TABLE OF CONTENTS

4.19 INUNDATION DUE TO DAM FAILURE

In addition to other impacts for the Project components described in this Chapter, this section of the EIR/EIS addresses the potential for inundation from dam failure at the reservoir sites.

Storage reservoirs dams will be designed and constructed in accordance with the state Division of Safety of Dams. The potential for dam failure caused by a seismic event, unstable slope conditions, or damage from corrosive or expensive soils is extremely remote. Nonetheless, the potential impact on the storage reservoirs dams from one of these events has been evaluated.

PROBABILITY OF DAM FAILURE

Since 1929, following the catastrophic failure of the St. Francis dam, the State of California has assumed jurisdiction over the design, construction, and operation of dams in California to prevent failure and to safeguard life and protect property. The California Department of Water Resources, Division of Safety of Dams is the regulatory agency charged with that mission. Refer to Section 4.3 Geology, Soils, and Seismicity regulatory framework discussion, for information about the Division's jurisdiction and legislative mandate. The Project will be required to meet the design, construction, and operational standards of safety established by the Division. Adherence to these standards greatly reduces the probability of dam failure and is protective of public safety (Head 1996).

California has the most stringent dam safety design and construction review standards in the country. The requirements for siting, engineering, construction, and monitoring of dams and reservoirs are continually improved as knowledge of how and why dams fail increases. Since the Division of Safety of Dams was established, three notable dam failures have occurred in California. These are discussed below. One of the three (Baldwin Hills Reservoir) resulted in loss of life.

Subsequent to the major earthquake damage at the Lower Van Norman Dam in 1971, the Division of Safety of Dams began a seismic rehabilitation program wherein existing dams, including those built before 1929, are inspected for earthquake resistance and remedial action is ordered if necessary. Division of Safety of Dams may order dam owners to reduce the volume of water stored in a reservoir, to drain reservoirs completely, or to develop and implement a seismic reinforcement plan. New dams are designed to withstand the maximum expected earthquake forces calculated for the proposed site.

Several dams were damaged during the 1989 Loma Prieta earthquake (magnitude 7.1). Austrian Dam, which impounds Lake Elsman west of San Jose, sustained significant damage. This dam was built in 1949 and since the earthquake has been rehabilitated. Many of the reservoirs in California were at low levels during the late 1980s due to a

prolonged drought. None of the dams that were damaged during the Loma Prieta Earthquake failed catastrophically, no uncontrolled releases of water occurred, and no loss of life resulted (Harder, no date).

Damage to earthen dams in California is often associated with poor operation and maintenance of dam facilities or with strong earthquake-induced ground shaking affecting older dams that have not been designed to modern standards. The risk of dam failure is highest in older dams built to lower design standards that have not been upgraded for seismic safety and when dams are poorly designed, constructed, operated, or maintained. Lack of proper maintenance and monitoring or inappropriate modifications to older structures are often contributing factors in dam failure (Jansen 1988). Maintenance, surveillance, and preparedness for emergencies are recognized as important activities that insure the safety of dams.

During operation, the reservoirs will be visually inspected on a regular basis to ensure that the embankments, control structures, access roads, and monitoring instrumentation are maintained. Impediments will be removed from the spillway and other control structures as soon as they are observed.

Seven of the reservoir sites, except Tolay and Sears Point, are located in small watersheds that have a drainage area of less than three square miles. Reservoirs located within larger watersheds, Tolay (5.3 square miles) and Sears Point (9.5 square miles) are designed with drainage diversion facilities that allow the major portion of the watershed runoff to be collected and conveyed to Tolay Creek downstream of the dams. The drainage diversion facilities effectively reduce runoff inputs into the reservoir. The reservoirs' spillways have been designed to accommodate the probable maximum flood[1], and 15 feet of freeboard (storage capacity which is not used for normal operations) between the dam spillway elevation and the crest of the dam has been included as a design feature.

Prior to dam construction, alluvium and colluvium will be excavated from the footprint of the dam and dam structures will be founded on bedrock (refer to the Chapter 3, Description of Existing System and Alternatives and Section 4.3, Geology, Soils, and Seismicity for a discussion of reservoir construction methods and potential impacts). Embankments will be designed to key into the foundation and structures will be designed to withstand the maximum anticipated ground acceleration at the site.

The dam and reservoir design will eliminate the possibility of failure by the major causes of dam failure. Overtopping will be preempted because dams will be sited in small tributary watersheds and spillways will be sized to accommodate the probable maximum flood. The possibility of foundation failure would be reduced by construction on a bedrock foundation and installation of an internal drainage system. Modern design and

[1] The Maximum Probable Flood (MPF) is a design flood frequency that is determined using statistical methods. The MPF Value should represent the largest flow that the reservoir spillway is likely to receive. The value is determined by using maximum historical precipitation values and determining the maximum runoff at the peak of the hydrograph.

construction, bedrock foundation[2], and conservative freeboard[3] would preempt serious earthquake damage. The Division of Safety of Dams requires appropriate instrumentation and monitoring and submittal of annual reports.

A probability analysis performed for a planned reservoir in Southern California *(The Reliability Analysis for a Major Dam Project)* indicates that the probability of failure of that dam was small (one in a billion). However, no similar analysis has been performed for the dams proposed for this Project and there remains a possibility that dam failure could occur and that inundation of areas downstream of the dam could result.

As discussed in Measure 2.2.14, the State requires that an inundation map be prepared for any dam which either is 25 feet or more in height or impounds 50 acre feet or more of water (California Water Code, §8589.5). The map is submitted by the dam owner to the Office of Emergency Services for review and approval. Following approval, the Office of Emergency Services transmits the map to the appropriate local government, which is required to produce evacuation plans within six months.

HYDROLOGIC AND HYDRAULIC ANALYSIS

To meet Office of Emergency Services requirements, hydrologic and hydraulic analysis was performed to estimate the approximate depth of flooding and approximate limits of inundation caused by a main dam break at each of ten proposed reservoir sites. For each reservoir, five breaching alternatives were analyzed; 15 minute failure of the full dam; 3 hour failure of the full dam; 15 minute failure of part of the dam; 3 hour failure of part of the dam; and 12 hour failure of part of the dam. It was assumed that, for purposes of these analyses, the initial water level in each reservoir was at the spillway crest elevation. The peak stage elevations, flooding depths, and inundation limits were calculated using the flood hydrograph computer model HEC-1 developed by the U.S. Army Corps of Engineers. Because the spillway for each dam would be designed to handle the Probable Maximum Flood, it was assumed that the dams would not be overtopped during the Probable Maximum Flood. Therefore, an overtopping analysis was not conducted.

At several sites there are one or more supplementary side dams in addition to the main dam. However, only the main dam was analyzed (except at Tolay Confined where the back dam was also analyzed) since failure of these back dams would result in the largest flood levels.

Based on the modeling results for each reservoir, the flood inundation limit for the catastrophic case scenario (failure of the full dam within 15 minutes) for each reservoir was plotted on USGS base maps. The flood inundation limits for the catastrophic for each reservoir are:

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[2] A bedrock foundation prevents damage from liquefaction.

[3] Adequate freeboard would allow the reservoir to safely retain the maximum storage capacity even if earthquake-induced settlement were to occur.

Tolay Extended

The Tolay Extended main dam would be sited on Tolay Creek southeast of the intersection of Highway 116 and Lakeville Highway. Discharge from the reservoir would flow down Tolay Creek to San Pablo Bay. The worst case scenario dam break would cause Tolay Creek to flood buildings in the vicinity of Sears Point and scattered buildings along Highway 121 and on Tubbs Island. State Highways 37 and 121, which are important transportation corridors, could be inundated. The estimated maximum water level at Sears Point would be 11 feet.

Adobe Road

The Adobe Road dam would be sited on Washington Creek upstream of the City of Petaluma. Discharge from the reservoir would flow down Washington Creek through Petaluma to the Petaluma River. A 15 minute dam failure would cause the inundation of most of Petaluma between Ely Road and the Petaluma River. Numerous public facilities, including schools, fire stations, one airport, and drinking water supplies are situated within the inundation area of the Adobe Road reservoir. The City of Petaluma's water tanks and the Old Adobe School, located near the intersection of Adobe Road and East Washington Boulevard, lie in the center of the flood inundation area and would be the first facilities reached by the flood waters. The estimated maximum water depth would range between 7 feet and 17 feet within Petaluma.

Tolay Confined

The Tolay Confined main dam would be sited in the same location as the Tolay Extended dam. Discharge and flooding would be similar, but the estimated maximum water level at Sears Point would be 12 feet.

Tolay Confined Back Dam

In addition to the analysis conducted for the main dams, an analysis was conducted for the Tolay Confined back dam. The discharge would backup beyond the headwaters of Tolay Creek and flow down a creek along the south side of Adobe Road and down to the Petaluma River near Browns Lane and Lakeville Highway. Also, the water would flow over a saddle north of Cannon Lane and into a tributary of Stage Gulch Creek. Most of the flooding would be limited to areas adjacent to the two creeks. However, several buildings near the Lakeville School would also be flooded.

Lakeville Hillside

The Lakeville Hillside dam would be sited on a tributary of the Petaluma River near Lakeville Highway and Hog Island. Discharge from the reservoir would flow down the tributary into the Petaluma River and from there into San Pablo Bay. The 15-minute dam break scenario would cause flooding between Lakeville Highway and the Petaluma River. No towns would be inundated and few buildings would be flooded. The estimated maximum water depth would be 30 feet at Lakeville Highway.

Sears Point

The Sears Point dam would be sited on Tolay Creek northwest of the intersection of Highways 37 and 121. Discharge from the reservoir would flow down Tolay Creek to San Pablo Bay. The worst case scenario dam break would cause Tolay Creek to flood buildings in the vicinity of Sears Point and scattered buildings along Highway 121 and on Tubbs Island. State Highways 37 and 121, which are important transportation corridors, could be inundated. The estimated maximum water level at Sears Point would be less than 5 feet.

Two Rock

The Two Rock dam would be sited a tributary of Stemple Creek north of Two Rock in the Roblar de la Miseria. Discharge from the reservoir would flow down the tributary into the main branch of Stemple Creek near Two Rock. From there, the water would flow through Marin County into the Estero de San Antonio to Bodega Bay. The worst case scenario dam break would cause Stemple Creek to flood the town of Two Rock. The flood waters would also back up Stemple Creek and would flood scattered buildings near Two Rock School. The Two Rock School and the Two Rock Fire Station lie on the edge of the flood inundation. Portions of the Coast Guard Reservation also appear to lie in the flood inundation area of the Two Rock Reservoir. The flood waters would back up several tributaries to Stemple Creek and Estero de San Antonio and would flood several buildings between Two Rock and Bodega Bay. The estimated maximum water depth at Two Rock would be 80 feet.

Bloomfield

The Bloomfield dam would be sited on a tributary of Americano Creek northwest of the town of Bloomfield. Discharge from the reservoir would flow down the tributary to the main branch of Americano Creek. From there, the discharge would flow down past the town to Bodega Bay. The dam break scenario would cause Americano Creek to inundate the town of Valley Ford. The flood waters would also back up into Americano Creek, Bloomfield Creek, and Ebabias Creek, as well as several other tributaries to Americano Creek. The backup along Americano Creek and Bloomfield Creek would inundate most of the town of Bloomfield. The Valley Ford and Bloomfield Fire Stations are the major public facilities that lie within the flood inundation area. There are other buildings scattered along Americano Creek that would be inundated. The estimated maximum water depth would be 13 feet at Valley Ford and 20 feet at Bloomfield.

Carroll Road

The Carroll Road dam would be sited on a tributary of Americano Creek between the towns of Bloomfield and Valley Ford. Discharge from the reservoir would flow down the tributary to the main branch of Americano Creek. From there, the discharge would flow down past Valley Ford to Bodega Bay. The 15 minute dam break scenario would cause Americano Creek to inundate the town of Valley Ford. The flood waters would

also back up Americano Creek, Bloomfield Creek, and Ebabias Creek, as well as several other tributaries to Americano Creek. The backup along Americano Creek and Bloomfield Creek would inundate most of the town of Bloomfield. The Valley Ford and Bloomfield Fire Stations are the major public facilities that lie within the flood inundation area. There are other buildings scattered along Americano Creek that would be inundated. The estimated maximum water depth would be 17 feet at Valley Ford and 26 feet at Bloomfield.

Valley Ford

The Valley Ford dam would be sited on a tributary of Americano Creek in the Canada de Pogolimi area northeast of Valley Ford. Discharge from the reservoir would flow down the tributary to the main branch of Americano Creek. From there, the discharge would flow down past Valley Ford to Bodega Bay. The 15 minute dam break scenario would cause Americano Creek to inundate the town of Valley Ford. The flood waters would also back up Estero Americano Creek, Bloomfield Creek, and Ebabias Creek, as well as several other tributaries to Estero Americano Creek. The backup along Estero Americano Creek and Bloomfield Creek would inundate part of the town of Bloomfield. The Valley Ford and Bloomfield Fire Stations are the major public facilities that lie within the flood inundation area. There are other buildings scattered along Americano Creek that would be inundated. The estimated water depth would be approximately 15 feet at Valley Ford and approximately 17 feet at Bloomfield.

Huntley

The Huntley dam would be sited on a tributary of Stemple Creek along Martinoni Road near the Sonoma-Marin County line. Discharge from the reservoir would flow down the tributary into Marin County and to the main branch of Stemple Creek. From there, the water would flow into Estero de San Antonio to Bodega Bay. The worst case scenario dam break would cause the Estero de San Antonio to back up to Fallon. The flood waters would also back up Stemple Creek and would flood scattered buildings near Two Rock School. The flood waters would also back up several tributaries to Stemple Creek and Estero de San Antonio and would flood several buildings between the Huntley dam and Bodega Bay. Portions of the Coast Guard Reservation also appear to lie in the flood inundation area of the Huntley reservoir. The estimated maximum water depth would be 76 feet at Fallon - Two Rock Road and 61 feet near Fallon.

Additional information about the analyses conducted may be found in the Technical Memorandum, *Dam Break Inundation Analysis* (Dames & Moore 1995), contained in Appendix J-1.

EFFECTS OF INUNDATION

In the event of inundation from dam failure, significant and widespread damage to property is likely within the areas of inundation. Within this area there would also be the possibility of personal injury and loss of life, the magnitude of which would be dependent

on the amount of warning before the dam failure, and the success of the evacuation procedures.

In addition to these effects on public safety, other effects would be likely to occur in the event of inundation from dam failure.

- Surface Water Hydrology - Streambank erosion in the event of a dam failure has not been quantified, but is assumed to be significant.

- Groundwater - Dam failure would release large quantities of reclaimed water, but would occur over a very short duration. Reclaimed water may pond in small depressions downstream of the dam, but most would enter a drainage and be carried out of the vicinity. The short duration of ponding would not significantly affect groundwater quality for nitrate.

- Surface Water Quality - If dam failure occurs, a large volume of water with an elevated ammonia, hydrogen sulfide, or cyanide concentration may be released to the streams below the dam.

- Terrestrial and Aquatic Biological Resources - Dam failure at any of the reservoir sites would result in inundation of large downstream areas and probable destruction of terrestrial and aquatic vegetation and wildlife habitat, and may impact endangered, threatened, or rare terrestrial wildlife or plant species in association with drainages downstream from a dam site.

- Jurisdictional Wetlands Resources - Dam failures at storage sites would result in inundation of streams below the dam site, scouring of stream channels, destruction of riparian vegetation and other wetland vegetation, and deposition of sediment from the reservoir into wetlands.

- Transportation - Inundation from dam failure would be likely to damage roads downstream of the dam.

- Public Services, Utilities, and Recreation - Inundation from dam failure would be likely to damage infrastructure downstream from the dam and would have a significant impact on emergency services. In the event of damage to infrastructure such as water and sewer mains, and gas, electricity and communications lines, these services could be disrupted for varying lengths of time until repairs could be made.

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References

HBA Team Documents

Dames & Moore. 1995. *Dam Break Inundation Analysis.* (Appendix J-1).

Other References

Harder, Leslie, F. *Performance of Earth Dams During the Loma Prieta Earthquake*. California Department of Water Resources.

Jansen, R.B. 1988. *Dam Safety in America,* Hydro Review, pp. 10-20. June.

Kollgaard, E. B., and Chadwick, W. L., editors. 1988. *Development of Dam Engineering in the United States*. Pergamon Press.

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