Strong and Chicken Ranch Slough Watershed Alternative Analysis

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Prepared for Sacramento County Public Works Department

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Executive summary

Situation

Homes and community facilities in the Woodside condominium complex in the Arden-Arcade neighborhood of Sacramento County were flooded by local storm runoff in 1986, in 1997, and again on New Year's Eve of 2005. This complex is located in the Strong Ranch Slough watershed, adjacent to the Strong Ranch and Sierra Branch channels.

Flooding in this watershed has been studied by, and remedies have been sought by, Sacramento County and the US Army Corps of Engineers (Corps). While the flooding is dramatic and a financial burden to property owners in the complex, these studies were able to identify only one flood management solution that was economically justified. That solution was doubling the capacity of the D05 pumping station. While a number of other options were identified, when evaluated, all were found to have implementation costs that exceed the long-term average value of damage reduced.

Tasks

The goal of the present study is to further evaluate the economically-justified solution along with other lower-cost, lower-impact alternatives. While not providing a high level of protection, these alternatives provide some relief from flooding to Woodside properties by either (1) reducing the water surface elevation in the slough along the Woodside properties, or (2) protecting the properties by keeping high water out of the development.

Specific tasks were to answer the following questions:

1. How would a flood wall have changed the flooding due to the storm of December 2005?
2. What is the channel capacity of Strong Ranch Slough adjacent to the Woodside properties?
3. What are the hydraulic impacts of constructing flood walls, of various heights along the Woodside properties, south of Northrop Avenue?
4. Can increasing pump capacity at the D05 pond mitigate any negative impacts, or can other measures do so?

Actions

To complete the tasks, we first developed a detailed hydraulic model of the channels, the pumping station, and the surrounding terrain. This model enabled computation of water levels throughout the complex. By adjusting the representation of the channel to include proposed walls and other options, we can, with the model, evaluate the reduction in water level due to the measures. We also developed a hydrologic model of the watersheds from which runoff flows into the channels; this provides estimates of runoff for various design storms (storms of specified probability). Finally, we collected data for the historical storms, including rainfall and water levels.

For the hydraulic model, we started with a model that was developed and used by the Corps for their 2001 study. (This model is described in the Corps of Engineers August 2001 report *Strong and Chicken Ranch Sloughs, California – Feasibility report: Phase I studies*.) To take advantage of recent advances in channel modeling available in the Corps of Engineers HEC-RAS computer application, we converted the Corps' hydraulic model to a format required for the new application. During that conversion, we:

- Used County-supplied state-of-the-art LIDAR-derived terrain data to update the floodplain representation in the model.
- Incorporated new field-survey data provided by the County to enhance representation of the channel.
- Refined the model's representation of drainage features, using new procedures available in the HEC-RAS application.

To confirm that the model represented well the behavior of the channels and the overflows into streets and property, we exercised the model with data from February 18, 1986, January 9, 1995, January 22, 1997, January 26, 1997, and December 31, 2005 historic storms. For each, observed water levels were available. We simulated channel behavior using upstream and downstream measurements to compute water levels along the channel and overflows into Woodside. We then compared the computed levels to those measured, concluding that the model represents well the system behavior.

Using the updated hydraulic model, we then simulated performance of inundation-reduction alternatives listed in Table 1. Each of the alternatives listed was evaluated for each following events:

- February 18, 1986 event.
- January 26, 1997 event.
- December 31, 2005 event.
- The 25-year (p=0.04), 50-year (p=0.02), 100-year (p=0.01), and 200-year (p=0.005) events. These are frequency-based design-storm events that are the standard of practice for drainage design in Sacramento County.

Water levels in the lower portion of the Strong and Chicken Ranch Slough watershed are affected by the water level in the D05 pond, which, in turn, is related to water level in the lower American River. For the historical events, historical levels were used. For the frequency-based design events, a coincident-frequency analysis framework is used; with that, all possible combinations of interior and exterior stages are considered, weighing each by the probability of occurrence. (The water levels reported for the frequency events were computed within this framework, so they are not the result of a single hydraulic model run.)

Table 1. Inundation-reduction alternatives evaluated

ID (1)	Modifications to channel (2)	Modifications to D05 pond (3)
1	—	Divide pond to raise water level at the pumps
2	32 ft embankment along Strong Ranch Slough to protect Woodside East and West properties	—
3	32 ft embankment along Strong Ranch Slough to protect Woodside East and West properties	Double the D05 pumping capacity
4	In addition to 32 ft embankment along Strong Ranch Slough, 33 ft floodwall along property line to protect Woodside East and West properties	—
5	In addition to 32 ft embankment along Strong Ranch Slough, 33 ft floodwall along property line to protect Woodside East and West properties	Double the D05 pumping capacity
6	In addition to 32 ft embankment along Strong Ranch Slough, 34 ft floodwall along property line to protect Woodside East and West properties	—
7	In addition to 32 ft embankment along Strong Ranch Slough, 34 ft floodwall along property line to protect Woodside East and West properties	Double the D05 pumping capacity

To display the hydraulic impact of the alternatives, we prepared a series of floodplain maps of the area surrounding Woodside. These maps show the area inundated for each of the evaluation events, without and with the alternatives listed in Table 1. All alternatives were evaluated to identify the hydraulic impacts, using approximate configurations of the embankments.

Findings

From the simulations, we found that with the 32-ft embankment, the channel capacity of Strong Ranch Slough near the Woodside properties is approximately 1500 cfs. This is approximately the 50-year flow. The 50-year flow has a probability of exceedence 0.02. However, if the stage in the D05 pond is high, the channel capacity is significantly less.

With higher embankments above, we found that the channel capacity is increased by approximately 50 cfs, when the lower American River stage is low, from the current (without-project) conditions. This increased capacity would result in fewer Woodside properties flooded in December 2005, but some flooding would still occur.

We found that constructing a floodwall to protect Woodside does have a hydraulic impact, as it increases the water levels elsewhere in Strong Ranch Slough and Sierra Branch. The floodplain maps illustrate the impact of this increased water level.

We found that doubling the existing pump capacity at the D05 pond will mitigate adverse impacts due to the floodwalls.

Figure 1 through Figure 7 show the floodplain boundaries for each storm event, illustrating how each alternative alters the inundated area. Additional details are presented in the text of this report.

The hydraulic model results and maps indicate changes in channel and floodplain water levels due to the alternatives. The floodplain water levels were computed and mapped using contours derived from County LiDAR data; the underlying elevations are accurate to +/- 0.7 ft vertically with 95% confidence. This is a high standard of accuracy, appropriate for comparison of alternatives and identification of changes. Nevertheless, water level differences computed and mapped should be interpreted with some caution when the uncertainty in the underlying elevation data is greater than the computed water level differences.

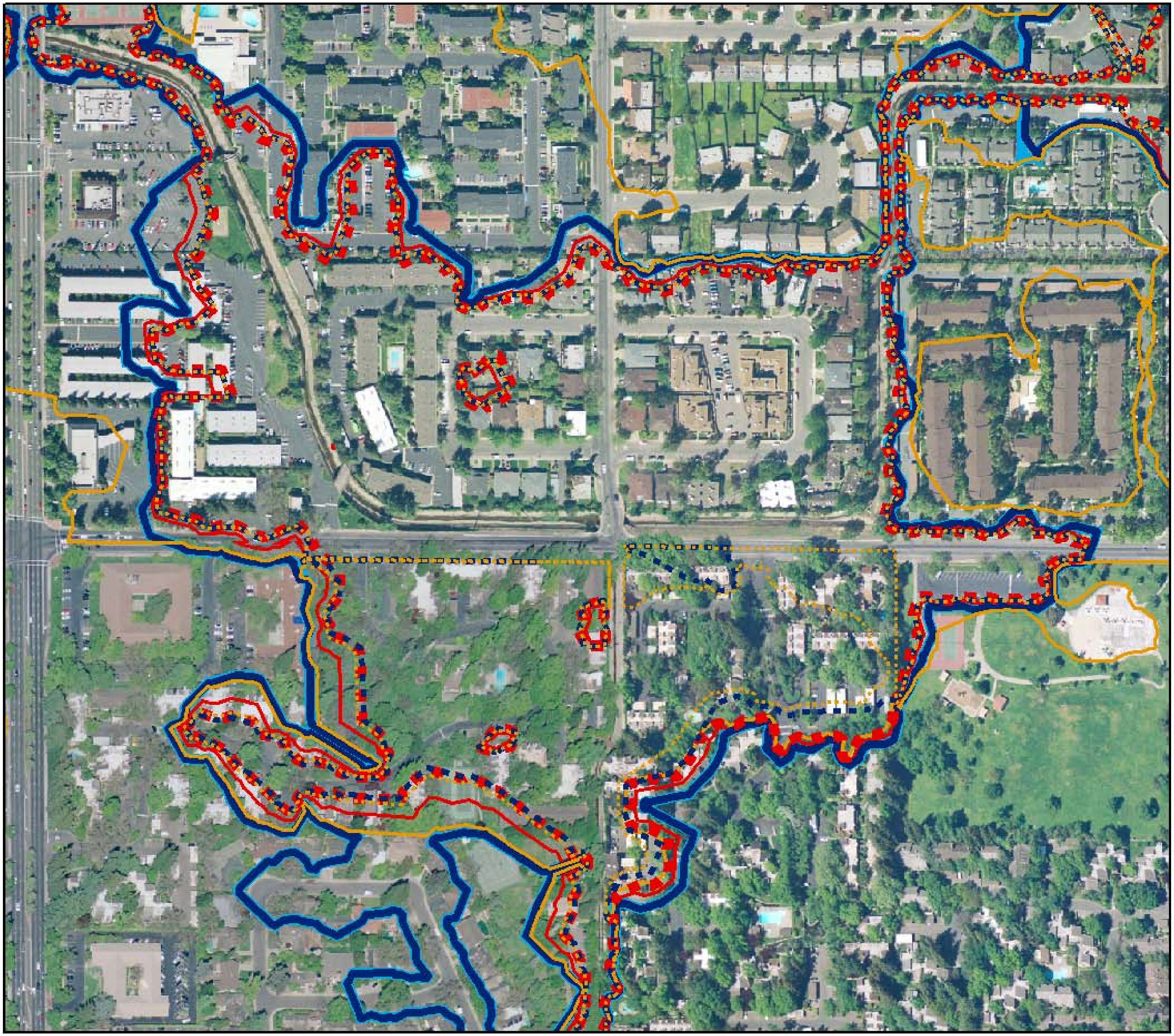

Figure 1

County of Sacramento
Strong and Chicken Ranch Slough
Alternative Analysis

February 18
1986 Event

N.T.S

Legend:

Floodplain Boundaries for:

- 34ft floodwall + double pump capacity
- 33ft floodwall + double pump capacity
- 32ft embankment + double pump capacity
- 34ft floodwall
- 33ft floodwall
- 32ft embankment
- Without-project conditions

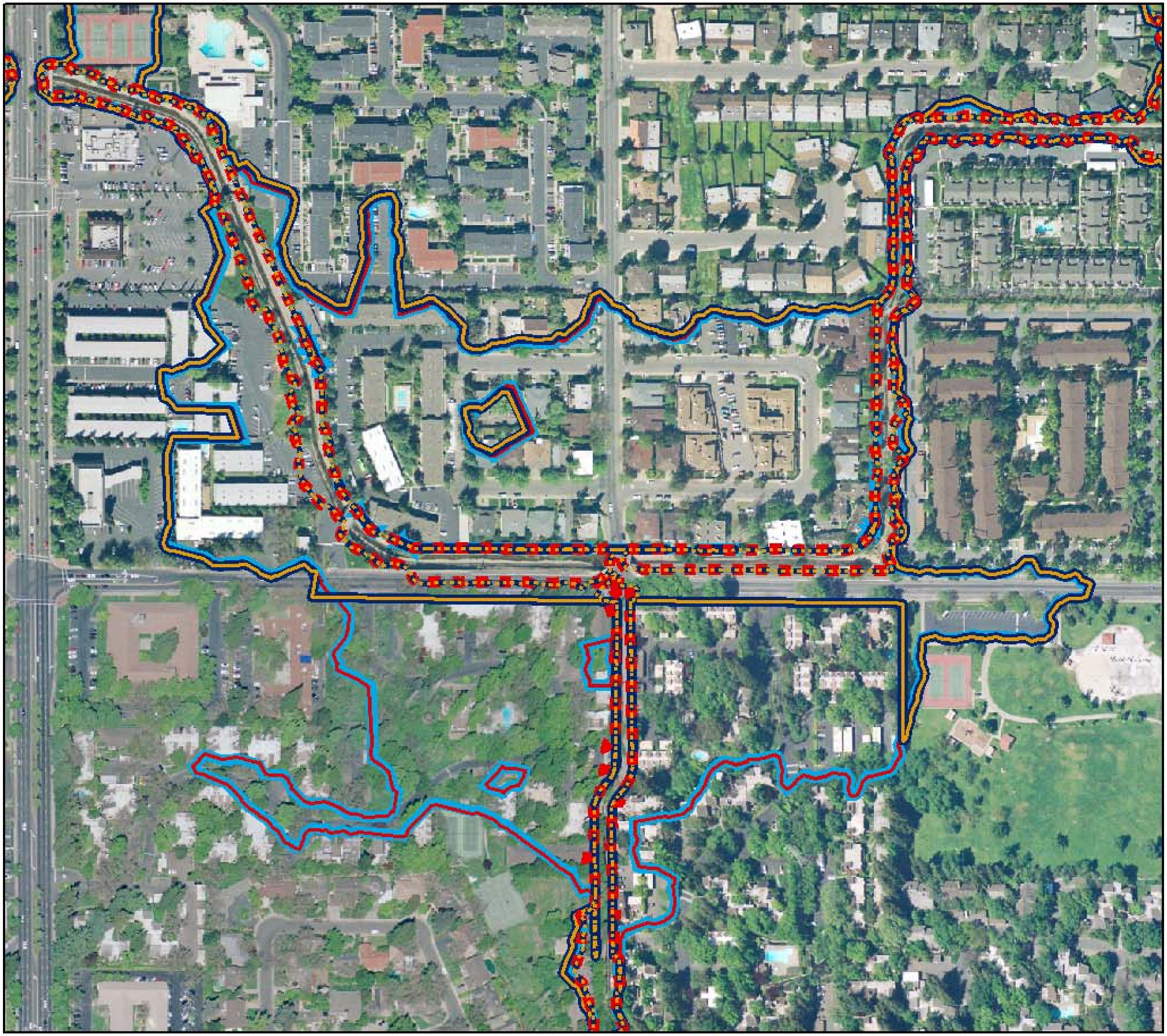

Figure 2

County of Sacramento
Strong and Chicken Ranch Slough
Alternative Analysis

January 26
1997 Event

N

Legend:

Floodplain Boundaries for:

- 34 ft floodwall + double pump capacity
- 33 ft floodwall + double pump capacity
- 32 ft embankment + double pump capacity
- 34 ft floodwall
- 33 ft floodwall
- 32 ft embankment
- Without project conditions

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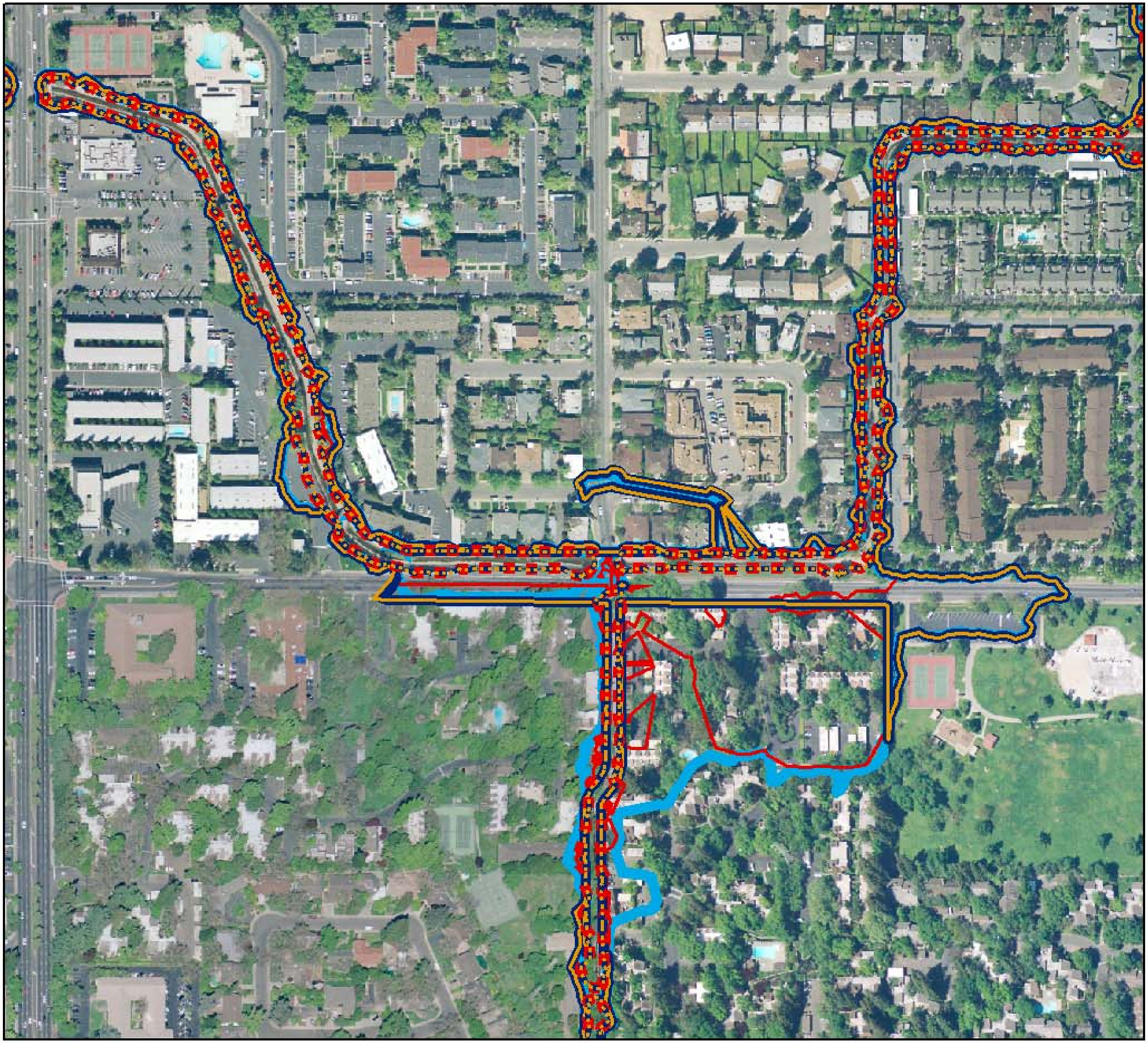

Figure 3

County of Sacramento
Strong and Chicken Ranch Slough
Alternative Analysis

2005 Event

Legend:

Floodplain Boundaries for:

- 34ft floodwall + double pump capacity
- 33ft floodwall + double pump capacity
- 32ft embankment + double pump capacity
- 34ft floodwall
- 33ft floodwall
- 32ft embankment
- Without-project conditions

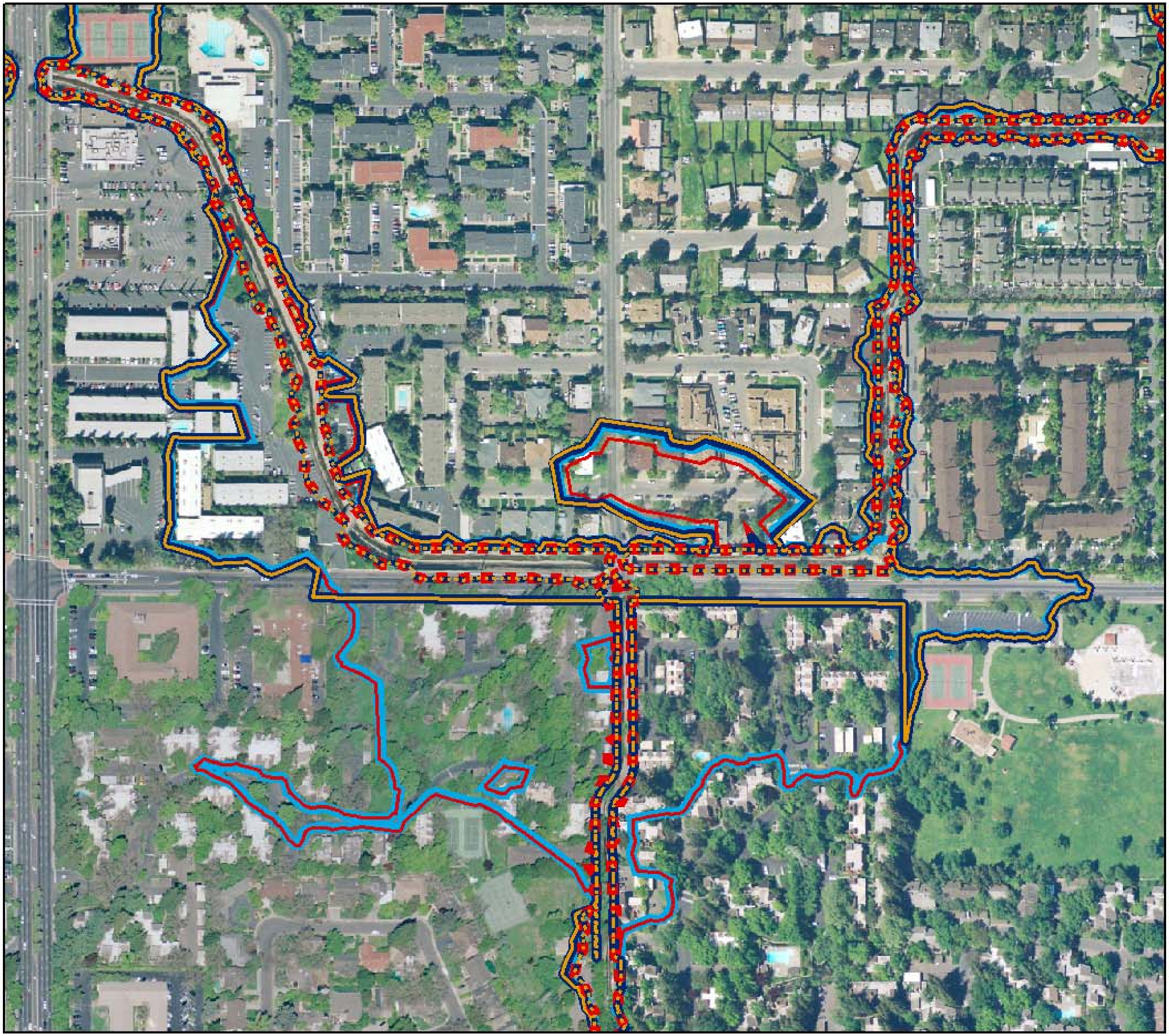

Figure 4

County of Sacramento
Strong and Chicken Ranch Slough
Alternative Analysis

25 year Event
(p=0.04)

Legend:

Floodplain Boundaries for:

- 34ft floodwall + double pump capacity
- 33ft floodwall + double pump capacity
- 32ft embankment + double pump capacity
- 34ft floodwall
- 33ft floodwall
- 32ft embankment
- Without-project conditions

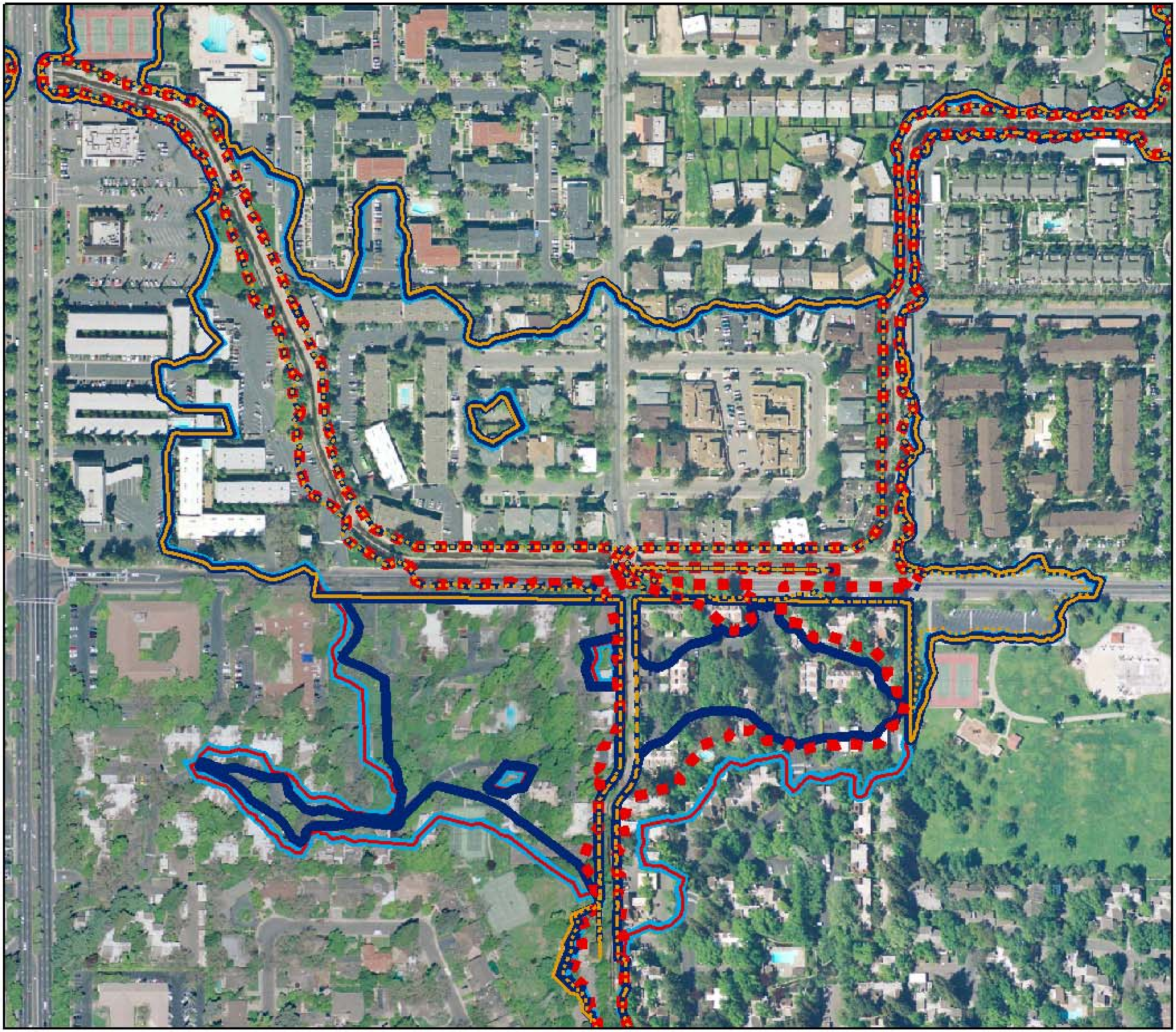

Figure 5

County of Sacramento
Strong and Chicken Ranch Slough
Alternative Analysis

50 year Event
(p=0.02)

N

Legend:

Floodplain Boundaries for:

- 34ft floodwall + double pump capacity
- 33ft floodwall + double pump capacity
- 32ft embankment + double pump capacity
- 34ft floodwall
- 33ft floodwall
- 32ft embankment
- Without-project conditions

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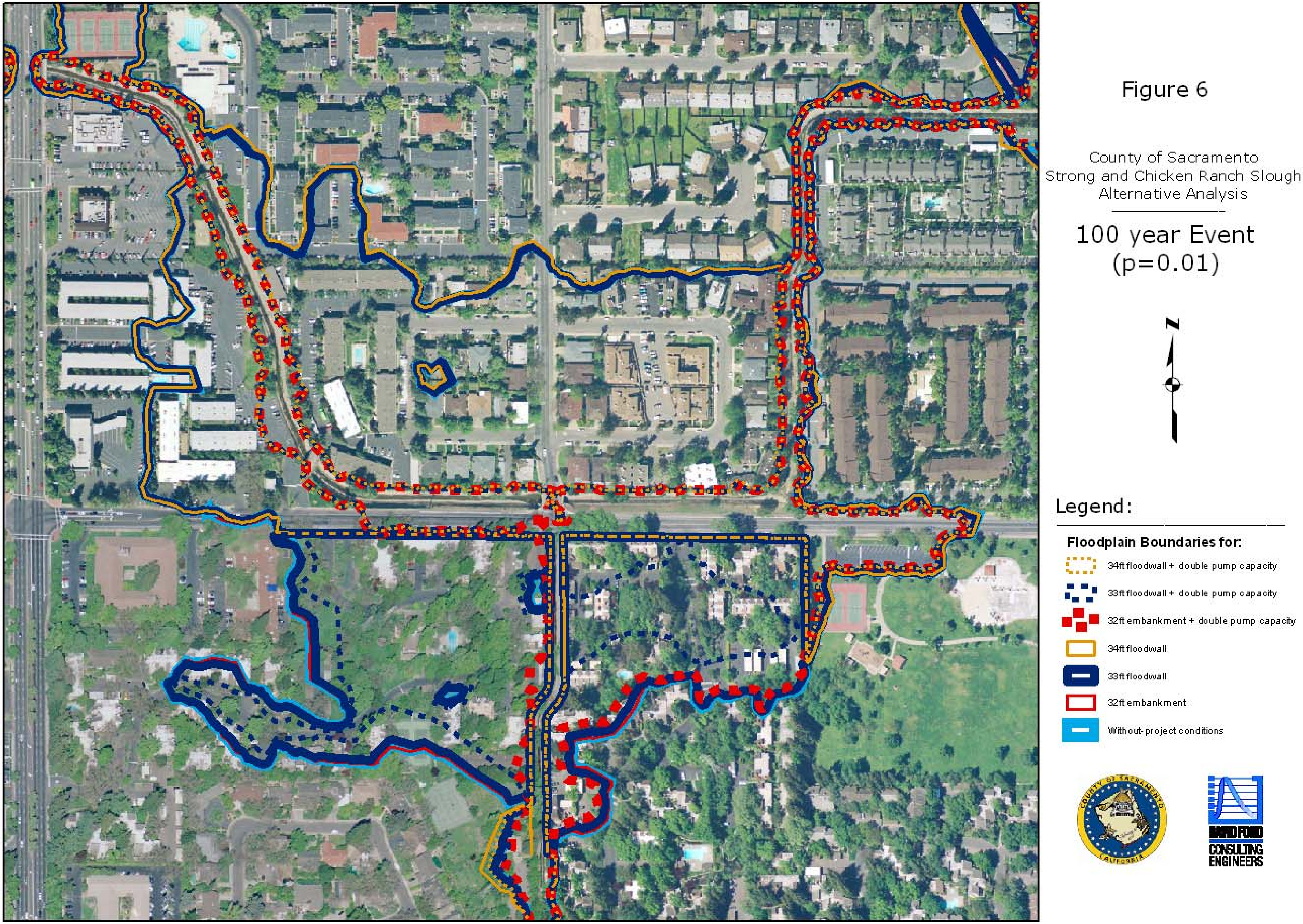
Figure 6
County of Sacramento
Strong and Chicken Ranch Slough
Alternative Analysis
100 year Event
(p=0.01)
N
Legend:
Floodplain Boundaries for:
34ft floodwall + double pump capacity
33ft floodwall + double pump capacity
32ft embankment + double pump capacity
34ft floodwall
33ft floodwall
32ft embankment
Without-project conditions
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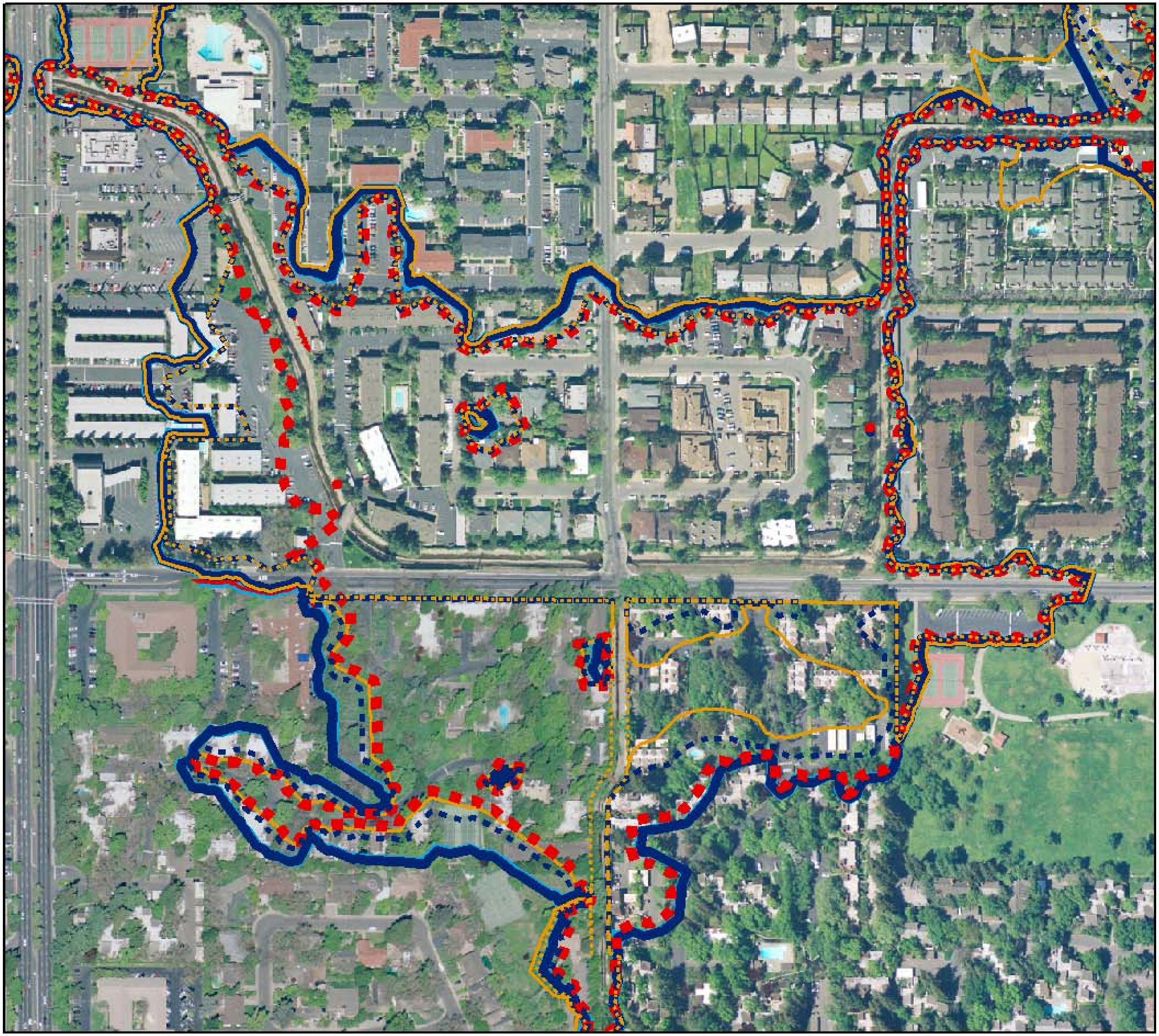

Figure 7

County of Sacramento
Strong and Chicken Ranch Slough
Alternative Analysis

200 year Event
(p=0.005)

N

Legend:

Floodplain Boundaries for:

- 34ft floodwall + double pump capacity
- 33ft floodwall + double pump capacity
- 32ft embankment + double pump capacity
- 34ft floodwall
- 33ft floodwall
- 32ft embankment
- Without-project conditions

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Overview of analysis

Strong and Chicken Ranch Slough

The Strong Ranch Slough and Chicken Ranch Slough (SRS / CRS) watershed is an urban watershed of approximately 15 square miles within Sacramento County, in northern California. The full watershed is bounded approximately by Howe Avenue on the west, Fair Oaks Boulevard on the southeast, and Edison Avenue on the north. In this study, we consider the flood problem in the Arden-Arcade neighborhood. This neighborhood is bounded approximately by Arden Way, Watt Avenue, Fair Oaks Boulevard, and Ethan Way. The watershed and surrounding area are shown in Figure 8.

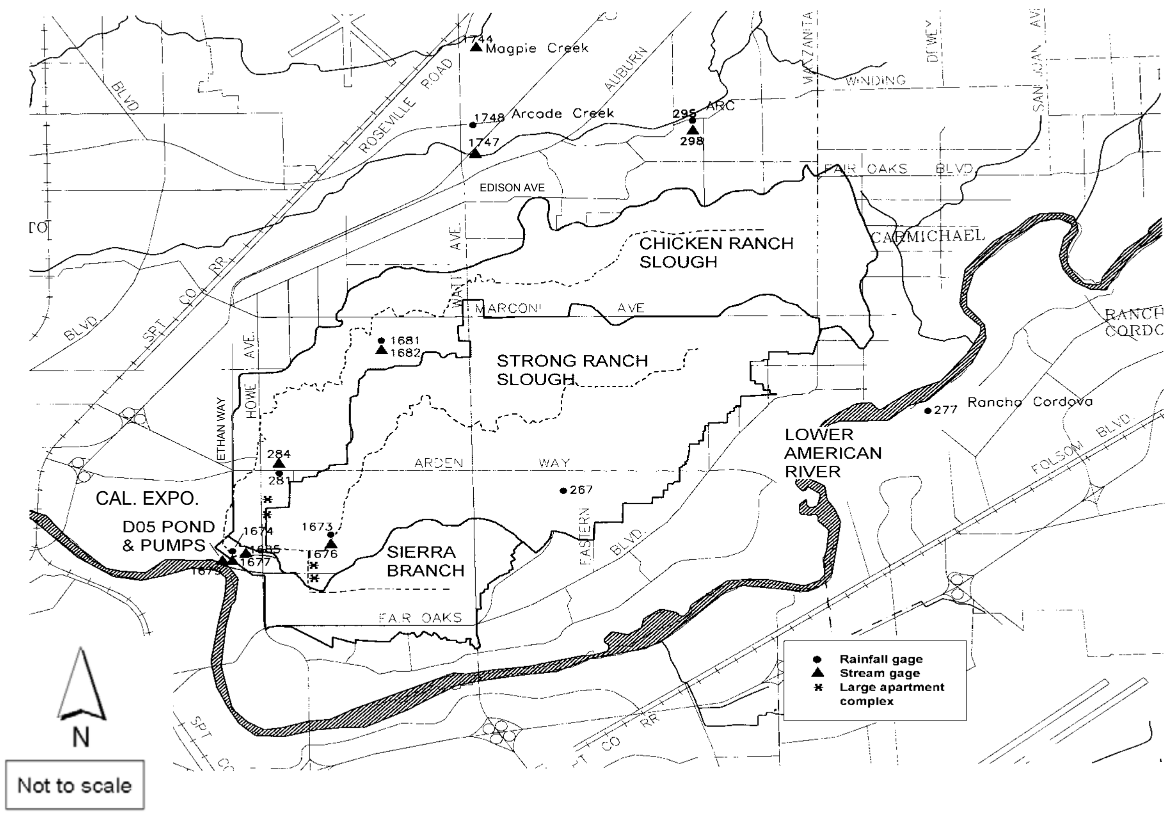

Figure 8. Strong and Chicken Ranch Slough watershed

The Woodside properties are located at the confluence of Sierra Branch and Strong Ranch Slough in the south-west portion of the watershed. Woodside condominiums have flooded in 1986, twice in 1997, and again on New Year's Eve of 2005. The Woodside properties and the adjacent streams are shown in Figure 9.

Figure 9. Woodside properties and adjacent streams

Watershed drainage features

As shown in Figure 8, the watershed is near the Lower American River (LAR). Levees along the LAR protect the watershed from the adverse impacts of high LAR stages. However, this line of protection restricts the natural flow from Chicken Ranch and Strong Ranch Sloughs into the LAR. To prevent interior flooding due to this restriction, the US Army Corps of Engineers (USACE) constructed, and Sacramento County maintains and operates, the D05 interior-drainage facility. This facility, which is located near the California State Exposition (Cal Expo), collects interior runoff from the sloughs in a 100 acre-foot pond. From there, the water is discharged into the LAR.

The D05 facility includes two five-foot by five-foot box culverts, a six-foot by six-foot box culvert, and six electrical pumps with total capacity of approximately 1,000 cubic feet per second (cfs). An additional 50-cfs pump is used during the start of events and to evacuate the pond after the event. However, because of power limitations, the 50-cfs pump can not be operated during peak flow periods when the other six electrical pumps are operating.

When the D05 pond elevation exceeds the LAR water-surface elevation, the culverts permit the pond to drain due to gravity alone. At higher LAR stages, gates on the culverts are closed to prevent flow into the pond from the LAR, and the pumps provide all outflow from the pond. Two types of gates are used to prevent this backflow; a gravity controlled flap gate and a motorized sluice gate. The sluice gate is controlled with a County operated supervisory control and data acquisition (SCADA) system. The pumps also may be turned on to supplement outflow through the gravity outlets.

Flow into the D05 pond from Chicken Ranch Slough and Strong Ranch Slough is a function of both the rate of runoff from the catchment and the water-surface elevation in the D05 pond. When the pond elevation is low, waters in the sloughs flow freely into the pond. However, as the pond elevation rises, water cannot flow out of the sloughs and is stored in the channels. With increasing inflow, the channels eventually fill and spill into adjacent property.

Rainfall and stage gages in the watershed

The SRS / CRS watershed is unusually well gaged. Rainfall is measured at nine rainfall gages in or near the watershed. Six gages measure stage in the channels, the D05 pond, and the LAR. The gages, which are listed in Table 2, are all automatic-reporting ALERT gages. Current gage readings are available on Sacramento County's Website at *http://www.sacflood.org/*. Most were installed after the 1986 flood, so the period of record is limited.

Table 2. ALERT gages in and adjacent to SRS / CRS watershed

Gage ID (1)	Location (2)	What's measured at the gage (3)
1682	Chicken Ranch Slough @ Corabel Lane	Stage
0284	Chicken Ranch Slough @ Arden Way	Stage
2778	Strong Ranch Slough @ Cottage Way (Channel Ct.)	Stage
1676	Strong Ranch Slough @ Hurley Way	Stage
1679	D05 pond elevation	Stage
1677	Lower American River at D05	Stage
1730	Strong Ranch Slough @ Bell Avenue	Stage
0295	ARC/Arcade Creek	Rainfall
0281	Chicken Ranch Slough @ Arden Way	Rainfall
1667	Mather Airport	Rainfall
0267	Cresta Park	Rainfall
1674	Lower American River at D05	Rainfall
0277	Rancho Cordova	Rainfall
1673	Strong Ranch Slough @ Hurley Way	Rainfall
2777	Strong Ranch Slough @ Cottage Way (Channel Ct.)	Rainfall

History of flooding

Causes of flooding

Figure 10 shows conceptually the components of the SRS / CRS system, including:

- *Mildly-sloping inflow channels*. Chicken Ranch Slough and Strong Ranch Slough carry runoff from the interior area to the Lower American River (LAR). These are mildly-sloping developed channels. In the lower reaches, both are concrete lined.

- *The LAR levee and the LAR*. The levee blocks the path of natural drainage into the LAR. Water rises and falls in the LAR independently of the runoff from the SRS / CRS watershed. Instead, LAR stage is a function of upstream releases from Folsom Reservoir and downstream stage in the Sacramento River.
- *The D05 pond*. This pond collects runoff from the upstream catchments. As noted elsewhere in this report, if the D05 pond elevation rises, flow from the channels into the pond is impeded. In that case, water may back up in the channels.
- *The gravity outlets (culverts) at the pond*. These outlets drain water from the pond into the LAR. The rate of outflow depends on the relative elevations of water in the river and water in the pond. When the LAR elevation exceeds the pond elevation, the outflow is zero. On the other hand, when the pond elevation exceeds the LAR elevation by 8 feet, the outflow is 1500 cfs.
- *The pumps at the pond*. These pumps also convey water from the pond to the LAR. The maximum rate of outflow depends on the difference in elevation of the pond and the elevation of the LAR water surface. If the elevations are the same, the pumps are most efficient. As the LAR elevation rises relative to the pond elevation, the pumping rate is reduced.

Flooding in the SRS / CRS watershed may be caused by (1) flow that exceeds the capacity of the channels, (2) high stages in the D05 pond, or (3) a combination of these. Recent flooding history illustrates each.

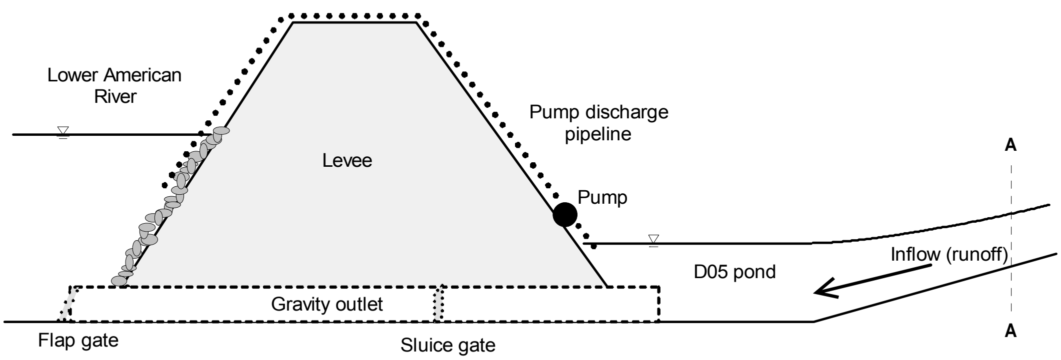

Figure 10. Conceptual design of SRS / CRS hydraulic system

Flow that exceeds channel capacity – 1995 flood

In this first case, the rate of flow simply exceeds the hydraulic capacity of the open channel, and water spills from the channel into the surrounding neighborhood. This almost occurred in January 1995.

In six hours on January 9, 1995, downtown Sacramento received 2.69 inches of rainfall—a 60-year record (*Sacramento Bee*, January 11, 1995). The resulting runoff caused property damage in Sacramento estimated at more than $50 million, with 600 homes and 350 businesses destroyed or damaged (*Sacramento Bee*, January 12, 1995). Flow in Chicken Ranch Slough, Strong Ranch Slough, and Sierra Branch reached near channel capacity; flooding was imminent.

Fortunately, the coincident LAR stage was not high, so the D05 pond drained with pumping and gravity flow. The reported peak stage at D05, where the maximum depth without overflow is 32 feet, was only 26.3 feet. This low pond stage, in turn, minimized backwater in the inflowing channels, thus permitting flow within banks.

High stages in the D05 pond – 1986 flood

In the second case, the volume of inflow to the pond exceeds the maximum rate of outflow from the pond: the storage in the pond increases, the corresponding water-surface elevation is greater than the elevation of the pond bank, and water spills into the surrounding neighborhood. The events of February 1986 illustrate this.

In early February 1986, a strong high-pressure ridge developed off of the western coast of the US. As the ridge built, it developed into a "blocking high" that created a split in the westerly atmospheric circulation. Cold arctic air moved into northern California, and rains started on February 11. On February 14, a second storm blew ashore in the northern San Francisco Bay area, dropping 6-8 inches of rain. Then on February 16, a warm Hawaii-born storm moved ashore. Rain continued through February 21. In Sacramento, total rainfall recorded from February 11-21 was 9.62 inches—54 percent of the annual average rainfall. Upstream, in the American River catchment, rainfall totals were 25-35 inches.

To accommodate the resulting runoff, releases from Folsom Reservoir, which is approximately 25 miles upstream from the D05 facility, were increased, eventually reaching 130,000 cfs. The corresponding LAR stage forced closure of the D05 gravity outlets. Interior runoff filled the pond. Additional inflow exceeded the capacity of the pumps, and the pond overflowed into the surrounding neighborhood. The March 3, 1986 *Sacramento Bee* reported that:

> *…there was… flooding in a number of places in the Sacramento area, including:*

- *Woodside condominiums at Howe and Northrop avenues, where an overwhelmed drainage canal* [Strong Ranch Slough and Sierra Branch] *caused flood damage to 160 homes.*
- *Cal Expo* [adjacent to the D05 facility], *where 6 feet of water submerged the horse stables, killing one racehorse and forcing the dramatic rescue of 250 others.*

Combination events – 1997 flood

In the third case, the "energy" of flowing water controls what happens. For water to flow freely from the Strong Ranch, Chicken Ranch, or Sierra Branch channel into the pond, it must have enough energy to do so. The amount of energy in flowing water depends upon both the flow rate and the flow depth. The water in the channels has energy, even though it is shallow, because the flow rate is great. Even the slow-moving water in the pond has energy, because the water is deep. For water to move from the channel into the pond, the energy of the flowing water must exceed the energy of the slow-moving pond water. Otherwise, the water will "stack up" in the channel, and the depth will increase until the water has enough energy, due to its depth, to flow into the pond. If that required depth is great, then water may spill from the channel into the neighborhood and cause damage.

The D05 pond stage depends upon storage in the pond; this storage is the difference in pond inflow and pond outflow. Pond inflow is a function of the rate of rainfall in the upstream catchments, the state of the catchments when the rain occurs, and the ability of the channels to move the water to the pond. Pond outflow is a function of the performance of the D05 pond gravity culverts and the pump station. As the LAR stage increases, the pumps become less efficient, so the rate of pumped outflow decreases. Similarly, as the LAR stage increases, gravity outflow is reduced. If the LAR stage exceeds the pond stage, no gravity outflow will occur. If the pond stage exceeds the LAR stage, then the rate of gravity outflow is a function of the difference between the pond stage and LAR stage. For example, when the pond stage is 30 feet and the LAR stage is 22 feet (pond stage exceeds the LAR stage by 8 feet), the gravity outlets flow at capacity (1700 cfs). When the LAR stage exceeds 30 feet, the water-surface elevation in the pond must exceed 30.5 feet for any significant outflow to occur through the culverts. Even at lower flows in the channels, a pond stage of 30.5 feet causes flooding upstream.

This third flooding case is illustrated by the 1997 event. On January 22, 1997, and again on January 26, 1997, heavy rainfall in the Chicken Ranch and Strong Ranch catchments caused significant runoff into the D05 pond. As reported in the Sacramento Bee (January 28, 1997): "…the Sacramento area was hit with about 2.6 inches of rain between Tuesday and Wednesday night [January 21 and 22, 1997], and another 2.9 inches between 6:30 p.m. Friday and 4 a.m. Saturday, according to the National Weather Service."

At the time of the local storms, release from Folsom Reservoir, upstream on the American River, was approximately 32,000 cfs. This is a relatively low release. However, a major storm in late December and early January had filled Oroville Reservoir, feeding flows upstream on the Sacramento River. Consequently, Sacramento River flow was great, as the California Department of Water Resources (DWR) released water from Oroville in anticipation of snowmelt runoff and subsequent rainfall. The Sacramento River stage at the I St. Bridge had reached approximately 25 feet on January 22. This high stage in the Sacramento River created a backwater condition, increasing the LAR stage at the D05 facility to a peak of approximately 25.7 feet during the time of peak runoff from the Chicken Ranch and Strong Ranch Slough watershed. At that stage, the gravity outlets could not evacuate any water from the pond until the pond stage exceeded approximately 26 feet. The pumps started to empty the pond as it began to fill with runoff.

During the January 22-23 storm, peak flows in Chicken Ranch and Strong Ranch sloughs were approximately 900 and 2000 cfs, respectively. During the January 25-26 storm, peaks reached approximately the same levels. In both cases, these peaks, coupled with pond stages of approximately 32 feet, caused overflows. According to the *Sacramento Bee* (August 11, 1997):

> *Water overflowing Strong Ranch Slough invaded 83 units [in the Woodside condominiums]…twice in one week during January's storms, causing more than $1 million in structural damage and an unknown loss of personal belongings.*

Figure 11 is a photograph of the entrance to the Woodside condominiums from Northrop Avenue on January 26, 1997.

Figure 11. Woodside flooding picture showing extent of flooding

Previous studies

Sacramento County and USACE have studied the flooding problem in the SRS / CRS watershed. These studies, which are summarized in Table 3, analyzed interior runoff and the interaction with the LAR, and they evaluated flood-reduction alternatives.

Table 3. Summary of previous studies

Reference (1)	**Summary (2)**
Nolte and Associates (1991)	Investigated past and potential future flooding of structures adjacent to Chicken Ranch Slough. Recommended improving maintenance procedures, modifying channels, restricting development, and elevating structures.
Sacramento County (1995)	Evaluated the effect of Folsom re-operation on Sacramento County drainage facilities. No significant adverse impact on the D05 pumping facility was found.
Sacramento County (1997a)	Examined sources of flooding in SRS / CRS watershed. Identified and evaluated damage reduction alternatives.
Sacramento County (1997b)	Developed charts to predict exterior LAR stage at the D05 pumping station, given Folsom release and Sacramento River stage at I Street bridge.
Sacramento County (1997c)	Examined effectiveness of radar information for SRS / CRS flood-warning system. Recommended postponing further investigation and focusing on existing surface-observation system in the watershed.
Sacramento County (1997d)	Calculated flood damages in the SRS / CRS watershed, and identified and evaluated damage reduction measures. Recommended further analysis of upstream storage, elevation of structures, and local floodwalls.
Federal Emergency Management Agency (1998)	The flood insurance study for the American River. The resulting American River floodplain map includes SRS and CRS.
Sacramento County (1998)	Evaluated flood-reduction measures and found that only large-scale solutions will significantly reduce the flooding. Concluded that these would not be economically justified. Suggested low floodwalls around valuable property, low floodwalls along major channels, or a flood-warning system.
USACE (1999)	Identified a serious flood problem in SRS / CRS watershed, identified likely alternatives, and identified a local sponsor.
USACE (2001)	Evaluated 17 flood-reduction alternatives for the SRS / CRS watershed. Evaluation of the alternatives included an economic analysis to calculate the inundation-reduction benefit of each of the alternatives considered.

Analysis overview

Objective

The focus of this study is to revisit alternatives that will either reduce the water surface elevation along the Woodside properties or reduce the flood risk to the frequently-flooded Woodside properties by protecting the properties from high water. Some of these alternatives have been evaluated in past watershed studies. However, here, they are analyzed using updated hydraulic modeling tools and watershed information such as channel bank elevations.

Alternatives

Alternatives that protect the Woodside properties as well as lower the risk of flooding in the lower portion of the watershed are considered. Descriptions of the actual alternatives evaluated are included in later portions of this report. However, the alternatives can be summarized as follows:

- Alternatives that protect Woodside properties with a floodwall.
- Alternatives that protect the lower portion of the watershed by increasing D05 pump capacity.
- Alternatives that do both of the above.

Hydrologic analysis

For this analysis, we use watershed model results from past studies, specifically the August 2001 analysis by the Corps of Engineers. For that analysis, runoff hydrographs of various annual exceedence probabilities were developed following the *Sacramento City / County Drainage Manual: Vol. 2 Hydrology Standards* (1996). The hydrologic model and results used for this analysis are described in the August 2001 report.

In addition to the design storm hydrographs, historic events are used to evaluate the alternatives. The 2001 Corps analysis describes the reconstitution of the 1995 and the 1997 event. The previous report describes the historic event analyses. We use those same events here, in addition to using the February 1986 event and December 2005 event, to evaluate alternatives.

Details regarding the reconstitution of the February 1986 event are described in Attachment A.

Hydraulic analysis

The basis of the hydraulic analysis is the UNET model documented in August 2001 report. However, for this analysis, we converted the UNET hydraulic model used in the August 2001 analysis to an HEC-RAS v3.1.3 hydraulic model. By doing so, we were able to utilize some of the additional modeling features in the updated model that were not available in the UNET model. These modeling features include:

- Representation of water spilling from the channel into the Woodside properties.

- Representation of the pumps at the D05 pond.
- Representation of the volume of water that flows into the floodplain.

HEC-RAS is the current standard-of-practice hydraulic modeling program used for these types of analyses.

In addition, since 2001, the County has collected detailed LIDAR data of the watershed. We used this LIDAR data to refine the representation of the floodplain and the volume of water in the floodplain in the hydraulic model and for floodplain mapping.

Coincident frequency analysis framework

Due to the complex interaction of the system components, the water-surface elevations in the SRS / CRS floodplain depend upon both the runoff from the upstream catchments (the upstream boundary condition) and the pond elevation, which, in turn, depends upon the LAR stage (the downstream boundary condition). For example, if the LAR stage is high, the D05 gravity outlets will close, and the pond stage will rise during a storm. If the pond stage is high, the elevation at section A-A in Figure 10 may reach a critical level as water backs up in the channel, even during a relatively small, frequent event. Consequently, water might overflow Strong Ranch Slough at section A-A during a 25-year (p=0.04) event, whereas similar flows would remain in the channel if the pond were lower.

Thus, the assumption of a unique relationship of stage to flow in the channel is not appropriate—we must consider both the inflow rate and the LAR stage to transform the discharge-probability function to a stage-probability function. To do so, we use coincident-frequency analysis (EM 1110-2-1413, USACE, 1987). This*…applies the total probability theorem to generate stage-frequency functions for interior areas affected by coincident interior and exterior flooding.*

Steps of the coincident-frequency method, which were used in the August 2001 analysis as well, are:

1. Develop a stage-frequency function for the exterior area; in this case, that is the LAR. Represent that function as intervals of stage and probability, as illustrated in Figure 12. For example, the probability is 0.54 that the stage is in the range 20-25 ft, which is represented by an average stage of 22.5 ft. The probability is 0.22 that stage is in the range represented by 27.0 ft. The probability is 0.14 that stage is in the range represented by 31.0 ft; and it is 0.10 that it is in the range represented by 36.0 ft. Note that the sum of the probability values for all intervals equals 1.00—that is, the entire range of exterior events is represented. A description of why the stage-frequency function was divided as such is included later in this report.

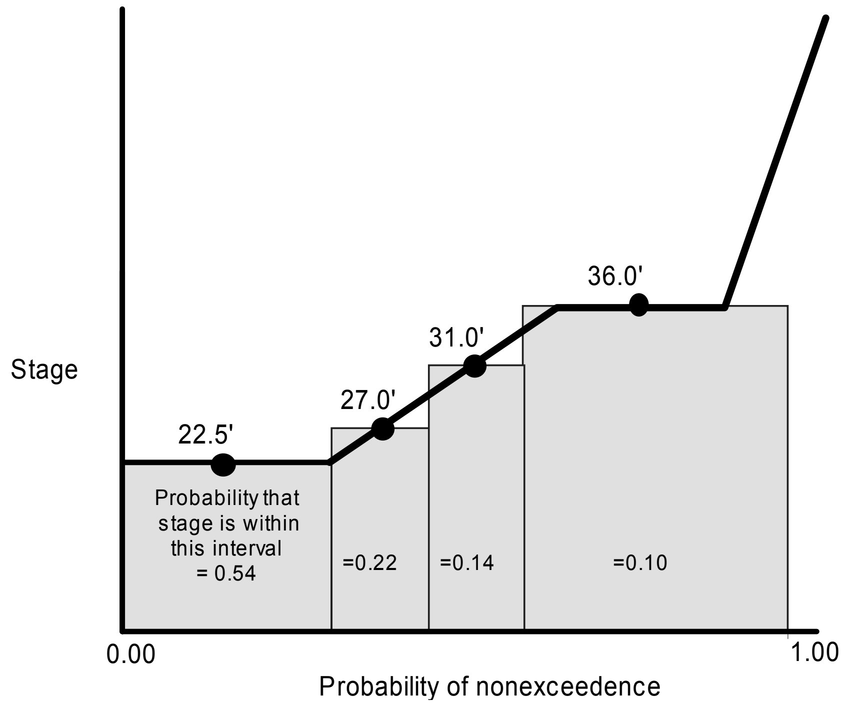

Figure 12. Stage-probability function intervals

2. Select one of the exterior stage conditions (one of the intervals from Step 1). For this (the downstream boundary condition for the SRS / CRS system) develop an interior-area conditional stage-frequency function. For example, develop a stage-frequency function for the 22.5-ft exterior stage condition by analyzing system performance and behavior with a range of interior events.
3. Repeat Step 2 for each exterior stage condition from Step 1. Figure 13 illustrates the difference in stages along SRS based upon the different LAR stage boundary conditions.
4. Develop the required interior stage-frequency function, using the total probability theorem and the conditional stage-frequency functions developed in Steps 2 and 3. The total probability theorem in this case is

$$F(stage_{interior}) = \sum_{\substack{exterior \\ conditions}} \left(F(stage_{interior} \mid stage_{exterior}) \times F(stage_{exterior}) \right) \quad (1)$$

in which $stage_{interior}$ = interior stage value; $stage_{exterior}$ = exterior stage value; $F(stage_{interior})$ = probability of exceedence of specified interior stage; and $F(stage_{exterior})$ = probability of exceedence of specified exterior stage. Figure 13 illustrates the resulting probability-weighted channel stage for a portion of SRS.

The fundamental idea is that the total probability of any interior stage is the sum of the probabilities of that interior stage, considering all possible exterior stages.

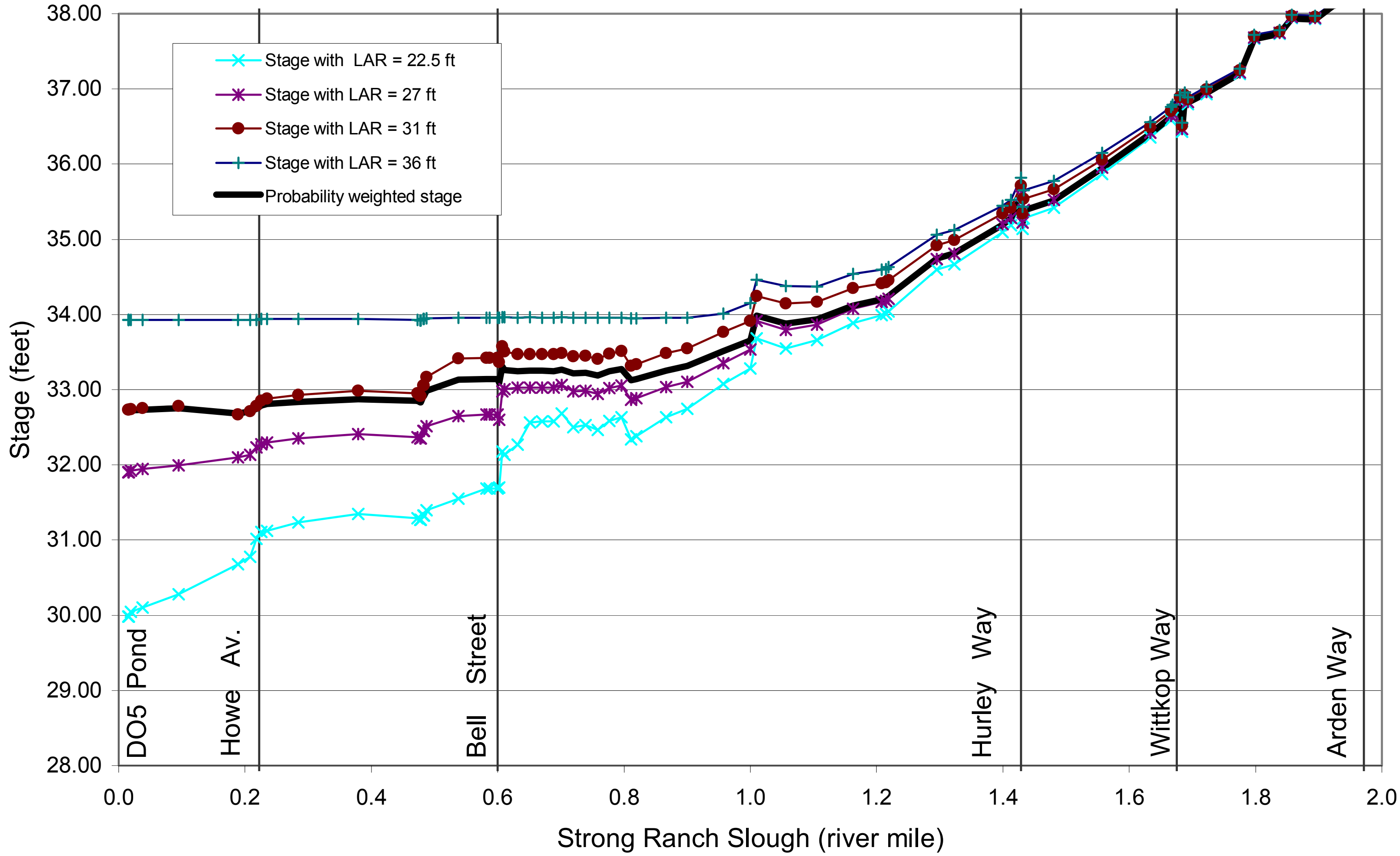

Figure 13. Without-project condition 100-yr (p=0.01) water surface profiles along portion of Strong Ranch Slough

Channel capacity analysis

Objective

As noted earlier, flooding along Strong Ranch Slough may be caused by:

1. Flow that exceeds the capacity of the channels.
2. High stages in the D05 pond.
3. A combination of the 2 cases above.

To better understand the capacity of Strong Ranch Slough channel near the Woodside properties, the County asked the question: How much flow can the channel convey if the D05 pond elevation is low?

Analysis

To evaluate the channel capacity of Strong Ranch Slough, we used the updated hydraulic model along with the design-storm hydrographs previously developed. We further modified the hydraulic model to remove the D05 pond representation, thus eliminating the effect of backwater on the flows near Woodside properties.

For the simulation, we started with the smallest event and computed channel water surface elevations. We compared the peak water levels with the channel bank elevations to see if the water level was high enough that it would flood Woodside properties. If the water level was still within the channel banks, we repeated the process with the next largest event.

For this analysis and for comparison of water level to the channel banks, we presumed that the County's 32-ft embankment project along the channel was already constructed.

Results

Through this iterative process, we found that the channel capacity is approximately 1450 cfs for the without-project condition. This corresponds to an event similar to the 25-year (p=0.04) and 50-year (p=0.02) events. For the 25-year event, no water floods the Woodside properties. For the 50-year event, approximately 1.7 ac-ft (50 cfs peak flow) floods Woodside East.

With the 32-ft embankment enhancement completed, the channel capacity increases. The approximate flow capacity is 1500 cfs. With this enhancement, the capacity is approximately equal to the 50-year event.

Alternative analysis and results

Overview

The County currently plans to complete a 32-ft embankment enhancement project this year. We refer to this as the working alternative. For this analysis, we consider this working alternative by itself and in combination with other measures. These other measures include enhancing the D05 pumping station and construction of a floodwall that surrounds the Woodside properties. Table 4 lists the alternatives that we evaluated.

Table 4. Alternatives evaluated

ID (1)	Modifications to channel (2)	Modifications to D05 pond (3)
1	—	Divide pond to raise water level at the pumps
2	32 ft embankment along Strong Ranch Slough to protect Woodside East and West properties	—
3	32 ft embankment along Strong Ranch Slough to protect Woodside East and West properties	Double the D05 pumping capacity
4	In addition to 32 ft embankment along Strong Ranch Slough, 33 ft floodwall along property line to protect Woodside East and West properties	—
5	In addition to 32 ft embankment along Strong Ranch Slough, 33 ft floodwall along property line to protect Woodside East and West properties	Double the D05 pumping capacity
6	In addition to 32 ft embankment along Strong Ranch Slough, 34 ft floodwall along property line to protect Woodside East and West properties	—
7	In addition to 32 ft embankment along Strong Ranch Slough, 34 ft floodwall along property line to protect Woodside East and West properties	Double the D05 pumping capacity

This chapter describes each alternative, how we represented the alternative in the hydraulic model, and the results of our analyses.

Each alternative is evaluated with:

- February 18, 1986 event
- January 26, 1997 event
- December 31, 2005 event

- Design 25-year (p=0.04) event
- Design 50- year (p=0.02) event
- Design 100-year p=0.01) event
- Design 200-year (p=0.005) event

The design events are frequency-based design-storm event developed following the Sacramento County hydrology manual. To evaluate these events, we followed the coincident frequency analysis framework described earlier. This involved simulating the full range of interior events (8) with each of the representative LAR stages (4). The total probability theorem was then used to compute the specified design event. The design event results are not the product of a single hydraulic model run of a given LAR stage but rather based on all these combinations.

Alternative 1. Modification of the D05 detention pond

What does this alternative include?

This alternative calls for modifying the D05 pond to maximize the use of the existing pumping capacity. This alternative includes constructing a 28-ft high berm that splits the D05 pond in half. The half that includes the pump station would fill first thus allowing the ponds to start pumping earlier in an event.

How does this alternative provide greater protection?

This alternative provides greater flood protection by increasing the D05 pond elevation at the pumping station. Thus, the pumps would turn on sooner resulting in an increased volume of water being evacuated from the pond sooner than would occur under the current D05 configuration. If the pond elevation is lower, the chance of flooding at the Woodside properties is less.

How did we model this alternative?

We modified the representation of the D05 pond in the hydraulic model and simulated the events. As noted, a 28-ft berm was used to divide the pond.

What are the results of the alternative?

We found that this alternative only slightly decreased the peak water level in the channel. Because the alternative only resulted in a small decrease in water level and not a reduction of flood risk at the Woodside properties, it was not considered further. Floodplain maps for this alternative were not developed.

Alternative 2. 32-ft embankment enhancement along Strong Ranch Slough

What does this alternative include?

This alternative includes a slight raise in the channel bank elevations along both sides of Strong Ranch Slough in the vicinity of Woodside properties. This is approximately the portion of the channel parallel with Northrop Avenue.

With this alternative, the channel bank will be enhanced such that the minimum elevation is at least 32 ft.

How does this alternative provide greater protection?

The goal is to increase the hydraulic capacity of the channel, and provide equal level of protection to both north and south sides of the channel along Northrop Avenue. This alternative will help reduce over bank spills during small storm events.

How did we model this alternative?

To examine this alternative, we altered the channel definition in the hydraulic model to represent the raised channel banks. Therefore, all of the flow will stay in the channel until the water surface exceeds elevation 32 feet.

What are the results of the alternative?

The results of this alternative are shown in Table 5. In the table, we compare water surface elevations for this alternative to the without-project condition. In the table, a value in column 5 that is negative indicates that the water level is reduced. A positive value indicates that the water level is increased. In addition, we prepared a floodplain map for this alternative for each of the evaluation events. The floodplain maps are included in the executive summary. For the tabular output, the location of the water surface elevations were chosen to show:

1. Changes in water surface elevation at the downstream end, the D05 pond.
2. Changes in water surface elevations at the current low point in the right bank of Sierra Branch, Sierra Branch river mile (RM) 0.06 as measured from the Sierra Branch and Strong Ranch Slough confluence.
3. Changes in water surface elevations at the current low point in the left bank of Strong Ranch Slough, RM 0.67 as measured from the D05 pond.
4. Changes in water surface elevations at the Hurley Way real-time stream gage, RM 1.295 as measured from the D05 pond.

These same representative points are used for comparison of all alternatives. For reference, these locations are shown in Figure 14.

Figure 14. Watershed locations for comparison of alternatives

Table 5.Alternative 2 results, comparison of water surface elevation, in ft

Event (1)	**Location (2)**	**Without-project (3)**	**Alternative 2 (4)**	**Impact on water level (5)**
1986	D05 pond	33.96	33.96	0.00
	Sierra Branch RM 0.06	33.98	33.98	0.00
	Strong Ranch RM 0.67	33.98	33.98	0.00
	Strong Ranch RM 1.295	35.07	35.07	0.00
1997	D05 pond	31.95	32.01	0.06
	Sierra Branch RM 0.06	32.63	32.93	0.30
	Strong Ranch RM 0.67	32.74	32.77	0.03
	Strong Ranch RM 1.295	34.16	34.20	0.04
2005	D05 pond	31.40	31.47	0.07
	Sierra Branch RM 0.06	32.00	32.09	0.09
	Strong Ranch RM 0.67	32.23	32.16	-0.07
	Strong Ranch RM 1.295	33.30	33.32	0.02
25-yr	D05 pond	31.85	31.87	0.02
	Sierra Branch RM 0.06	32.67	32.90	0.23
	Strong Ranch RM 0.67	32.53	32.55	0.02
	Strong Ranch RM 1.295	33.96	34.00	0.04
50-yr	D05 pond	32.42	32.43	0.01
	Sierra Branch RM 0.06	32.92	33.03	0.11
	Strong Ranch RM 0.67	32.92	32.96	0.04
	Strong Ranch RM 1.295	34.37	34.41	0.04
100-yr	D05 pond	32.73	32.73	0.00
	Sierra Branch RM 0.06	33.25	33.28	0.03
	Strong Ranch RM 0.67	33.26	33.28	0.02
	Strong Ranch RM 1.295	34.74	34.77	0.03
200-yr	D05 pond	32.97	32.97	0.00
	Sierra Branch RM 0.06	33.56	33.58	0.02
	Strong Ranch RM 0.67	33.57	33.61	0.04
	Strong Ranch RM 1.295	35.08	35.11	0.03

Alternative 3. 32-ft embankment enhancement along Strong Ranch Slough and double D05 pumping capacity

What does this alternative include?

This alternative includes the 32-ft high embankment along Strong Ranch Slough as discussed in Alternative 2 and doubles the pumping capacity at the D05 pond.

How does this alternative provide greater protection?

This alternative would reduce inundation damage by reducing the water elevation in Strong Ranch Slough, Chicken Ranch Slough, and Sierra Branch. As explained earlier in this report, the elevation in those channels is influenced by the elevation of water in the D05 pond. With increased pumping-plant capacity, the pond elevation can be lowered quicker. With lowered pond elevation, the channel will carry a greater volume rate without overflowing.

How did we model this alternative?

The pumping station has 6 pumps with an average capacity of 160 cfs each. We modeled the doubling of capacity by duplicating the entire pump station. This doubles the pumping rate, and maintains the pump efficiency information specified and the current pump operation schedule.

What are the results of the alternative?

The results of this alternative, as compared to the without-project condition, are shown in Table 6. As shown in the table, the increased pumping capacity decreases the water level as high upstream as the Hurley Way gage at RM 1.295. The floodplain maps, which best illustrate the impacts of the alternative are included in the executive summary.

Table 6. Alternative 3 results, comparison of water surface elevation, in ft

Event (1)	Location (2)	Without-project (3)	Alternative 3 (4)	Impact on water level (5)
1986	D05 pond	33.96	32.12	-1.84
	Sierra Branch RM 0.06	33.98	32.82	-1.16
	Strong Ranch RM 0.67	33.98	32.83	-1.15
	Strong Ranch RM 1.295	35.07	34.74	-0.33
1997	D05 pond	31.95	29.54	-2.41
	Sierra Branch RM 0.06	32.63	32.49	-0.14
	Strong Ranch RM 0.67	32.74	31.49	-1.25
	Strong Ranch RM 1.295	34.16	33.86	-0.30
2005	D05 pond	31.40	24.39	-7.01
	Sierra Branch RM 0.06	32.00	29.46	-2.54
	Strong Ranch RM 0.67	32.23	29.45	-2.78
	Strong Ranch RM 1.295	33.30	32.56	-0.74
25-yr	D05 pond	31.85	27.09	-4.76
	Sierra Branch RM 0.06	32.67	32.52	-0.15
	Strong Ranch RM 0.67	32.53	31.20	-1.33
	Strong Ranch RM 1.295	33.96	33.76	-0.20
50-yr	D05 pond	32.42	28.62	-3.80
	Sierra Branch RM 0.06	32.92	32.71	-0.21
	Strong Ranch RM 0.67	32.92	31.77	-1.15
	Strong Ranch RM 1.295	34.37	34.16	-0.21
100-yr	D05 pond	32.73	30.34	-2.39
	Sierra Branch RM 0.06	33.25	32.81	-0.44
	Strong Ranch RM 0.67	33.26	32.43	-0.83
	Strong Ranch RM 1.295	34.74	34.56	-0.18
200-yr	D05 pond	32.97	31.30	-1.67
	Sierra Branch RM 0.06	33.56	32.92	-0.64
	Strong Ranch RM 0.67	33.57	32.88	-0.69
	Strong Ranch RM 1.295	35.08	34.90	-0.18

Alternative 4. 33-ft floodwall along Woodside property line to protect Woodside East and West properties

What does this alternative include?

This alternative includes construction of a floodwall on the Woodside property at an elevation of 33 ft, along the south side of Northrop Ave, and both banks of the Sierra Branch. Figure 15 shows the approximate location of the floodwall. This alternative also includes the 32-ft embankment enhancement as described in alternative 2.

Figure 15. Approximate location of 33-ft floodwall

How does this alternative provide greater protection?

This alternative would reduce flooding by increasing the hydraulic capacity of the channels and preventing channel spills due to high pond stages. The stage in the channel will exceed the natural top of bank elevation, but the floodwall will prevent spills onto adjacent property until the stage exceeds the top of floodwall elevation.

How did we model this alternative?

To model this alternative, we modified the hydraulic model to include a wall surrounding the Woodside properties. The wall has a minimum elevation of 33 ft and ties into natural ground.

What are the results of the alternative?

The results of this alternative, as compared to the without-project condition, are shown in Table 7 As shown in the table, the floodwall increases the water level in the channel. The floodplain maps, which best illustrate the impacts of the alternative are included in the executive summary.

Table 7. Alternative 4 results, comparison of water surface elevation, in ft

Event (1)	Location (2)	Without-project (3)	Alternative 4 (4)	Impact on water level (5)
1986	D05 pond	33.96	33.96	0.00
	Sierra Branch RM 0.06	33.98	33.98	0.00
	Strong Ranch RM 0.67	33.98	33.98	0.00
	Strong Ranch RM 1.295	35.07	35.05	0.02
1997	D05 pond	31.95	32.14	0.19
	Sierra Branch RM 0.06	32.63	32.88	0.25
	Strong Ranch RM 0.67	32.74	32.85	0.11
	Strong Ranch RM 1.295	34.16	34.27	0.11
2005	D05 pond	31.40	31.57	0.17
	Sierra Branch RM 0.06	32.00	32.19	0.19
	Strong Ranch RM 0.67	32.23	32.32	0.09
	Strong Ranch RM 1.295	33.30	33.41	0.11
25-yr	D05 pond	31.85	32.00	0.15
	Sierra Branch RM 0.06	32.67	32.88	0.21
	Strong Ranch RM 0.67	32.53	32.61	0.08
	Strong Ranch RM 1.295	33.96	34.04	0.08
50-yr	D05 pond	32.42	32.48	0.06
	Sierra Branch RM 0.06	32.92	33.10	0.18
	Strong Ranch RM 0.67	32.92	33.00	0.08
	Strong Ranch RM 1.295	34.37	34.42	0.05
100-yr	D05 pond	32.73	32.73	0.00
	Sierra Branch RM 0.06	33.25	33.23	-0.02
	Strong Ranch RM 0.67	33.26	33.27	0.01
	Strong Ranch RM 1.295	34.74	34.78	0.04
200-yr	D05 pond	32.97	32.91	-0.06
	Sierra Branch RM 0.06	33.56	33.52	-0.04
	Strong Ranch RM 0.67	33.57	33.59	0.02
	Strong Ranch RM 1.295	35.08	35.09	0.01

Alternative 5. 33-ft floodwall along Woodside property line to protect Woodside East and West properties and double D05 pumping capacity

What does this alternative include?

This alternative includes construction of a floodwall at elevation 33 feet as discussed in alternative 4 and doubling the pumping capacity at the D05 pond. This alternative also includes the 32-ft embankment enhancement as described in alternative 2.

How does this alternative provide greater protection?

This alternative would reduce flooding by increasing the hydraulic capacity of the channels and preventing channel spills due to high pond stages. The stage in the channel will exceed the natural top of bank elevation, but the floodwall will prevent spills onto adjacent property until the stage exceeds the top of floodwall elevation.

In addition, this alternative would reduce damage by lowering the elevation at the downstream end of Chicken Ranch Slough and Strong Ranch Slough. It does so by (1) increasing the outflow from the pond, and (2) increasing the pond storage volume so that a given volume of water can be stored in the pond with lesser depth.

How did we model this alternative?

To model this alternative, we used the same floodwall as with alternative 5 and doubled the pumping capacity in the same manner as with alternative 3.

What are the results of the alternative?

The results of this alternative, as compared to the without-project condition, are shown in Table 8. As shown in the table, the combination of floodwall and increased pumping capacity results in a lowered channel water level. The floodplain maps, which best illustrate the impacts of the alternative are included in the executive summary.

Table 8.Alternative 5 results, comparison of water surface elevation, in ft

Event (1)	Location (2)	Without-project (3)	Alternative 5 (4)	Impact on water level (5)
1986	D05 pond	33.96	32.21	-1.75
	Sierra Branch RM 0.06	33.98	33.16	-0.82
	Strong Ranch RM 0.67	33.98	33.01	-0.97
	Strong Ranch RM 1.295	35.07	34.82	-0.25
1997	D05 pond	31.95	29.54	-2.41
	Sierra Branch RM 0.06	32.63	32.52	-0.11
	Strong Ranch RM 0.67	32.74	31.49	-1.25
	Strong Ranch RM 1.295	34.16	33.86	-0.30
2005	D05 pond	31.40	24.40	-7.00
	Sierra Branch RM 0.06	32.00	29.46	-2.54
	Strong Ranch RM 0.67	32.23	29.45	-2.78
	Strong Ranch RM 1.295	33.30	32.56	-0.74
25-yr	D05 pond	31.85	27.10	-4.75
	Sierra Branch RM 0.06	32.67	32.60	-0.07
	Strong Ranch RM 0.67	32.53	31.22	-1.31
	Strong Ranch RM 1.295	33.96	33.76	-0.20
50-yr	D05 pond	32.42	28.66	-3.76
	Sierra Branch RM 0.06	32.92	33.06	0.14
	Strong Ranch RM 0.67	32.92	31.89	-1.03
	Strong Ranch RM 1.295	34.37	34.19	-0.18
100-yr	D05 pond	32.73	30.37	-2.36
	Sierra Branch RM 0.06	33.25	33.13	-0.12
	Strong Ranch RM 0.67	33.26	32.42	-0.84
	Strong Ranch RM 1.295	34.74	34.60	-0.14
200-yr	D05 pond	32.97	31.41	-1.56
	Sierra Branch RM 0.06	33.56	33.18	-0.38
	Strong Ranch RM 0.67	33.57	32.86	-0.71
	Strong Ranch RM 1.295	35.08	34.93	-0.15

Alternative 6. 34-ft floodwall along Woodside property line to protect Woodside East and West properties

What does this alternative include?

This alternative includes construction of a floodwall on the Woodside property at an elevation of 34 ft, along the south side of Northrop Ave, and both banks of the Sierra Branch. Figure 16 shows the approximate location of the floodwall. This alternative also includes the 32-ft embankment enhancement as described in alternative 2.

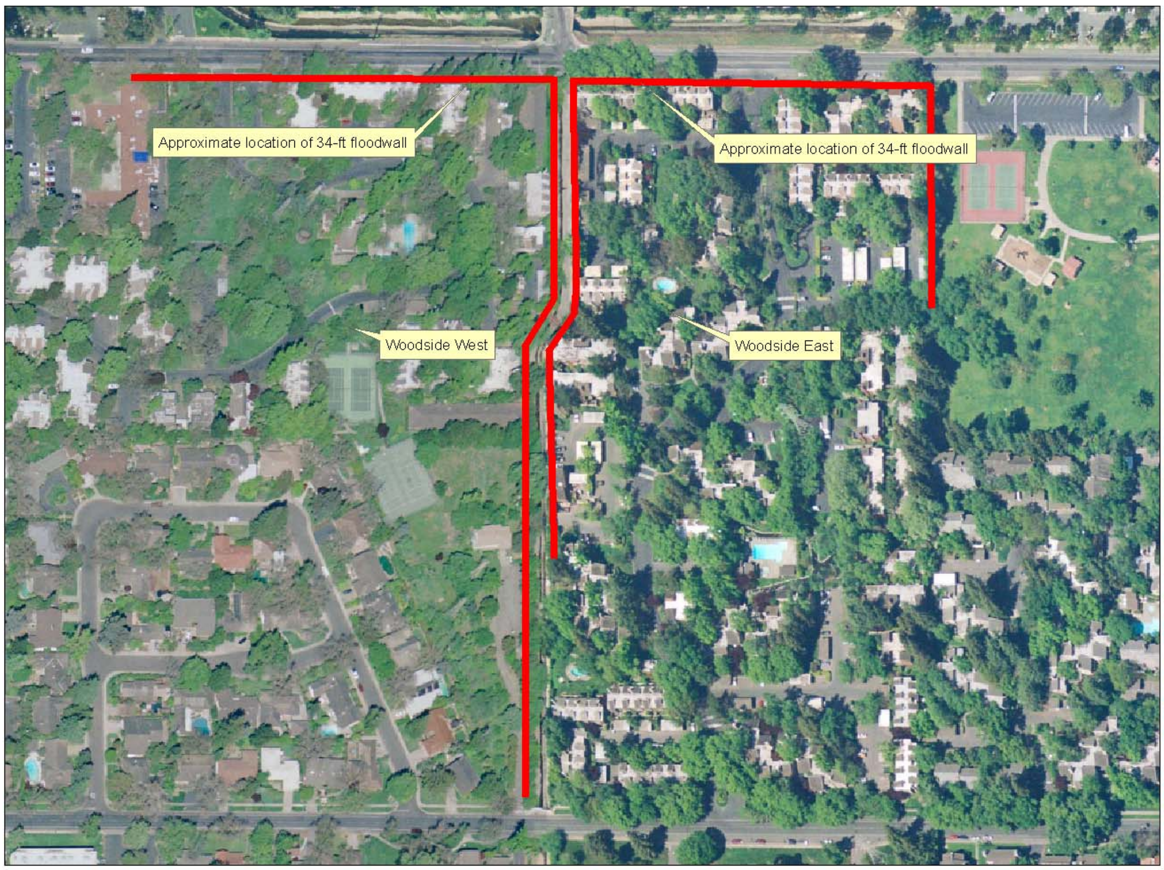

Figure 16. Approximate location of 34-ft floodwall

How does this alternative provide greater protection?

This alternative would reduce flooding by increasing the hydraulic capacity of the channels and preventing channel spills due to high pond stages. The stage in the channel will exceed the natural top of bank elevation, but the floodwall will prevent spills onto adjacent property until the stage exceeds the top of floodwall elevation. With the flood wall height at 34 feet instead of at 33 feet as in Alternative 4, there will be fewer storms that top the floodwall.

How did we model this alternative?

We modeled this alternative in the same way as with alternative 4 but increased the height of the floodwall to 34 ft.

What are the results of the alternative?

The results of this alternative, as compared to the without-project condition, are shown in Table 9 As with alternative 4, the floodwall increases the water level in the channel. The floodplain maps, which best illustrate the impacts of the alternative are included in the executive summary.

As noted in the table, with the alternative, the water level is increased to an elevation greater than 34 ft for the 1986 event in the area surrounding Woodside properties. Thus, the Woodside properties still flood. As a sensitivity analysis for this alternative, we used the hydraulic model to find how high the wall would have to be such that it is not overtopped for the 1986 event. We found that the wall would need to be increased approximately another 0.6 ft along Sierra Branch and approximately another 0.3 ft along Strong Ranch Slough. So, approximately a 34.6-ft floodwall is needed. (Note that this elevation does not include any freeboard or other design considerations.) With this higher wall, the Strong Ranch Slough water level would increase approximately 0.3 ft and Sierra Branch would increase approximately 0.6 ft as compared to the without-project condition using the same representative cross sections as used in Table 9.

Table 9.Alternative 6 results, comparison of water surface elevation, in ft

Event (1)	Location (2)	Without-project (3)	Alternative 6 (4)	Impact on water level (5)
1986	D05 pond	33.96	34.09	0.13
	Sierra Branch RM 0.06	33.98	34.09	0.11
	Strong Ranch RM 0.67	33.98	34.09	0.11
	Strong Ranch RM 1.295	35.07	35.17	0.10
1997	D05 pond	31.95	32.13	0.18
	Sierra Branch RM 0.06	32.63	32.88	0.25
	Strong Ranch RM 0.67	32.74	32.84	0.10
	Strong Ranch RM 1.295	34.16	34.27	0.11
2005	D05 pond	31.40	31.57	0.17
	Sierra Branch RM 0.06	32.00	32.19	0.19
	Strong Ranch RM 0.67	32.23	32.32	0.09
	Strong Ranch RM 1.295	33.30	33.41	0.11
25-yr	D05 pond	31.85	32.02	0.17
	Sierra Branch RM 0.06	32.67	32.94	0.27
	Strong Ranch RM 0.67	32.53	32.61	0.08
	Strong Ranch RM 1.295	33.96	34.04	0.08
50-yr	D05 pond	32.42	32.51	0.09
	Sierra Branch RM 0.06	32.92	33.46	0.54
	Strong Ranch RM 0.67	32.92	33.05	0.13
	Strong Ranch RM 1.295	34.37	34.46	0.09
100-yr	D05 pond	32.73	32.78	0.05
	Sierra Branch RM 0.06	33.25	33.91	0.66
	Strong Ranch RM 0.67	33.26	33.49	0.23
	Strong Ranch RM 1.295	34.74	34.83	0.09
200-yr	D05 pond	32.97	33.02	0.05
	Sierra Branch RM 0.06	33.56	34.06	0.50
	Strong Ranch RM 0.67	33.57	33.84	0.27
	Strong Ranch RM 1.295	35.08	35.17	0.09

Alternative7.34-ft floodwall along Woodside property line to protect Woodside East and West properties and double D05 pumping capacity

What does this alternative include?

This alternative includes construction of a floodwall on the Woodside property at an elevation of 34 feet as discussed in alternative 6, and doubles the pumping capacity at the D05 pond. This alternative also includes the 32-ft embankment enhancement as described in alternative 2.

How does this alternative provide greater protection?

This alternative would reduce flooding by increasing the hydraulic capacity of the channels and preventing channel spills due to high pond stages. The stage in the channel will exceed the natural top of bank elevation, but the floodwall will prevent spills onto adjacent property until the stage exceeds the top of floodwall elevation.

In addition, this alternative would reduce damage by lowering the elevation at the downstream end of Chicken Ranch Slough and Strong Ranch Slough. It does so by (1) increasing the outflow from the pond, and (2) increasing the pond storage volume so that a given volume of water can be stored in the pond with lesser depth.

How did we model this alternative?

We modeled this alternative in the same way as with alternative 5 but increased the height of the floodwall to 34 ft.

What are the results of the alternative?

The results of this alternative, as compared to the without-project condition, are shown in Table 10. As with alternative 5, the combination of floodwall and increased pumping capacity results in a lowered channel water level. However, this alternative provides greater protection to the Woodside properties. The floodplain maps, which best illustrate the impacts of the alternative are included in the executive summary.

Summary of results

In summary, construction of a floodwall around the Woodside properties does increase the channel water levels. The greatest increase water levels, as shown in the result tables, occur in Sierra Branch near the confluence with Strong Ranch Slough. The floodplain maps, included in the executive summary, are the best illustration of the impacts of each of the alternatives over a wide range of events. In all cases, doubling the current D05 pump capacity mitigates for any increase in channel water level.

Table 10.Alternative 7 results, comparison of water surface elevation, in ft

Event (1)	Location (2)	Without-project (3)	Alternative 7 (4)	Impact on water level (5)
1986	D05 pond	33.96	32.20	-1.76
	Sierra Branch RM 0.06	33.98	34.06	0.08
	Strong Ranch RM 0.67	33.98	33.01	-0.97
	Strong Ranch RM 1.295	35.07	34.82	-0.25
1997	D05 pond	31.95	29.54	-2.41
	Sierra Branch RM 0.06	32.63	32.52	-0.11
	Strong Ranch RM 0.67	32.74	31.49	-1.25
	Strong Ranch RM 1.295	34.16	33.86	-0.30
2005	D05 pond	31.40	24.39	-7.01
	Sierra Branch RM 0.06	32.00	29.46	-2.54
	Strong Ranch RM 0.67	32.23	29.45	-2.78
	Strong Ranch RM 1.295	33.30	32.56	-0.74
25-yr	D05 pond	31.85	27.13	-4.72
	Sierra Branch RM 0.06	32.67	32.61	-0.06
	Strong Ranch RM 0.67	32.53	31.22	-1.31
	Strong Ranch RM 1.295	33.96	33.76	-0.20
50-yr	D05 pond	32.42	28.71	-3.71
	Sierra Branch RM 0.06	32.92	33.29	0.37
	Strong Ranch RM 0.67	32.92	31.93	-0.99
	Strong Ranch RM 1.295	34.37	34.19	-0.18
100-yr	D05 pond	32.73	30.40	-2.33
	Sierra Branch RM 0.06	33.25	33.81	0.56
	Strong Ranch RM 0.67	33.26	32.48	-0.78
	Strong Ranch RM 1.295	34.74	34.60	-0.14
200-yr	D05 pond	32.97	31.43	-1.54
	Sierra Branch RM 0.06	33.56	34.00	0.44
	Strong Ranch RM 0.67	33.57	32.88	-0.69
	Strong Ranch RM 1.295	35.08	34.94	-0.14

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Attachment A. Reconstitution of February 1986 event

The February 1986 event is the flood of record for the Strong and Chicken Ranch Slough watershed. Using available observed precipitation data, observed flows, and existing hydrologic and hydraulic models, we reconstituted the event.

Three rain gages are within or near the SRS / CRS watershed. The cumulative precipitation totals at those gages during the most intense portion of the event are illustrated in Figure 17. We simulated the event from February 15, 1986 through February 19, 1986 and found the highest flows in Strong Ranch Slough results from the intense precipitation period on February 18, 1986, thus we selected this period as our analysis period. This period is indicated in the figure. The greatest 9-hr rainfall total for this period results in the accumulated rainfall totals shown in Table 11. Based on the precipitation depth-duration-frequency function that is part of the Sacramento County hydrology standards, this is approximately a 100-year (p=0.01) event.

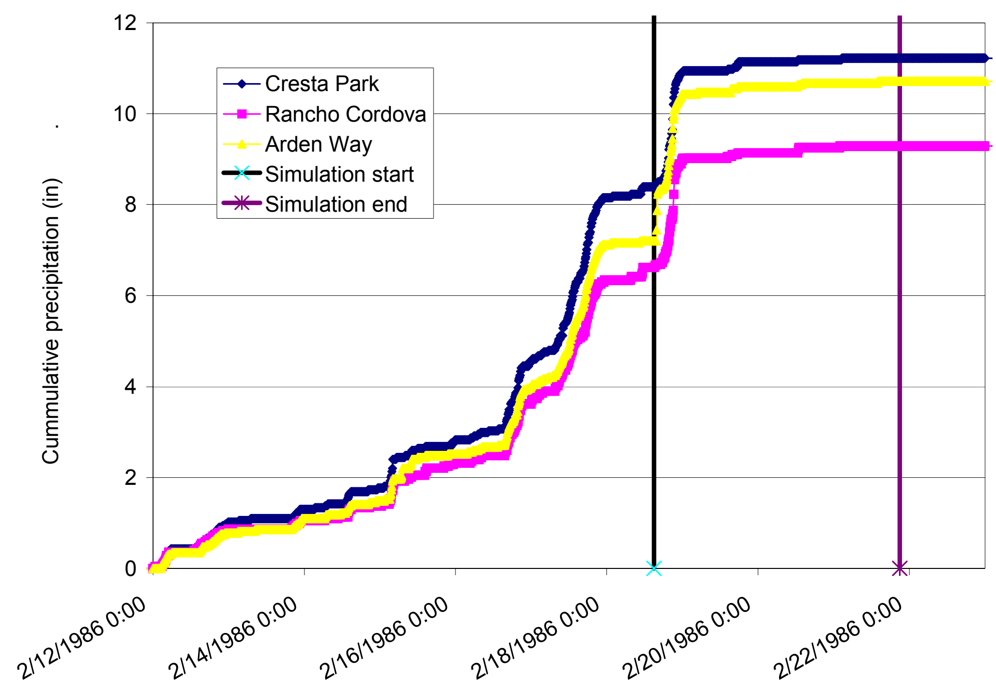

Figure 17. Cumulative precipitation totals at nearby rain gages

Table 11. Total rainfall between February 18, 1986 3PM to midnight

Gage (1)	**Total rainfall depth (in) (2)**
Arden Way	3.11
Cresta Park	2.48
Rancho Cordova	2.29

To reconstitute the event, we:

1. Configured the HEC-1 model used to compute the p-0.01 runoff hydrographs to use the observed rainfall data.
2. Because significant rainfall occurred prior to the analysis period, set the loss model in the HEC-1 input file to represent saturated soil conditions.
3. Computed runoff hydrographs for the event and input those into the HEC-RAS model. As part of this configuration, we scaled the observed stage hydrograph at the H st bridge gage, over the LAR, to match the observed highwater in the LAR at the D05 pond. The D05 pond is a short distance downstream from the H st bridge. The observed value in the LAR at the D05 pond was 39.2 ft.
4. Exercised the hydraulic model with the 1986 flows and compared the results to observed high water marks and a partial observed flow hydrograph along Chicken Ranch Slough at Arden Way.
5. Modified the boundary conditions and re-exercised the model as necessary such that the computed results matched the observed values. To calibrate the model and match high water marks, we scaled the inflow hydrographs by approximately 10%.

Figure 18 is a screen shot from computer program HEC-RAS. In the figure, we can see a comparison of the computed stage hydrograph and the observed flow hydrograph. (The observed flow hydrograph was actually computed from an observed stage hydrograph as part of earlier studies by the County.) Although not a direct comparison, the plot shows that the timing of the rising limb of the computed hydrograph matches the "observed" data.

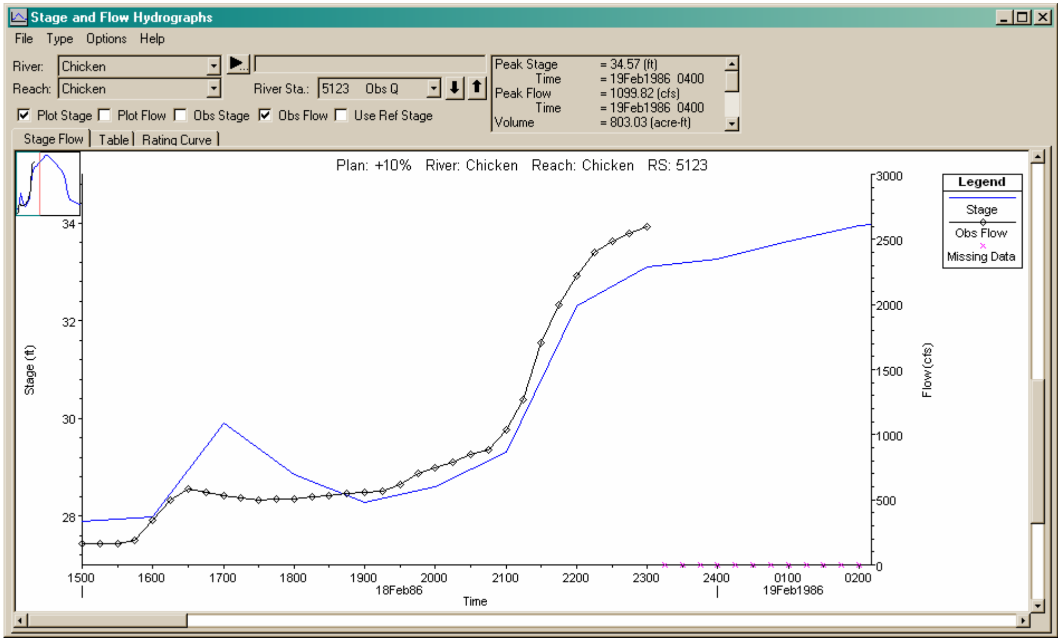

Figure 18. HEC-RAS screen shot comparing observed and computed values downstream of Arden Way on Chicken Ranch Slough

Table 12 compares observed high water marks collected by the County with computed maximum water levels at several locations in Strong Ranch Slough. As seen in the table, the observed and computed values match well.

Table 12. Comparison of computed water levels to observed high water marks along Strong Ranch Slough, February 19,1986 event

Location (1)	**Observed high water (ft) (2)**	**Computed level (ft) (3)**
D05 pond	34.0	33.94
Howe Avenue	34.0	33.94
N. of Northrop	34.0	33.94
Hurley Way (upstream)	35.6	35.68
Wittkop Way	36.3	36.94
Arden Way (downstream)	38.8	38.3
Arden Way (upstream)	39.6	42.14