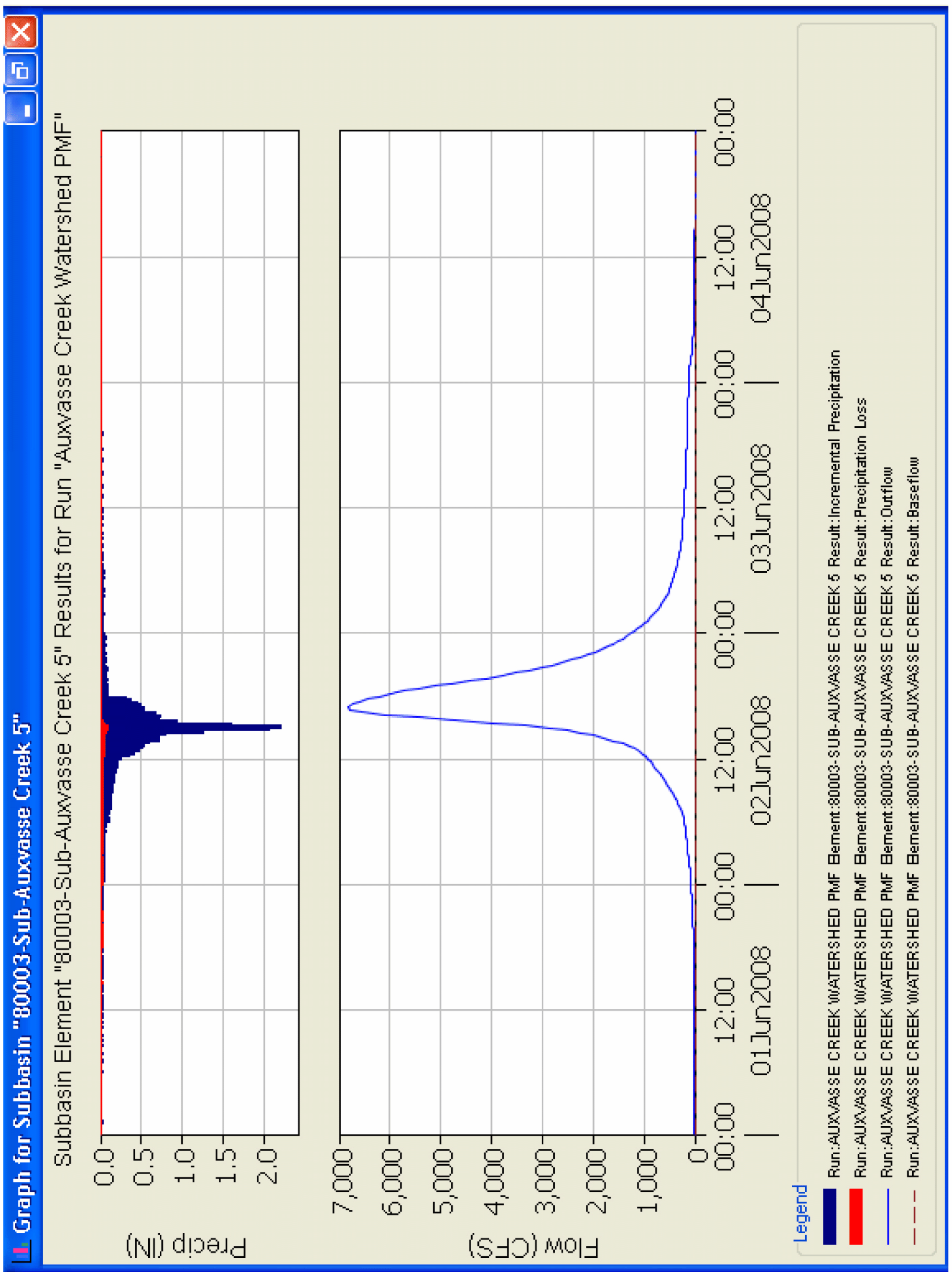


Figure 2.4-23—{Sub-Basin 80004 Auxvasse Ck2 Hydrograph}



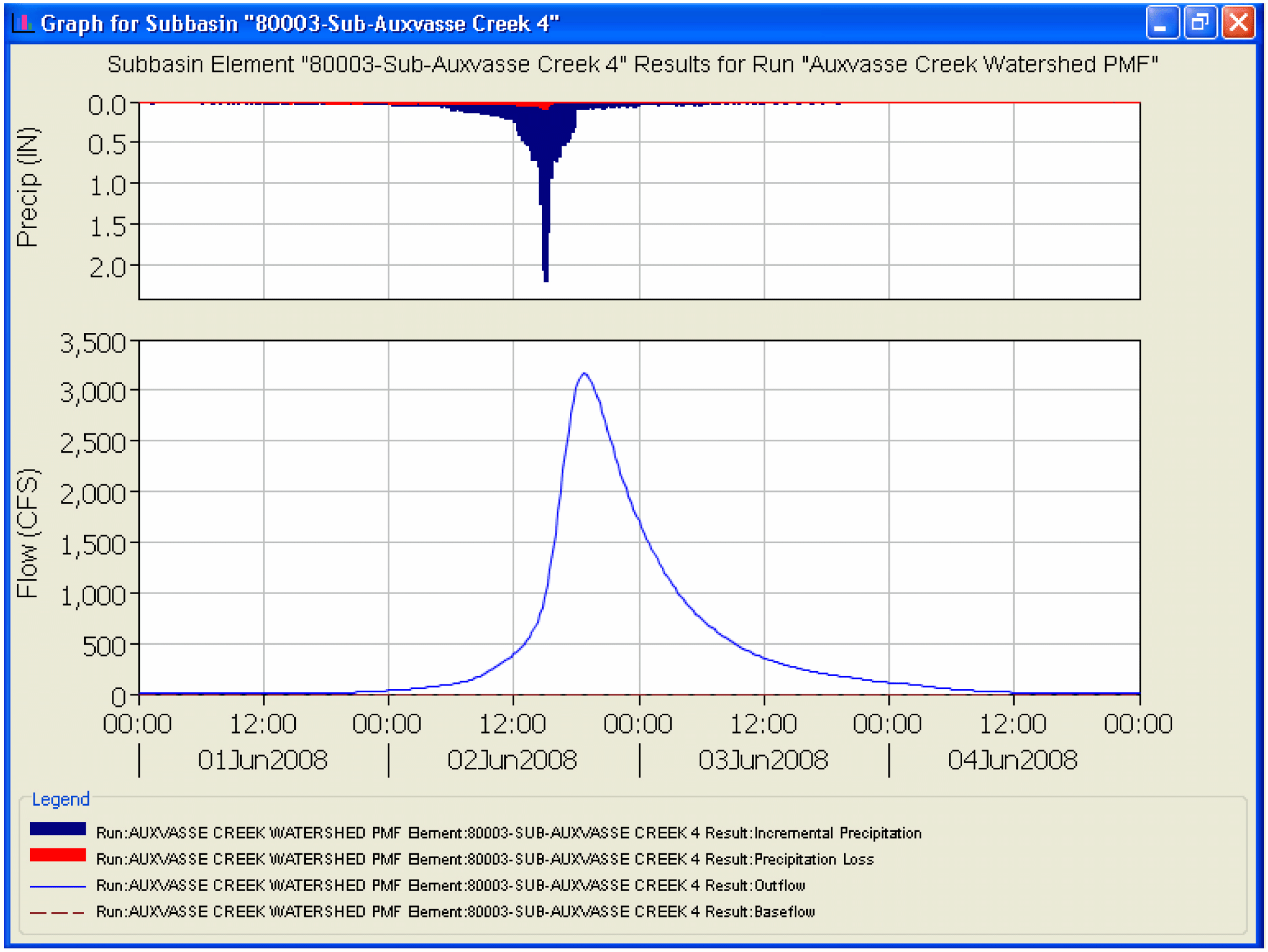
FSAR: Section 2.4

Figure 2.4-24—{Sub-Basin 80003 Auxvasse Ck5 Hydrograph}



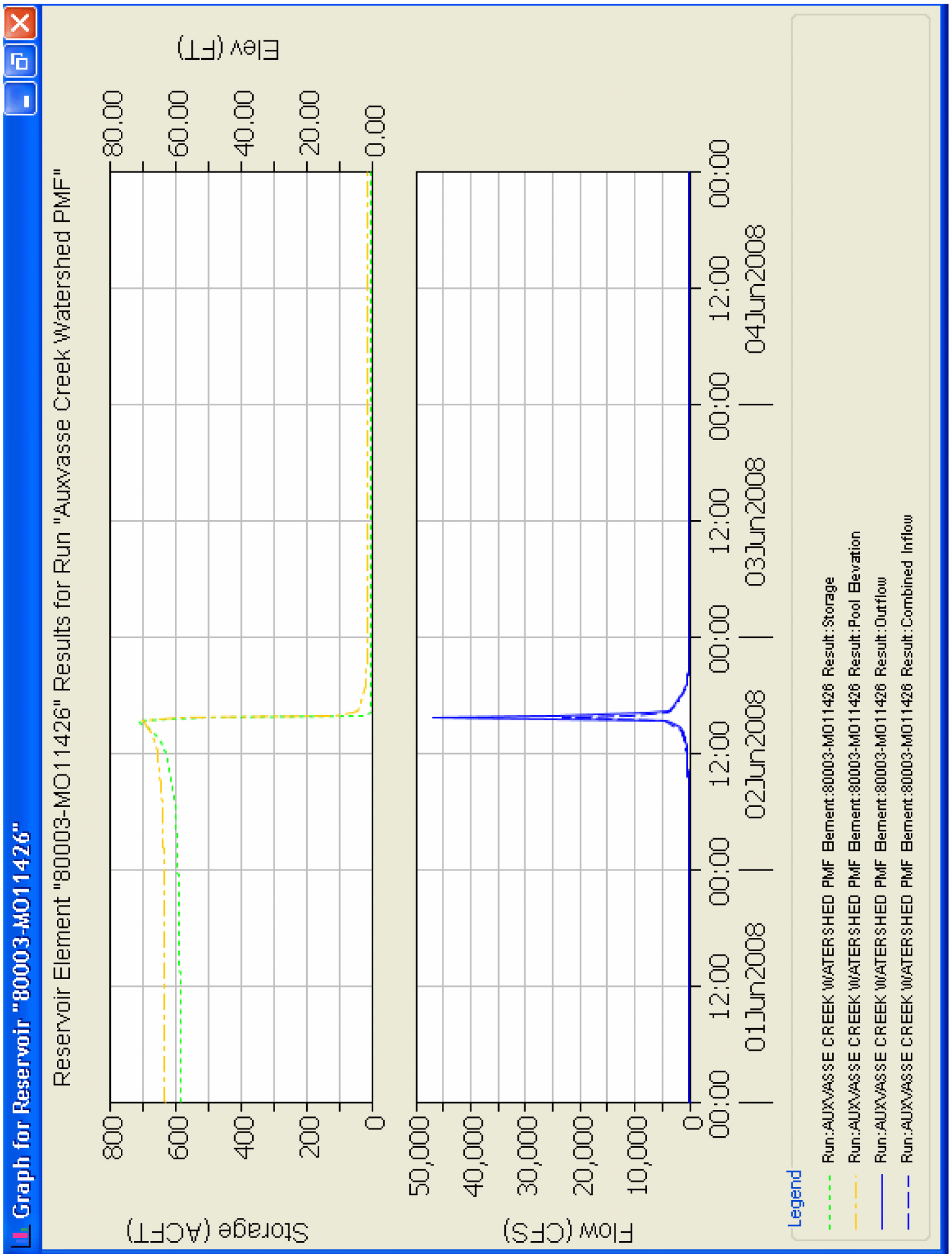
FSAR: Section 2.4

Figure 2.4-25—{Sub-Basin 80003 Auxvasse Ck4 Hydrograph}



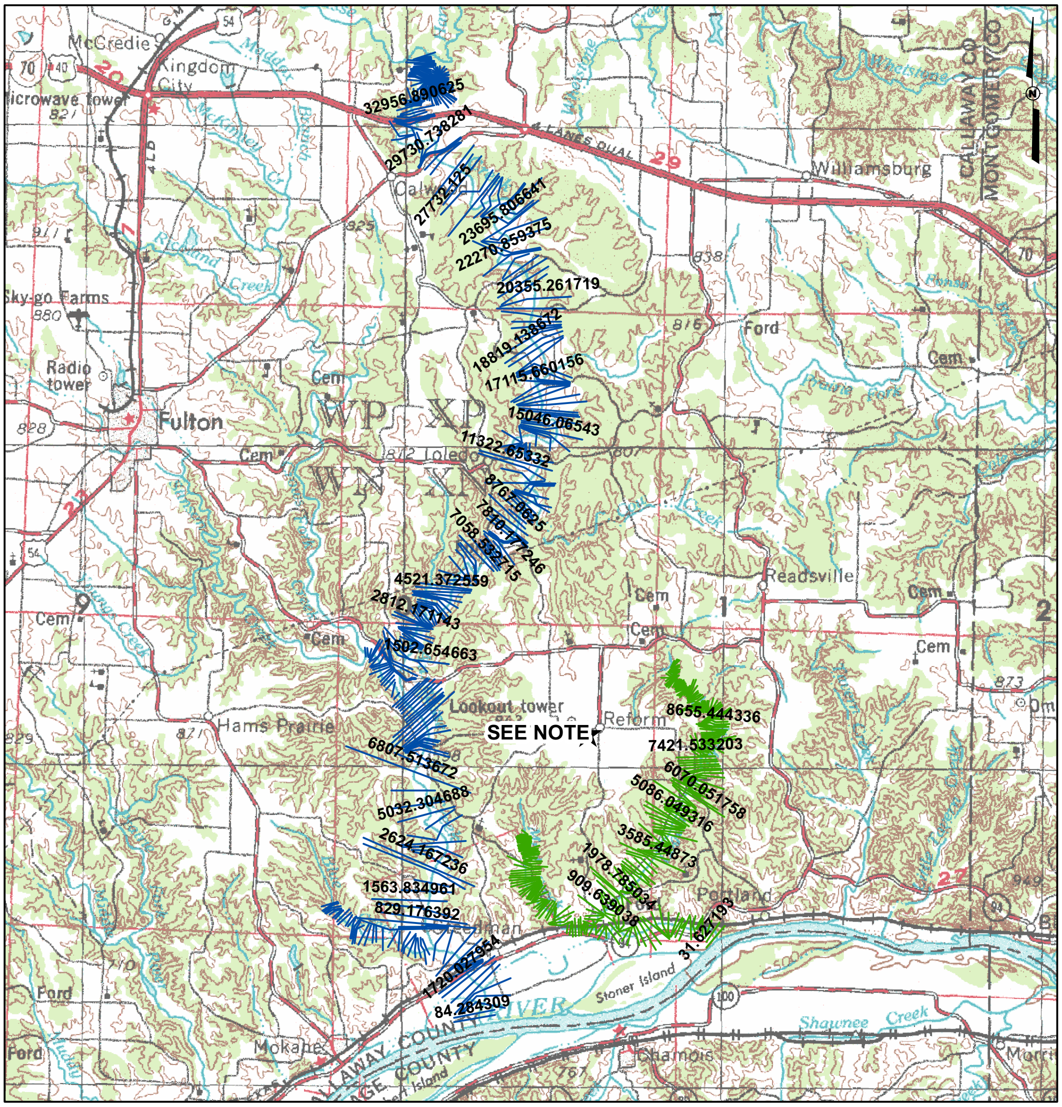
FSAR: Section 2.4

Figure 2.4-26—{Storage Inflow & Outflow Thunderbird Lake Lower}



FSAR: Section 2.4

Figure 2.4-27—{HEC-RAS Cross Section Cut Lines}



contours in meters 840 feet = 256 meters

0 1.5 3 6 Miles

LEGEND

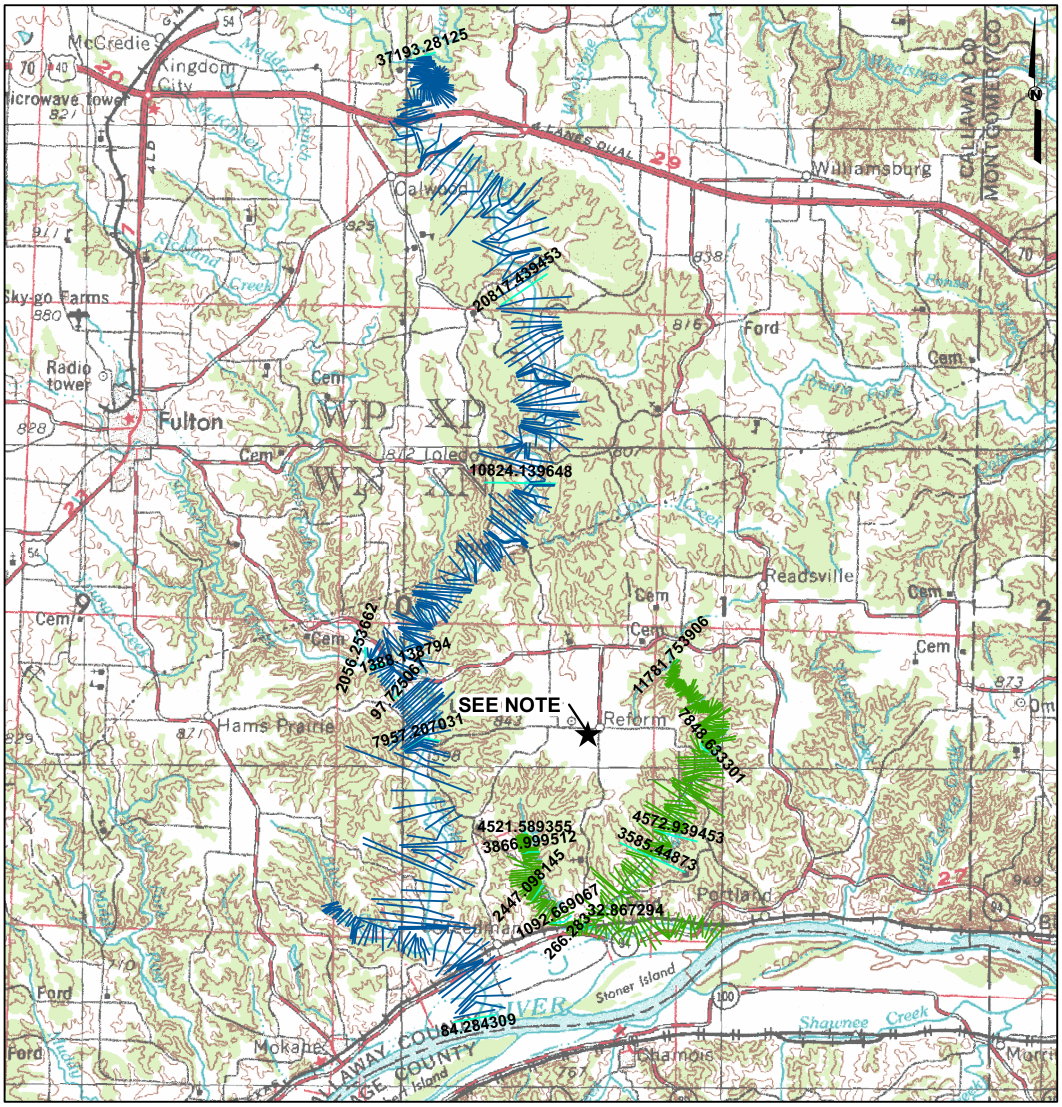
6807.513672 CROSS SECTION STATION NUMBER

- Auxvasse Creek Cross Section Cut Lines
- Logan Creek Cross Section Cut Lines
- Intermittent Stream
- Perennial Stream

NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AS THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY PLANT UNIT 1 AND REACTOR FOR CALLAWAY PLANT UNIT 2.

REFERENCES:
USGS 1:250K 1x2 degree series Topographic Map; St Louis, 1969.
Cross section lines created using GeoRAS.

Figure 2.4-28—{Specific HEC-RAS Cross Section Cut Lines }



LEGEND

6807.513672 CROSS SECTION STATION NUMBER
- Auxvasse Creek Cross Section Cut Lines
- Logan Creek Cross Section Cut Lines
- Intermittent Stream
- Perennial Stream

NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AS THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY PLANT UNIT 1 AND REACTOR FOR CALLAWAY PLANT UNIT 2.

REFERENCES
USGS 1:250K 1x2 degree series Topographic Map; St Louis, 1969.
Cross section lines created using GeoRAS.

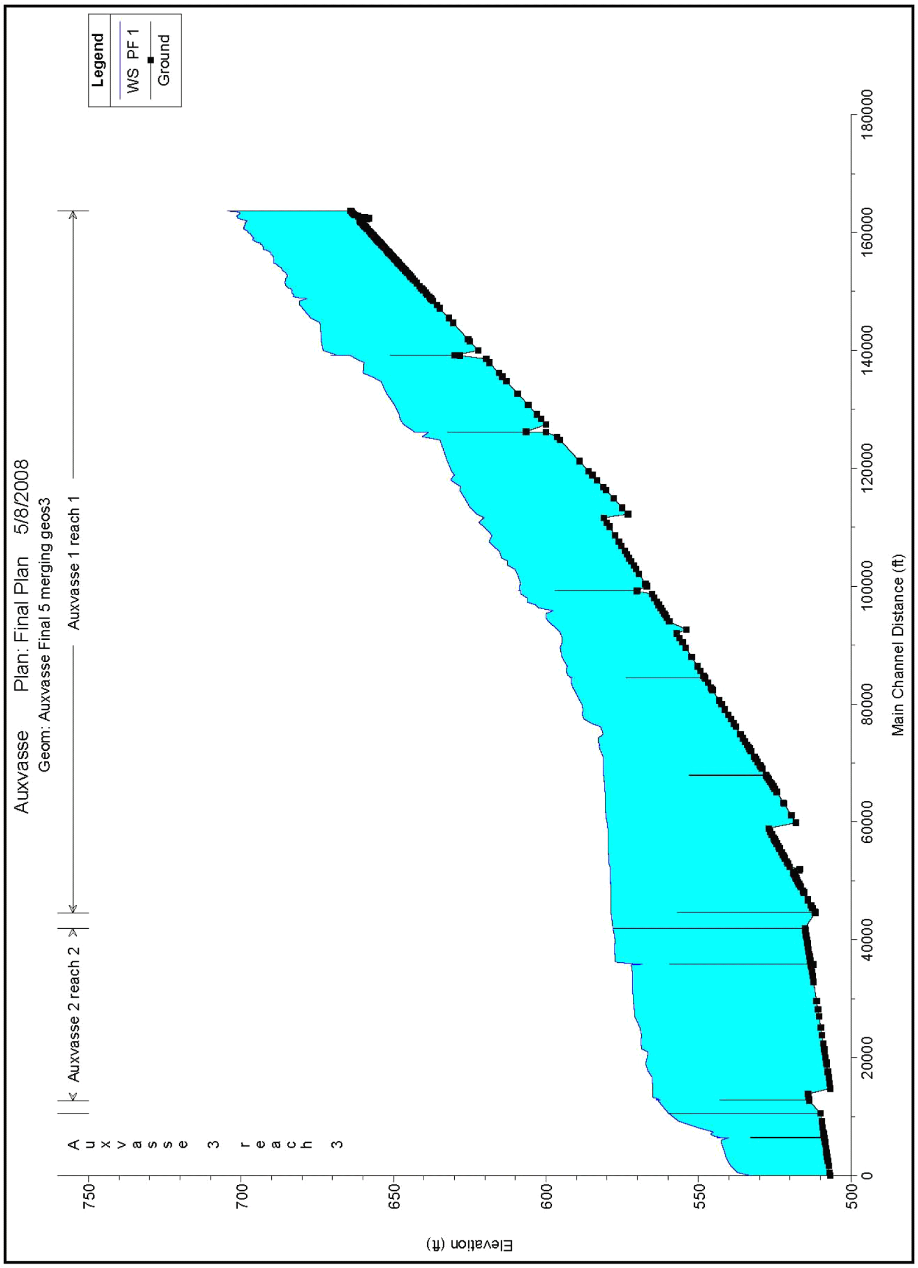


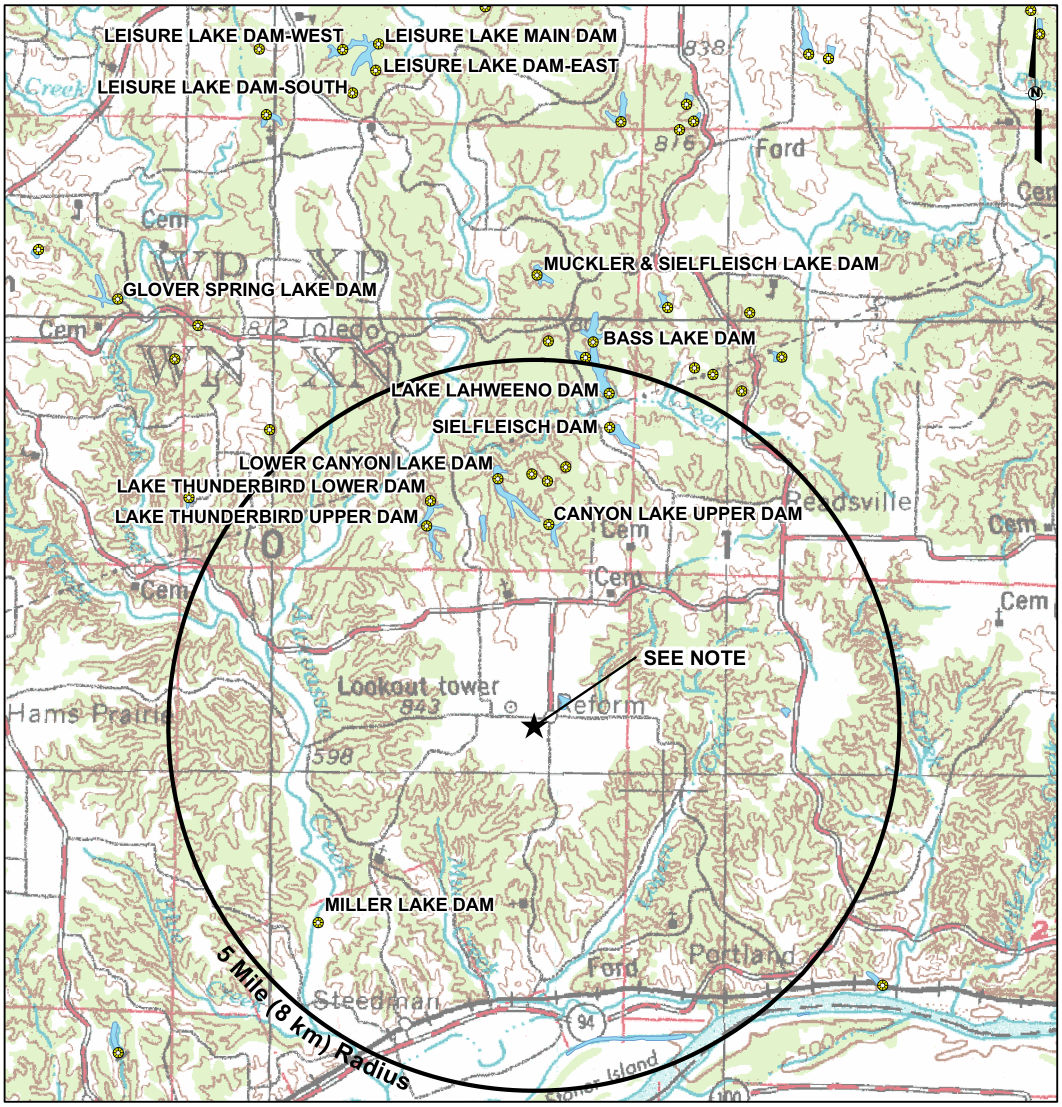
Figure 2.4-29—{Auxvasse Creek Surface Water Profile}

Figure 2.4-30—{Streams and Lake Near Site}

NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AT THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY PLANT UNIT 1 AND REACTOR FOR CALLAWAY PLANT UNIT 2.

REFERENCE
USGS 100K 30x60 Minute Series Topographic Map: Fulton, 1985.

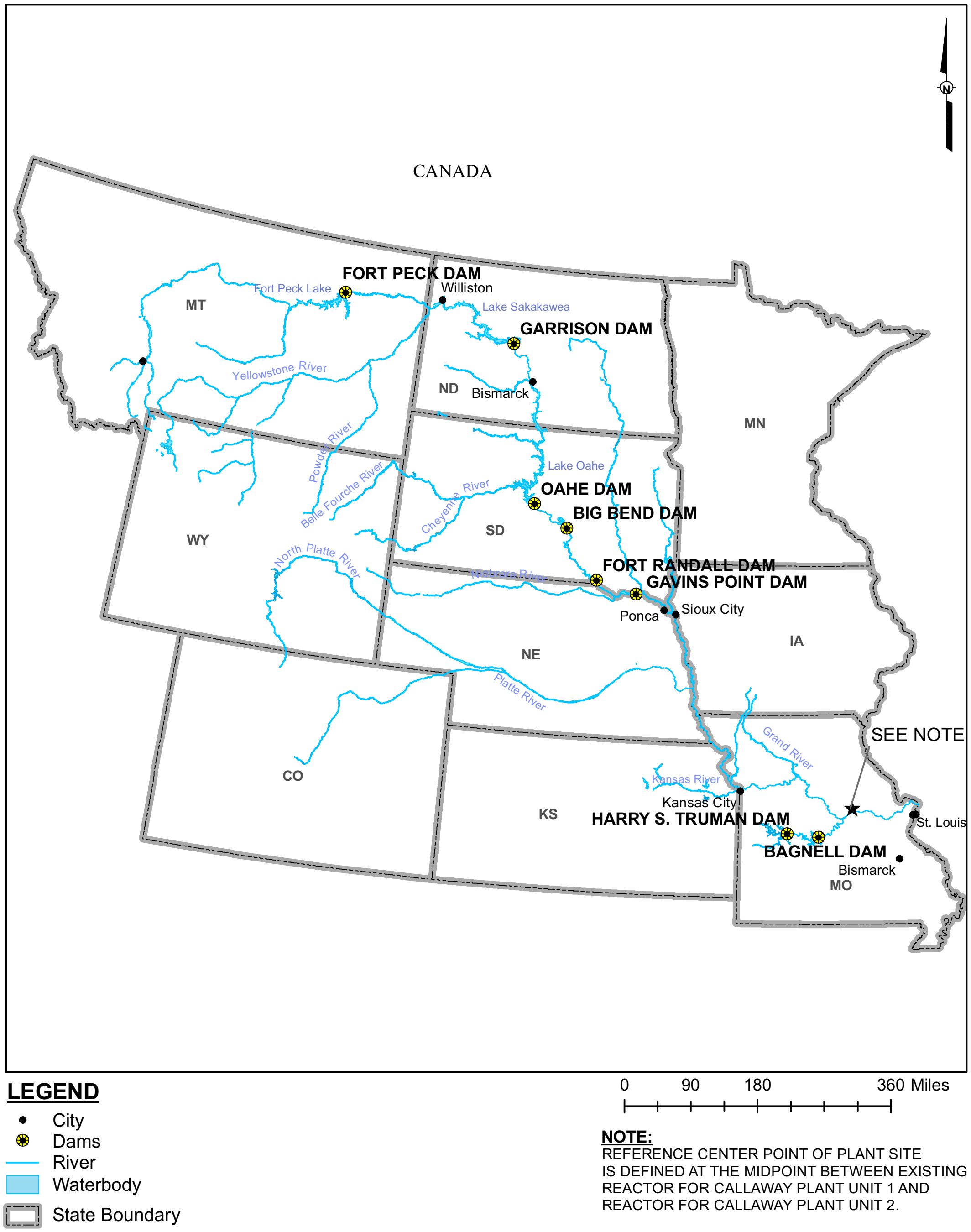
Figure 2.4-31—{Dams Within a 5 Mile (8 km) Radius}



NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AT THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY PLANT UNIT 1 AND REACTOR FOR CALLAWAY PLANT UNIT 2.

REFERENCES:
USGS 1:250K 1x2 degree series Topographic Map; St Louis, 1969.
ESRI StreetMap Pro [CD-ROM], 2007, Waterbody.
MoDNR, Water Resources Center, 2007, Regulated and Non-Regulated Dams in Missouri.

Figure 2.4-32—{Missouri River Mainstem and Osage River Dam}

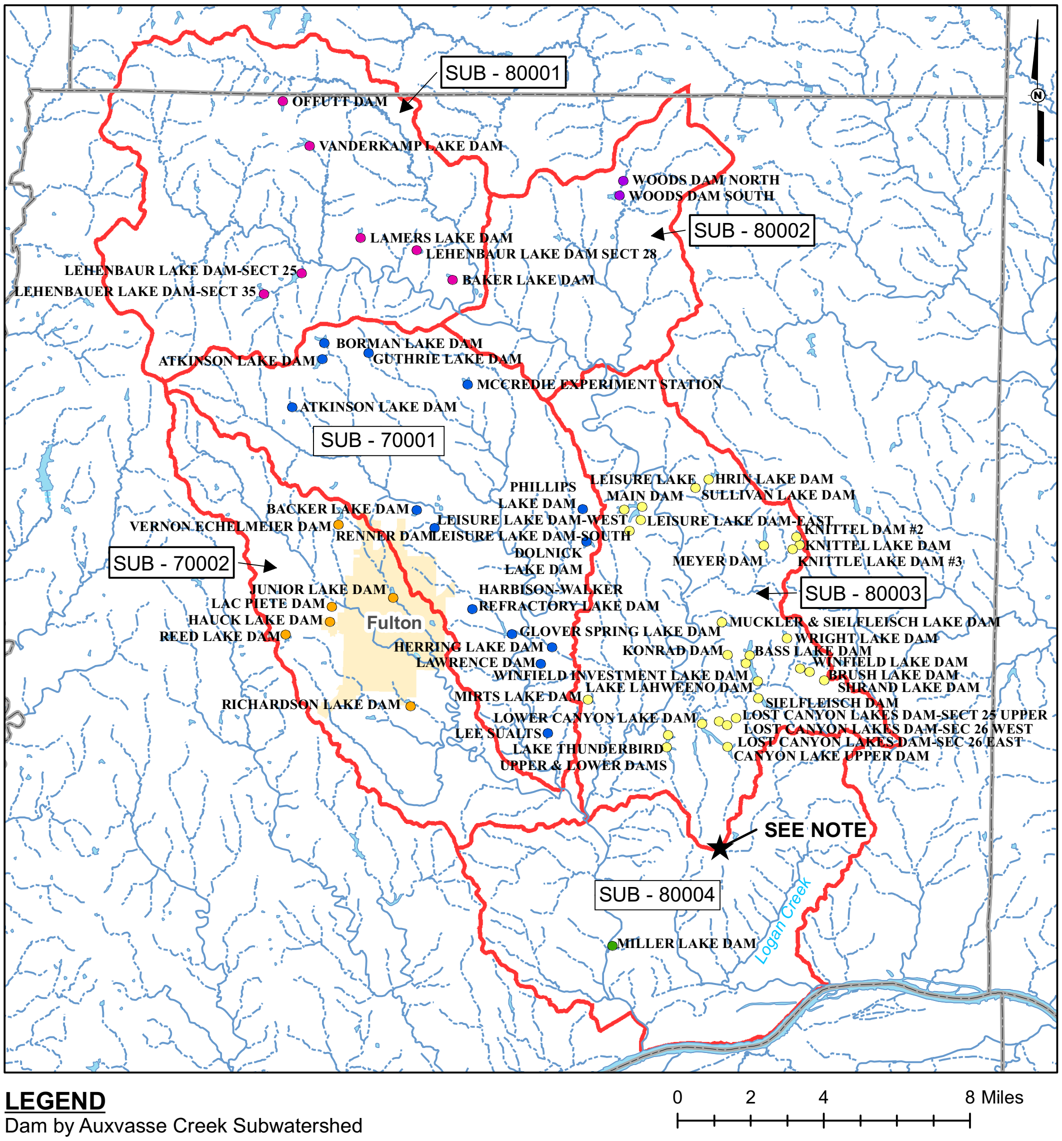


NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AT THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY PLANT UNIT 1 AND REACTOR FOR CALLAWAY PLANT UNIT 2.

REFERENCES:
ESRI StreetMap Pro [CD-ROM], 2007, City, River & Waterbody, & State Boundaries.
National Atlas of the United States, 2006, Major Dams of the United States.
Watershed boundaries created by theUSDA, NRCS (1998).

FSAR: Section 2.4

Figure 2.4-33—{Dams Within Auxvasse Creek Watershed}



LEGEND

Dam by Auxvasse Creek Subwatershed

- 70001
- 70002
- 80001
- 80002
- 80003
- 80004
- Stream
- Waterbody
- County Boundary
- Incorporated Area

NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AT THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY PLANT UNIT 1 AND REACTOR FOR CALLAWAY PLANT UNIT 2.

REFERENCE:
ESRI StreetMap Pro [CD-ROM], 2007,
Streams, Waterbody, Incorporated Area, and County Boundary.
MoDNR, Water Resources Center, 2007,
Regulated and Non-Regulated Dams in Missouri.
USDA, NRCS 14-digit HUC boundaries, 1998, Auxvasse Creek Watershed boundary.

Figure 2.4-34—{Schematic Layout of Callaway Plant Unit 2 Site}

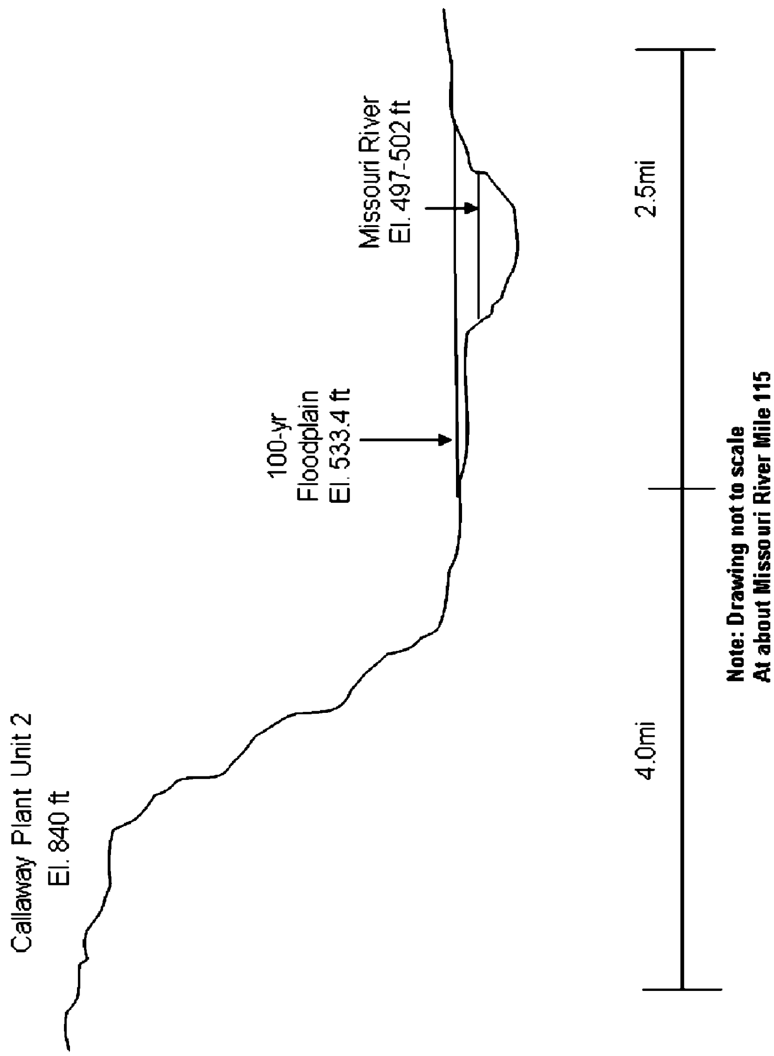
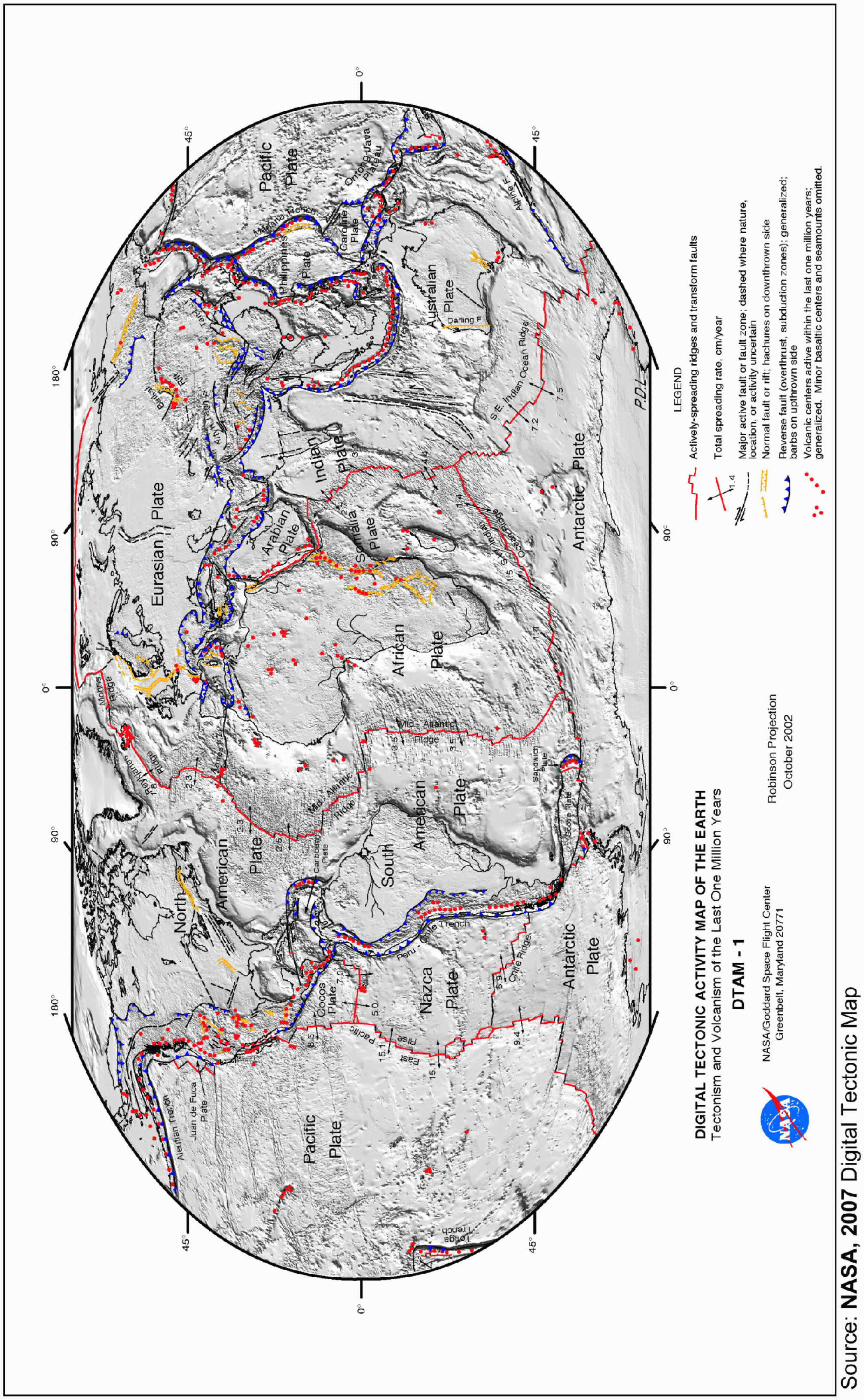
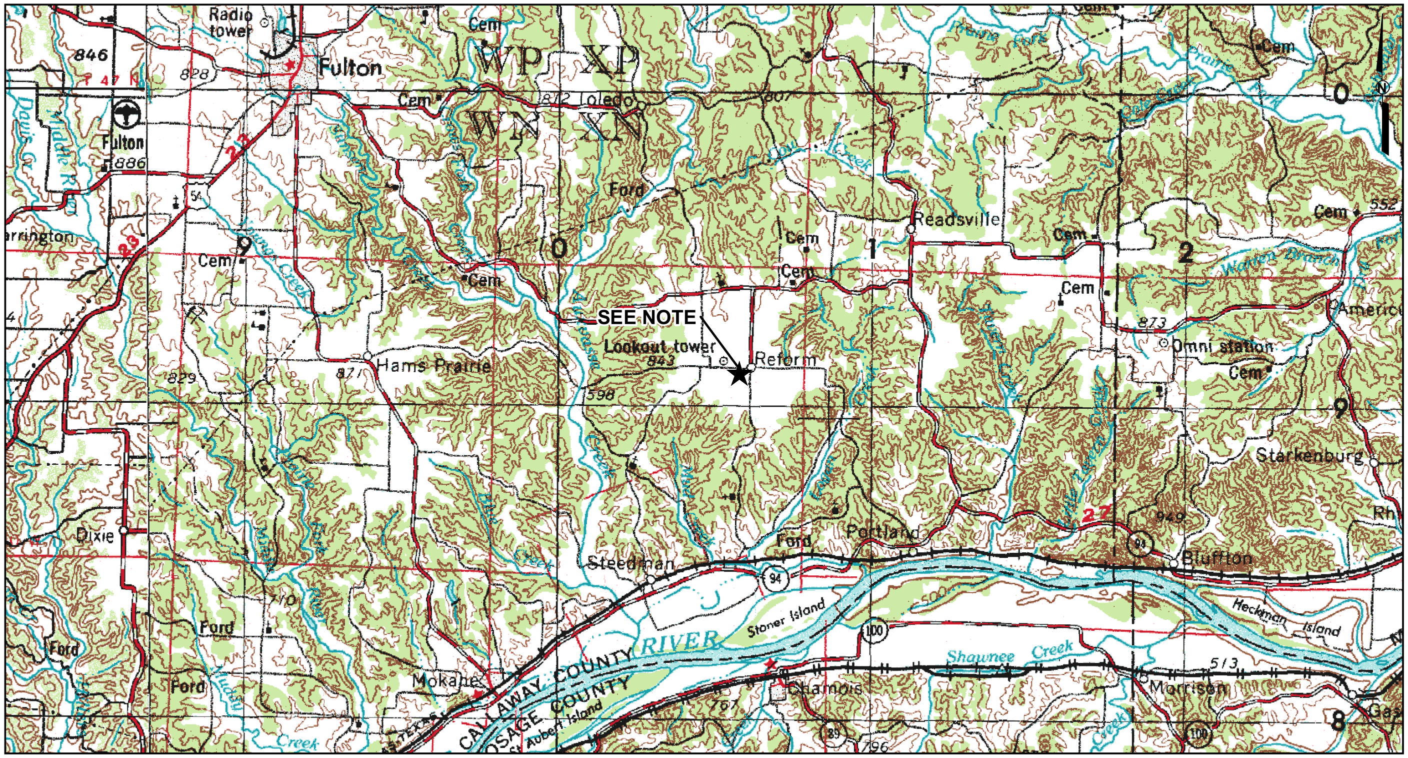


Figure 2.4-35—{Digital Tectonic Activity Map of the Earth}



Source: **NASA, 2007** Digital Tectonic Map

Figure 2.4-36—{Site Location}



contours in meters   840 feet = 256 meters

LEGEND

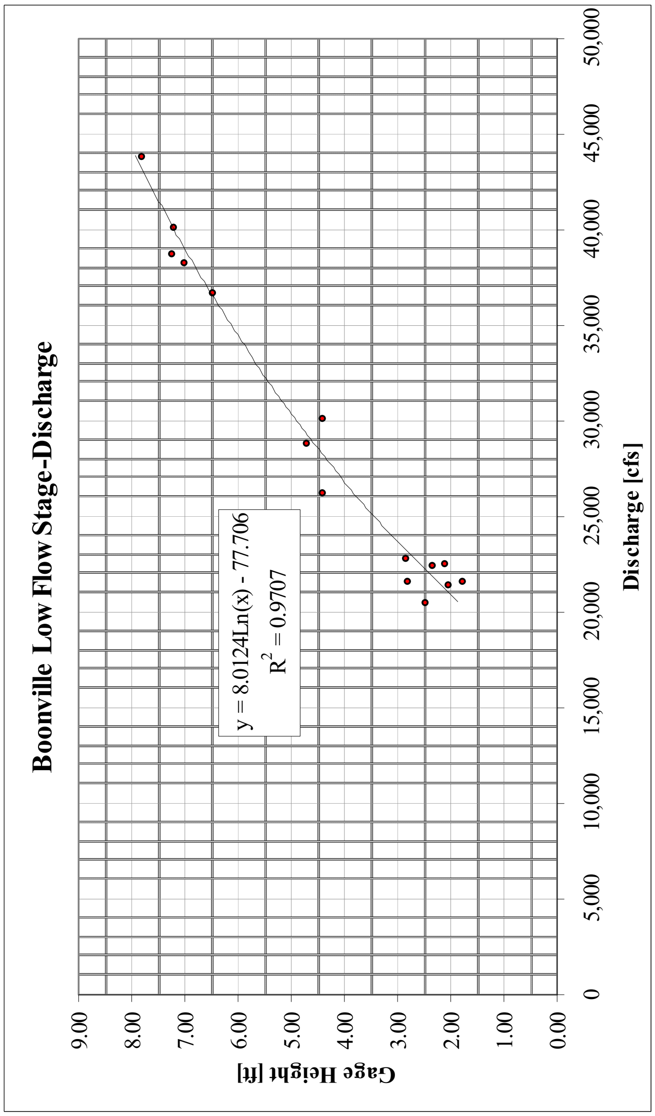
- Waterbody
- Perennial Stream
- Intermittent Stream

0 1.5 3 6 Miles

REFERENCE:
USGS 1:250K 1x2 degree series:
Jefferson City, Rolla, Springfield, & St. Louis

NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AT THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY PLANT UNIT 1 AND REACTOR FOR CALLAWAY PLANT UNIT 2.

Figure 2.4-37—{Low Flow Stage-Discharge Curve for Boonville Station}



FSAR: Section 2.4

Figure 2.4-38—{Low Flow Stage-Discharge Curve for Hermann Station}

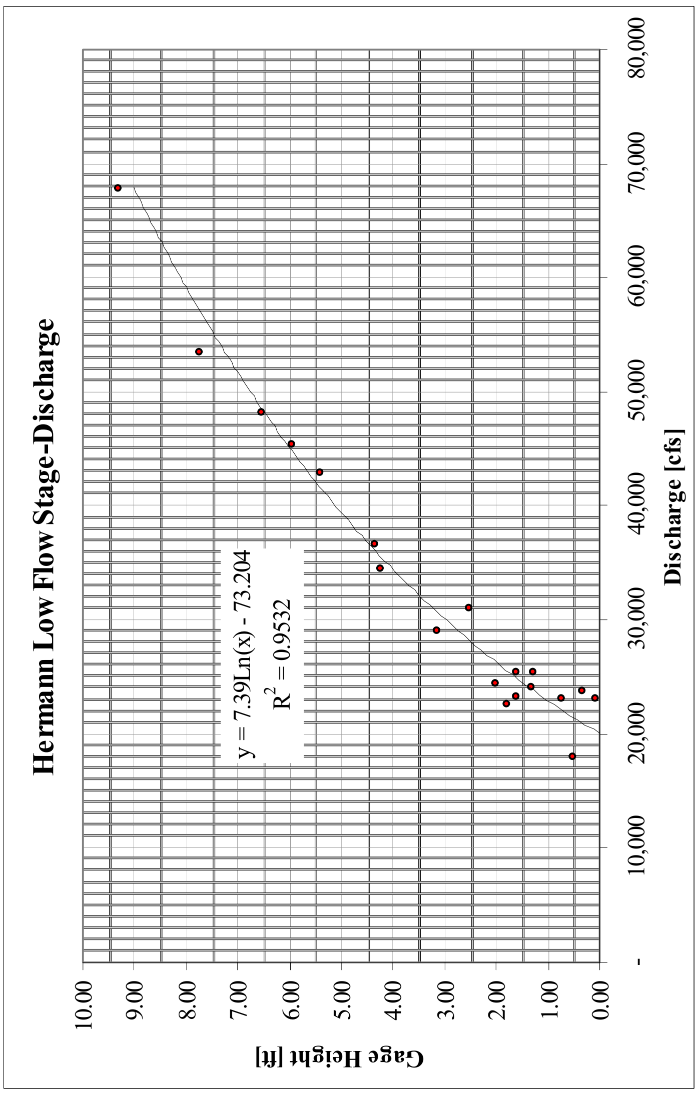


Figure 2.4-39—{Low Water Level Data of Boonville Station and Curve Fitting}

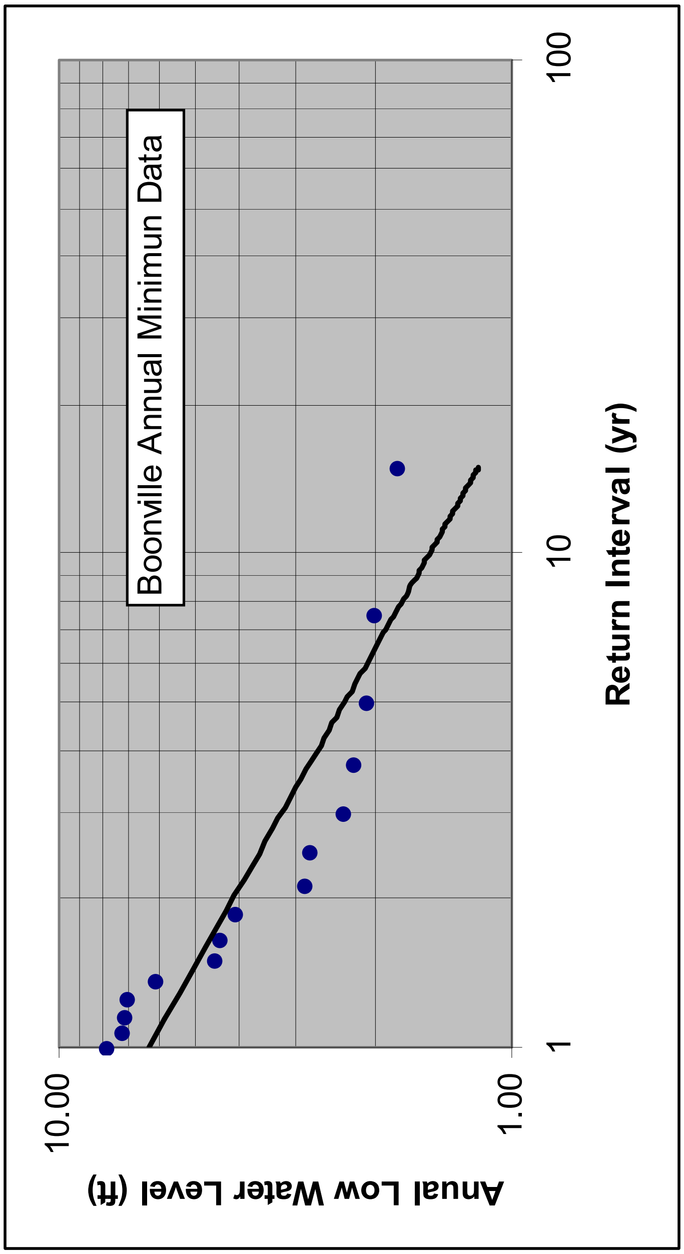
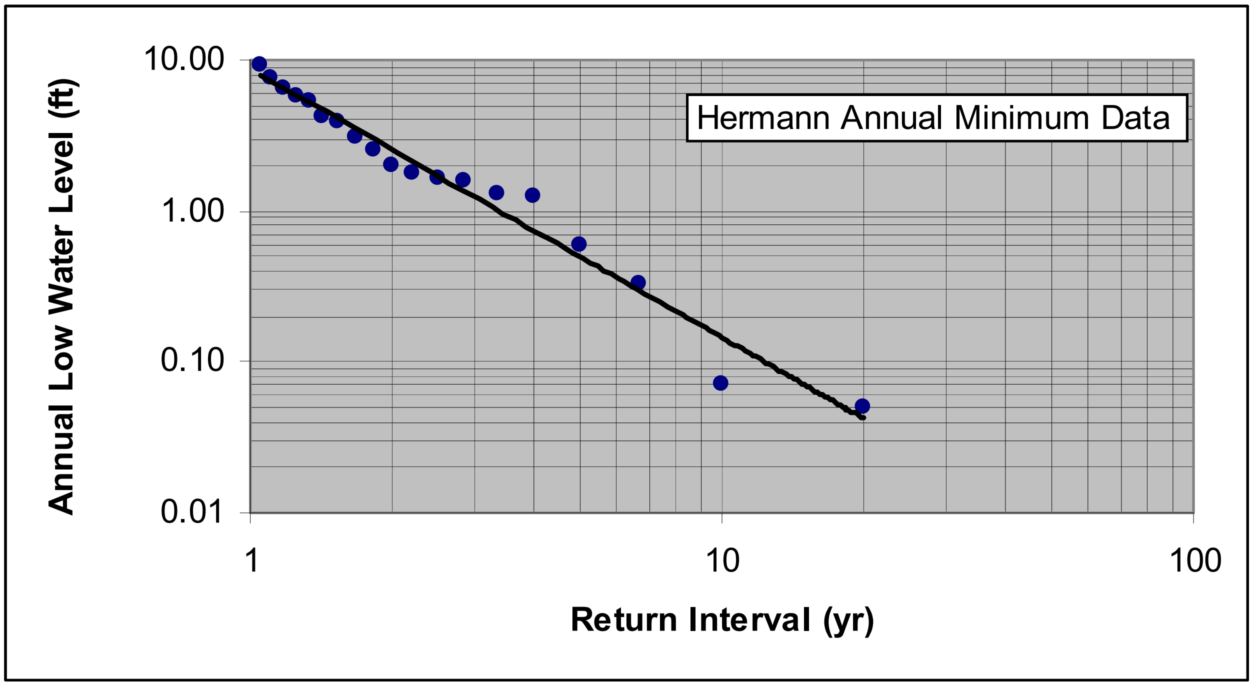
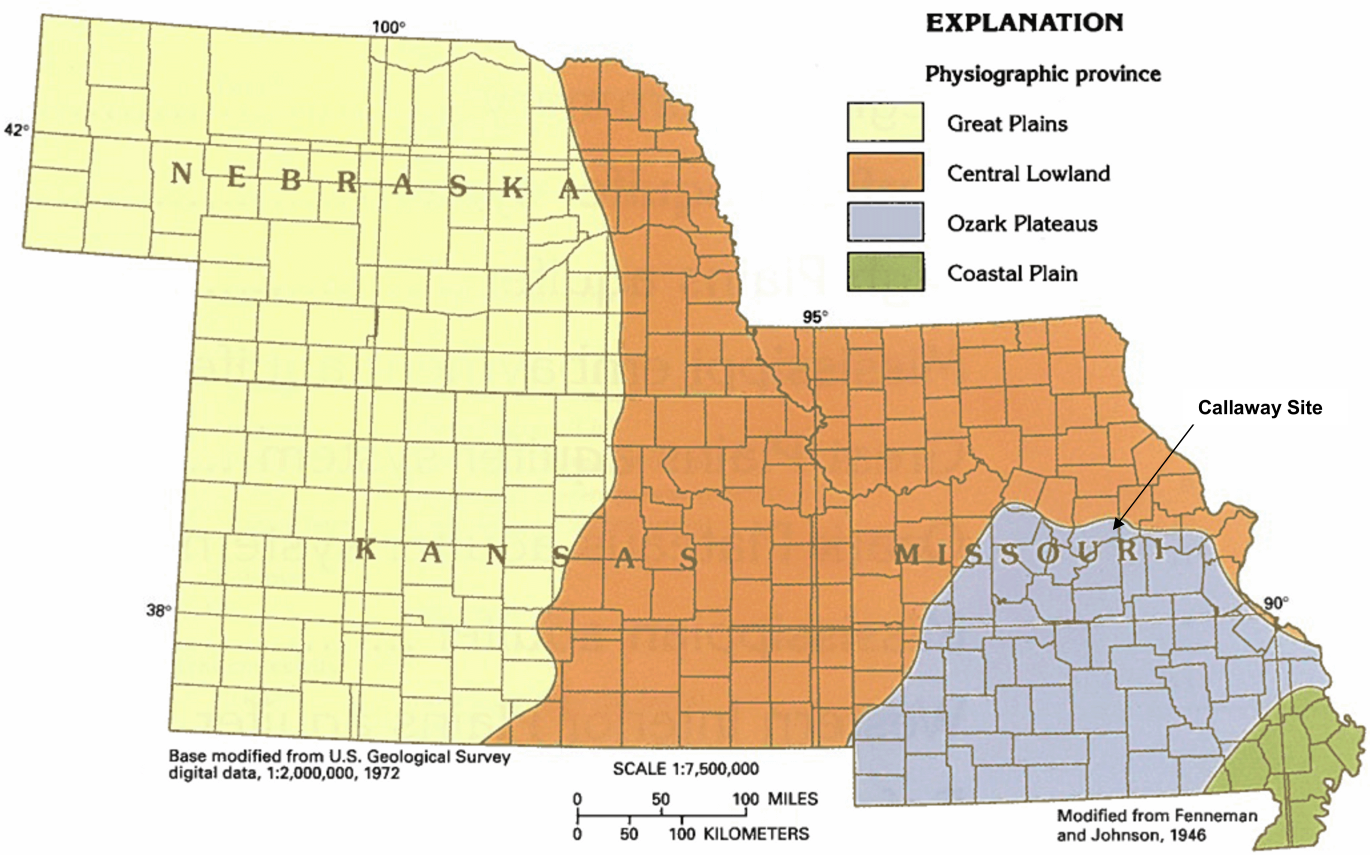


Figure 2.4-40—{Low Water Level Data of Hermann Station and Curve Fitting}



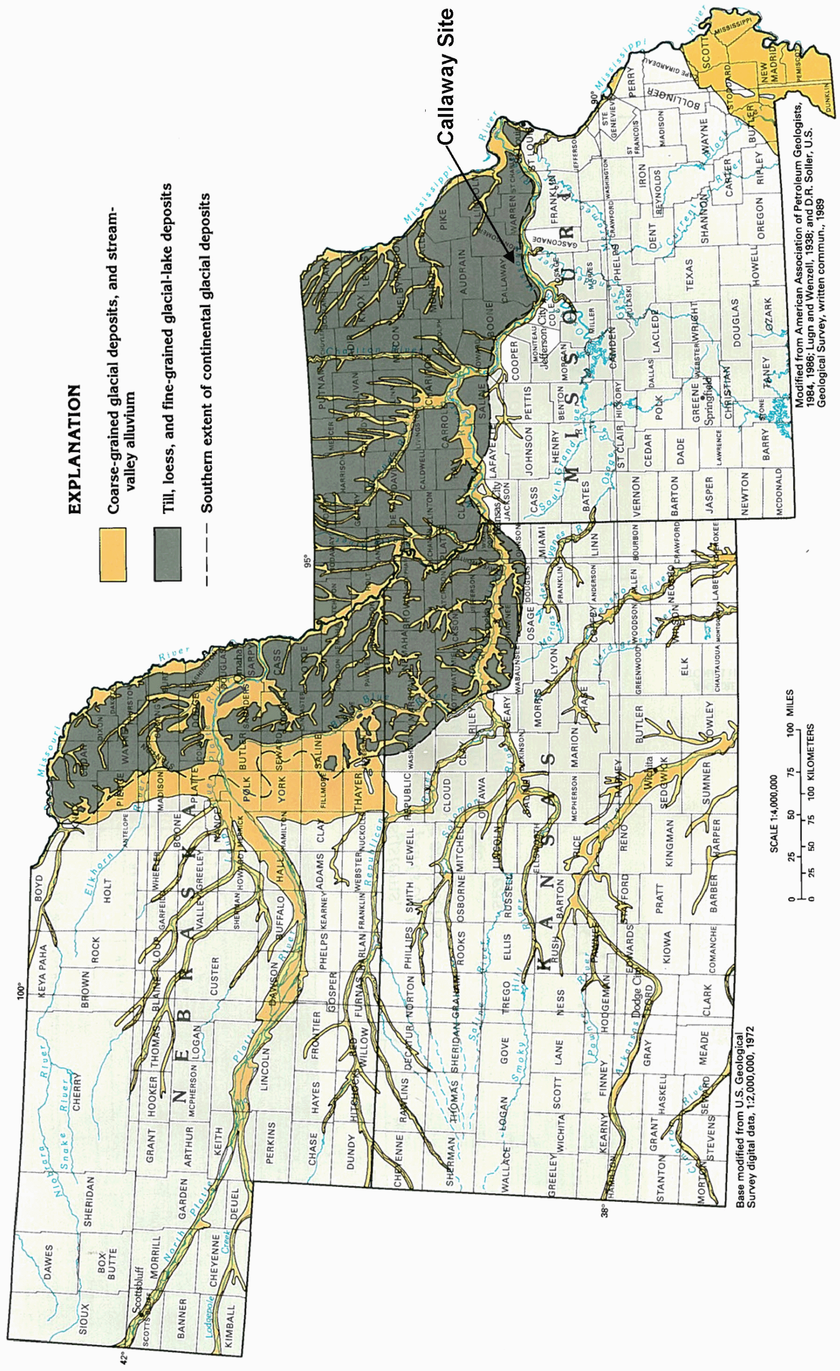
FSAR: Section 2.4

Figure 2.4-41—{Regional Physiographic Provinces}



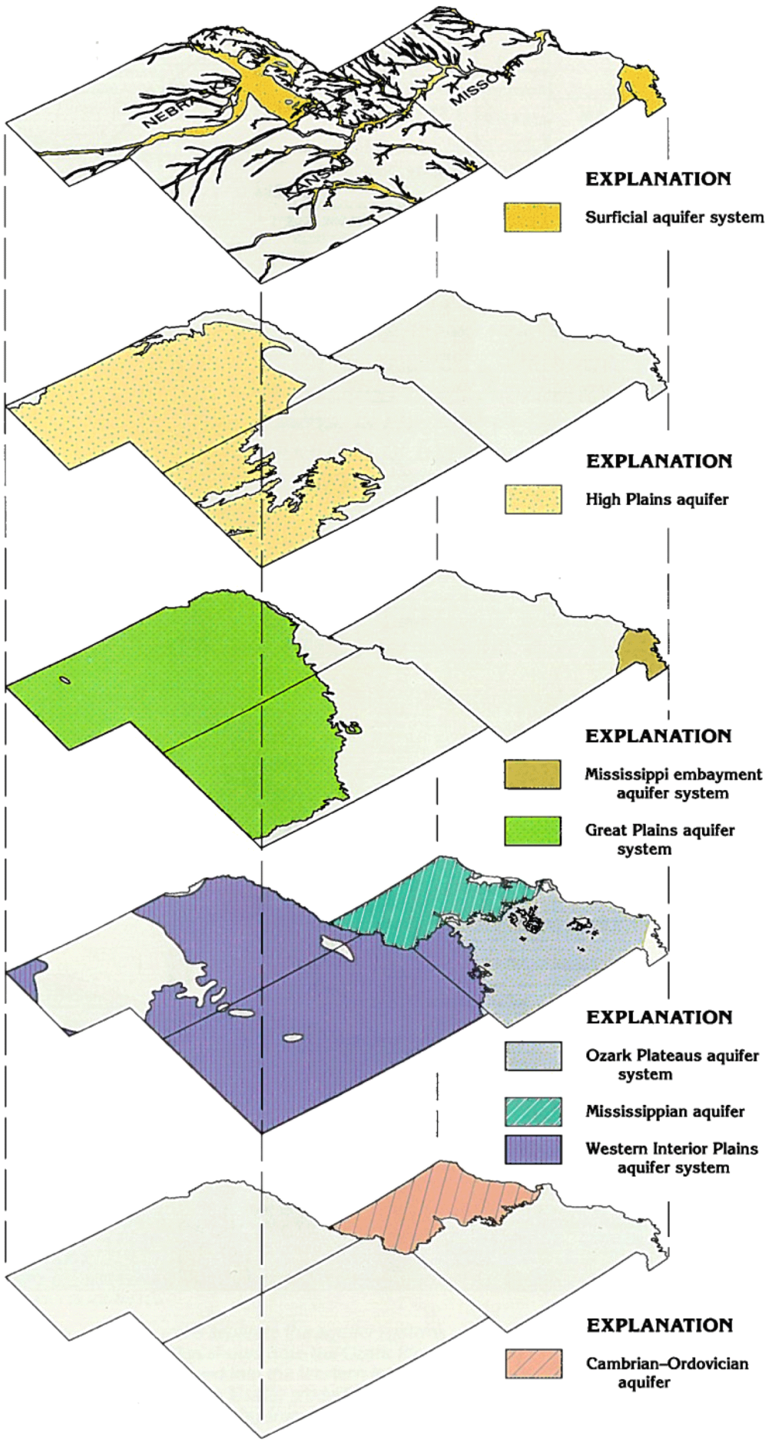
Reference: Groundwater Atlas of the United States, Segment 3, USGS, 1997.

Figure 2.4-42—{Regional Extent of Glaciation and Alluvium}



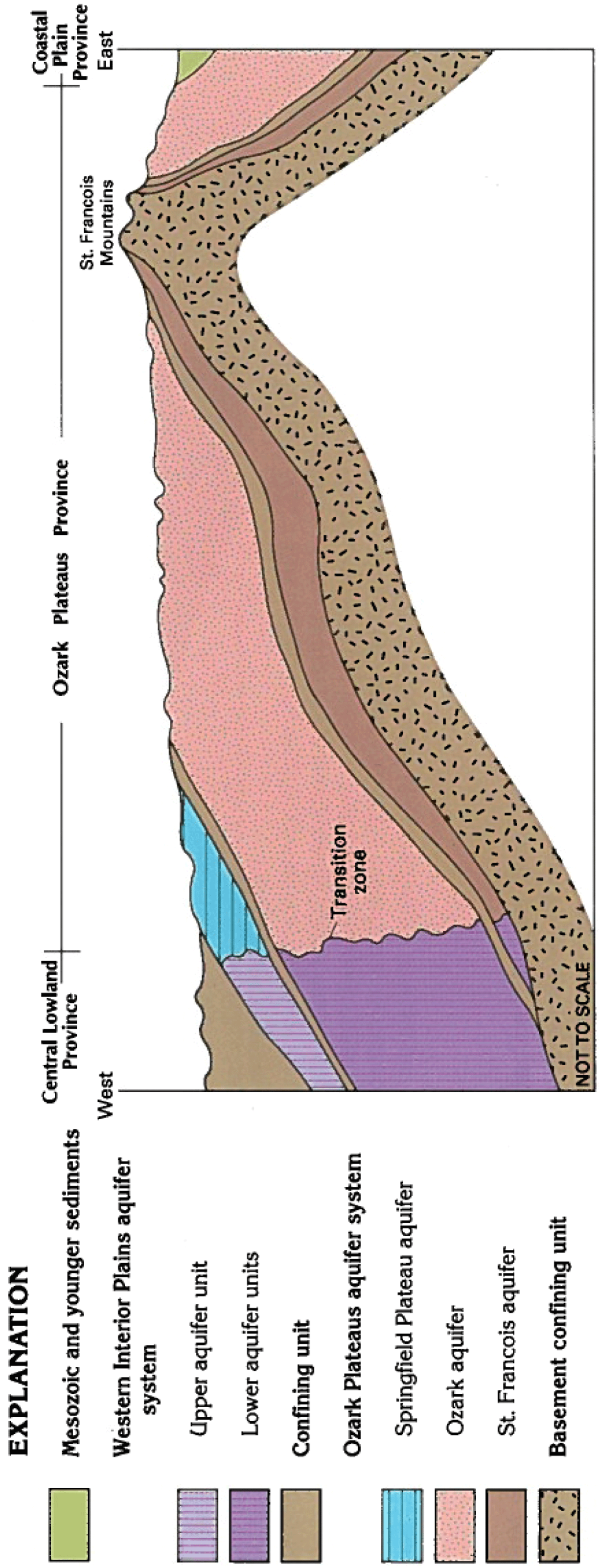
Reference: Groundwater Atlas of the United States, Segment 3, USGS, 1997.

Figure 2.4-43—{Regional Vertical Sequence of Aquifers}



Reference: Groundwater Atlas of the United States, Segment 3, USGS, 1997.

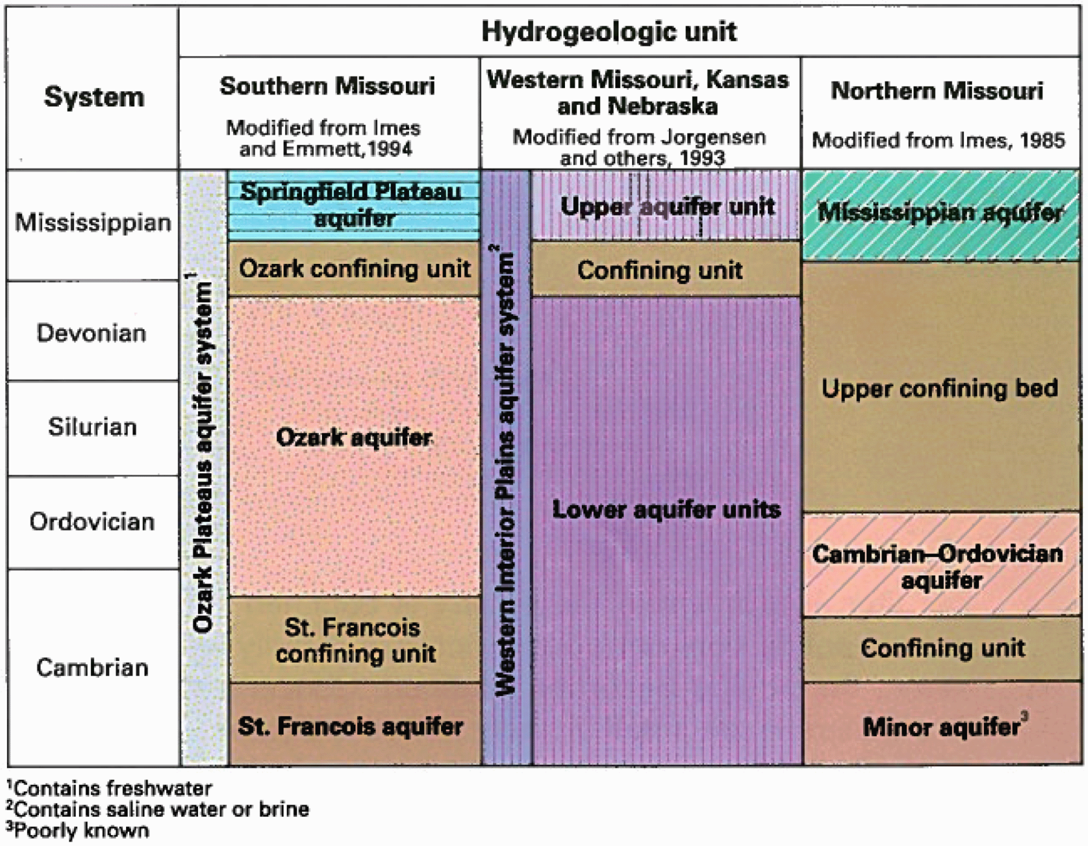
Figure 2.4-44—{Aquifer Systems of Missouri}



Note: This is a regionally generalized section. The Ozark Plateau aquifer system is present in southern Missouri. The Cambrian-Ordovician aquifer and overlying Mississippian aquifer are the corresponding aquifers in northern Missouri.

Reference: Groundwater Atlas of the United States, Segment 3, USGS, 1997.

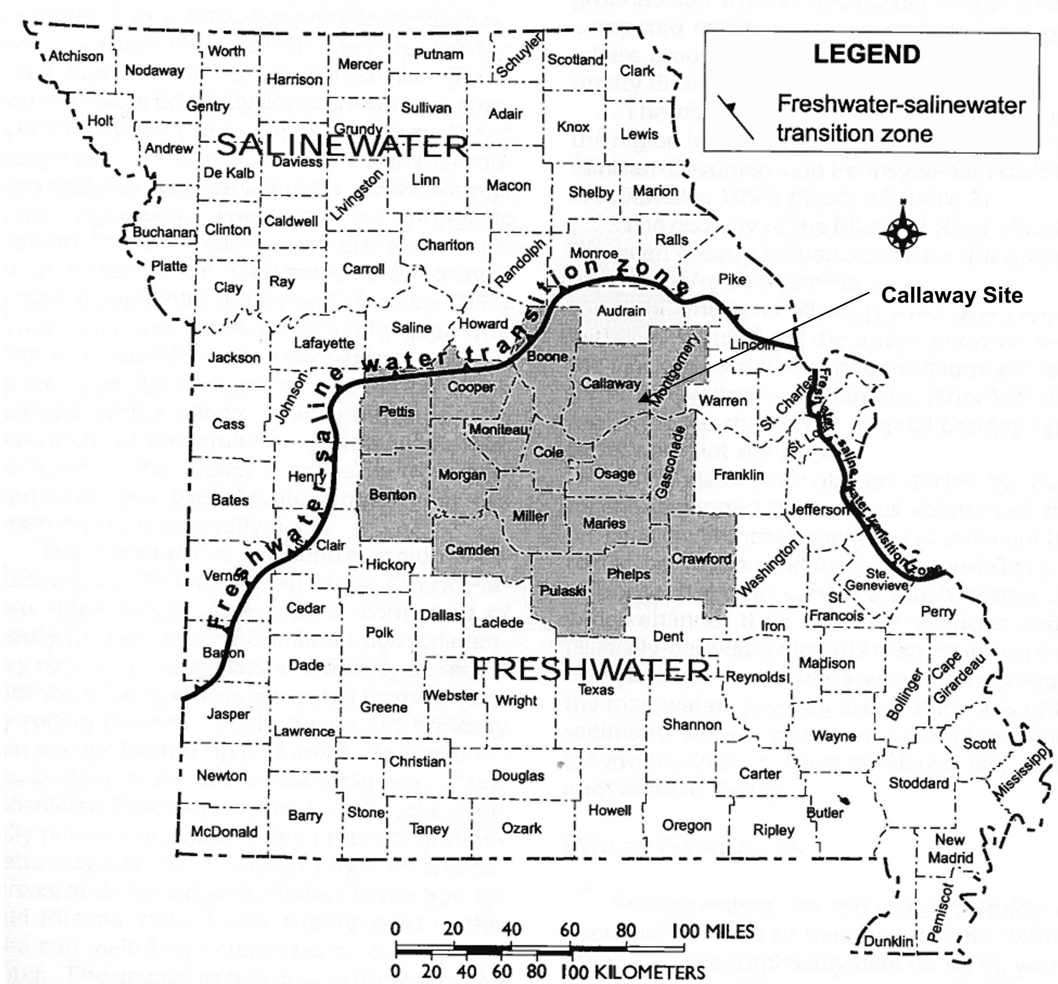
Figure 2.4-45—{Aquifer Systems of Northern, Western, and Southern Missouri}



Reference: Groundwater Atlas of the United States, Segment 3, USGS, 1997.

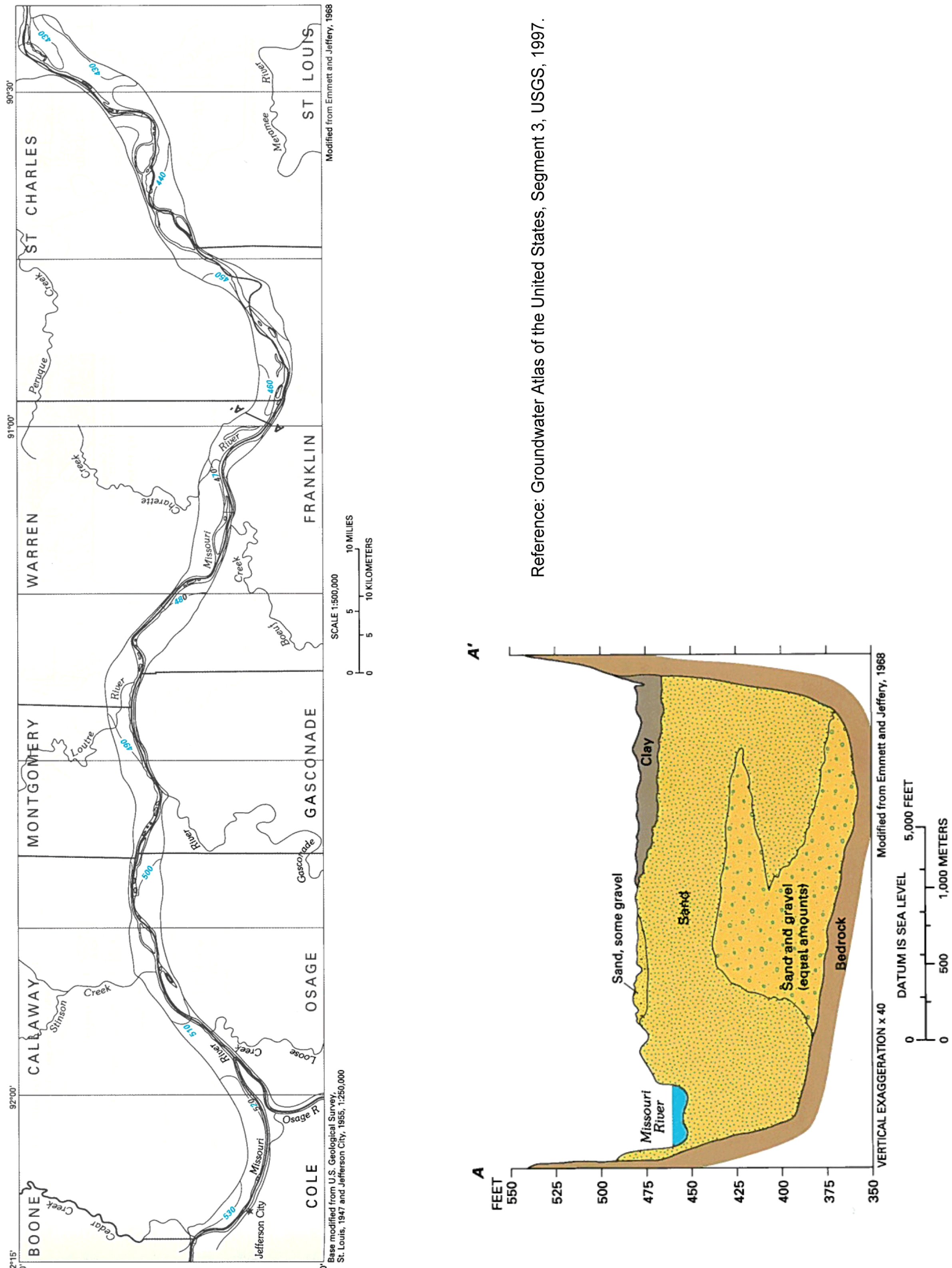
FSAR: Section 2.4

Figure 2.4-46—{MDNR Central Missouri Area and Groundwater Transition Zone}



Reference: Topics in Water Use: Central Missouri, MDNR, 2002.

Figure 2.4-47—{Missouri River and Alluvial Aquifer Section}



Reference: Groundwater Atlas of the United States, Segment 3, USGS, 1997.

Figure 2.4-48—{Hydrogeological Units}

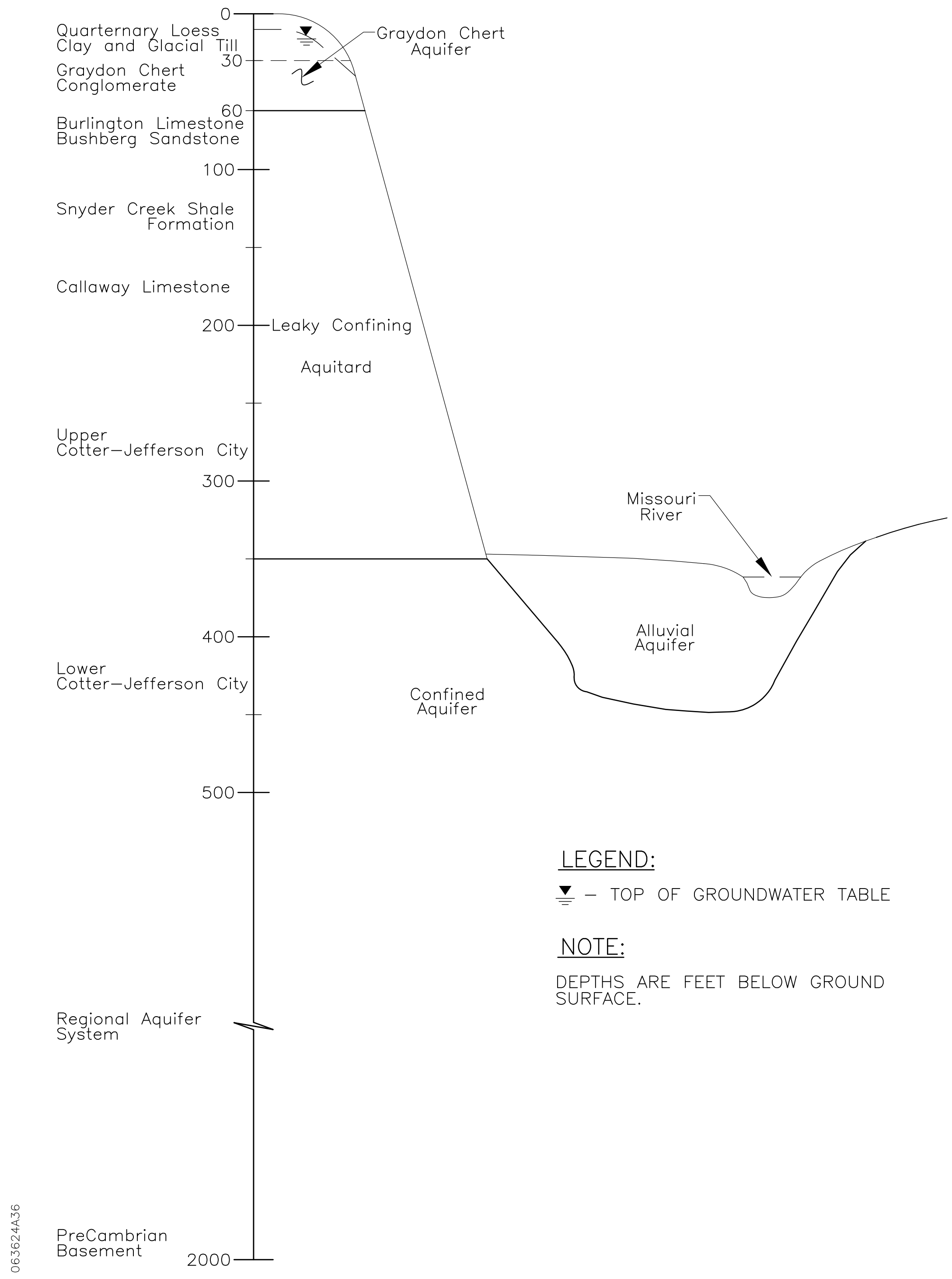
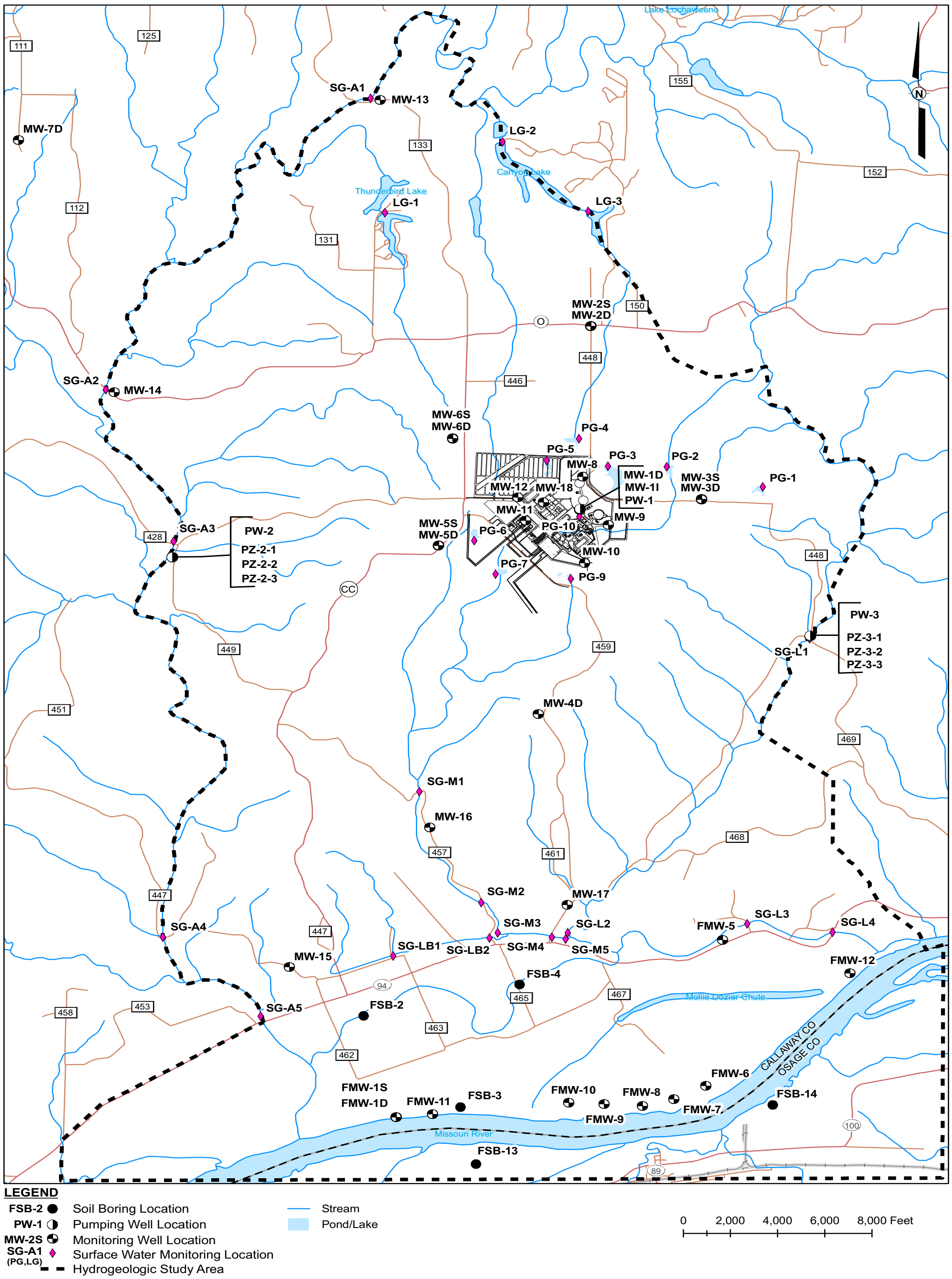
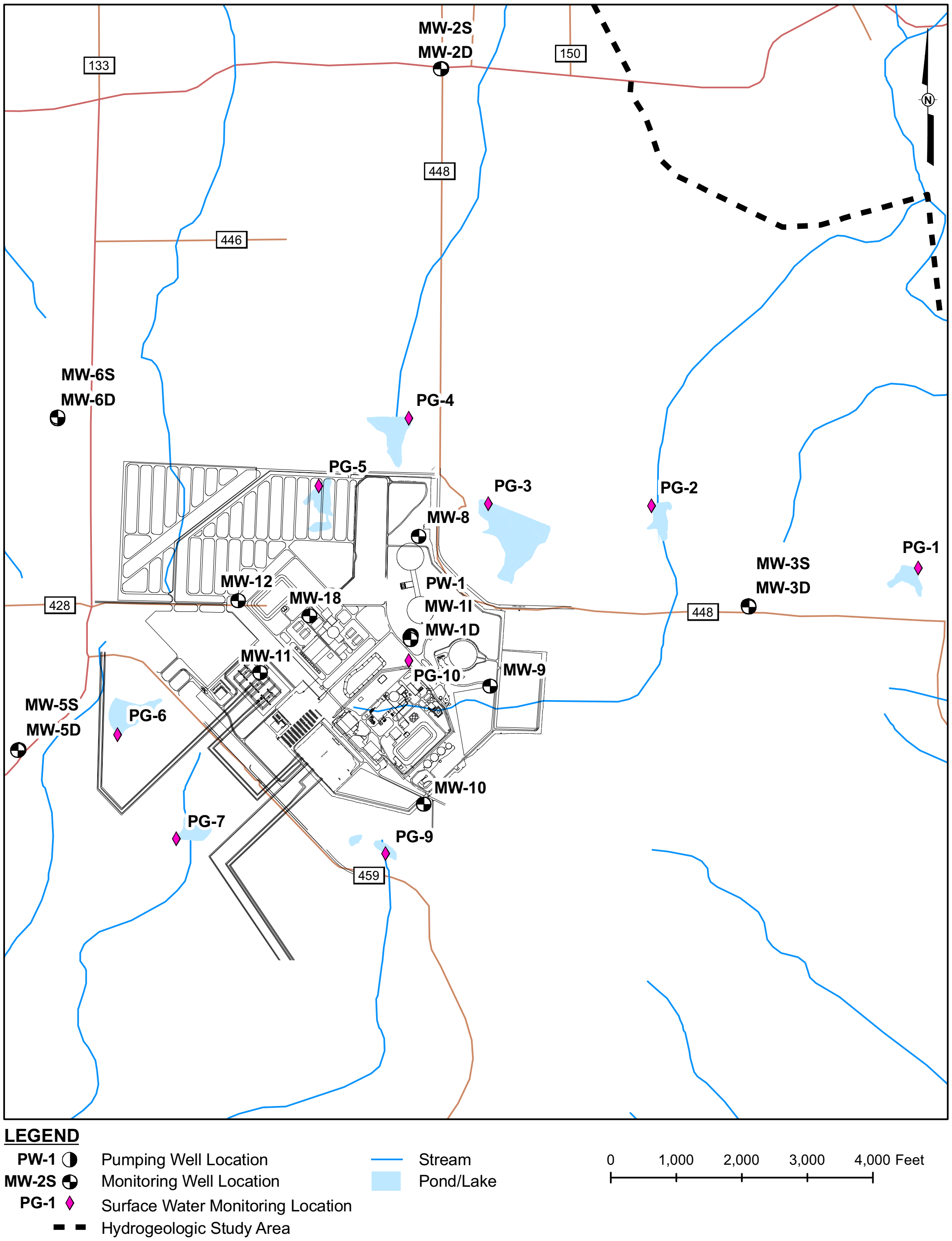


Figure 2.4-49—{Hydrogeologic Study Area with Site Investigation Locations}



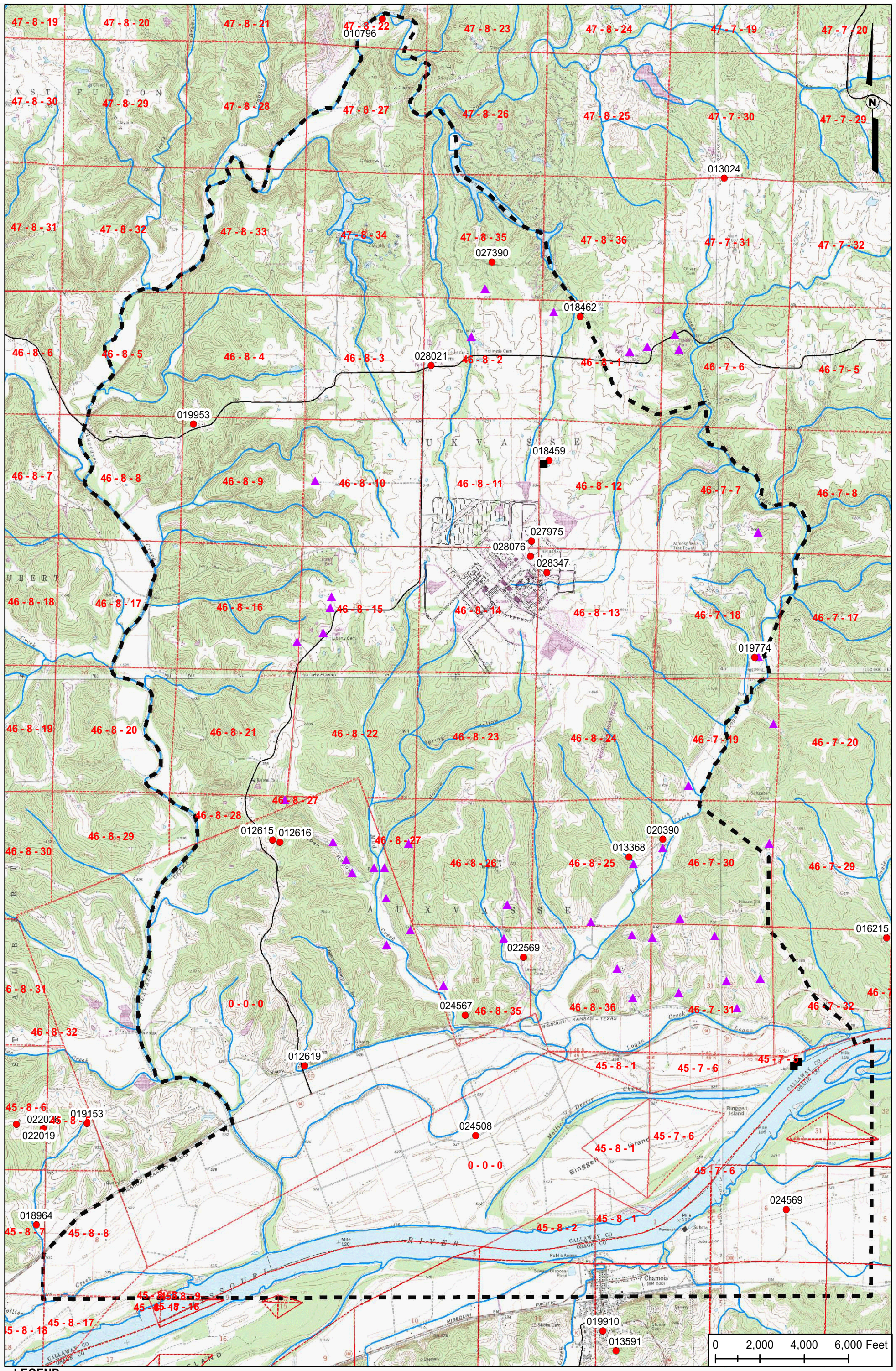
REFERENCES:
ESRI StreetMap Pro [CD-ROM), 2007,Roads & Railroad.
Ponds/Lakes delineated by MACTEC, March 17, 2007.
Streams downloaded from Missouri Spatial Data Information Service
(MSDIS) web site http://www.msdis.missouri.edu/. Accessed September 2007.

Figure 2.4-50—{Hydrogeologic Site Investigation Locations - Inset}



REFERENCES:
ESRI StreetMap Pro [CD-ROM}, 2007,Road & Railroad.
Ponds/Lakes delineated by MACTEC, March 17, 2007.
Streams downloaded from Missouri Spatial Data Information Service
(MSDIS) web site http://www.msdis.missouri.edu/. Accessed September 2007.

Figure 2.4-51—{Hydrogeologic Study Area Public and Private Wells}

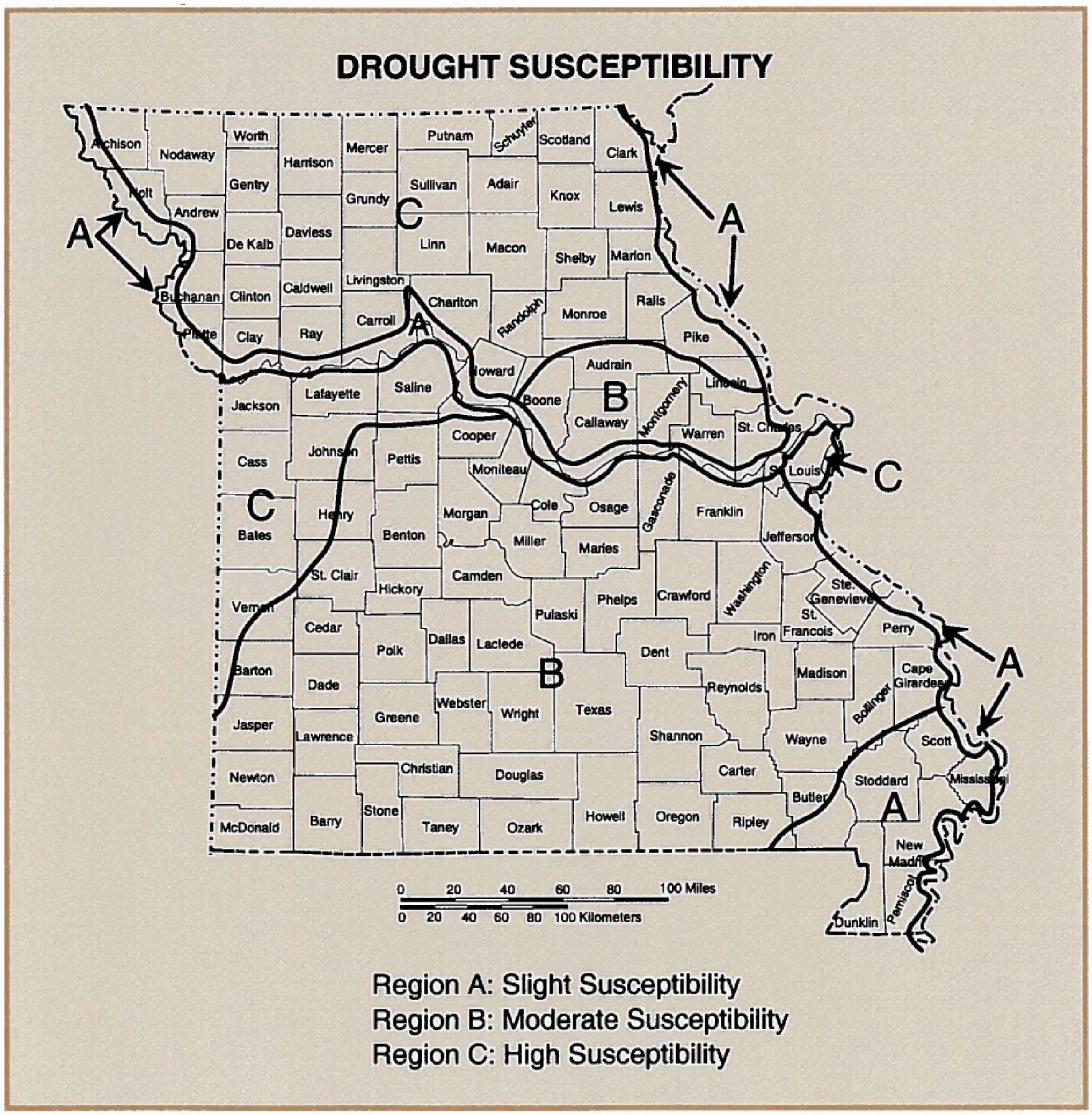


LEGEND

028076 MDNR Database Well
Land Use Survey Well
Ameren Confirmed Well
Hydrogeologic Study Area
Stream
46-8-14 Public Land Net Boundary (Township-Range-Section)

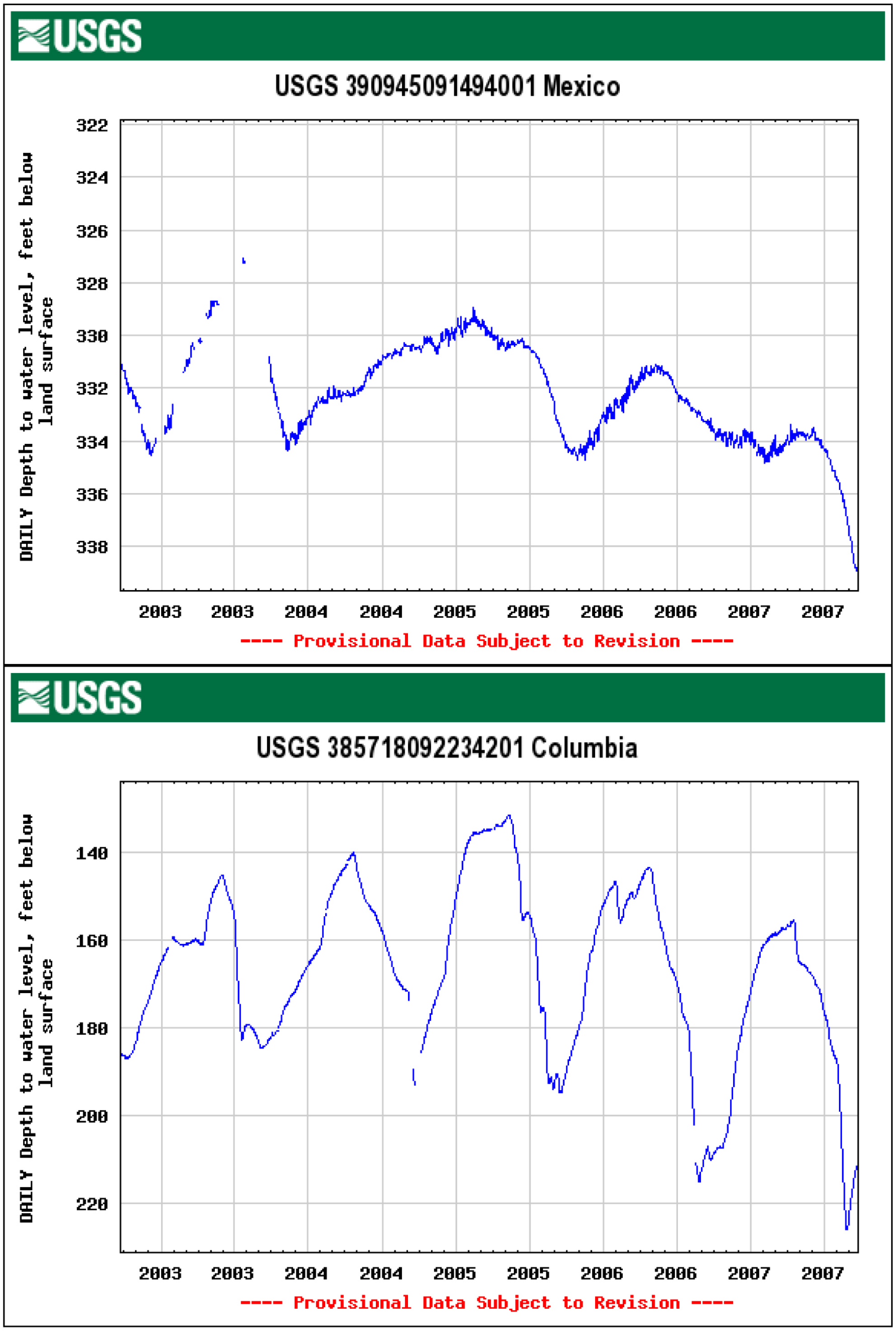
REFERENCE:
USGS 7.5-minute Quadrangles:
Mokane East, Morrison, Readsville, & Reform. Photo revised 1985.
2006 Land Use Census Report, Well Water Survey.
Communications with Ameren, Farm Well on County Road North of Cooling Tower, dated November 29, 2007.
Communications with Ameren, Intake Deep Well & Intake Shallow Well, both dated November 14, 2007
Missouri Spatial Data Information Service Website
http://www.msdis.missouri.edu/

Figure 2.4-52—{Missouri Drought Susceptibility}



Reference: Missouri Drought Plan, MDNR, 2002.

Figure 2.4-53—{Groundwater Monitoring Hydrographs, Audrain and Boone Counties}

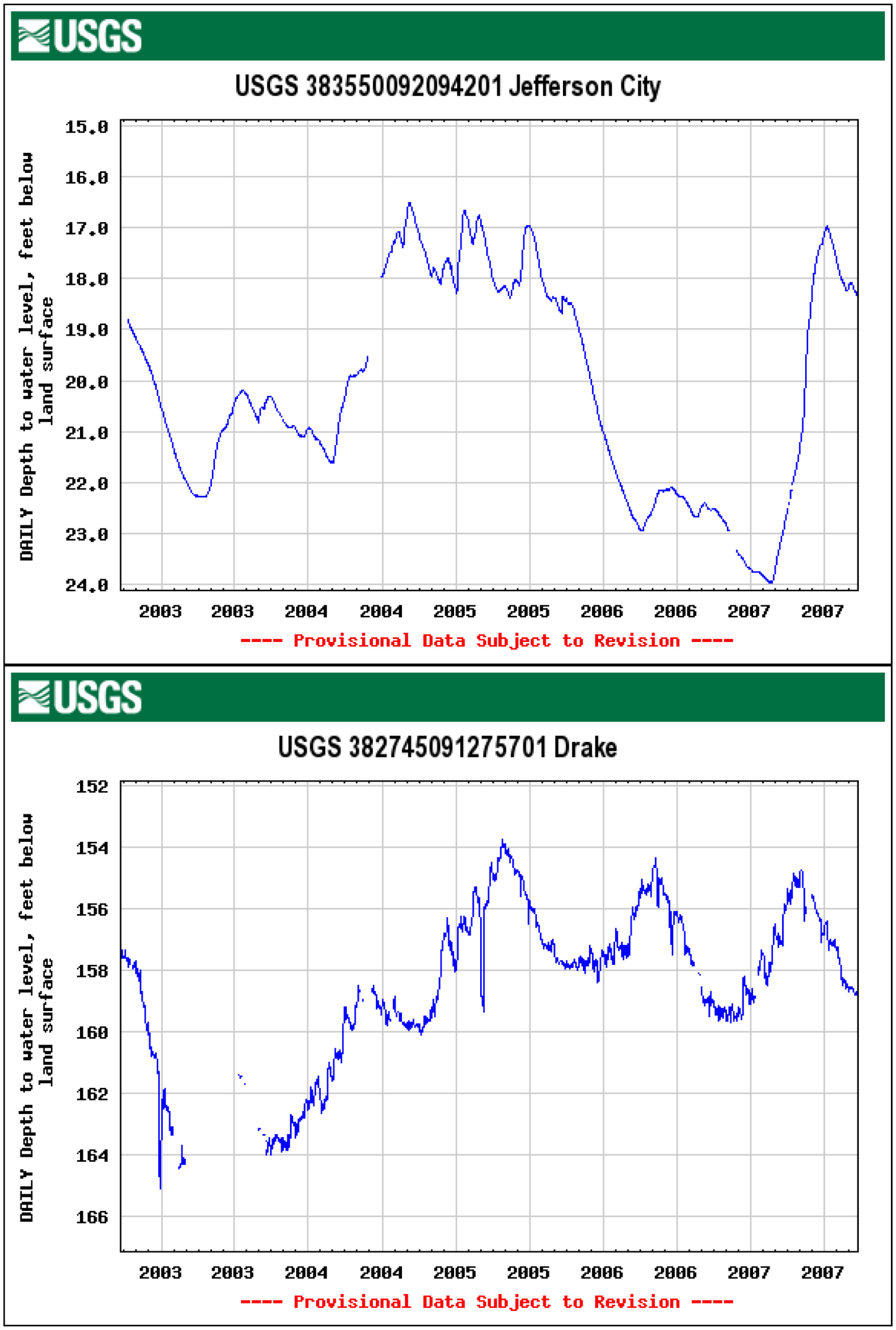


Audrain County

Boone County

Note: MDNR operates a water-level monitoring well network at sites throughout Missouri. The monitoring wells are equipped with data collection platforms that transmit the data to a GOES satellite which relays the data to a USGS Land Receiving Ground Station so that the data can be provided cooperatively by the DNR and USGS on a real-time basis. Reference: USGS National Water Information System, http://nwis.waterdata.usgs.gov/mo/nwis/, September 24, 2007.

Figure 2.4-54—{Groundwater Monitoring Hydrographs, Callaway and Gasconade Counties}

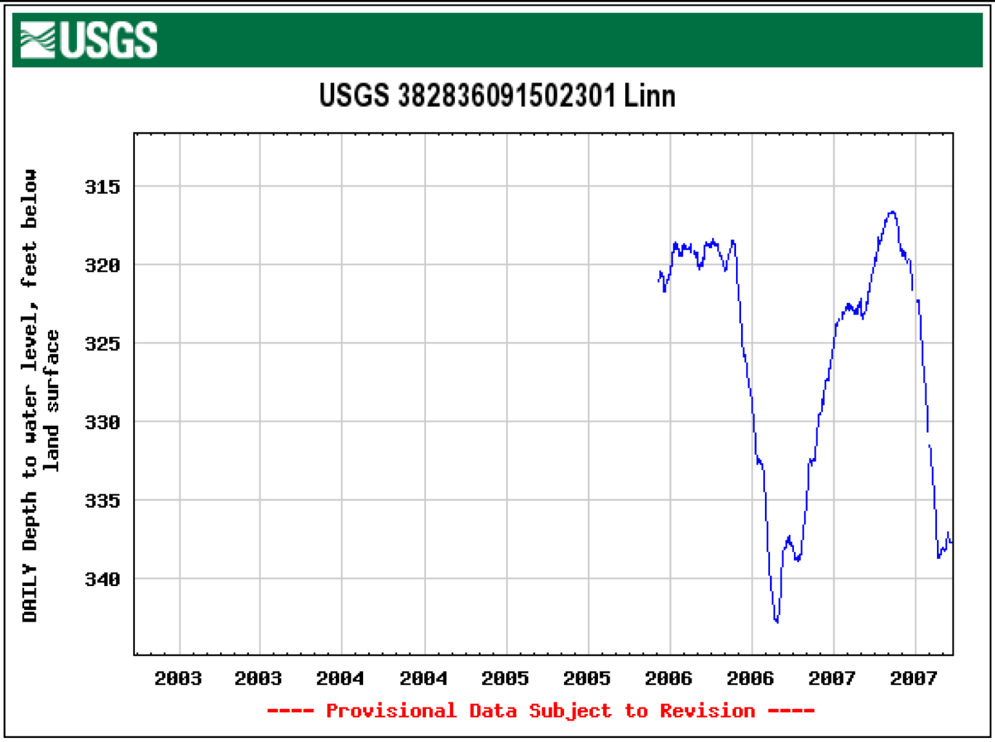


Callaway County

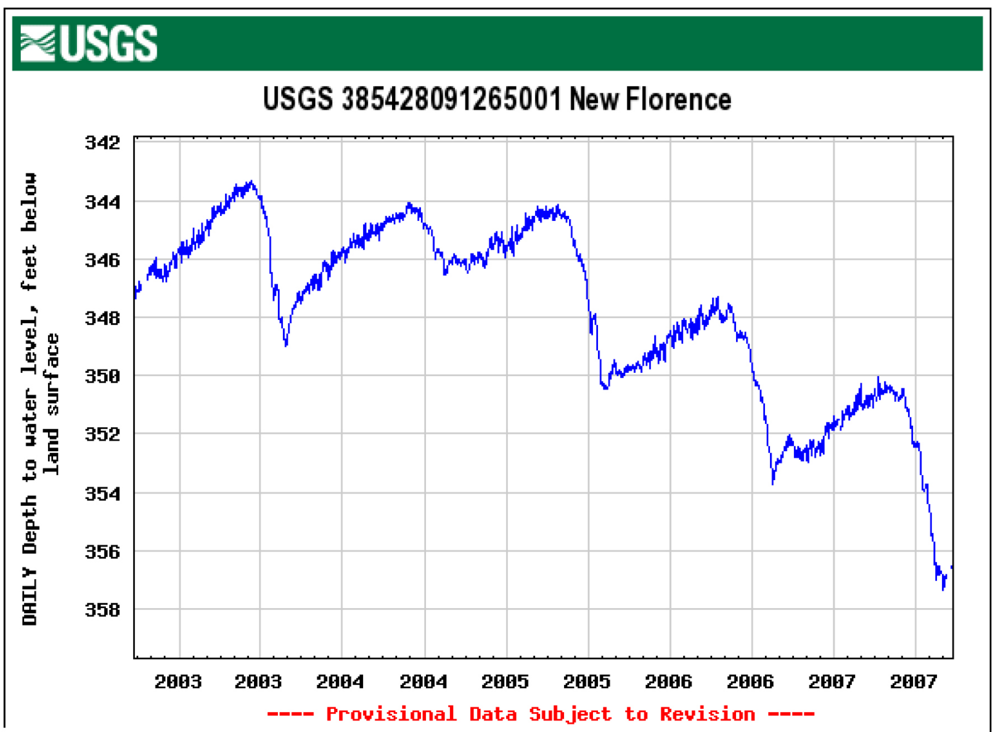
Gasconade County

Note: MDNR operates a water-level monitoring well network at sites throughout Missouri. The monitoring wells are equipped with data collection platforms that transmit the data to a GOES satellite which relays the data to a USGS Land Receiving Ground Station so that the data can be provided cooperatively by the DNR and USGS on a real-time basis. Reference: USGS National Water Information System, http://nwis.waterdata.usgs.gov/mo/nwis/, September 24, 2007.

Figure 2.4-55—{Groundwater Monitoring Hydrographs, Montgomery and Osage Counties}



Montgomery County

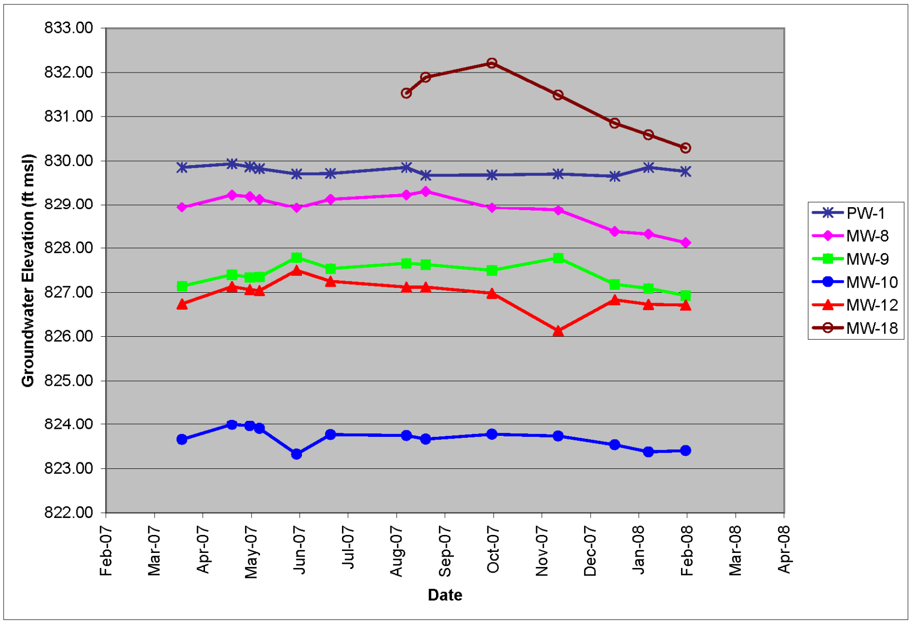


Osage County

Note: MDNR operates a water-level monitoring well network at sites throughout Missouri. The monitoring wells are equipped with data collection platforms that transmit the data to a GOES satellite which relays the data to a USGS Land Receiving Ground Station so that the data can be provided cooperatively by the DNR and USGS on a real-time basis. Reference: USGS National Water Information System, http://nwis.waterdata.usgs.gov/mo/nwis/, September 24, 2007.

FSAR: Section 2.4

Figure 2.4-56—{Groundwater Elevation versus Time, Graydon Chert Aquifer Wells}



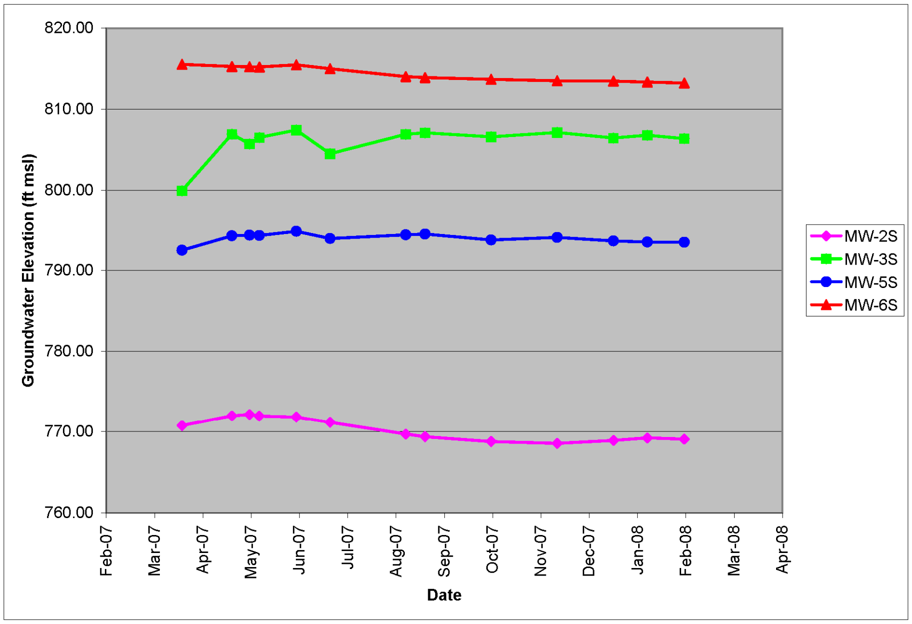
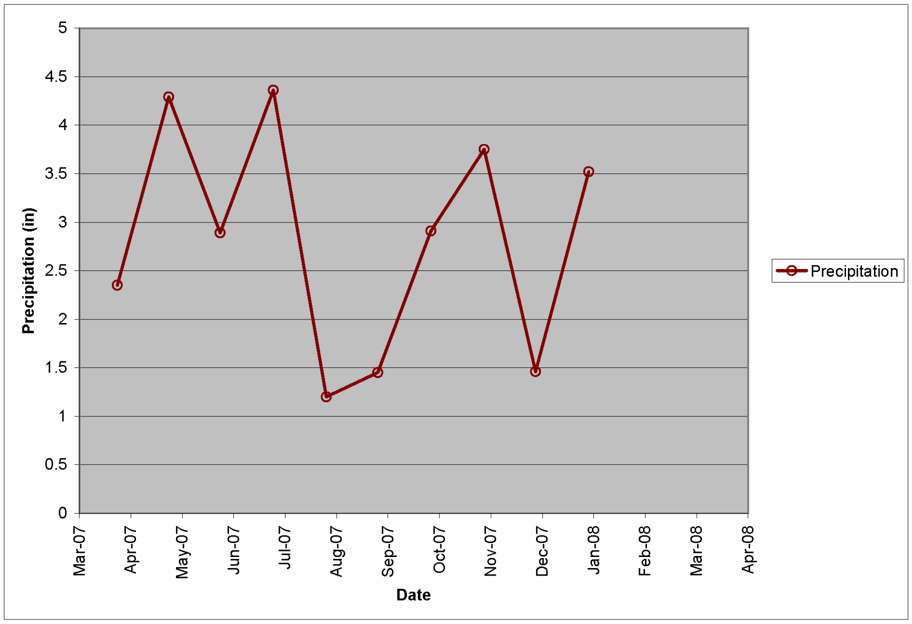
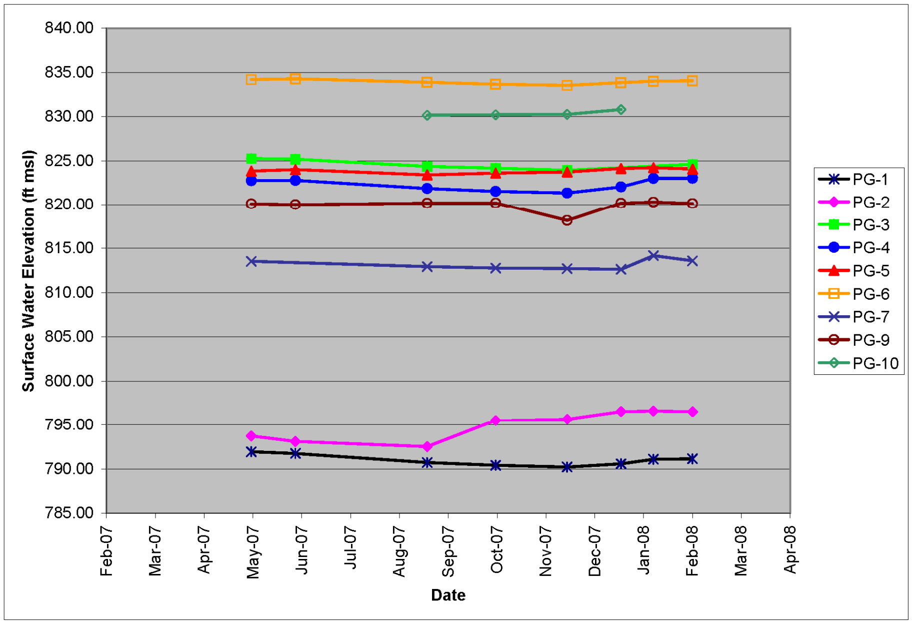


Figure 2.4-57—{Precipitation versus Time, Columbia Regional Airport Station}



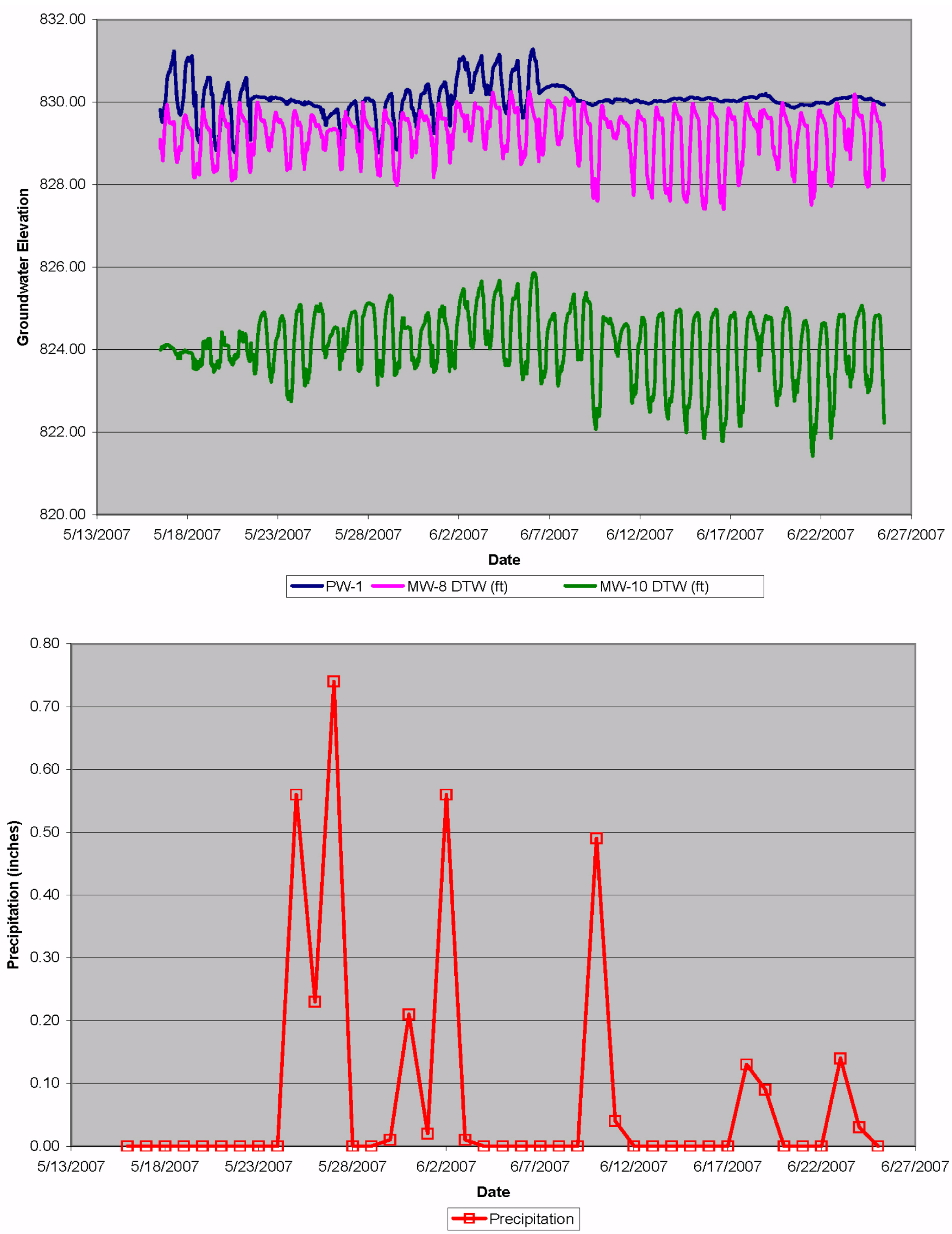
Note: The Columbia Regional Airport Station is located approximately 25 miles from the Callaway site.

Figure 2.4-58—{Surface Water Elevation versus Time, Plateau Ponds}



FSAR: Section 2.4

Figure 2.4-59—{Groundwater Elevation and Precipitation versus Time}



Note: Precipitation was measured with an on-site rain gauge.

Figure 2.4-60—{Potentiometric Surface Map, Graydon Chert Aquifer, May 2007}

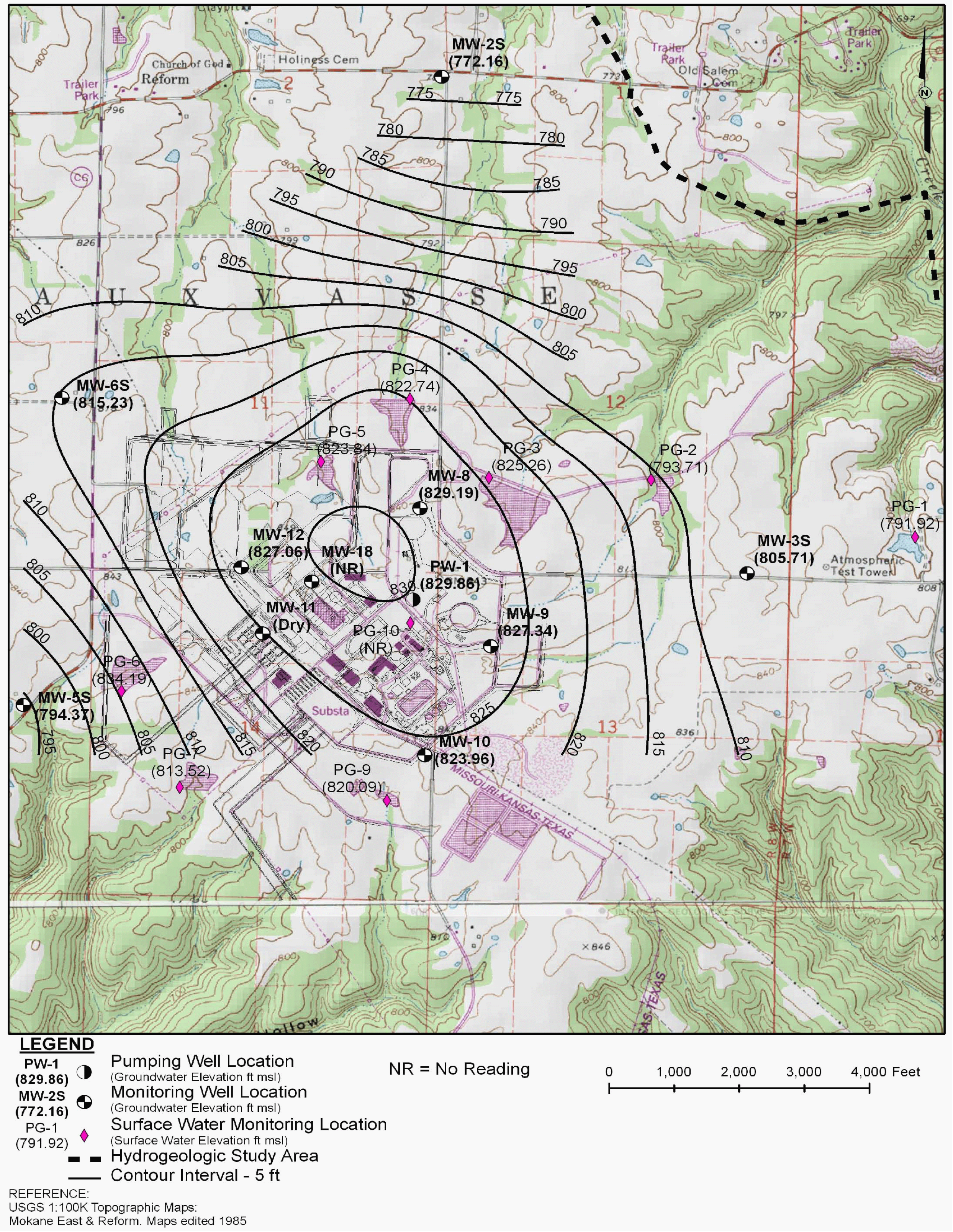


Figure 2.4-61—{Potentiometric Surface Map, Graydon Chert Aquifer, August 2007}