Part IV-D – Dam Failure
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IV-D Dam Failure

A. The California Dam Failure Threat

OVERVIEW OF DAM

What is a Dam?

A dam is a barrier preventing the flow of water or loose solid materials (such as soil or snow); or a barrier built across a watercourse for impounding water. Dams are artificial barriers, which are 25 feet or more in height or have an impounding capacity of 50 acre-feet or more.

Advantages of Dams

Dams are important because they provide water for drinking, industry, irrigation, fishing and recreation, water for hydroelectric power production, water for navigation in rivers, and other needs. Dams also protect people by reducing or preventing floods.

Causes of Dam Failure

Dam failures can result from a number of natural or man-made causes such as earthquakes, erosion of the face or foundation, and improper sitting of the dam, rapidly rising floodwaters, and structural/design flaws. Dam failure can result in severe flood events to lower-lying areas. A dam failure from Prado Dam and some of the smaller dams could severely impact much of Orange County and several of the RSCCD sites.

Impacts of Dam Failure

A dam failure may cause loss of life, damage to property, and other ensuing hazards, as well as the displacement of persons residing in the inundation path. Damage to electric generating facilities and transmission lines as well as sewer and water facilities could also impact life support systems in communities outside the immediate hazard areas.

A catastrophic dam failure, depending on the size of the dam and the population downstream, could exceed the response capability of local communities especially overtaxing the public safety personnel and resources. Damage control and disaster relief support would be required from other local government agencies, private organizations, the Orange County Operational Area, the State of California, and possibly the Federal government.

Identifying Dam Failure Hazards

Dam failure is the uncontrolled release of impounded water from behind a dam. Flooding, earthquakes, blockages, landslides, lack of maintenance, improper operation, poor construction, vandalism, and terrorism can all cause a dam to fail. Dam failure causes downstream flooding that can affect life and property.

The primary purpose of this report is to review dams that could cause a threat to the RSCCD.

PROFILING DAM FAILURE HAZARDS

Dams and reservoirs of jurisdictional size are defined in the California Water Code Sections 6000 through 6008. There are currently more than 1,400 dams of jurisdictional size in California. Approximately 1,250 of these dams are under the jurisdiction of California's Department of Water Resources, Division of Safety of Dams. Dams and reservoirs owned by the federal government are not subject to state jurisdiction except as otherwise provided by federal law. In California, there are currently 149 dams owned by federal government agencies such as the United States Forest Service, Bureau of Reclamation, Army Corps of Engineers and the U.S. Military.

Los Angeles leads the state as being the county with the most jurisdictional-size dams, with 100 dams. The county of Sonoma is second behind Los Angeles with 63 dams. Del Norte County is the only county in the state having no dams of jurisdictional size.

The term "dam failure" encompasses a wide variety of circumstances. Situations that would constitute a dam failure vary widely, from developing problems to a partial or catastrophic collapse of the entire dam. Potential causes of a dam failure are numerous and can be attributed to deficiencies in the original design of the dam, the quality of construction, the maintenance of the dam and operation of the appurtenances while the dam is in operation, and acts of nature including precipitation in excess of the design, flood and damage from earthquakes. Water over-topping the dam crest is a common cause of failure in earth dams. Overtopping will cause erosion and the dam crest and eventual dam breach. Piping of each dam is another common form of failure. Piping is a form of erosion that occurs underground caused by rodent burring and the presence of extensive root systems from vegetation growing on and around the dam.

In the past 50 years, there have been only a small number of dam failures in California. The most catastrophic dam failure in California's history is that of the infamous St. Francis Dam in Los Angeles County, which failed in March 1928 shortly after construction of the dam was completed. This failure resulted in the deaths of more than 450 people and destruction of nearly 1,000 homes and buildings. Numerous roads and bridges were also destroyed and/or damaged beyond repair. The Division of Safety of Dams came into existence as a direct result of this catastrophe. Other significant dam failures in California's history include Baldwin Hills in 1963 and the near-failure of the Lower San Fernando Dam in 1971.

ASSESSMENT OF LOCAL VULNERABILITY AND POTENTIAL LOSSES

Information related to community vulnerability and loss assessments may be found in some City and County Hazard Mitigation Plans. Local planning departments have access to the state's inventory of inundation maps, which are kept on a server and published annually as DVDs.

At this time the Cities of Santa Ana and Orange have not developed Hazard Mitigation Plans. The County of Orange has a Hazard Mitigation Plan but has not conducted an assessment of potential losses for Orange County. FEMA's Hazus software does not cover dam failure indents.

TYPES OF DAMS

There are four general types of dams: Arch, Buttress, Gravity (Prado), and Embankment (Seven Oaks). Each of these types of dams has different failure characteristics.

ARCH DAMS

Arch dams are best suited to narrow canyons where they divert the force of the water behind the dam to the sides of the cavern in order to help support the weight. Therefore, arch dams need not be as thick as gravity dams since the dam itself supports less weight making them less expensive to construct. Arch dams may carry less weight than other dams; however, they are affected by the same kinds of force. These forces must be considered when building one, and include pressure of the water, weight of the water, and weight of the dam. A well-known example of an arch dam is Hoover Dam, which sits in the Colorado River on the border of Nevada and Arizona. Dams are also used to generate energy by harnessing the potential energy of water contained in the reservoir.

Pressure of the Water

Pressure applied by the water: For any type of dam, the force of the water pushing on the dam is proportional to the depth of the water contained behind the dam. Therefore, the pressure exerted by the water in the reservoir must be considered before building a dam. So, as the depth increases, the pressure increases. At the bottom of a dam, the pressure is always the highest.

Weight of the Water and Weight of the Dam

The weight of the water and the weight of the dam must be considered to ensure that the foundation can support the dam. The earth supporting the dam must be strong enough to support the weight of the dam. Therefore, the normal force (N) must be sufficient to support the weight (W) of the dam and the water.

BUTTRESS DAMS

Buttress dams can also be called Ambursen dams after the American engineer who used this type of dam in the early 20th century.

Originally, buttress dams were used in areas requiring irrigation, but where the land was not capable of supporting the size and weight of other types of dams. Generally, buttress dams are built in wide valleys. The name "buttress" dam comes from the structure of the dam itself. The dam is supported at intervals by several buttresses, concrete slabs reinforced with steel, which form a watertight seal against the river. There are two main types of buttress dams: flat slab and multiple arch dams. Multiple arch dams are generally more expensive and time consuming to build. This is because the front of the dam consists of several arches that face upstream instead of just a flat front.

Physics Involved in Buttress Dams

As with the arch dam and the gravity dam, the same forces must be considered for a buttress dam. The weight of the dam is also another factor involved. This is the downward force exerted by the concrete. To determine this, the specific weight of the concrete is used. This is the volume of concrete times the specific weight of the concrete. The specific weight of the concrete and the ratio of the density of concrete are compared to the density of water at 4 degrees Celsius. For concrete, the specific gravity is 23.6 N/m3. The weight of the dam times the gravity is the total downward force that is exerted by the dam.

The normal force is the upward force that is exerted by the Earth. Since the dam is not in motion, the normal force provides equilibrium for the weight. Thus, the normal force for a dam is equal but opposite in direction to the weight of the dam times gravity.

GRAVITY DAMS

Gravity dams serve the same purposes as arch and buttress dams; however, they differ in structure and method of retaining water. This type of dam is solid and triangular in shape; therefore, it requires a large amount of concrete or other construction material. The immense weight of the concrete provides stabilization and allows the dam to maintain control of the water. As you can see, gravitational force holds the dam to the ground, hence the name. Some well-known examples of Gravity Dams are Prado and Friant Dam.

Forces Acting on Gravity Dams

The forces acting on gravity dams include the force of the water in the reservoir (acting horizontally and vertically), the weight of the concrete (acting in a downward direction), and the uplift force that results from the water pressure under the dam pushing in an upward direction (a result of the buoyant force of water) if there is not a drainage source. The overall force acts one-third of the way from the bottom of the dam, which is its center of gravity.

Pressure Acting on the Dam

Gravity dams must be able to withstand the pressure of the reservoir water. As a result of the triangular shape of the dam, the pressure of the water is also distributed in the shape of a triangle. The amount of pressure on the dam increases proportionally to the depth of the water; therefore, the pressure is at a maximum at the bottom of the reservoir. A portion of the weight of the dam is cancelled by the water pressure resulting from the uplift force, so if the dam is not properly constructed, it could be uplifted and overturned.

Energy Production

As far as energy production is concerned, gravity dams are also used in the generation of hydroelectric power by the conversion of the potential energy of the water into mechanical energy.

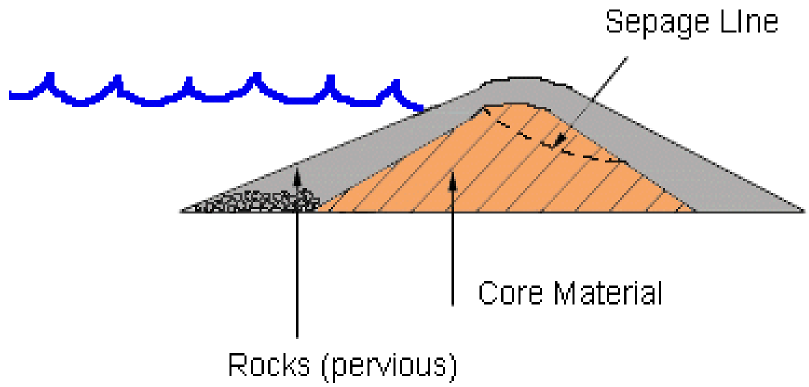
EMBANKMENT DAMS

Embankment dams in the US prior to 1930 had a poor track record. Of those over 490 feet high, almost 10% failed, usually due to overtopping in a flood. Overtopping is when the water level in the reservoir reaches maximum height and begins to flow over the top of the dam. The South Fork dam in Johnstown, PA was one of the first to use rockfills, or loose rocks, on the downstream face. This dam failed after being overtopped in 1889, killing over 2,000 people.

Embankment dams are massive dams made of earth or rock. Embankment dams usually have some sort of waterproof interior (called the core), which is covered with earth or rock fill. Grass may even be grown on the earth fill. Water will seep in through the earth or rock fill, but should not seep into the core. They rely on the weight to resist the flow of water, just like concrete gravity dams.

The main force on an embankment dam is the force of the water. The weight of the dam is also a force, but each material has a different weight, so it is not shown here as one force the way it is on the concrete dams. The uplift force is also acting on the embankment dam, but some of the water seeps into the dam so the force is not the same as on a concrete dam.

The embankment dam is the only dam type that is not made of concrete. Embankment dams may be made of earth or rock, both of which are pervious to water that is, water can get into it. The water will seep into the core material and should stop at the seepage line. The core material is usually more watertight than the rock or earth that is on the outside of the dam, but the core material is still not totally impervious to water. Concrete is not truly impervious either, but it does not allow as much seepage as other materials do.



The diagram shown to the right is only one configuration of what an embankment dam may look like. It could be any combination of earth, rock, and core material in any number of arrangements. Other forces that may act on an embankment dam are:

- There may be water on the downstream side of the dam as well; this water will have the same sort of vertical and horizontal forces on the dam as the water on the upstream side
- Internal hydrostatic pressure: in pores, cracks, joints, and seams
- Silt pressure: silt will build up over time on the upstream side. Silt provides about one and a half times the horizontal pressure of water and twice the vertical pressure of water
- Ice load on the upstream side
- Wave load on the upstream side
- Earthquake loads
- Settlement of the foundation or abutments
- Other structures on top of the dam -- gates, bridge, cars, etc.

CURRENT CALIFORNIA DAM FAILURE HAZARD MITIGATION EFFORTS

Since 1929, the state has supervised all non-federal dams in California to prevent failure for the purpose of safeguarding life and protecting property. Supervision is carried out through the state's Dam Safety Program under the jurisdiction of the Department of Water Resources. The legislation requiring state supervision was passed in response to the St. Francis Dam Failure and ongoing concerns about the potential risks to the general populace from a number of water storage dams. The law requires:

- Examination and approval or repair of dams completed prior to August 14, 1929 (the effective date of the statute)

- Approval of plans and specifications for and supervision of construction of new dams and the enlargement, alteration, repair, or removal of existing dams
- Supervision of maintenance and operations of all dams under the state's jurisdiction

The 1963 failure of the Baldwin Hills Dam in Southern California led the legislation to amend the California Water Code to include within state jurisdiction both new and existing off-stream storage facilities.

Dams and reservoirs subject to state supervision are defined in California Water Code Sections 6002 through 6004, with exemptions defined in Sections 6004 and 6025. In administering the Dam Safety Program, the Department of Water Resources must comply with the provisions of the California Environmental Quality Act. As such, all formal dam approval and revocation actions must be preceded by appropriate environmental documents.

In 1972, Congress moved to reduce the hazards from the 28,000 non-federal dams in the country by passing Public Law 92-367, the National Dam Inspection Act. With the passage of this law, Congress authorized the US Army Corps of Engineers to inventory dams located in the United States. The action was spurred by two disastrous earthen dam failures during the year in West Virginia and South Dakota that caused a total of 300 deaths.

The Water Resources Development Act of 1986 (Public Law 99-662) authorized the US Army Corps of Engineers to maintain and periodically publish an updated National Inventory of Dams. The Water Resources Development Act of 1996 (Public Law 104-303, Section 2215), reauthorized periodic updates by the Army Corps of Engineers. Section 215 further established the National Dam Safety Program and named the Administrator of FEMA as its coordinator. The Dam Safety Act of 2006 (Public Law 109-460) reauthorized the National Dam Safety Program through 2011.

FEMA has recently launched an effort under its Risk MAP program to communicate risk of dam failure and to coordinate state and private mitigation and preparedness efforts. According to FEMA, most people living downstream of a dam are unaware of the potential hazards associated with dam failure, have never seen the respective dam failure inundation maps, and are unaware of an evacuation plan or an Emergency Action Plan associated with the failure of that dam. There is a need, therefore, to include dam failure risk awareness as part of a comprehensive flood risk communications strategy and develop a communications strategy that reports on dam failure risk and promotes dam safety. The audience for these strategies includes dam owners/operators, dam regulators, emergency managers, floodplain managers, planners, public and private decision makers and the population at risk.

Mitigation of dam failure is constantly occurring at both the federal and state level. For example, the US Bureau of Reclamation is planning to replace the longest earthen section of Folsom Lake's dam in order to mitigate earthquake damage. At the state level, officials are currently reviewing an $84 million project to remove a 106-foot-high dam on the Carmel River to mitigate earthquake damage and deal with flood safety issues. These are just two examples of the numerous dam mitigation projects currently being undertaken.

Engineers and engineering geologists at the California Division of Safety of Dams review and approve plans and specifications for the design of dams and oversee their construction to ensure compliance with the approved plans and specifications. Reviews include site geology, seismic setting, site investigations, construction material evaluation, dam stability, hydrology, hydraulics and structural review of appurtenant structures. In addition, division engineers inspect over 1,200 dams on a yearly schedule to ensure they are performing and being maintained in a safe manner.

There are 696 high hazard dams in the State of California. The progress report below describes a subsection of those high hazard dams that are on the remediation list.

PROGRESS SUMMARY 6.G: REMEDIATION

Progress as of 2010: For the period 2007-2009, remediation needs were identified at 45 dams, of which 30 are high hazard. Remediation was completed at 77 dams, of which 51 are high hazard. The remediation included work to address remediation needs identified before 2007. As of July 2010, remediation was under way (i.e., identified or under construction) at 102 dams, of which 72 are high hazard.

OPPORTUNITIES FOR ENHANCED DAM FAILURE HAZARD MITIGATION

California Office of Emergency Services (OES) is required by state law to work with other state and federal agencies, dam owners and operators, floodplain managers, planners and public in making available dam inundation maps for the benefit of citizens interested in learning their dam failure inundation risk. Dam inundation maps can be useful in the preparation of Local Hazard Mitigation Plans and general plan safety elements updates. An opportunity for enhanced outreach to local governments and the public lies with inclusion of digital dam inundation mapping data on the *MyPlan* website under design by State OES. In the development of this plan, the *MyPlan* was accessed and the State OES Hazard Mitigation Section provided dam inundation disk. However, *MyPlan* does not include dam failure maps.

Unfortunately, the dam inundation maps provided were of poor quality and impossible to read.

RESULTS OF A DAM FAILURE

Levee and dam failures can result from a number of natural or human caused threats such as earthquakes, erosion of the face or foundation, improper sitting, rapidly rising flood waters, and structural/design flaws.

Extended damage may require governmental assistance which may continue for an extended period. Efforts would be required to remove debris and clear roadways, demolish unsafe structures, assist in reestablishing public services and utilities, and provide continuing care and welfare for the affected population including, as required, temporary housing for displaced persons.

B. The Orange County Dam Failure Threat

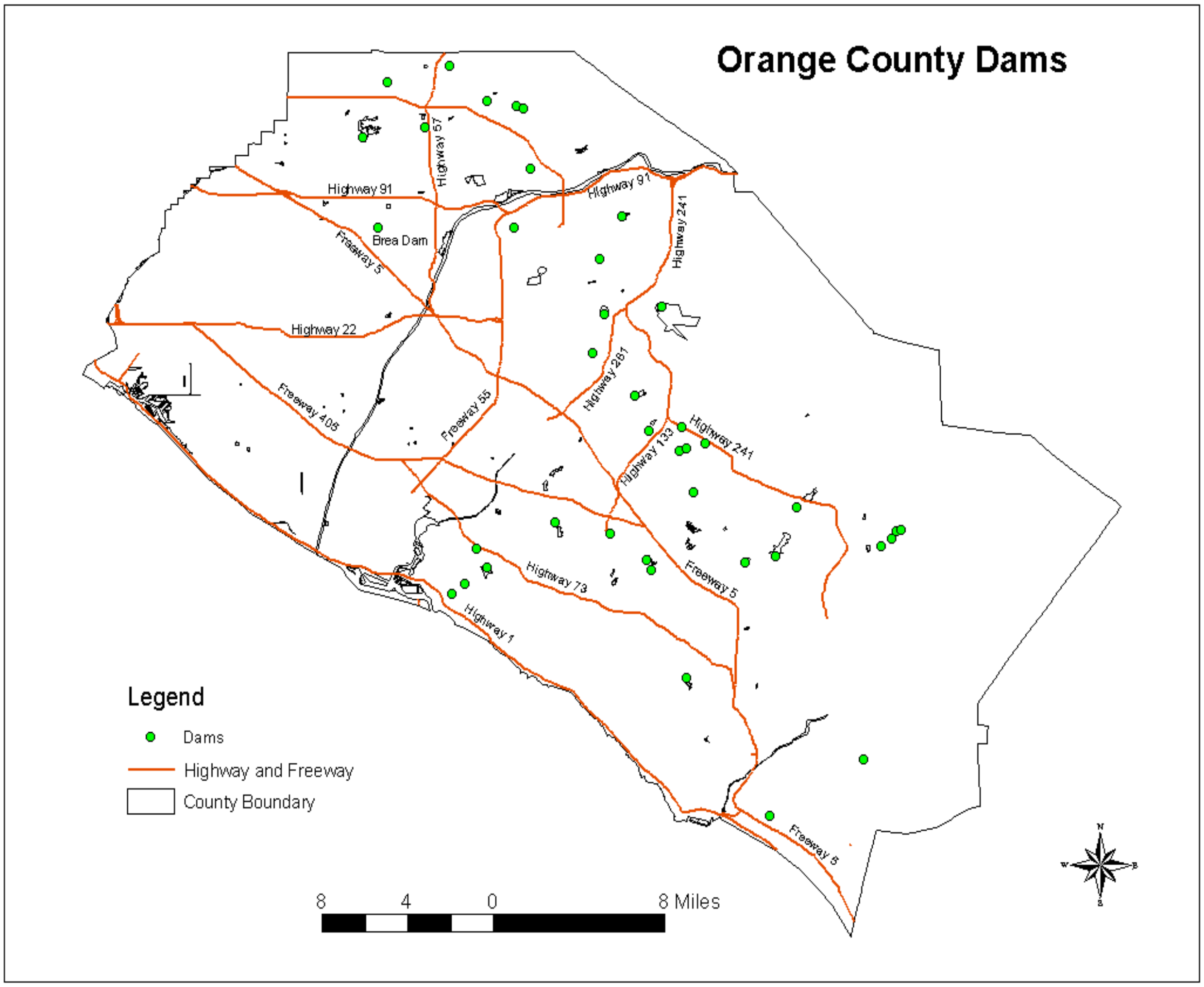
In Orange County, seismic activity can compromise the dam structures, resulting in catastrophic flooding. There are several earthquake faults located in close proximity to local dams and hundreds of thousands of individuals are in the inundation zones.

Per the Orange County Hazard Mitigation Plan, the dams in Orange County are also considered as potential terrorist targets. The weapon most likely to be used would be explosives with the goal of collapsing the dam. Such an event would result in a dam inundation event with little or no warning. The potential of using other types of weapons such as chemical or biological are considered low due to the large amount of material that would be required to contaminate dams used as reservoirs (drinking water).

There are a total of 32 dams in Orange County. The ownership ranges from the Federal government to Home Owners Associations. These dams hold billions of gallons of water in reservoirs. The major reservoirs are designed to protect Southern California from flood waters and to store domestic water. Their sizes range from 18 acre-feet to 196,235 acre-feet (Prado Dam) holding capacity. The following is a list of the larger reservoirs and dams in Orange County and their Owners/Operators:

Name of Facility	Owner
Santiago Reservoir (Irvine Lake)	Irvine Ranch Water District / Serrano Water District
Villa Park Dam	Orange County
Sulpher Creek Dam	Orange County
Peters Canyon Dam	Orange County
Walnut Canyon Reservoir	City of Anaheim
San Joaquin Reservoir	Irvine Ranch Water District
Sand Canyon Reservoir	Irvine Ranch Water District
Rattlesnake Canyon Reservoir	Irvine Ranch Water District
Big Canyon Reservoir	City of Newport
Lake Mission Viejo	Lake Mission Viejo Association
El Toro Reservoir	El Toro Water District
Orange County Reservoir (out of service)	Metropolitan Water District
Palisades Reservoir	South Coast Water District
Portola Reservoir	Santa Margarita Water District
Syphon Canyon Reservoir	The Irvine Company
Trabuco Dam	Trabuco Canyon Water District
Upper Oso Dam	Santa Margarita Water District
Brea Dam	U. S. Army Corps of Engineers
Fullerton Dam	U. S. Army Corps of Engineers
Carbon Canyon Dam	U. S. Army Corps of Engineers

FIGURE 1: ORANGE COUNTY DAMS



SANTIAGO DAM AND VILLA PARK DAM

Santiago Dam is an earth-fill structure with a 25,000 acre-feet capacity reservoir (Irvine Lake). The dam is jointly owned by the Irvine Ranch Water District and the Serrano Water District. Villa Park Dam is a flood control dam located downstream from Santiago Dam. It is an earth-fill structure with a capacity of 15,600 acre-feet and is owned by the Orange County Flood Control District.

Initial alerting is expected from Dam Keepers who are on duty at both Santiago Dam and Villa Park Dam

RATTLESNAKE DAM

Rattlesnake Dam is an earth-filled structure with a storage capacity of about 1,700 acre-feet with a surface area of approximately 46 acres. The reservoir is owned by the Irvine Ranch Water District and is presently being used for the storage of pressure pipe treated sewage effluent which in turn is used for irrigation.

Alerting is provided by Operations personnel at the Irvine Ranch Water District who will notify the Sheriff's Department Control One of dam failure or possible dam failure

WALNUT CANYON RESERVOIR

Walnut Canyon Reservoir is an earth-filled asphalt lined structure owned by the City of Anaheim and is operated by the Anaheim Water Department. The Olive Hills reservoir has a storage capacity of about 197 acre-feet with a surface area of approximately 555 sq. feet. The reservoir presently is used for the storage of potable water for use by residents of the City of Anaheim.

Alerting comes from Operations personnel at the Olive Hills Reservoir who will make the initial call to Anaheim authorities who, in turn, would contact Sheriff's Department Control One.

EL TORO RESERVOIR

El Toro Reservoir is an earth-filled structure owned by the El Toro Water District. The impounded reservoir has a storage capacity of about 722 acre-feet with a surface area of approximately 20.6 acres. The reservoir is presently being used as a seasonal and operational storage site for the El Toro Water District's imported Colorado River Water.

Alerting comes from Operations personnel at the El Toro Water District who will notify the Sheriff's Department Control One of dam failure or possible dam failure.

SAN JOAQUIN RESERVOIR

San Joaquin Reservoir is an earth-filled structure and is owned and operated by the Irvine Ranch Water District. The reservoir has a storage capacity of about 3,000 acre-feet with a surface area of about 54 acres. San Joaquin Reservoir is a recycled-water supply reservoir.

Alerting comes from Operations personnel from the Metropolitan Water District who will notify the Irvine Ranch Water District who, in turn, will notify the Sheriff's Department Control One of dam failure or possible dam failure.

SULPHER CREEK DAM

Sulpher Creek Dam is an earth-filled structure owned by Orange County. It has a capacity of 382 acre-feet and maintained at a water surface elevation of 189 feet above MSL.

Alerting comes from the Park Ranger on duty who will notify Sheriff's Department Control One of dam failure or possible dam failure.

PETERS CANYON DAM

Peters Canyon Dam is an earth-filled structure owned by Orange County and has a capacity of 626 acre-feet at the spillway pipe elevation of 537 feet MSL. Water stored varies from 200 acre-feet to 600 acre-feet depending on seasonal rain amounts.

Alerting would come primarily from the Park Ranger at Peters Canyon Regional Park who would notify the Sheriff Department, Control One of dam failure or possible dam failure.

Dams outside Orange County that may impact Orange County include:

Location	Riverside County, California, United States
Coordinates	33°40′42″N 117°02′30″W33.67833°N 117.04167°WCoordinates: 33°40′42″N 117°02′30″W33.67833°N 117.04167°W[1]
Lake type	Reservoir
Basin countries	United States
Max. length	4.5 mi (7.2 km)
Max. width	2 mi (3 km)
Surface area	4,500 acres (18 km²)
Max. depth	260 ft (79 m)

DIAMOND VALLEY LAKE/RIVERSIDE COUNTY

This lake is in Riverside County. It is owned by the Metropolitan Water District in Riverside and a major source of water for Southern California. Diamond Valley Lake is a man-made off stream reservoir located near Hemet, California. It is one of the largest reservoirs in Southern California and also one of the newest. With a capacity of 800,000 acre feet (990,000,000 m3) (four times that of Prado Dam), the lake nearly doubled the area's surface water storage capacity and provides additional water supplies for drought, peak summer, and emergency needs. The Metropolitan Water District of Southern California began the $1.9 billion construction project in 1995. Filling of the lake, by way of the Colorado River Aqueduct, began in 1999 and was completed in 2003. The lake is currently served by the Inland Feeder. The lake features three earth fill dams, two located on either side of the valley and one on the north rim.

SEVEN OAKS DAM/SAN BERNARDINO COUNTY

Seven Oaks Dam is one of the largest earth and rock filled dams in the world. It is as high as a fifty story building and ten football fields in length from side to side. Situated between the north and south branches of the San Andreas Fault, the dam has been designed to withstand an earthquake of eight plus on the Richter scale. Seven Oaks Dam is a zoned earth and rock fill dam with a maximum height of 550 feet above the existing streambed at the dam axis and 650 feet above the lowest foundation bedrock contact. The dam crest is 40 feet wide, 2,760 feet long and has a minimum crest elevation of 2610 feet NGVD.

Installation of the Seven Oaks Dam in San Bernardino County has lessened the impact of a Prado Dam failure.

PRADO DAM/RIVERSIDE COUNTY

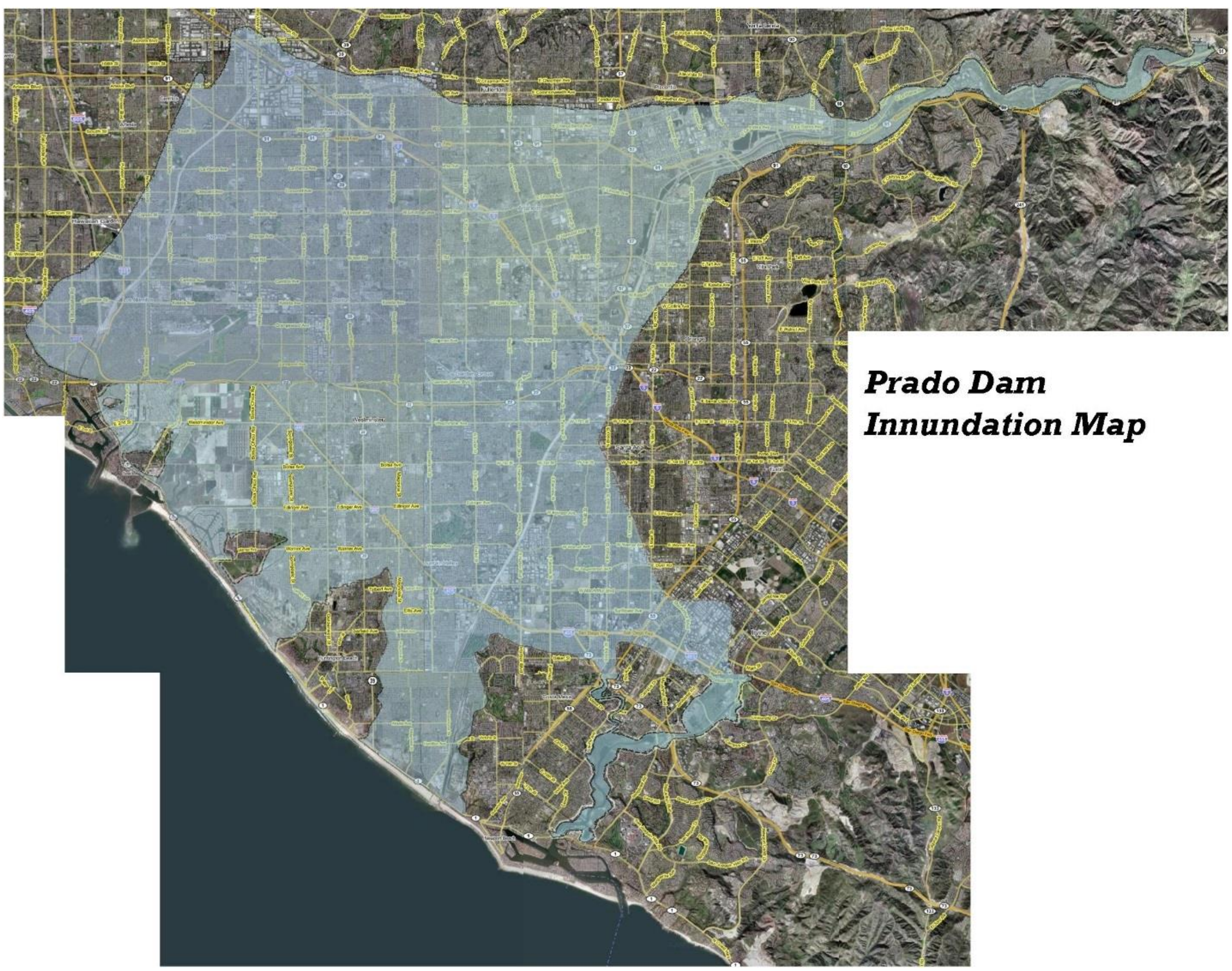
Prado Dam is owned and operated by the Los Angeles District, Corps of Engineers, and was constructed for the primary purpose of providing protection from floods for the metropolitan areas in Orange County.

In the event that downstream interests need to be alerted, the Corps of Engineers will contact the following:

Orange County Sheriff's Department Control One
Riverside County Office of Emergency Services
California Emergency Management Agency, Sacramento

Once contacted, the above agencies will notify all pertinent Federal, state, county and local agencies through the state's National Warning System hookup (fan out communication system). RSCCD will be notified by the Orange County Sheriff's Department Control One, the warning point for Orange County.

FIGURE 2: ORANGE COUNTY PRADO DAM MAP



DAM FAILURE FLOODING

Loss of life and damage to structures, roads, and utilities may result from a dam failure. Economic losses can also result from a lowered tax base and lack of utility profits. These effects would certainly accompany the failure of one of the major dams in Orange County. There are 10 major dams or reservoirs in Orange County some of which hold millions of gallons of water. Because dam failure can have severe consequences, FEMA and the California Emergency Management Agency require all dam owners develop Emergency Action Plans for warning, evacuation, and post-flood actions. Although there may be coordination with county officials in the development of the Emergency Action Plans, the responsibility for developing potential flood inundation maps and facilitation of emergency response is the responsibility of the dam owner.

For more detailed information regarding dam failure flooding, and potential flood inundation zones for a particular dam in the county, refer to the Orange County, Operational Area Emergency Action Plan as well as the Cities of Orange and Santa Ana Emergency Operations Plans.

ORANGE COUNTY HISTORICAL FAILURE FLOODING

WESTMINSTER WATER TANK FAILURE


This 31-year-old storage tank ruptured in Westminster, California, sending a 6-foot wave of water through the city that damaged or destroyed about 50 buildings and over a dozen vehicles. Storage tanks should be replaced or periodically rehabilitated to preserve their structural integrity.

In September of 1998, a smaller version of a municipal water storage unit in the City of Westminster failed, collapsing about 12 feet of the 100,000 gallon tank. The flow of water from the tank destroyed most of the facility as well as several private residents. Luckily, the home that was hit hardest was not occupied at the time. Additionally, there were approximately 30 more homes inundated with water and silt. An Orange County Fire Authority fire station was located within 100 feet of the water tank. The large quantity of water and its tremendous force from the dam swept the firefighters away and through the fire station. Through the Public Works Mutual Aid Agreement, the Orange County Public Works Department assisted in the cleanup and temporary repair of the streets.

BREA DAM OVERTOPPING

On February 22, 2005, the Brea Dam failed following a large rain storm. An extended period of very wet weather dumped more than 6.8 inches at the Fullerton Airport. The dam was overtopped, flooding the Fullerton Golf Course and Bastanchury Road. The road remained closed for a day, while the golf course was closed for several days. The golf course sustained damage as did a storm channel that was eroded as a result of the flooding.

PRADO DAM SEEPAGE

In January 2005, due to preceding storm activity which produced near record water levels behind Prado Dam, the reservoir water surface elevation behind the dam peaked at 527.4 feet above sea level on January 11, 2005. On January 13, the U.S. Army Corps of Engineers discovered minor seepage on the downstream face of Prado Dam, the seepage was located in an area that was under construction to build new outlet works as part of the overall flood control improvement to Prado Dam. As a precautionary measure Corona city officials evacuated over 800 homes below the dam and Orange County officials relocated campers in the Canyon RV Park because of their proximity to the adjacent floodplain.

To decrease the amount of water behind Prado dam the release of water was increased from 5,000 cubic feet per second (cfs) to 10,000 cfs to reduce the level of water being held to 505 feet. In addition to the increase in water release, the U.S. Army Corps began holding back floodwaters upstream at both the San Antonio Dam in Los Angeles County and Seven Oaks Dam near Redlands to reduce the inflow of water to Prado Dam. As the water level was lowered the hydraulic pressure on the dam abutment subject to seepage was reduced. When the water was reduced to 505 feet (25,750 acre feet of water) on Monday, January 17, 2005 the USACE was able to start the reconditioning of the cofferdam in order to be ready for subsequent flood inflows to the dam.

LOS ANGELES HISTORIC DAM FAILURES

Since dam failures are rare, reviewing these incidents can help us understand the consequences of a dam failures.

ST. FRANCIS DAM

The failure of the St. Francis Dam, and the resulting loss of over 500 lives in the path of a roaring wall of water, was a scandal that resulted in the almost complete destruction of the reputation of its builder, William Mulholland. It was he who proposed, designed, and supervised the construction of the Los Angeles Aqueduct, which brought water from the Owens Valley to the city. The St. Francis Dam, built in 1926, was 180 feet high and 600 feet long; it was located near Saugus in the San Francisquito Canyon. Because Los Angeles County is adjacent to Orange County, the tales of this incident have been passed down by several Orange County generations.

The dam gave way on March 12, 1928, three minutes before midnight. Its waters swept through the Santa Clara Valley toward the Pacific Ocean, about 54 miles away. Sixty-five miles of valley was devastated before the water finally made its way into the ocean between Oxnard and Ventura. At its peak, the wall of water was said to be 78 feet high; by the time it hit Santa Paula, 42 miles south of the dam, the water was estimated to be 25 feet deep. Almost everything in its path was destroyed: livestock, structures, railways, bridges, and orchards. By the time it was over, parts of Ventura County lay under 70 feet of mud and debris. Over 500 people were killed and damage estimates topped $20 million.

BALDWIN HILLS DAM

The Baldwin Hills dam failed during the daylight hours, and was one of the first disaster events documented by a live helicopter broadcast. The telecast of the collapse from a KTLA-TV helicopter is considered the precursor to airborne news coverage that is now routine everywhere.

The Baldwin Hills Dam collapsed with the fury of a thousand cloudbursts, sending a 50-foot wall of water down Cloverdale Avenue and slamming into homes and cars on December 14, 1963. Five people were killed. Sixty-five hillside houses were ripped apart, and 210 homes and apartments were damaged. The flood swept northward in a V-shaped path roughly bounded by La Brea Avenue and Jefferson and La Cienega Boulevards.

The earthen dam that created a 19-acre reservoir to supply drinking water for West Los Angeles residents ruptured at 3:38 PM. As a pencil-thin crack widened to a 75-foot gash, 292 million gallons surged out. It took 77 minutes for the lake to empty. But it took a generation for the neighborhood below to recover. Two decades passed before the Baldwin Hills ridge top was reborn. The cascade caused an unexpected ripple effect that is still being felt in Los Angeles and beyond. It foreshadowed the end of urban-area earthen dams as a major element of the water storage systems. It prompted a tightening of Division of Safety of Dams control over reservoirs throughout the state.

C. THE RSCCD DAM FAILURE THREAT

The main dam threat to the RSCCD is Prado Dam while three other dams/reservoirs could impact one or more RSCCD facility if they were to fail while at near capacity. North Orange County has two major drainage courses with potential for significant flooding: Santiago Creek and the Santa Ana River.

LIST OF DAMS AND RESERVOIRS THAT MAY THREATEN RSCCD INCLUDE:

1. Villa Park Dam
2. Santiago Dam
3. Peters Canyon Dam
4. Olive Hill Reservoir
5. Prado Dam

Two small dams are present along Santiago Creek: Villa Park Dam and Santiago Dam (Irvine Lake). Both are located in the foothills section of East Orange. Peters Canyon Dam is located along Peters Canyon about two miles west of Irvine Lake. Like Santiago Creek, which flows generally northwest, Peters Canyon drains in a similar direction, along Handy Creek and ultimately into Santiago Creek. The areas below (downstream from) the dams are areas of potential flood hazard in case of dam failure, which presumably could result from a major earthquake.

The areas below the dams are also zoned for flood hazard on the FEMA maps, and the areas of potential flooding are similar in width to other areas along Santiago Creek and Peters Canyon. Should one of these facilities fail, properties along Santiago Creek and a large section of Old Towne in Orange could be flooded. Flood flows would move at rates which would allow persons to be evacuated, but significant property damage could result. However, as is the case for Prado Dam, these facilities are maintained and safety inspected to ensure that risks are minimized. The City of Orange will minimize flood-related risks and hazards in the event of dam or reservoir failure, protecting residences and businesses by encouraging the County's Flood Control District to continue proper inspection of storm drains, ensure maintenance of the flood control facilities, and prevent earthquake damage. The City of Orange will also monitor water storage facilities to determine potential inundation hazards to surrounding properties. (City of Orange Safety Element.)

VILLA PARK DAM

Villa Park Dam is an embankment dam on Santiago Creek in Orange, California. Along with the upstream Santiago Dam, the dam serves primarily for flood control for the cities of Villa Park, Orange, Tustin and Santa Ana and also regulates the inflow of Santiago Creek into the Santa Ana River. RSCCD facilities are located in the cities of Orange, Santa Ana and Tustin and along the Santa Ana River.

Villa Park Reservoir, at an elevation of 581 feet, was an earthen reservoir located upstream from the RSCCD on the Santiago Creek, was created for flood control purposes for water flow from Irvine Lake. Santiago Reservoir, at an elevation of 804 feet, creates Irvine Lake and functions as a reservoir for the area. It was an earthen reservoir that was started in 1933.

Construction was completed in 1963, and the dam is owned by the County of Orange. Standing 118 feet (36 m) high, the dam forms a reservoir with a maximum capacity of 15,600 acre feet (19,200,000 m3), controlling runoff from a catchment area of 83.9 square miles (217 km2). Due to flood control requirements, the reservoir is typically at a very low level or empty during the dry season.

During years with heavy precipitation, release gates in Santiago Reservoir can be operated to prevent water from overflowing the face of the dam. Villa Park Reservoir then meters these heavy flows to prevent flooding of low lying areas downstream. Normally there is no water behind Villa Park Reservoir. These facilities are maintained and safety-inspected to ensure their integrity and that risks are minimized.

Dam History
As noted by Carl Nelson, P.E. on the 50th anniversary of the Villa Park Dam:
The Santa Ana Mountains of Orange County constitute a northwesterly extension of the Peninsular Range of Southern California trending southeasterly from the Chino Hills in Orange County to northern San Diego County. Santiago (5,687 ft.), Modjeska (5,496 ft.) and Pleasants (4,007 ft.) peaks form the ridgeline between Orange and Riverside Counties and drain westerly to Santiago Canyon, there melding with the alluvial plain of the Santa Ana River. The watershed of Santiago Creek runs westerly from Santiago Peak through the Trabuco District of the Cleveland National Forest before crossing the northerly portion of Irvine Ranch. Principal tributaries are Silverado, Black Star, Limestone and Fremont Canyons.

Long-term records kept by Orange County Flood Control District at Santiago Peak, indicate an average annual rainfall of 34 inches. In contrast, the driest year recorded at the peak was 2006-07 with a total of 8 inches, and 1997-98, the wettest total was 105 inches. Over the lower elevations of the valley, annual rainfall averages about 13 inches. Important to agriculturists, the median annual rainfall (half the years are lower and half the years higher) is only 11.85 inches.

Early settlers found water for domestic purposes only in spring-fed streams at the mouths of canyons; for instance, the narrows of Santiago Creek at Villa Park. The Carpenter and Serrano Irrigation districts, established around 1878, constructed a clay barrier across the shallow alluvium of the creekbed, acquired riparian rights, and developed an irrigation system for orchards along the banks of lower Santiago Creek easterly of the City of Orange.

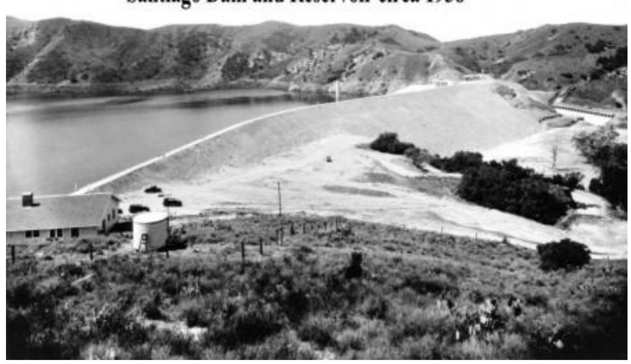
Early occupants of the floodplain lands bordering the creek would be deceived by long periods of drought between damaging floods. By the late 19th century rural and urban encroachments within the new cities of Orange and Santa Ana would be overwhelmed when the wide, sandy bed of Santiago Creek would become a raging torrent for a day or two following torrential rainstorms. The flood threat would be partially improved with the development of Santiago Dam and Reservoir upstream from the original Orange County Park.

During the 1920s James Irvine II and the Carpenter and Serrano water interests resolved a water rights dispute with a cooperative agreement to construct Santiago Dam and Reservoir for conservation of flood water. Conserved water would be shared equally, and Irvine's share would be diverted to irrigation of the Irvine's land on the Tustin Plain.


Photo from Orange Daily News, Jan. 1916

Villa Park Dam 1916

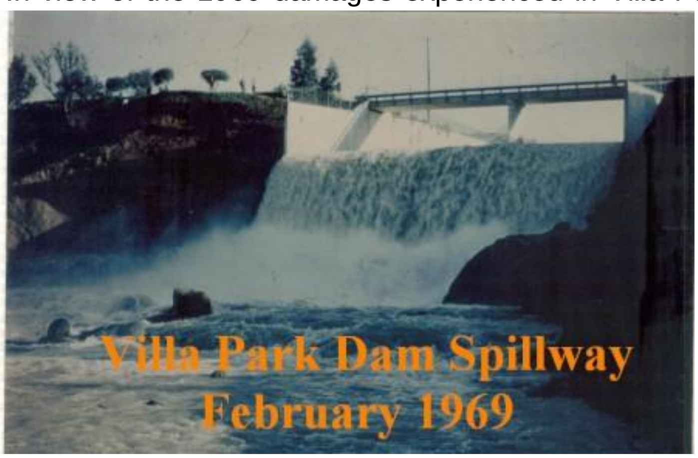
When a water supply reservoir is filled before the advent of a large flood, the emergency spillway safely passes the excess flood waters, but with only a small reduction of the peak flow. The cities of Orange and Santa Ana experienced damaging floods even after construction of the Santiago Dam and water supply reservoir (better known as Irvine Lake). A federal flood control program in1936 had authorized a flood control dam on Santiago Creek at the Villa Park narrows; however after two decades without federal appropriations, funding for the dam was included in Orange County Flood Control District's successful 1956 bond election.

Santiago Dam and Reservoir circa 1938


Construction of the dam was completed in 1963. Sequential floods during January and February of 1969 filled both Santiago and Villa Park dams to capacity as actual runoff volumes exceeded design estimates for the theoretical 100 year storm.

Whereas the dam had been designed for a gated discharge of 3,500 cubic feet per second for the 100 year storm, uncontrolled spillway discharge had peaked at 4,500 CFS in February 1969. For several days after the February storm residual flow from the dam damaged several highway bridges and commercial gravel pit operations. In locations where little or no bank protection existed, residential properties experienced severe damages from lateral erosion.

In view of the 1969 damages experienced in Villa Park, Orange and Santa Ana, the Corps of engineers consented to inclusion of lower Santiago Creek improvements within the Congressional legislation that authorized Santa Ana River Mainstem project.



Construction anticipated upon completion of Prado Dam enlargement by the Corps of Engineers provided increased flood storage, outlet gates at Prospect Street and downstream protection for storm runoff exceeding the 100 year Villa Park Dam design.

Villa Park Dam 1969

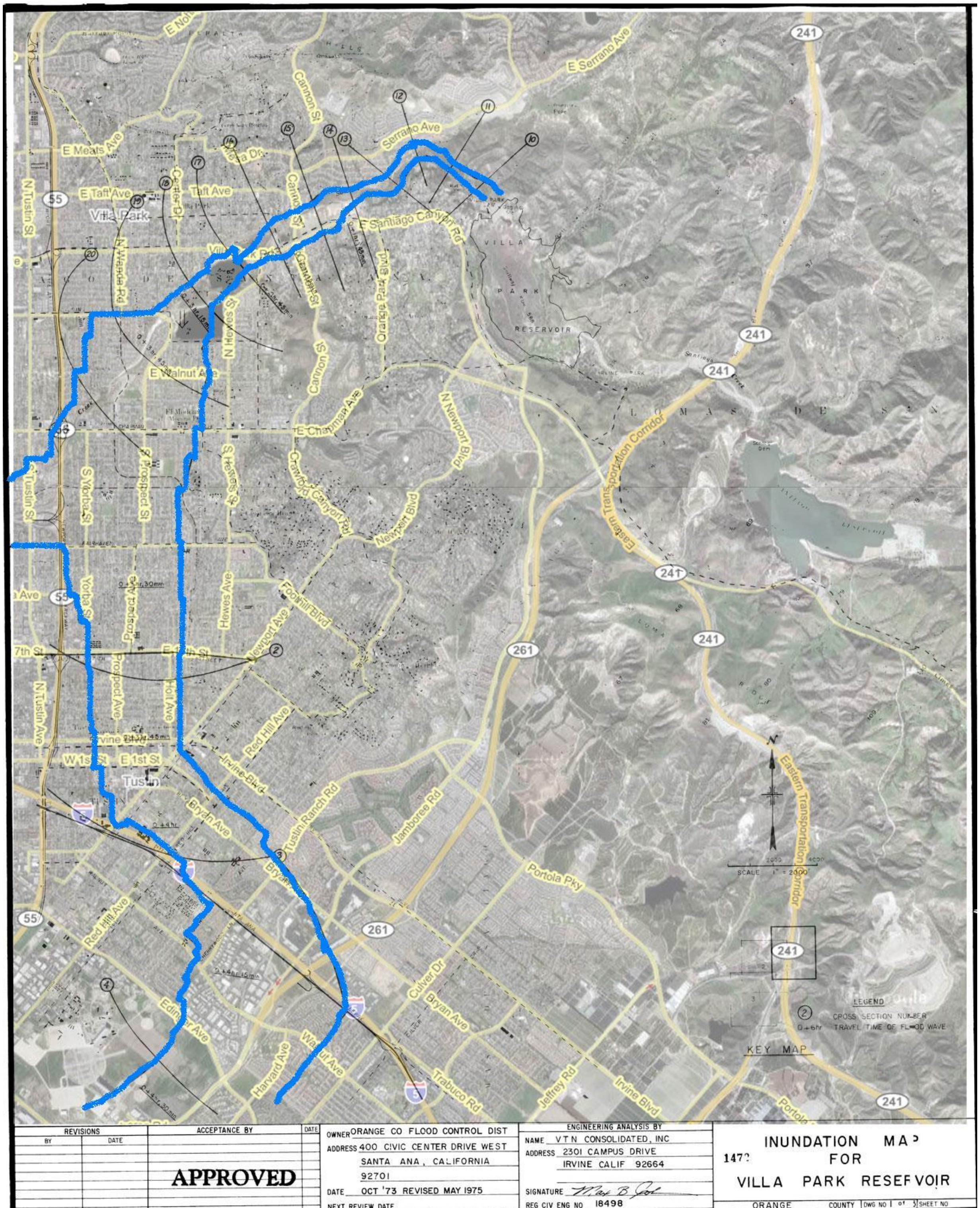
TABLE 1: VILLA PARK DAM AND RESERVOIR WATER MOVEMENT TIMETABLE

Location	Arrival Time	Distance from Dam	Peak Elevation	Time of Peak Elevation	Avg. Over Bank Depth
Santiago Canyon & Orange Park Blvd	1 hours 45 min				
Villa Park Rd & Hewes	2 hours 45 min				
North of Collins & Prospect	3 hours 15 min				
South of Collins & Prospect	3 hours 45 min				
Santa Ana River Channel Fork:					
55 Freeway & Chapman	4 hours 30 min				
22 Freeway & Cambridge	5 hours				
22 Freeway & Main Street	5 hours 30 min				
17th & Bristol	6 hours 15 min				
1st Street	6 hours 30 min				
Between Edinger & Warner	7 hours				
MacArthur	7hours 15 min				
Sunflower	7 hours 45 min				
Gisler	8 hours 15 min				
Just north of Adams	8 hours 45 min				
Victoria	9 hours 15 min				
San Diego Creek Channel Fork:					
Newport Ave & Bryan Ave	4 hours				
261 Toll Road & Edinger	4 hours 15 min				
Old Tustin USMC base	4 hours 30 min				
Red Hill & Alton Pkwy	5hours				
405 Freeway	5 hours 15 min				
South of Campus Drive	5 hours 30 min				
73 Toll Road	5 hours 15 min				
East side of Irvine Ave & Santa Isabel	6 hours 15 min				

**above reference points are the closest approximate main street along plotted timeline of RDMD inundation maps

NAVD = North American Vertical Datum (NAVD). In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929 it will differ to actual sea level by 71 cm or 2.3 feet. The acronym has been adopted by FEMA FIS and FIRM maps to NAVD.

FIGURE 3: VILLA PARK DAM OVERLAY 1



Map provided by the County of Orange

FIGURE 4: VILLA PARK DAM OVERLAY 2

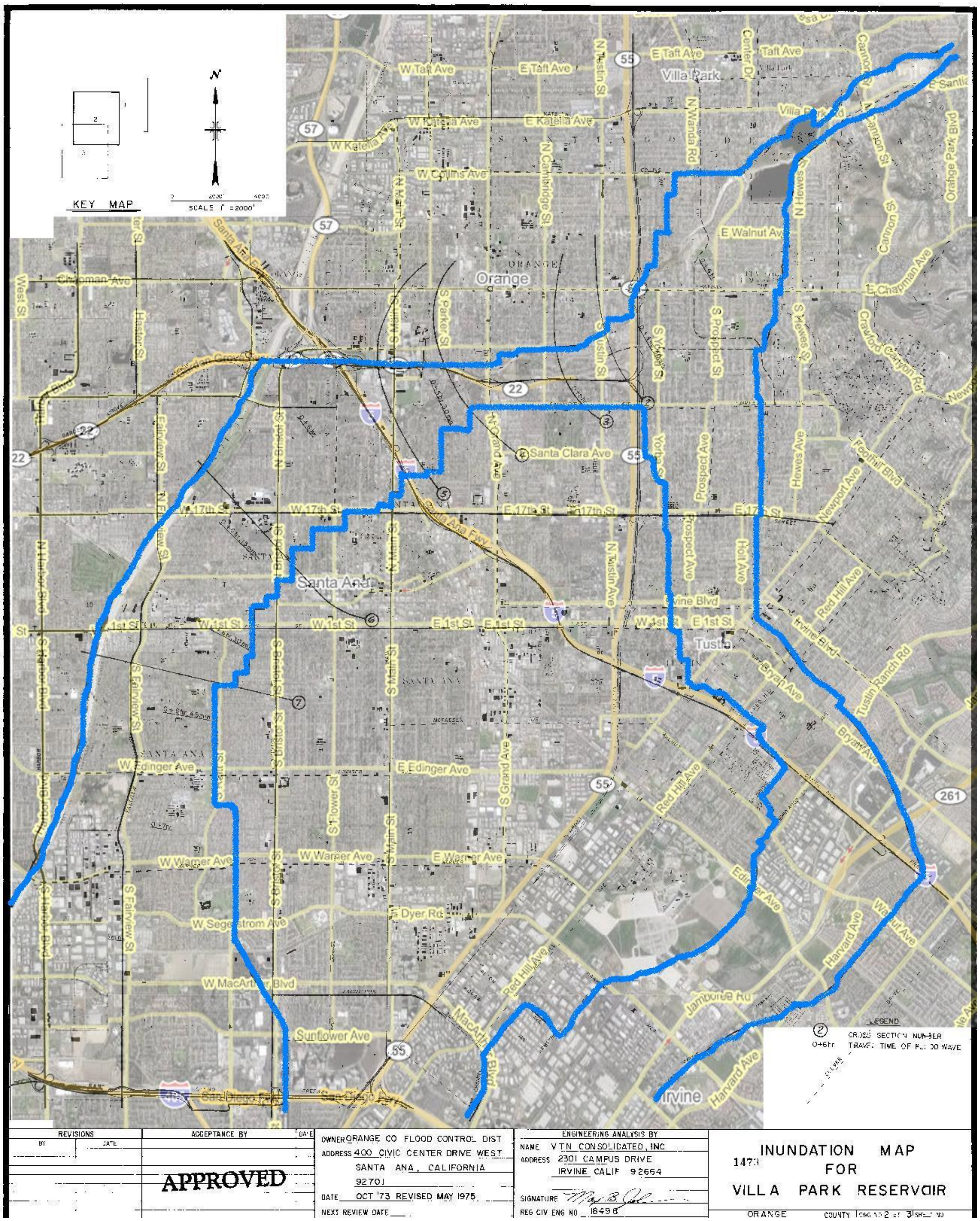


FIGURE 5: VILLA PARK DAM OVERLAY 3

Maps provided by County of Orange. These maps are such poor quality that is impossible to tell which RSCCD facilities are in which dam inundation zones

FIGURE 6: RSCCD SITE IMPACT AS A RESULT OF A VILLA PARK DAM AND RESERVOIR FAILURE

Item	District Location	Address	Elevation Feet Above Sea Level	In Dam Inundation Zone
1	District Operations Center	2323 North Broadway, Santa Ana 92706	147 feet	Yes 5 Hours 30 Minutes
2	Santa Ana College (SAC)	1530 West 17th Street, Santa Ana 92706	106 feet	Yes 6 Hours 15 Minutes
3	Santiago Canyon College (SCC)	8045 East Chapman Avenue, Orange 92869	557 feet	No
4	Centennial Education Center (CEC)	2900 West Edinger Avenue, Santa Ana 92704	91 feet	Yes 7 Hours
5	Orange Education Center (OEC)	1465 North Batavia Street, Orange 92867	176 feet	No
7	Orange County Sheriff's Regional Training Academy (OCSRTA)	115991 Armstrong Avenue, Tustin 92782	57 feet	Border
8	Digital Media Center (DMC)	1300 South Bristol Street, Santa Ana 92704	71 feet	No

Note: Site 6 is the Regional Fire Training Center; land not owned by RSCCD; lease terminated May 2015

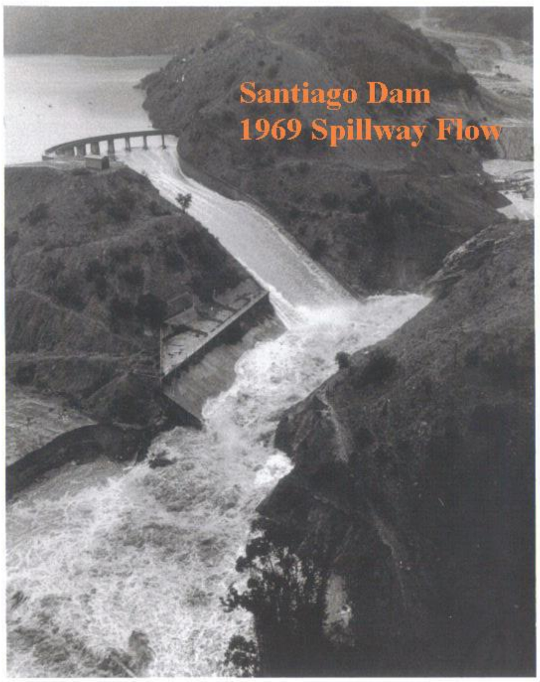
SANTIAGO DAM

Santiago Dam is an earth-fill structure with a 25,000 acre-feet capacity reservoir (Irvine Lake). The dam is jointly owned by the Irvine Ranch Water District and the Serrano Water District. Villa Park Dam is a flood control dam located downstream from Santiago Dam. It is an earth-fill structure with a capacity of 15,600 acre-feet and is owned by the Orange County Flood Control District.

The Register

History

Construction on the dam started in 1929 with a joint venture by the Irvine Company and Serrano Irrigation District. After the site was graded, the dam was built using dirt and rock excavated from the sides of the canyon and from the streambed both above and below the dam site. The structure was completed in 1931 at a cost of $1 million and its reservoir, Irvine Lake, filled by 1933. In the late 1930s, the lake was stocked with fish, and was opened to the public for recreational use in 1941.



The dam was built to serve the purpose of flood control, irrigation and municipal water use. With heavy suburban sprawl downstream encroaching since the 1960s, agriculture along the lower Santiago Creek has practically ceased. It is currently owned by the Irvine Ranch Water District and the Serrano Water District. Today the dam marks the usual ending point of surface flow in Santiago Creek, as all the discharge is retained in the reservoir and downstream flow is limited to seepage and stormwater.

Statistics

The Santiago Dam is a roller compacted earth and rockfill structure 136 feet (41 m) high and 1,425 feet (434 m) long. It is roughly 760 feet (230 m) wide at the base and contains some 790,000 cubic yards (600,000 m3) of material. The dam's spillway is a concrete overflow structure to the left side, equipped with nine openings each 15 feet (4.6 m) wide and 28 feet (8.5 m) high, able to pass a flow exceeding 30,000 cubic feet per second (850 m3/s). This spillway has only been used a few times, such as the floods of 1938, 1969, 1983, 1998 and 2005. The dam crest is 804 feet (245 m) above sea level.

Irvine Lake is the reservoir formed behind the dam, and has a normal storage of 25,000 acre feet (31,000,000 m3) at 791 feet (241 m) elevation. Maximum storage is 28,000 acre feet

(35,000,000 m3) in the event of a flood. This reservoir is not only the largest man-made lake in Orange County, but is also the largest body of fresh water entirely in the county. The lake covers about 700 acres and is stocked with several species of fish.

The dam and reservoir receive water from a catchment area totaling 64 square miles (170 km2), controlling water from about two-thirds of the Santiago Creek watershed. Santiago Dam is designed to contain up to a 50-year flood and withstand a 500-year flood of over 30,000 cubic feet per second (850 m3/s). Aside from Santiago Creek, Limestone Wash and various unnamed streams flow into the reservoir. Upstream tributaries of Santiago Creek include Silverado and Modjeska Creeks. The dam operates in conjunction with the downstream Villa Park Dam, which can store up to 15,600 acre feet (19,200,000 m3).

Santiago Dam

Santiago Dam, viewed from the eastern end of the lake

Location	Orange County, California
Coordinates	33°47'10"N 117°43'31"W33.78611°N 117.72528°WCoordinates: 33°47'10"N 117°43'31"W33.78611°N 117.72528°W[1]
Construction began	1929 (Irvine Company, Serrano Irrigation District) Opened in 1931
Owner(s)	Serrano Water District/Irvine Ranch Water District
Dam and spillways	
Type of dam	Roller-compacted earth and rock fill
Impounds	Santiago Creek
Height	136 ft (41 m)
Length	1,425 ft (434 m)(
Width (crest)	29 ft (8.8 m)
Width (base)	760 ft (230 m)
Dam volume	790,000 cu yd (600,000 m^3)
Spillway type	Uncontrolled concrete overflow
Spillway capacity	31,700 cu ft/s (900 m^3/s)

Reservoir	
Creates	Irvine Lake
Total capacity	38,800 acre·ft (47,900,000 m^3) (max) 25,000 acre·ft (31,000,000 m^3) (conservation)
Catchment area	64 square mi (170 km^2)
Surface area	700 acres (280 ha)
Power station	
Hydraulic head	120 ft (37 m)

TABLE 2: SANTIAGO DAM & RESERVOIR WATER MOVEMENT TIMELINE

Location	Arrival Time	Distance from Dam	Peak Elevation	Time of Peak Elevation	Avg. Over Bank Depth
Santiago Canyon & Orange Park Blvd	4 hours 15 min				
Villa Park Rd & Hewes	4 hours 45 min				
North of Collins & Prospect	5 hours 15 min				
South of Collins & Prospect	5 hours 45 min				
55 Freeway & 17th street	6 hours				
Santa Ana River Channel Fork:					
22 Freeway & Cambridge	6 hours 30 min				
22 Freeway & Main Street	7 hours				
17th & Bristol	7 hours 30 min				
1st Street	8 hours				
Between Edinger & Warner	9 hours				
MacArthur	10 hours				
Sunflower	10 hours 30 min				
Gisler	12 hours				
Just north of Adams	12 hours 30 min				
Victoria	13 hours				
San Diego Creek Channel Fork:					
Newport Ave & Bryan Ave	6 hours 15 min				
261 Toll Road & Edinger	6 hours 45 min				
Old Tustin USMC base	7 hours				
Red Hill & Alton Pkwy	7 hours 15 min				
405 Freeway	7 hours 45 min				
South of Campus Drive	8 hours				
73 Toll Road	8 hours 15 min				
East side of Irvine Ave & Santa Isabel	8 hours 45 min				

**above reference points are the closest approximate main street along plotted timeline of RDMD inundation maps

NAVD = North American Vertical Datum (NAVD). In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929 it will differ to actual sea level by 71 cm or 2.3 feet. The acronym has been adopted by FEMA FIS and FIRM maps to NAVD.

FIGURE 7: SANTIAGO DAM OVERLAY 1

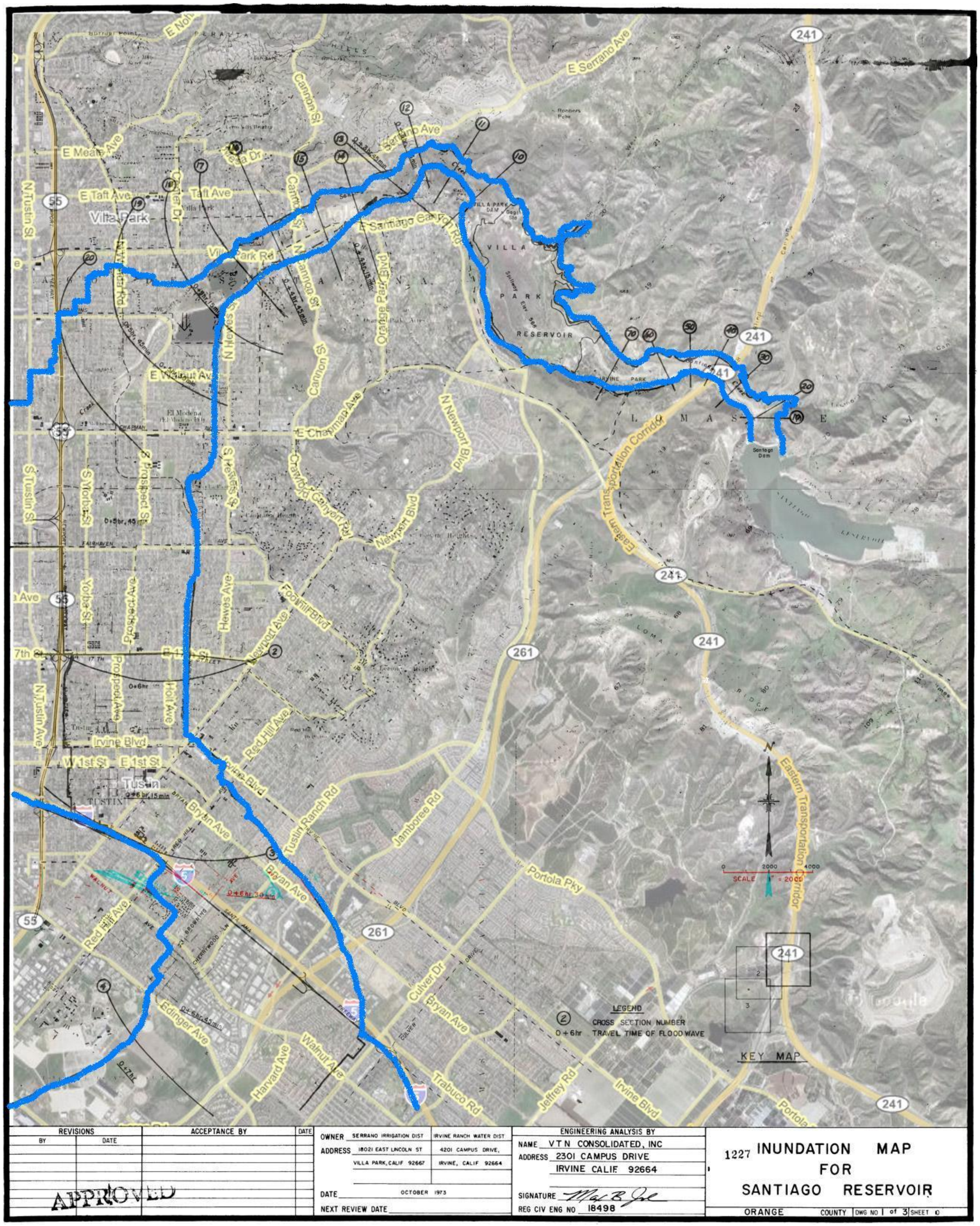


FIGURE 8: SANTIAGO DAM OVERLAY 2

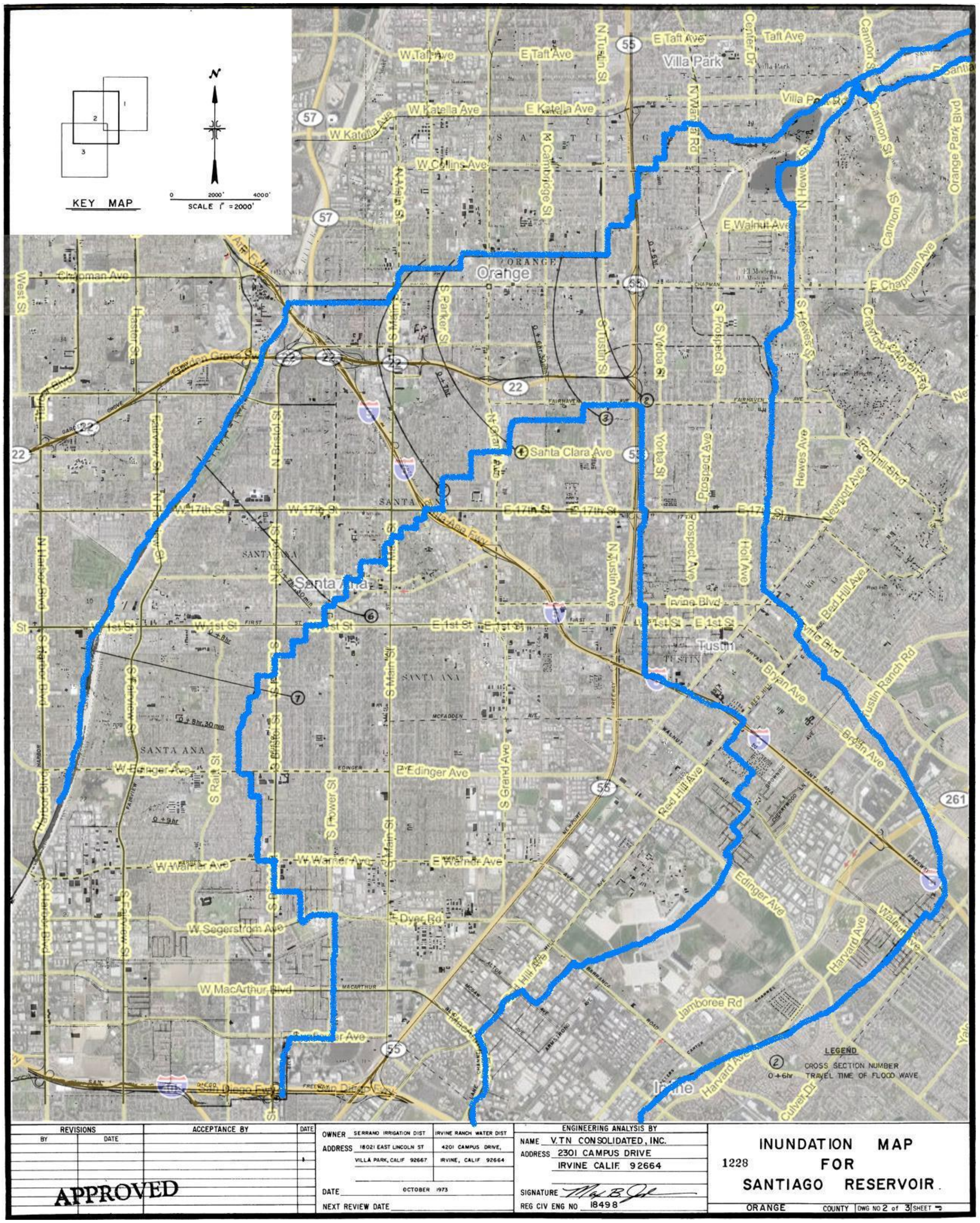


FIGURE 9: SANTIAGO DAM OVERLAY 3

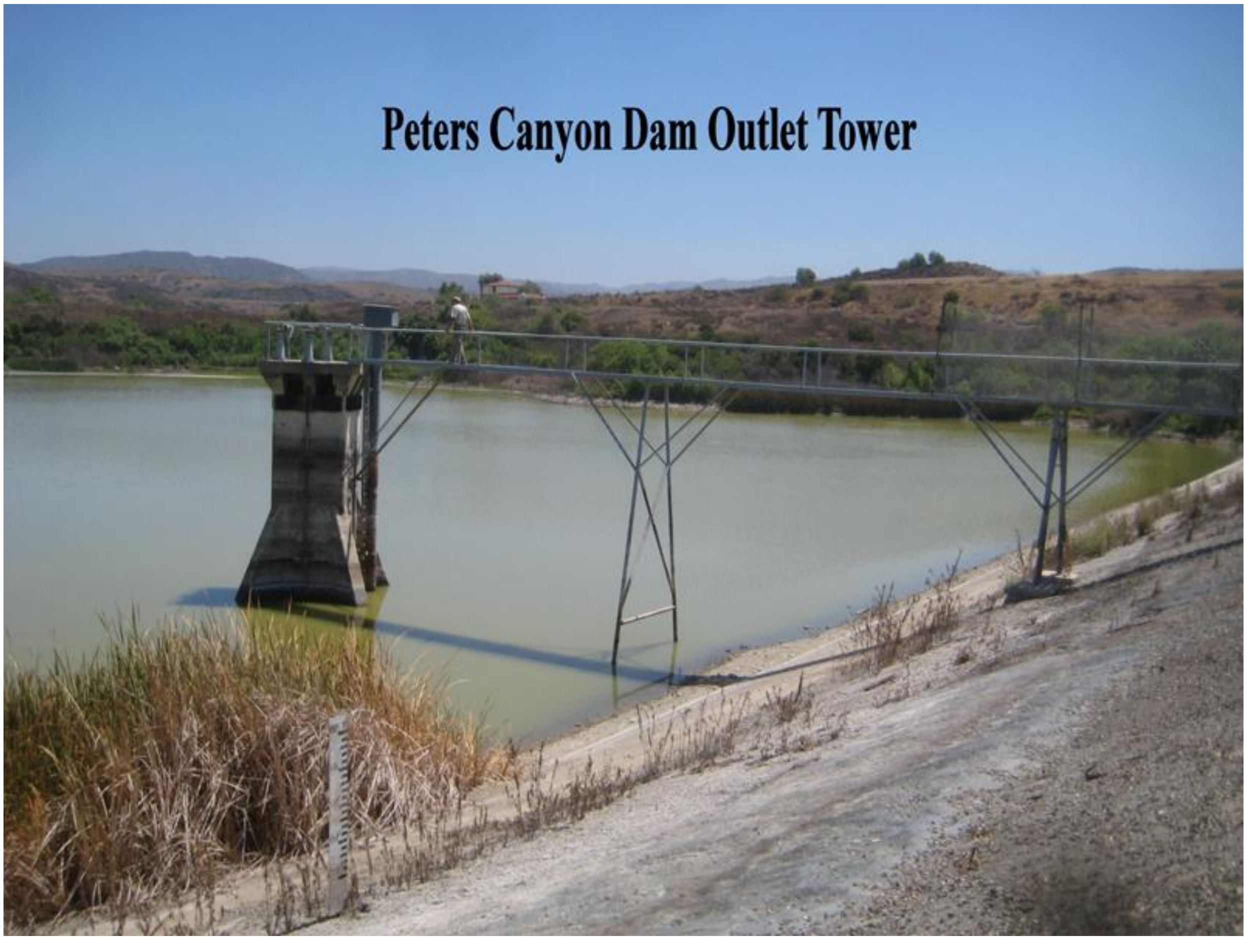
Maps provided by County of Orange.

FIGURE 10: RSCCD SITE IMPACT AS A RESULT OF A SANTIAGO DAM AND RESERVOIR FAILURE

Item	District Location	Address	Elevation Feet Above Sea Level	In Dam Inundation Zone
1	District Operations Center	2323 North Broadway, Santa Ana 92706	147 feet	Yes 7 Hours
2	Santa Ana College (SAC)	1530 West 17th Street, Santa Ana 92706	106 feet	Yes 7 Hours 30 Minutes
3	Santiago Canyon College (SCC)	8045 East Chapman Avenue, Orange 92869	557 feet	No
4	Centennial Education Center (CEC)	2900 West Edinger Avenue, Santa Ana 92704	91 feet	Yes 9 Hours
5	Orange Education Center (OEC)	1465 North Batavia Street, Orange 92867	176 feet	No
7	Orange County Sheriff's Regional Training Academy (OCSRTA)	115991 Armstrong Avenue, Tustin 92782	57 feet	Border 6 Hours
8	Digital Media Center (DMC)	1300 South Bristol Street, Santa Ana 92704	71 feet	Border 9 Hours

Note: Site 6 is the Regional Fire Training Center; land not owned by RSCCD; lease terminated May 2015

PETERS CANYON DAM



Peters Canyon Dam is located approximately 3 miles westerly of Santiago Dam, near the upper part of the Peters Canyon watershed. Irvine constructed an earth-fill dam, 50 foot high with 700 acre-feet of capacity. Its purpose is to regulate the draft from Santiago Dam (Irvine Lake) to lower reservoirs. Distribution to southerly Irvine Ranch was via underground pipeline for one mile to the "High Line Canal. The open channel then carried the flow by gravity several miles easterly across the ranch.

The County of Orange did not develop a Timetable for this dam due to its limited impact per Vicki Osborn, County of Orange Emergency Management Bureau October 2015.

Maps were reviewed by the Risk Manager and the Plan Writer and it was determined that no RSCCD sites would be impacted by a Peters Canyon Dam failure.

FIGURE 11: RSCCD SITE IMPACT AS A RESULT OF A PETERS CANYON DAM FAILURE

Item	District Location	Address	Elevation Feet Above Sea Level	In Dam Inundation Zone
1	District Operations Center	2323 North Broadway, Santa Ana 92706	147 feet	No
2	Santa Ana College (SAC)	1530 West 17th Street, Santa Ana 92706	106 feet	No
3	Santiago Canyon College (SCC)	8045 East Chapman Avenue, Orange 92869	557 feet	No
4	Centennial Education Center (CEC)	2900 West Edinger Avenue, Santa Ana 92704	91 feet	No
5	Orange Education Center (OEC)	1465 North Batavia Street, Orange 92867	176 feet	No
7	Orange County Sheriff's Regional Training Academy (OCSRTA)	115991 Armstrong Avenue, Tustin 92782	57 feet	No
8	Digital Media Center (DMC)	1300 South Bristol Street, Santa Ana 92704	71 feet	No

Note: Site 6 is the Regional Fire Training Center; land not owned by RSCCD; lease terminated May 2015

The RSCCD would like to thank Vicki Osborn, County of Orange Emergency Management Bureau, for providing dam inundation maps for this plan. The maps provided by the State were impossible to read. The maps provided by the County of Orange were difficult to read. According to Ms. Osborn, no other dams in Orange County will impact the RSCCD.

OLIVE HILL RESERVOIR (NO LONGER EXISTS)

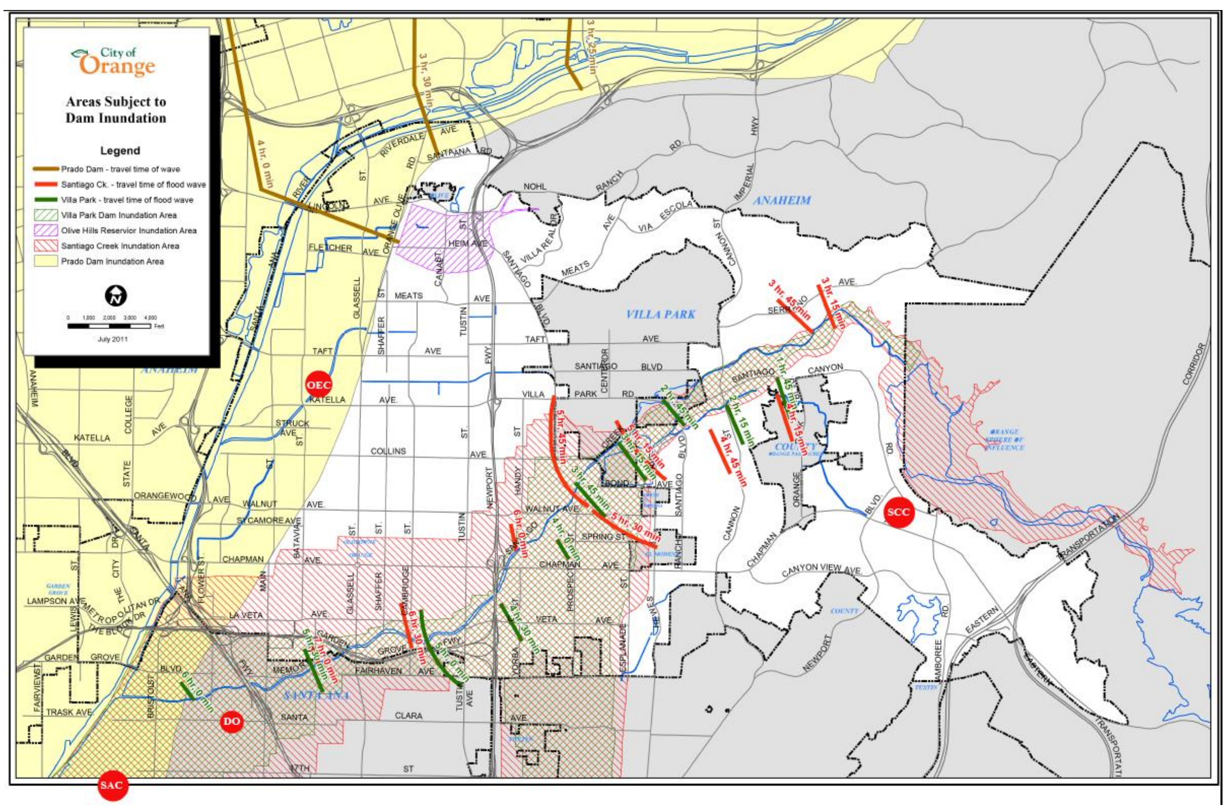
At one point, the Olive Hill Reservoir in Anaheim threatened some areas of Orange. The Olive Hill Reservoir is located in the City of Anaheim. It was an open reservoir with 80 million gallons of water. However, this reservoir was ordered in 1999 to by an Orange County judge to be drained due to possible leaks. Residents sued the City of Anaheim due to a landslide they claimed was caused by a reservoir leak. According to an interview with the City of Anaheim, Bill Moorhead, Principal Engineer (October 2015), the open reservoir was drained and closed in early 2000. A 10 million gallon enclosed water storage tank which is partially buried was built in its place. It is called Nohl Canyon Water Storage Tank. Anaheim has no reservoir/dam inundation maps for this storage tank so it is unknown if it could impact any RSCCD sites. The Olive Hill Reservoir is only being mentioned because it is listed on the City of Orange Map of Areas Subject to Dam Failure. It took considerable time and research to find out the above information and this plan writer wanted to document it for future knowledge.)

FIGURE 12 – CITY OF ORANGE MAP OF AREAS SUBJECT TO DAM INUNDATION

This map includes:

- Prado Dam Travel Time of Wave & Inundation Areas
- Santiago Dam Travel Time of Wave & Inundation Area
- Villa Park Dam Inundation Area
- Olive Hill Reservoir Inundation Areas within the City of Orange.

No City of Santa Ana or Tustin Dam Inundation maps were available in their General Plans.



PRADO DAM

Throughout the Santa Ana River Basin in Orange County the potential exists for massive downstream flooding from the failure of the Prado Dam and overflow of the Santa Ana River. Located in Riverside County at the head of Santa Ana Canyon, Prado Dam is a single purpose dam designed to reduce the flood risk for metropolitan area in Orange County.

Prado Dam is the largest dam that threatens RSCCD facilities. The Seven Oaks Dam is located above Prado dam and feeds in to Prado Dam; Prado Dam feeds into the Santa Ana River; the Santa Ana River flows through the Cities of Orange and Santa Ana where the RSCCD sites are located, to Huntington Beach and out to the ocean.

North Orange County has two major drainage courses with potential for significant flooding: Santiago Creek and the Santa Ana River. The Santa Ana River, with its normally dry riverbed and broad engineered channel and armored levees, does not appear to present a significant flood hazard. However, the Santa Ana River has a long history of overflowing its banks and flooding in the surrounding areas. To reduce this risk, the U.S. Army Corps of Engineers (Corps) constructed the $2.2 billion Santa Ana River Mainstem Project which includes raising the height of Prado Dam and constructing new gate-works allowing for controlled water releases up to 30,000 cubic feet per second and constructing channel improvements between Prado Dam and the ocean. The Corps' project provides 100-year flood protection for Orange County. When completed, the project is designed to provide 190-year level protection from flooding due to the Santa Ana River.

In order to assure acceptable levels of risk to people and property from flooding, the County of Orange and the Cities of Orange, Santa Ana and Tustin have established flood plain management regulations in the flood prone areas. The flood plain management regulations require that new construction or substantial improvements in the flood prone areas must be elevated above the base flood level.

The impact of a Prado Dam failure could cause loss of life, injuries and $15 billion of dollars in property damage, to residential, business and to educational facilities. The flood could extend to most of north, west and central Orange County.

Areas below (downstream from) Prado Dam, including large areas within the Cities of Orange and Santa Ana, as well as some areas of Tustin have high potential for inundation in the unlikely event of catastrophic dam failure. These dams and their reservoirs prevent periodic flooding that would be expected to occur in a natural setting. Recognizing and mitigating floods allows the district to avoid associated dangers. (City of Santa Ana Safety Element)

Prado Dam was completed in April 1941. It is located at the upper end of the Lower Santa Ana River Canyon, which is a natural constriction controlling 2,255 square miles (5,840 square kilometers) of the 2,450 square mile (6,345 square kilometer) Santa Ana River watershed. Authorization for the project is contained in the Flood Control Act of June 22, 1936 (PL 74-738). Modifications to the dam affect the basin below 566 feet elevation. The basin comprises more than 11,500 acres, 4,100 acres of which are riparian habitat (mostly willow woodland), a 4,823-acre recreation area (1,041 developed, 3,782 undeveloped) and 2,400 acres owned by the Orange County Water District.

Prado Dam provides flood control and water conservation storage for Orange County. It is the downstream element of the Santa Ana River flood control system. The purpose of the project is to collect runoff from the uncontrolled drainage areas upstream along with releases from other storage facilities. Generally, when the water surface elevation in the reservoir pool is below the top of the buffer pool elevation (494.0 feet NGVD during the flood season, 505.0 feet NGVD during the non-flood season), water conservation releases are made. These releases are coordinated with the Orange County Water District and are based upon the capacity of their groundwater recharge facilities and agreements with other agencies. If the water surface in the reservoir exceeds the top of the buffer pool, flood control releases commence. The objective of the flood control operation is to drain the reservoir back to the top of the buffer pool as quickly as possible without exceeding the capacity of the channel downstream. In current practice, when the water surface in the reservoir exceeds the top of the buffer pool, releases are increased to match inflow up to 5,000 cfs. When inflows exceed 5,000 cfs, the excess water is stored in the reservoir.

When the water surface elevation in the reservoir reaches 543.0 feet NGVD, uncontrolled releases from the spillway will commence. The 5000 cfs limit on controlled releases from Prado Dam is based upon the old non-damaging capacity of the downstream channel. In the event of Prado Dam failure, floodwaters would flow through the Santa Ana Canyon on its way to the Pacific Ocean. The flood would range from about 3,000 feet wide in the canyon to over 15 miles wide downstream at the Santa Ana Freeway (Interstate 5). The flooding would impact over one million people and 110,000 acres.

If the dam were at capacity, within 4 hours from the failure of Prado Dam, the water is estimated to travel 16 miles to the City of Orange at Lincoln and the Santa Ana River causing severe wave action and flooding. The water could reach heights of 7 feet high by 4 hours and 45 minutes.

By 5 hours and 15 minutes, the water would reach Katella & Batavia in Orange and be 6 feet in depth.

Within 6 hours and 15 minutes, the water would hit Bristol & Civic Center in Santa Ana and peak at 4 feet in 7.5 hours.

In some areas the water depth could reach 25 feet high. The greatest flooding would occur in the area between the Bolsa Chica Mesa in Huntington Beach and the Newport Beach Mesa where flood depths can vary from one to nine feet. From there it flows into the Pacific Ocean.

In 1983 El Nino, the flood waters and wave action were pouring down the Santa Ana River towards the ocean and at the same time, high tides hit causing major flooding in coastal areas. The Army Corps of Engineers has learned from that incident to time the water releases from Prado Dam (whether a flooding or dam failure incident) into the Santa Ana River to avoid high tides.

Once the downstream channel improvements that were part of the Corps of Engineers' Santa Ana River project were completed, the downstream channel capacity was increased dramatically to over 30,000 cfs (850 cms). The Santa Ana River project also increased the capacity of the reservoir behind Prado Dam. The modifications to the dam, which took place in three phases consisted of:

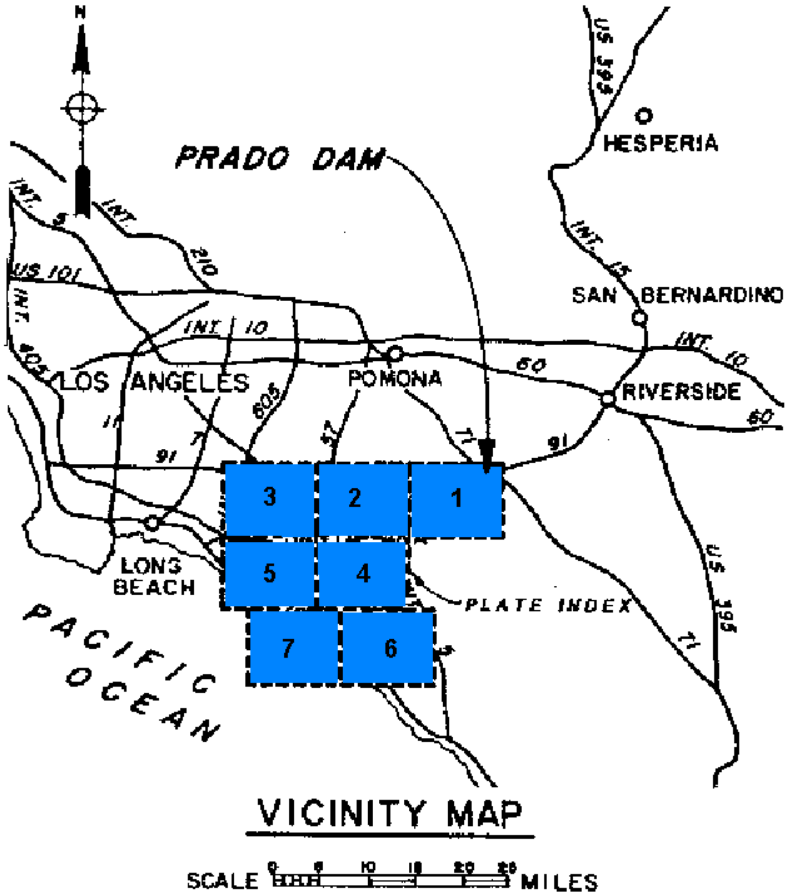
- Raising the height of the dam 30 feet; building a new intake tower; and, constructing improvements to the dam's outlet works (March 2003 – October 2006)
- Constructing dikes in the basin to protect property (September 2004 – September 2007)
- Raising the height of the adjacent spillway 20 feet (July 2006 – January 2008)

The modifications provided an additional 140,000 acre-feet to the reservoir. (One acre-foot is the volume of water that would cover one acre with one foot of water.) These changes increased Prado Dams' 70-year level of protection to 190-year protection. These improvements are expected to prevent $15 billion in damages.

The total cost of the improvements to Prado Dam was approximately $430 million ($221 federal, $209 non-federal). The non-federal sponsor for this project is Orange County Flood Control District. This project is a perfect example of a FEMA/State/Local hazard mitigation project.

The project was authorized under the 1986 Water Resources Development Act (WRDA), the 1988 Energy and Water Appropriation Act (San Timoteo), and Section 309 of WRDA 1996. In 1997 federal officials, following the appropriate laws, concluded that Prado Dam was distinct from the Santa Ana River project. ("Santa Ana Mainstem Project") These improvements enabled the dam to take full advantage of the improved channel capacity downstream and greatly increased the level of flood protection to the Orange County communities in the Santa Ana River floodplain.

FIGURE 13 - PRADO DAM DOWNSTREAM INUNDATION MAP



Plates 2 and 4 are displayed below.

No dam failure maps were available from the Cities of Santa Ana or Tustin General Plan Safety Elements.

FIGURE 14: PRADO DAM DOWNSTREAM INUNDATION MAP PLATE 2

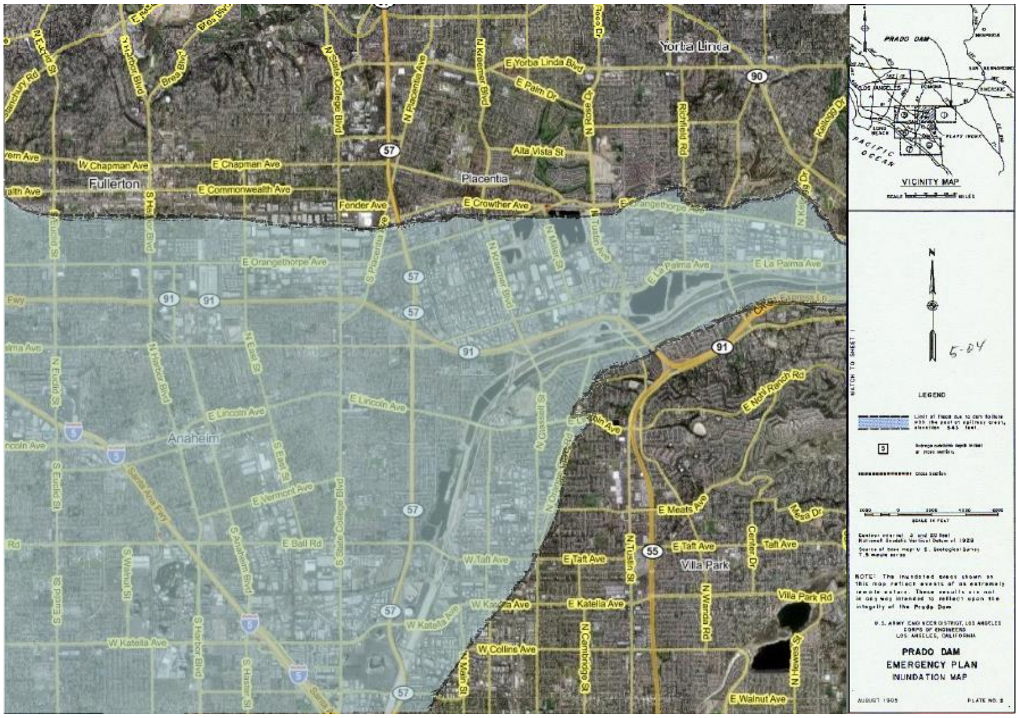


Figure 15: Prado Dam Downstream Inundation Map Plate 3

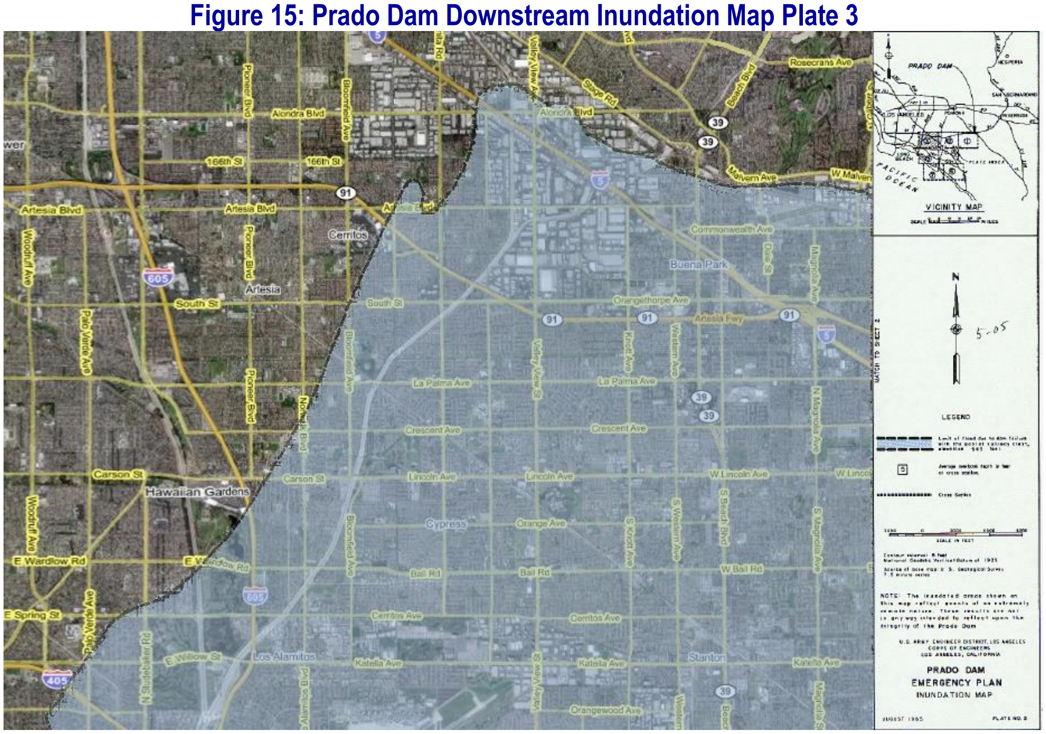


FIGURE 16: PRADO DAM DOWNSTREAM INUNDATION MAP PLATE 4

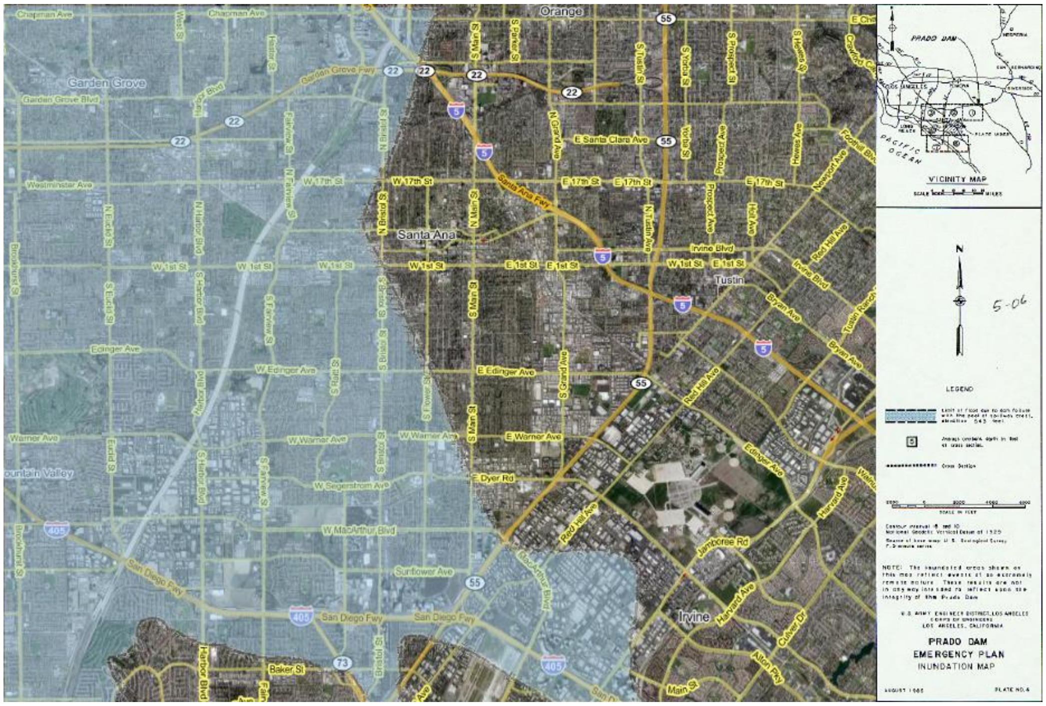


FIGURE 17: PRADO DAM DOWNSTREAM INUNDATION MAP PLATE 5

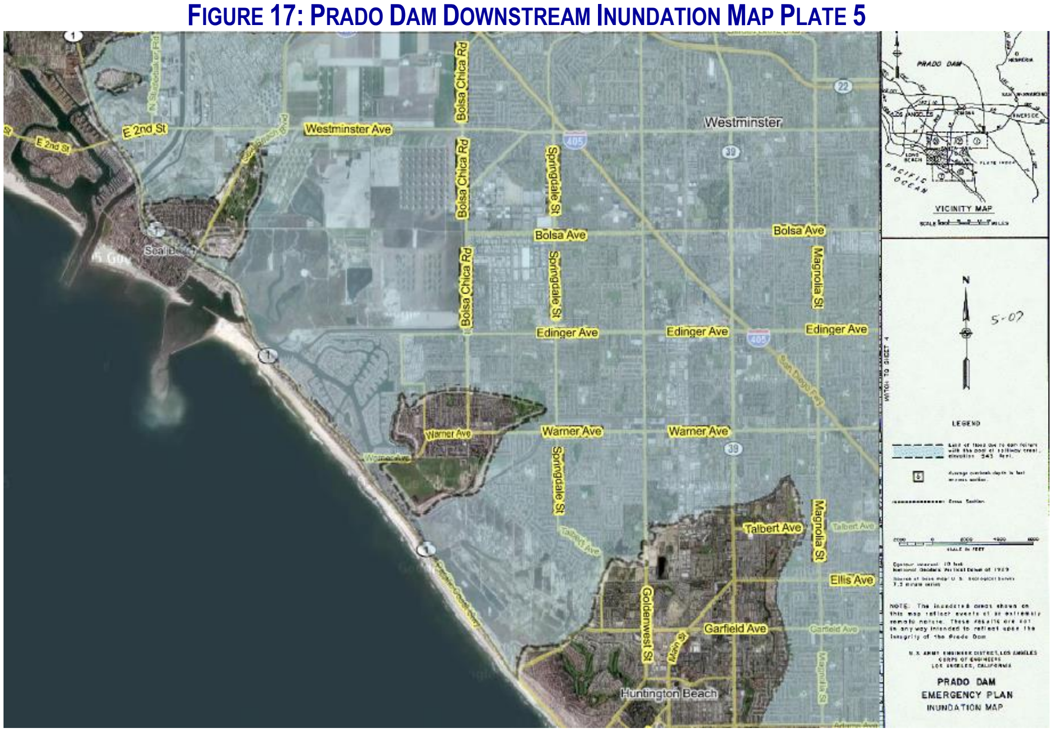


TABLE 3 - PRADO DAM PHYSICAL DATA

Embankment		
Type	Earth Fill	
Crest Elevation	566 feet NGVD	172.5 meters NGVD
Maximum height above streambed	106 feet	32.3 meters
Crest Length	2,280 feet	695 meters
Freeboard during PMF	(-4.3) feet	(-1.3) meters
Spillway		
Type	Concrete Ogee Crest with Converging Chute	
Spillway Crest	543.0 feet NGVD	165.5 meters NGVD
Crest Length	1000 feet	305 meters
Outlet Works		
Number of Passages	6	
Gate Type	Vertical Lift	
Height x Width (each)	12 x 7 feet	3.7 x 2.1 meters
Entrance Invert Elevation	460.0 feet NGVD	140.2 meters NGVD
Maximum Capacity	17,000 cfs	481 cms
Reservoir		
Debris Pool		
Elevation of top of Pool	490.0 feet NGVD	149.4 meters NGVD
Area at top of Pool	768 Acres	311 ha
Gross Storage at top of Pool	4,689 Acre-feet	5.8 MCM
Flood Season Buffer Pool		
Elevation of top of Pool	494.0 feet NGVD	150.6 meters NGVD
Area at top of Pool	1,081 Acres	438 ha
Gross Storage at top of Pool	8,437 Acre-feet	10.4 MCM
Non-Flood Season Buffer Pool		
Elevation of top of Pool	505.0 feet NGVD	153.9 meters NGVD
Area at top of Pool	2,123 Acres	859 ha
Gross Storage at top of Pool	25,760 Acre-feet	31.8 MCM
Top of Dam		
Elevation of top of Pool	566.0 feet NGVD	172.5 meters NGVD
Area at top of Pool	11,030 Acres	4,468 ha
Gross Storage at top of Pool	383,500 Acre-feet	473.0 MCM
Historic Maximum Water Surface		
Date	22 February 1980	
Maximum Elevation	528.0 feet NGVD	160.9 meters NGVD
Historic Maximum Release		
Date	22 February 1980	
Maximum Release	5,992 cfs	169.7 cms

PRADO DAM CURRENT UPDATE AS OF SEPTEMBER 2015

Prado Dam received a Dam Safety Action Class III, or DSAC III, rating in December 2009 based on a Screening Portfolio Risk Analysis, or SPRA, completed in July 2009. A DSAC III rating is given to dams where the dam is ***significantly inadequate***, or ***the combination of life, economic or environmental consequences with probability of failure is moderate to high.***

Prado Dam received a DSAC III rating because of the potential for:

- Embankment seepage and piping
- Overtopping of the dam in the vicinity of the existing spillway

As a result of Prado Dam's DSAC III rating, the Corps has implemented the following Interim Risk Reduction Measures, or IRRMs:

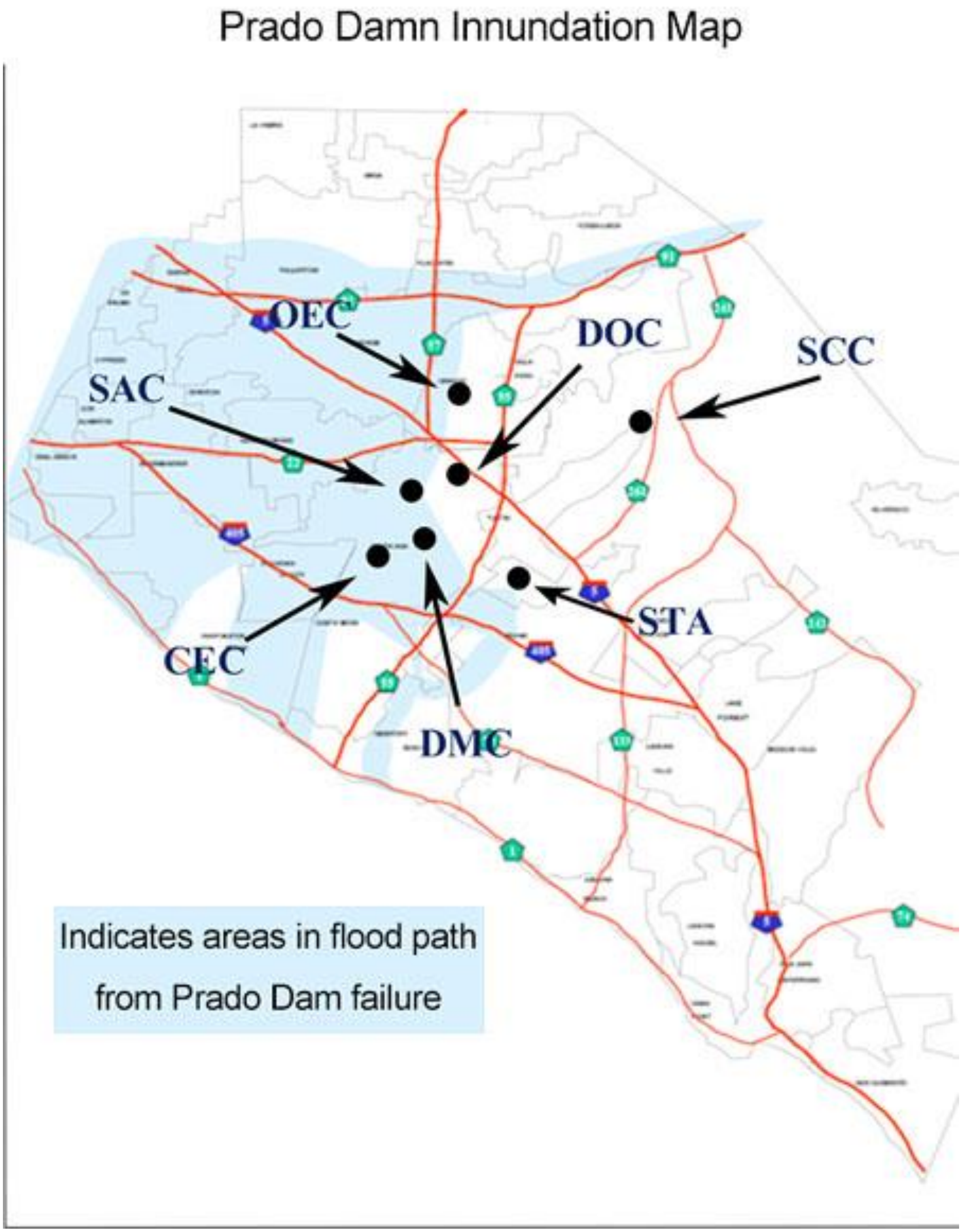
- Inspection by Special Dam Inspection Team when trigger elevation of 528 feet has reached.
- Update the Emergency Action Plan annually.
- Coordinate with local interests and downstream agencies to discuss the predicted failure modes identified in the SPRA report and their associated risks.
- Conduct an orientation seminar dam safety exercise.

Prado Dam Flood Maps
The Army Corps of Engineers will be updating flood maps to derive downstream inundation mapping for various events including dam failure under different failure modes. It is anticipated that this Interim Risk Reduction Measure will be completed by 2020.

On the map on the following page, GIS was not used to place the sites on the map. Locations were estimated.

Six of the seven RSCCD sites are either in or bordering the Prado Dam Inundation Zone. Santiago Canyon Community College is the only site outside or not bordering the inundation zone.

FIGURE 18 - – RSCCD PRADO DAM INUNDATION MAP



Note: GIS was not used to place the RSCCD sites on this map. Locations were estimated.

SANTA ANA RIVER

There are two flood control dams that control flood flow in the Santa Ana River. The Seven Oaks Dam is located on the river in the upper Santa Ana Canyon about eight miles northeast of the City of Redlands in San Bernardino County. This dam was completed in 1999. The Prado Dam is about 40 miles downstream of the Seven Oaks Dam. Approximately 47 billion gallons (145,600 acre-feet) of water can be stored in the Seven Oaks reservoir and 61 billion gallons (187,600 acre-feet) in the Prado Dam, reservoir.

In the event of Prado Dam failure, floodwaters would flow through the Santa Ana Canyon on its way to the Pacific Ocean. The flood would range from about 3,000 feet wide in the canyon to over 15 miles wide downstream at the Santa Ana Freeway (Interstate 5). The flooding would impact over one million people and 110,000 acres.

Most RSCCD facilities lie within the Santa Ana River floodplain. The Santa Ana River begins near the Mt. San Gorgonio summit in the San Bernardino Mountains at an elevation of over 8,000 feet. Its course drains over 90 miles through both the San Bernardino and Santa Ana ranges; 27 miles of the river course flows through Orange County to the Pacific Ocean. The Santa Ana River drainage basin covers 2,450 square miles and is the largest basin in southern California. This was once considered the “worst flood threat west of the Mississippi River.” However, with the Mainstem mitigation project on the two dams, the river and flood control channels, the flood threat has been considerably decreased.

SANTA ANA RIVER PROJECT

Exerts from the Orange County Flood Control Division

Lower Santa Ana River Improvements: The Mainstem Project improved 23 miles of existing channel from Weir Canyon Road to the Pacific Ocean include channel widening, improvement to the existing Greenville-Banning Channel located parallel to the river near the coast, relocation of Talbert Channel ocean outlet and construction of rock jetties and derrick stone jetties at the mouth of the river, and bridge modifications to accommodate the widened channel. In the Santa Ana Canyon area, construction will be limited to levee extension and a dike to protect a mobile home park. The construction in the Santa Ana Canyon Area also include the bank protection on the south side along the SR-91(upstream of SAVI Ranch) and on the north side upstream of Weir Canyon Road. In the future, the stretch of channel from Coal Canyon to the Green River Golf Course entrance bridge will be improved.

LOWER SANTA ANA RIVER PROJECT FEATURES

- Improve 23 mile channel from Prado Dam to the Pacific Ocean
- Restore/Enhance 92 acre (8-acre mitigation) wetlands
- Estimated Cost: $367 million
- Acquire 1,123 acres of canyon lands to ensure safe releases from Prado Dam and provide open space habitat
- Modify 37 bridges
- Landscaping and esthetic treatment
- Sucker Conservation Program
- Habitat Management Plan
- Cooperation with the SARI proponents

SANTA ANA MAINSTEM MITIGATION PROJECT

The Santa Ana Mainstem Project extends approximately 75 miles along the Santa Ana River from the upper canyon in the San Bernardino Mountains downstream to the Pacific Ocean at Newport Beach. The project provides urban flood protection to growing communities in Orange, Riverside, and San Bernardino counties. The system is designed to provide various levels of flood protection ranging from 100 to 190 years for areas most susceptible to damages from flooding.

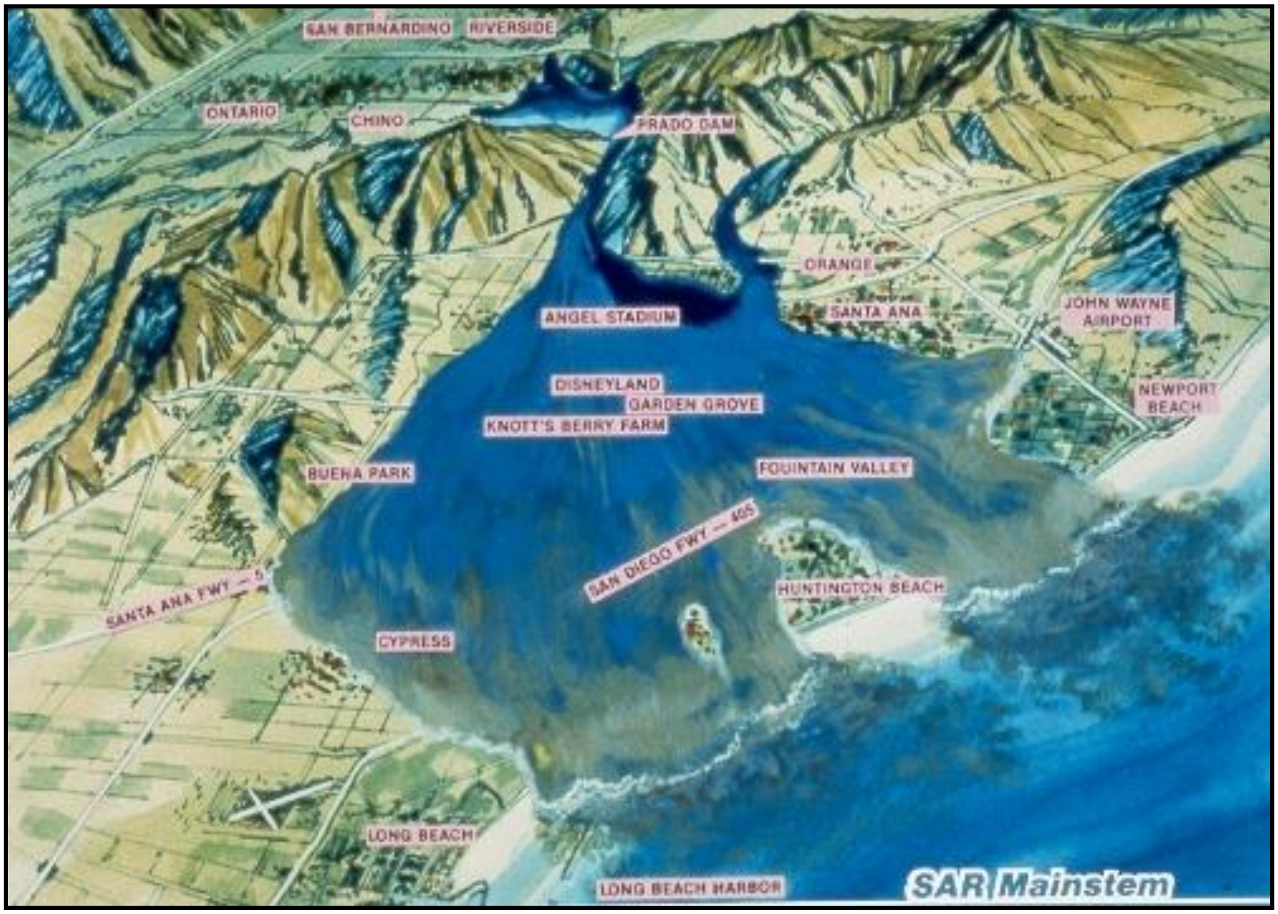
The Mainstem Project includes the following:

- Seven Oaks Dam in the upper Santa Ana River Canyon, to control a 350-year flood event at the dam site
- 5.4 miles of trapezoid-shaped channel and 18 sediment basins inside the channel of San Timoteo Creek in the cities of San Bernardino, Loma Linda, Redlands, and Colton
- Delineation of the 100-year floodway and floodway fringe between Seven Oaks Dam and Prado Dam
- Local authorities now manage this area according to guidelines established by the Federal Emergency Management Agency (FEMA)
- Modifications to the existing federal flood control levees at Mill Creek to restore the original Standard Project Flood level of protection
- Construction of a 100-year level of flood protection channel on the Oak Street Drain in the City of Corona
- Changes in the existing Prado Dam to provide a 190-year level of protection

- Channel improvements along Santiago Creek in Orange County provided 100-year-level flood protection
- Construction of the lower Santa Ana River channel provided 190-year level flood protection
- Enhancement of 84 acres of degraded marshland at the mouth of the Santa Ana River for endangered species and the restoration of eight acres of marshland for wildlife habitat

Construction of the Mainstem project started in 1990 and various stages have been phased-in based on budget approval and appropriations, engineering requirements, safety and environmental scheduling windows. This project is now complete and provides improved flood protection to the RSCCD

FIGURE 19 - SANTA ANA MAINSTEM MAP



The Mainstem project prevented this worst case flooding scenario shown above. Six of the seven RSCCD sites are in or bordering the Santa Ana River Mainstem Project improvement area. The Santa Ana River Mainstem Project is a perfect example of a successful federal, state and multi-county joint hazard mitigation partnership project.

LOCAL HISTORY OF DAM FAILURE

The RSCCD sites have never been impacted by a Prado Dam failure. However, on January 13 and 14, 2005, Prado Dam had seepage from the Prado Dam. The following are news articles and personal recollections of the incident:

A great deal of water escaped into the sea during big storms in 2005. The Jan. 13-14, 2005, deluge underscored the risk of flooding. It triggered seepage in a dike behind the dam, resulting in evacuations of some Corona residents as well as pupils at Riverdale and Woodsboro Elementary School in Anaheim Hills. OC Register

On January 14, 2005, after days of heavy rain, water began seeping through an earthen extension. Authorities released water in order to relieve pressure and sent a flood warning to areas downriver of the dam. Over 3,000 residents were evacuated from their homes for nearly twenty-four hours for fear of flooding. The gymnasium at Corona High School was converted by the American Red Cross into a temporary shelter. Wikipedia
CORONA, Calif. Authorities are evacuating 500 homes and 330 mobile homes this morning because of a possible leak in the Prado Dam east of Los Angeles. The neighborhood is near the city of Corona and north of the 91 freeway.

Corona police Sergeant Jerry Rodriguez says a series of rainstorms caused water level to rise, to the point where the dam is releasing 10-thousand cubic feet of water per second.
He says the evacuation is a "precautionary measure." KESQ News

The following is the personal recollection of Glorria Morrison, City of Huntington Beach Emergency Services Coordinator on January 13 and 14 incidents in 2005. (Glorria Morrison is the plan writer for this plan.)

Cities and other public agencies were all notified of the January 2005 Prado Dam incident by the Orange County Operational Area Emergency Operations Center (EOC). They were told that the heavy rains had caused a potential problem at Prado Dam. Huntington Beach is at the mouth of the Santa Ana River and parts of the city are at sea level and some areas below sea level. 75% of the City is in the Prado Dam Inundation Zone including Golden West College. That equates to approximately 150,000 people or ¾ of the city. Schools and the college were of particular concern. The Huntington Beach EOC had completed a Natural Hazard Mitigation Plan in 2004 and one of the hazards researched was on Prado Dam. The maps and information from the plan were immediately reviewed and duplicated on the day of the incident. The Power Point slides and maps used at the Hazard Mitigation Community Forum were set up in the EOC. The Hazard Mitigation Plan, Prado Dam section was studied. We learned that if Prado Dam failed that it would take 8 hours for the water to arrive in Huntington Beach and it could reach heights of 8 feet in depth. The Huntington Beach EOC was activated.

Management representatives were activated from the following departments:

- Police Chief and key department personnel (responsible for alerting and warning the public and evacuations)
- Fire Chief and key department personnel (responsible for emergency medical, fire suppression, search & rescue, and hazardous materials)
- Public Works Director, City Engineer and key department personnel (responsible for infrastructure [water, sewers, roads, flood channels] and debris removal)

- Marine Safety Chief (responsible for water rescues and Santa Ana swift water rescues)
- Key EOC personnel (Emergency Manager, Public Information Officer and GIS)

Not much information was available from the County or the Army Corps of Engineers. The city of Corona in Riverside County was evacuating areas of the city close to the dam. An American Red Cross shelter was set up for their evacuees. The city of Huntington Beach EOC decided to develop an Incident Action Plan should it become necessary to evacuate areas in the inundation zones. The plan discussed where would we evacuate 150,000 people to since most of Orange County was in the inundation zone and most people would have to be moved to shelters on higher elevation outside the city of Huntington Beach. The plan would only be activated if the situation worsened and the Army Corps of Engineers ordered evacuations. The Huntington Beach EOC personnel were determined to be ready to activate the plan at a moment's notice; to be prepared to activate and brief the Director of Emergency Services, City Council, all EOC personnel as well as Police, Fire, Public Works and Marine Safety field units, the 6 school districts and the public.

All public safety personnel were removed from training classes and placed in fire and police stations ready to respond. The city was prepared to respond but fortunately, the Army Corps of Engineers repaired the problem and never had to order an evacuation. The incident was informative for all EOC and public safety personnel and created a greater awareness of the threat Prado Dam poses to Orange County and particularly to Fountain Valley and Huntington Beach where all the water flows through to the ocean. The Huntington Beach/Fountain Valley Hazard Mitigation Plan provided invaluable information during this incident.

PROBABILITY OF A PRADO DAM FAILURE

The Prado Dam has a Dam Safety Action Class III (DSAC III) rating and has a probability of failure of **moderate to high**. This information was obtained from the US Army Corp of Engineers Los Angeles District website at http://www.spl.usace.army.mil/. When water surface elevation in the reservoir reaches 543.0 feet above MSL, uncontrolled releases from the spillway will commence. The 5000 cfs limit on controlled releases from Prado Dam is based upon the old non-damaging capacity of the downstream channel.

Recent modifications made to Prado Dam have upgraded the facility to ensure that it will withstand a 7.5 magnitude earthquake. Based on the proximity to activate earthquake faults within Southern California, the San Andreas Fault would be the most likely cause of an earthquake of that magnitude. However, the location of the dam in relation to the anticipated source is not anticipated to generate seismic shaking of that magnitude at the dam location. For this reason failure of the Prado Dam and resulting downstream inundation is considered unlikely. In addition, the Army Corps of Engineers has established strict protocols and procedures for assessing the dam facility after a strong seismic event, which will provide downstream communities with up to date information regarding damage that may have occurred.

Prado Dam received a Dam Safety Action Class III, or DSAC III, rating in December 2009 based on a Screening Portfolio Risk Analysis, or SPRA, completed in July 2009. A DSAC III rating is given to dams where the dam is significantly inadequate, or the combination of life, economic or environmental consequences with probability of failure is moderate to high.

Prado Dam received a DSAC III rating because of the potential for:

- Embankment seepage and piping.
- Overtopping of the dam in the vicinity of the existing spillway.

As a result of Prado Dam's DSAC III rating, the Corps has implemented the following Interim Risk Reduction Measures, or IRRMs:

- Inspection by Special Dam Inspection Team when trigger elevation of 528 ft has reached
- Update the Emergency Action Plan annually
- Coordinate with local interests and downstream agencies to discuss the predicted failure modes identified in the SPRA report and their associated risks
- Conduct an orientation seminar dam safety exercise

The probability of a dam failure on the other dams mentioned in this plan is unknown. No information could be found on their probability in either the State or Orange County Hazard Mitigation Plans.

PRADO DAM PEAK ELEVATION DISTANCE AND TIME

The following are examples of "distance from the dam" and "peak elevation times" to assist in planning evacuations. Evacuation areas would include all residents in low-lying areas.

TABLE 4 -PRADO DAM WATER MOVEMENT TIMELINE

Location	Arrival Time	Distance from Dam	Peak Elevation	Time of Peak Elevation	Avg. Over Bank Depth
Hwy 71 (Riverside Co.)	.25 hour	.4 mile	480 NAVD	1.75 hours	15 feet
Green River	.5 hour	1.7 miles	449 NAVD	2.25 hours	15 feet
91 Fwy between Green River & Weir Canyon (east)	.75 hour	2.9 miles	440 NAVD	2.5 hours	16 feet
91 Fwy between Green River & Weir Canyon (west)	1.0 hour	3.9 miles	426 NAVD	2.5 hours	25 feet
91 Fwy @ Weir Canyon	1.25 hours	5.3 miles	393 NAVD	2.75 hours	15 feet
91 Fwy between Weir Canyon & Yorba Linda Blvd	1.5 hours	6.7 miles	371 NAVD	3.0 hours	15 feet
91 Fwy @ Yorba Linda Blvd	2.0 hours	9.3 miles	325 NAVD	3.25 hours	13 feet
91 Fwy between Yorba Linda Blvd & Imperial Hwy	2.5 hours	11.1 miles	299 NAVD	3.75 hours	13 feet
91 Fwy @ Imperial Hwy	3.25 hours	13.0 miles	267 NAVD	4.0 hours	11 feet
Santa Ana Canyon & Tustin to Tustin & Orangethorpe (Anaheim)	3.5 hours	14.5 miles	239 NAVD	4.25 hours	9 feet
Lincoln & Orange Olive (Orange) to 57 Fwy & Chapman (Fullerton)	4.0 hours	16.0 miles	207 NAVD	4.75 hours	7 feet
Katella & Batavia (Orange) to Raymond Ave Commonwealth (Fullerton)	4.5 hours	17.5 miles	181 NAVD	5.25 hours	6 feet

Bristol & Civic Center (Santa Ana) to Malvern & Dale (Buena Park)	6.25 hours	22.0 miles	96 NAVD	7.5 hours	4 feet
Past LA County Line to Harbor and Baker (Costa Mesa) * timeline border runs parallel to south side of 405 Fwy.	8.5 hours	27.0 miles	32 NAVD	10.25 hours	7 feet
Past LA County Line to Warner east of PCH (Huntington Beach) to Seapoint (Huntington Beach)	9.5 hours	31.0 miles	9 NAVD	15.5 hours	4 feet
Atlanta & Beach (Huntington Beach) to Victoria east of SAR (Costa Mesa)	9.5 hours	31.5 miles	9 NAVD	15.5 hours	4 feet
Jamboree & Main St (Irvine) to Jamboree & Michaelson (Irvine)	21.5 hours	28.0 miles	32 NAVD	26.5 hours	2 feet
Campus Drive (Irvine) between Jamboree and University	21.75 hours	30.0 miles	19 NAVD	32.25 hours	9 feet
Jamboree between Bison and University (Newport Beach)	22.0 hours	31.0 miles	7 NAVD	32.75 hours	2 feet

**above reference points are the closest approximate main street along plotted timeline of USACE inundation maps

NAVD = North American Vertical Datum (NAVD). In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929 it will differ to actual sea level by 71 cm or 2.3 feet. The acronym has been adopted by FEMA FIS and FIRM maps to NAVD.

Major roads subject to flooding include Interstate Highway 5 (Santa Ana Freeway), #405 (San Diego Freeway), and #605 (San Gabriel River Freeway) and State Highways #l (Pacific Coast Highway), #22 (Garden Grove Highway), #55 (Newport Freeway), #57 (Orange Freeway), #7l (Corona Highway), #90 (Imperial Highway), and #9l (Riverside Freeway).

TABLE 5 - RSCCD SITE IMPACT AS A RESULT OF A PRADO DAM FAILURE

Item	District Location	Address	Elevation Feet Above Sea Level	In Dam Inundation Zone
1	District Operations Center	2323 North Broadway, Santa Ana 92706	147 feet	Bordering
2	Santa Ana College (SAC)	1530 West 17th Street, Santa Ana 92706	106 feet	Yes
3	Santiago Canyon College (SCC)	8045 East Chapman Avenue, Orange 92869	557 feet	No
4	Centennial Education Center (CEC)	2900 West Edinger Avenue, Santa Ana 92704	91 feet	Yes
5	Orange Education Center (OEC)	1465 North Batavia Street, Orange 92867	176 feet	Bordering
7	Orange County Sheriff's Regional Training Academy (OCSRTA)	115991 Armstrong Avenue, Tustin 92782	57 feet	Bordering
8	Digital Media Center (DMC)	1300 South Bristol Street, Santa Ana 92704	71 feet	Yes

Note: Site 6 is the Regional Fire Training Center; land not owned by RSCCD; lease terminated May 2015. The County of Orange Prado Dam Inundation Map from the county's Hazard Mitigation Plan was used to make the site impact determination.

COMMUNITY DAM FAILURE ISSUES

WHAT IS SUSCEPTIBLE TO DAM FAILURE?

Life and Property

Based on the "local" history events of flooding along the Santa Ana River, we can conclude that the RSCCD sites would be heavily impacted. The largest impact on the communities from a dam failure event is the loss of life and property.

The County and Orange County Cities would utilize every method known to warn the public of an impending dam failure including the following systems:

- Emergency Alerting System (EAS) on the AM/FM radio

- Alert OC (residents should register for this service)
- Police and Fire sirens
- Police helicopter loudspeakers
- Door-to-door canvassing
- Warning Siren System (throughout Huntington Beach; on Newport Beach beaches; and in the San Onofre planning zone)

This would greatly reduce injuries and loss of life.

Residential
Property along the flood channel and coastline could be devastated. Dam failure could potentially destroy or damage hundreds to thousands of homes spreading debris for miles. A dam failure could devastate the local economy.

Commercial
The local governments in California and Orange County rely heavily on tourism and sales tax. A dam failure event would heavily impact tourism and businesses by damaging property and infrastructure and by interrupting business and services. Any residential or commercial structure with weak reinforcement in the impact area would be susceptible to damage.

Infrastructure
A Prado Dam failure can cause damaged buildings, power lines, and other property and infrastructure due to flooding. It could result in collapsed or damaged buildings or blocked roads and bridges, damaged traffic signals, streetlights, and parks, among others. Damage to public water and sewer systems, transportation networks, and flood channels would greatly impact the life of the RSCCD students, faculty and staff.

Roads blocked by objects during a dam failure may have severe consequences to people who are attempting to evacuate campuses or who need emergency services. Emergency response operations can be complicated when roads are blocked by water or when power supplies are interrupted. Industry and commerce can suffer losses from interruptions in electric services and from extended road closures. They can also sustain direct losses to buildings, personnel, and other vital equipment. There are direct consequences to the local economy resulting from dam failure related to both physical damages and interrupted services.

Campuses
Campuses must evacuate as soon as a dam failure warning is issued to the local area. Each campus should understand how the threat impacts their facilities and be able to give students, staff and faculty instructions for safely evacuating the impact area. The District EOC would be activated to coordinate between the Orange County Operational Area EOC and the activated Campus EOCs.

Campuses not in the inundation zones should stand by and be ready to set up their facilities as shelters for the evacuated and displaced residents. During the recovery phase of the incident, campuses should offer their sites as Local Assistance Centers. It must be understood that the Water Movement Timeline and Over the Banks Depth figures are for worse-case scenario when the dam is filled to capacity. Less water in the dam would result in a less severe impact. All of this must be taken into consideration.

EXISTING MITIGATION ACTIVITIES

Orange County, the State of California, and Federal government agencies have implemented dam failure mitigation activities over the years. Orange County and its cities have received many awards and been acknowledged for being leaders in terms of preparing and training its residents for disasters. Some of the current mitigation programs include:

- Improvements of the Santa Ana River Flood channel (Mainstem Project)
- City/County Flood Control Projects
- City/County Master Plan Storm Drain Projects
- City/County Master Plan Pump Station Projects
- City Emergency Operations Plans
- Orange County Operational Area Emergency Operations Plans
- Rancho Santiago Community College District Emergency Operations Plan
- Orange County Operational Area Dam Failure Plan, 2006 (under revision)

CONCLUSIONS

The RSCCD sites may be impacted by the following dams:

1. Prado Dam
2. Villa Park Dam
3. Santiago Dam
4. Peters Canyon Dam

Other dams within Orange County may also impact the RSCCD sites. Any time a dam failure notice is received by the Orange County Operational Area, the incident should be taken seriously, maps should be consulted and evacuation of sites considered.

Due to the extremely poor quality of the dam inundation maps provided by State OES and the lack of maps provided by the city of Santa Ana, it was difficult to impossible to determine which other dams could impact the RSCCD sites. The County of Orange provided Prado Dam, Villa Park, Santiago and Peters Canyon Dam Inundation Maps and the City of Orange Areas Subject to Dam Inundation Map provided the best sources of information used in this plan.

The following is a summary of information on the impact of a dam failure to the RSCCD.

TABLE 6: DAM FAILURE – RSCCD SITE ESTIMATED IMPACTS

RSCCD Site	Prado Dam	Villa Park Dam	Santiago Dam	Peters Canyon	Olive Hill
District Office	Bordering	Yes	Yes	No	No
Santa Ana CC	Yes	Yes	Yes	No	No
Santiago Canyon CC	No	No	No	No	No
Centennial Education Center	Yes	Yes	Yes	No	No
Orange Education Center	Bordering	No	No	No	No
OC Sheriff Training Academy	Bordering	Bordering	Bordering	No	No
Digital Media Center	Yes	No	Bordering	No	No

Note: The City of Orange Areas Subject to Dam Failure Map was used to determine non-scientific estimates of the impact on RSCCD. The City of Santa Ana did not have a Dam Failure Map per their Emergency Manager. Neither cities have hazard mitigation plans. This table should be redone as soon as GIS Dam Inundation Maps become available and should be redone at the time of a dam failure in Orange County.

TABLE 7: DAM FAILURE – RSCCD DAM ESTIMATED IMPACT TIMES

RSCCD Site	Prado Dam	Villa Park Dam	Santiago Dam	Peters Canyon	Olive Hill
District Office	4 Hours.	6 Hours 30 Minutes	7 Hours.	No	No
Santa Ana CC	4 Hours.	6.Hours 15 Minutes.	7 Hours 30 Minutes	No	No
Santiago Canyon CC	No	No	No	No	No
Centennial Education Center	4 Hours.	7 Hours. +	9 Hours. +	No	No
Orange Education Center	4 Hours.	No	No	No	No
OC Sheriff Training Academy	4 Hours.	5 Hours. +	6 Hours. +	No	No
Digital Media Center	4 Hours.	No +	9 Hours. +	No	No

Note: The City of Orange Areas Subject to Dam Failure Map was used to determine non-scientific estimates of the impact on RSCCD sites. The City of Santa Ana did not have a Dam Failure Map available. Neither city has a hazard mitigation plan. THESE TIMES ARE ***ESTIMATES ONLY.*** This table should be redone as soon as GIS Dam Inundation Maps become available and should be redone at the time of a dam failure in Orange County.

D. THE DAM FAILURE MITIGATION STRATEGIES

A dam failure is a much larger incident than one school district can mitigate or manage. RSCCD does not own or control any dam. Prado Dam is owned by the Army Corps of Engineers and operated by the Army Corps of Engineers and the County of Orange. The RSCCD can only work in conjunction with other public agencies in most dam failure mitigation partnership projects.

The dam failure mitigation strategies provide direction or specific activities that organizations and residents can undertake to reduce risk and prevent loss from a dam failure event.

SHORT TERM MITIGATION STRATEGIES

Hazard	Dam Failure #1	
Action Item	**The District needs readable, up-to-date GIS Dam Failure maps for all dams that impact the District.** **Note: The existing inundation maps are extremely poor quality. The Risk Manager and the Plan Writer reviewed every identified dam's inundation maps to determine if RSCCD facilities would be impacted but it was impossible to determine accurately which facilities would be vulnerable due to the poor quality of the maps. Need these maps in GIS format and they are not in GIS format yet.**	
Coordinating Organization	Chief, District Safety & Security	
Ideas for Implementation	Work closely with the County of Orange and Army Corps of Engineers (Prado Dam) to get improved GIS inundation maps. (They are not available at this time.) Once received, review and update site impact and timetable impact on each map. ▪ Contact each of these agencies annually to see if maps have been updated, are maps available in GIS, and will any of the agencies place the RSCCD sites on the inundation maps. Send a formal letter requesting this assistance. ▪ For the update of this plan (5 years), contact MMI Engineering or other engineering companies to see if GIS data is available for mapping these sites. (GIS data not available as of 2015.) ▪ Send a letter to the County of Orange and request their assistance in: o Determining if other dams within Orange County that may impact RSCCD facilities, especially in Santa Ana where the City General Plan did not have any information or maps on dam failures o Receiving improved inundation maps o In having Orange County provide GIS mapping information service on impact to RSCCD facilities from a dam failure	
Time Line	Ongoing	
Constraints	Learning of proposed projects	
Funding Sources	General Fund	
Cost Estimate	Staff Time	
Benefits: Losses Avoided	These planning documents will improve emergency response resulting in life saving and limiting injuries at little cost to the district	
Priority	Medium/High	
Plan Goals Addressed		
X	Promote Public Awareness	
X	Create Partnerships and Implementation	
X	Protect Life and Property	
X	Protect Natural Systems	
X	Strengthen Emergency Services	

Hazard	Dam Failure #2	
Action Item	**Consider writing Dam Failure Evacuation Plans for each dam that may impact the 7 RSCCD sites. Complete plans for the sites with the greatest dam failure threat first and take into consideration greater populations.**	
Coordinating Organization	Chief, District Safety & Security	
Ideas for Implementation	▪ Review each Dam Inundation Map for dams that may impact the RSCCD sites and document site impacts ▪ Develop evacuation plans for each RSCCD site depending on which dams may impact them ▪ Conduct a tabletop exercise with the district EOC personnel and 7 site EOC personnel on dam failure ▪ Participate in any dam failure exercises held in Orange County especially Prado Dam (greatest impact on Orange County)	
Time Line	Ongoing	
Constraints	Learning of proposed projects	
Funding Sources	General Fund	
Cost Estimate	Staff Time	
Benefits: Losses Avoided	These planning documents will improve emergency response resulting in life saving and limiting injuries at little cost to the district	
Priority	Medium/High	
Plan Goals Addressed		
X	Promote Public Awareness	
X	Create Partnerships and Implementation	
X	Protect Life and Property	
X	Protect Natural Systems	
X	Strengthen Emergency Services	

Hazard	Dam Failure #3	
Action Item	**Conduct a Dam Failure Education Campaign for Campus Facility Captains, EOC personnel and key management staff members at each site**	
Coordinating Organization	Risk Manager and Chief District Safety & Security	
Ideas for Implementation	Include dam failure education in all emergency preparedness training classes. Utilize research from this plan to educate staff, faculty and students	
Time Line	Ongoing	
Constraints	▪ Time constraint - Need to hire District Emergency Services Coordinator ▪ Classes are voluntary often resulting in low attendance	
Funding Sources	General Fund	
Cost Estimate	Staff Time	
Benefits: Losses Avoided	Sustained education/outreach programs have minimal cost and will help build support district-wide for disaster mitigation and preparedness. This type of activity enables the district faculty, students, and the public to prepare for, respond to and recover from a dam failure.	
Priority	High	
Plan Goals Addressed		
X	Promote Public Awareness	
	Create Partnerships and Implementation	
	Protect Life and Property	
	Protect Natural Systems	
	Strengthen Emergency Services	

Hazard	Dam Failure #4	
Action Item	**Participate in the County of Orange and the Army Corps of Engineers Dam Safety Planning, Trainings, and Exercises for Prado Dam and other Orange County dams .**	
Coordinating Organization	Chief, District Safety & Security	
Ideas for Implementation	▪ Work through the Orange County Emergency Management Organization (OCEMO) and the Orange County Operational Area to participate in these exercises	
Time Line	Ongoing	
Constraints	Time	
Funding Sources	General Fund	
Cost Estimate	Staff Time	
Benefits: Losses Avoided	Exercises allow the district to practice its emergency plans which will improve their response to life saving, limiting injuries, expedite the protection of property and the environment, and assist the district in providing community shelters and Local Assistance Centers.	
Priority	High	
Plan Goals Addressed		
X	Promote Public/College Community Awareness	
X	Create Partnerships and Implementation	
X	Protect Life and Property	
	Protect Natural Systems	
X	Strengthen Emergency Services	