

**M&T/Llano Seco Fish Screen Facility, Short-Term/  
Long-Term Protection Project, Phase II**

**TECHNICAL MEMORANDUM: WORKSHOP #5 SUMMARY  
December 19, 2008**

**1. INTRODUCTION**

In 1997, the M&T/Llano Seco Pumping and Fish Screen Facility (M&T Pumps) was moved from Big Chico Creek to the east (left) bank of the Sacramento River just south of Bidwell State Park and downstream from the mouth of the creek at RM 192.75 (**Figure 1**) with a project cost of approximately \$5M. The relocated pumps and fish screens were designed to meet National Marine Fisheries Service (1997) and California Department of Fish and Game (DFG) (2000) fish screening criteria. Relocation of the pumps increased the amount of flow in Big Chico Creek, eliminated reverse flows in Big Chico Creek, reduced the incidence of fish entrainment and allowed for dedication of 40 cfs to Butte Creek to assist the recovery of Spring-run Chinook salmon. The pumps had previously been located since about 1915 in Big Chico Creek about 0.5 miles upstream from the confluence with the Sacramento River.

Since 1997, unforeseen geomorphic changes have occurred in the Sacramento River channel that pose a significant risk to the continued operation of the M&T Pumps and the adjacent City of Chico's Wastewater Treatment Plant Outfall (City of Chico Outfall) that is located about 300 feet downstream. Geomorphic changes include erosion and lateral migration of the west bank of the river and concomitant downstream growth of the large gravel bar that is located at the mouth of Big Chico Creek, just upstream from the intake. The bank-attached bar on the east side of the river migrated about 850 feet downstream towards the M&T and City of Chico facilities between 1995 and 2001 (Stillwater Sciences, 2001). Comparative aerial photography and survey measurements by the Department of Water Resources (DWR) show that the west bank of the Sacramento River eroded by up to 400 feet just upstream from the M&T Pumps and City of Chico Outfall between 1996 and 2007. In 2001 and 2007, 200,000 tons and 100,000 tons of material, respectively, was dredged from the gravel bar as a short-term solution to limit sedimentation at the M&T and City of Chico facilities. The extent of the October 2007 bar removal was limited by the higher than expected flows in the river and the requirement for work to be conducted within a constructed containment berm before the end of October. The 300,000 tons of gravel that are owned by the DFG are currently stockpiled on the M&T Ranch. However, as shown in **Figure 2**, the bar has continued to grow in the downstream direction and currently the downstream terminus of the subaqueous bar is located opposite the M&T pump inlets and fish screens.

In 2007, 1,500 feet of short-term, toe-protection bank protection was installed on the west side of the river on the U.S. Fish and Wildlife Service's (USFWS) Capay Unit of the Sacramento River National Wildlife Refuge. The downstream extent of the toe protection was limited by The Nature Conservancy's (TNC) 1991 Conservation Easement on the Shaw property. As mitigation for bank swallow habitat, a 20-acre erosion easement was provided by the M&T Ranch at about RM 192.4. The intent of the short-term (5-year) bank protection project was to preserve alternatives for the long-term solution. Currently, the City of Chico is planning to move their wastewater outfall 1,200 feet downstream, which is estimated to provide them with 15 to 20 years of project life (Tamara Miller, City of Chico, personal communication).

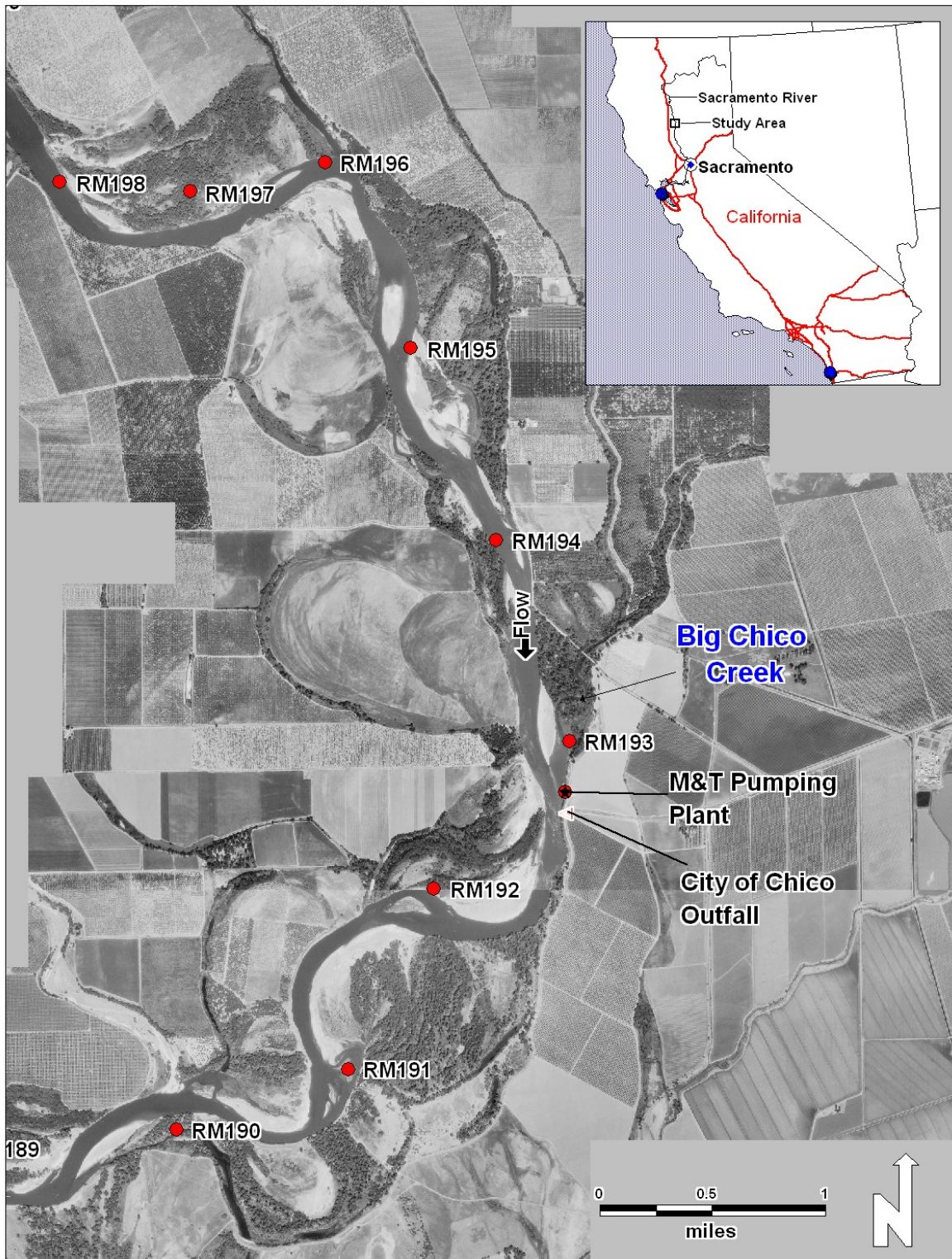


Figure 1. Location of the Sacramento River and the M&T Pumping Plant and City of Chico Wastewater Treatment Plant Outfall.

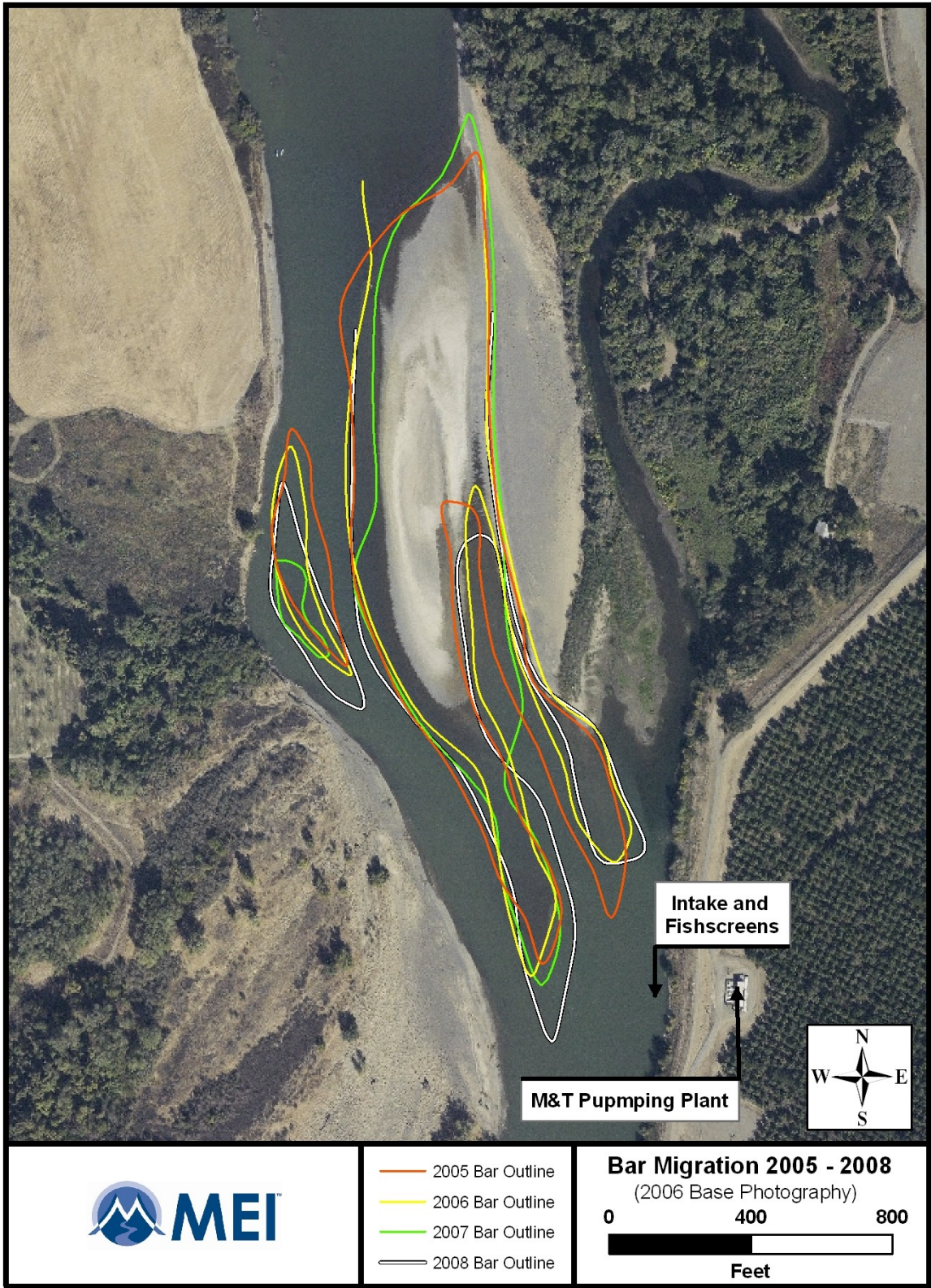


Figure 2. Subaqueous bar limits between 2005 and 2008 based on aerial photographs taken during low-flow conditions in 2005, 2006, 2007 and 2008.

At the conclusion of Workshop #4, which was conducted in April 2006, the findings of Phase I of the project were summarized in the Workshop #4 Technical Memorandum (Ducks Unlimited, 2006). At Workshop #4, the Expert Panel composed of Drs. Yantao Cui, Eric Larsen, Bob Mussetter, P.E. and Mike Harvey, P.G. recommended to the Steering Committee two in-river Technical Alternatives, (1) spur dikes/groins and (2) a dredging alternative, for further evaluation and refinement in Phase II of the project that would involve further analysis of the preliminary conceptual design, environmental documentation and final engineering. They concluded that resolution of most, but not all, of the technical uncertainties regarding both alternatives could be achieved with additional physical and numerical modeling and engineering analysis. Completion of the additional analyses was expected to permit a Preferred Alternative and a Contingent Alternative to that selected by the Stakeholders. Permitting issues would be addressed by consultation with Regulatory Agencies, and Social and Environmental issues would be addressed through the CEQA/NEPA process.

### **1.1. Workshop # 5 Objectives**

Workshop #5 was conducted on September 30, 2008, and the objectives of the workshop were to report on the findings of the Phase II additional analyses and to provide implementable alternatives to the stakeholders that could then be carried into the permitting and environmental assessment (CEQA/NEPA) process. The additional analyses conducted in Phase II included:

1. Meander modeling to evaluate the long-term (50 years) behavior of the river and environmental benefits with and without existing revetments (Larsen),
2. Two-dimensional hydrodynamic modeling to evaluate the hydraulic consequences of removing revetments on the overflows at the M&T flood relief structure and any upstream hydraulic impacts of the spur dike/groins alternative (Mussetter Engineering, Inc),
3. Physical modeling (1:75 scale) of the M&T reach to evaluate spur dike/groins and dredging alternatives (Colorado State University), and
4. Engineering analyses and development of preliminary alternative designs and costs (MWH Global).

Prior to Workshop#5, following completion of the Physical Modeling that indicated that neither dredge alternative was viable as a long-term solution, and following indications from TNC that spur dikes/groins would not be permitted on the Shaw property (Memo from Greg Werner to SCRAF Board, September 11, 2008), two additional pump relocation alternatives were preliminarily considered in a conference call (September 24, 2008) by the Expert Panel: (1) relocation 2,200 feet downstream, and (2) relocation 3,600 feet downstream. Subsequent to the Workshop, the Expert Panel members discussed addition of Iowa vanes to the 2,200 feet relocation and the possibility of a self-scouring intake tower alternative. These alternatives are addressed in this Technical Memorandum. A verbatim transcript of the Workshop is provided in **Appendix A.1.**

## **2. WORKSHOP # 5**

The agenda for the one-day workshop conducted on September 30, 2008, at the Llano Seco Ranch Headquarters and the list of attendees are provided in **Appendix A.2**.

### **2.1. Mr. Les Heringer, Manager M&T Ranch: Project History**

Mr. Heringer provided a timeline for the project that commenced in 1991. A feasibility study of relocation of the M&T pumps from Big Chico Creek, where they had been located since about 1915, to the current location on the Sacramento River was conducted by CH2MHILL in 1994. The approximately \$5M relocation, that was designed by MWH to meet NMFS and DFG fish screen criteria, was funded primarily by CALFED, and was constructed between 1996 and 1997. Environmental benefits from the relocation included more water in Chico Creek, elimination of flow reversals in Big Chico Creek, reduced fish entrainment and dedication of 40 cfs to Butte Creek. Relocation of the pumps was intended to guarantee 150 cfs of pumping capacity for an annual yield of approximately 40,000 acre-feet.

By 2000, it was apparent that there were sedimentation problems at the pump inlets and fish screens due to the downstream migration of a gravel bar. To allow continued pumping, 200,000 tons of sand and gravel were dredged from the bar in 2001 at a cost of about \$400,000. Funding for developing a long-term solution was acquired from CALFED in 2002 and an expert panel was selected in 2003. Alternatives and supporting studies have been developed between 2003 and 2008 at a cost of about \$1.4M. In the meantime, the gravel bar was dredged again in 2007 that removed an additional 100,000 tons of gravel was removed at a cost of \$409,000. An interim, short-term, bank protection project (1,500 feet) was installed on the west side of the river in 2007 to maintain alternatives for a long-term solution at a cost of \$620,000.

Mr. Heringer pointed out that approximately \$2.8M had been spent on the project since 2001, and eight years after the initial problems were identified, there was still no long-term solution identified, to guarantee water delivery to the stakeholders including the M&T and Llano Seco Ranches as well as USFWS and DFG easements and Refuges. He pointed out that the City of Chico was being forced to move their wastewater outfall for a cost of about \$5M due to the same problems, and concluded that the spur dike/groins alternative was the only one that met the needs of both entities. Further, Mr. Heringer stated that the intent of SB 1086 was to not only permit river meandering but to also protect river margin infrastructure such as the M&T pumps.

### **2.2. Dr. Mike Harvey: Review of Phase I Goals, Alternatives and Studies**

Dr. Harvey provided a brief review of the historical and present geomorphological and hydrodynamic conditions in the M&T Pumps reach of the Sacramento River based on studies that has been conducted by members of the Expert Panel and others and that are summarized in the Workshop #4 Technical Memorandum. He identified the physical causes of the current problems at the fish screens and pumps as being related to the downstream migration of a gravel bar that had migrated at a rate of between 60 and 140 feet/year depending on the period of record being considered. Concurrently, retreat of the west bank of the river by about 400 feet has widened the river and reinforced the depositional characteristics of the reach. Removal of about 300,000 tons of sand and gravel in 2001 and 2007 has reduced the rate of bar migration. He reminded the participants that maintenance of the current geometry of the river was not in

itself a solution to the problems at the fish screens and pump inlets or the City of Chico's wastewater outfall.

The primary objective of the M&T/Llano Seco Fish Screen Facility, Short-term/Long-term Project was to resolve the apparent contradiction between protecting ecosystem functions by accommodating natural river meander processes while also protecting the present pumping plant facility in order to provide a fish-screened diversion without threatening the anadromous species and providing water for crops, habitat and waterfowl. The overall project objective was subdivided into specific objectives as follows:

1. Obtain an authoritative and unbiased description of the state of scientific knowledge related to Sacramento River meander and fish screen and pumping plant technologies by convening a multidisciplinary team of experts in the fields of fluvial geomorphology, sediment transport, hydraulic modeling, fish screen and pumping plant technology.
2. Provide an opportunity for stakeholders and scientists to test and refine an understanding of the potential for unintended effects between managing the natural riverine system, fisheries requirements and pumping requirements.
3. Conduct an exhaustive literature search, fill identified data gaps and conduct modeling to provide important data essential to answering specific questions that support a strong research approach in accomplishing the primary project goal.
4. Determine performance measures/indicators that will guide the long-term solution in meeting the primary project goal.
5. Fully document the investigative process of determining, identifying and justifying the long-term solution that will meet the primary goal of the project.

Dr. Harvey discussed the CALFED-approved project conceptual model (**Figure 3**) and reminded participants that a non-goal alternative that did not satisfy all criteria was always a possibility. The conceptual model was used to develop ranking criteria that were then used in a decision matrix to evaluate alternatives. Ranking criteria included:

1. Ability to provide a reliable water supply
2. Ability to let the river meander
3. Ability to meet fish screen criteria
4. Engineering feasibility
5. Capitol cost
6. Operation and maintenance costs, and
7. Compatibility with the City of Chico wastewater outfall needs

A large number of alternatives were identified and evaluated during the course of four workshops between 2003 and 2006. Higher levels of investigation were applied to those alternatives that passed initial screening by the Expert Panel.

### **2.2.1. Workshop # 1 (November 2003)**

Potential alternative water supplies were identified and these included:

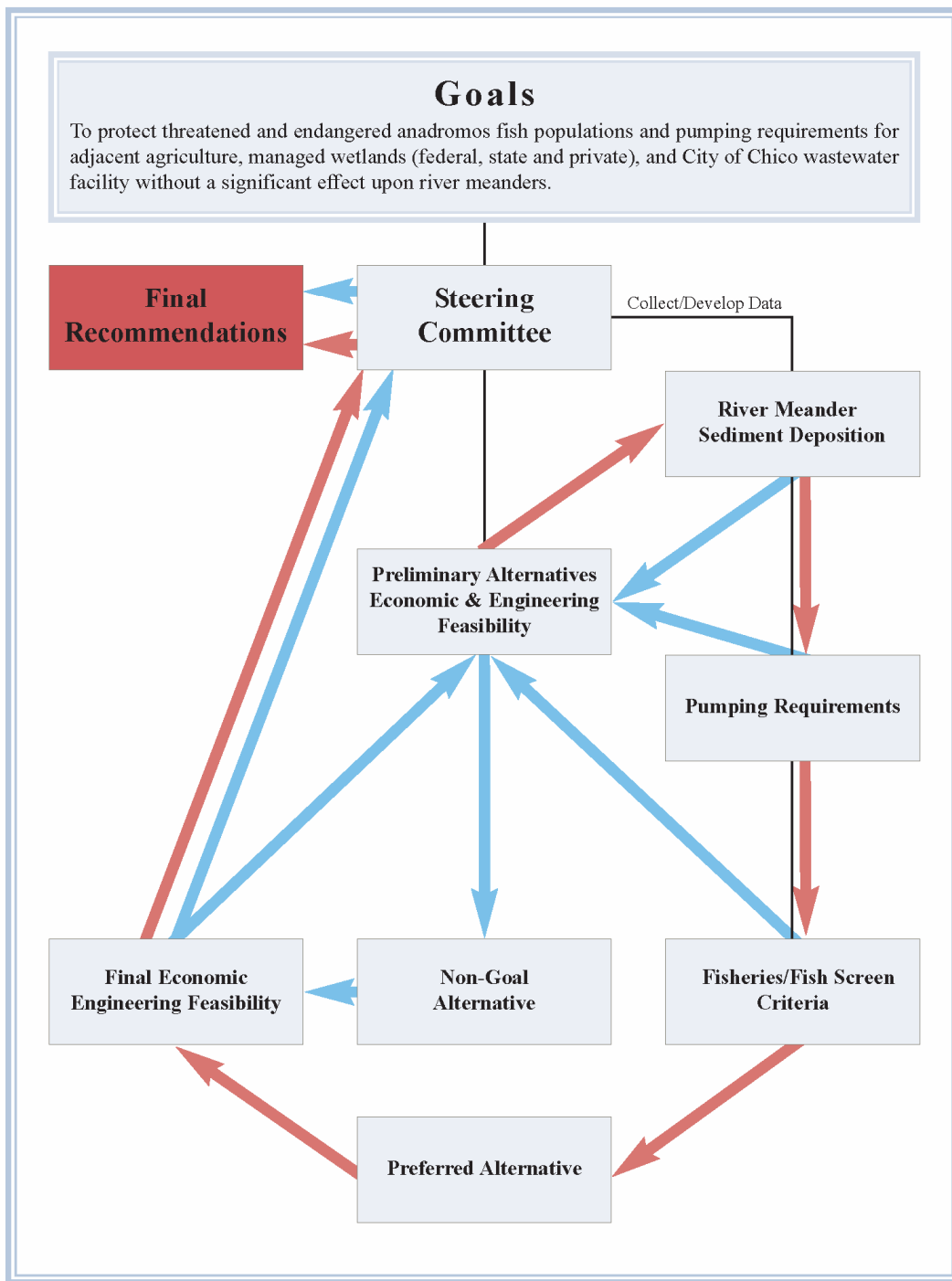


Figure 3. Project Conceptual Model.

1. Local groundwater sources,
2. Ranney Collector Wells,
3. Water supply from the Chico Wastewater Treatment plant, and
4. Increasing the water supply from the Parrott-Phelan Diversion on Butte Creek.

The water from the wastewater treatment plant was not acceptable to the Wildlife Refuges or to the agricultural water users. Increasing the water supply from the Butte Creek diversion would leave insufficient flows for spring-run Chinook salmon in Butte Creek during critical times of the year. Therefore, these potential alternatives to in-river pumping were rejected from further consideration. Changing the point of diversion to a downstream location or back into the Big Chico Creek diversion area was discussed. Moving the point of diversion downstream would likely put it below the discharge of the City of Chico Wastewater Treatment Plant outfall which would possibly impact the water quality of the diverted water supply. Moving the point of diversion back to the original Big Chico Creek site would cause adverse biological impacts to the fishery on the Sacramento River. There would also be adverse impacts to the fishery on Big Chico Creek.

Alternatives that were retained for further evaluation included:

1. Installation of additional "Tee" Fish Screens across or downstream from the current location,
2. Groundwater extraction from production wells,
3. Groundwater extraction from Ranney Collector Wells, and
4. Installation of rock spur dikes/groins on the west bank of the river.

Insufficient information was available to provide a sound basis for choosing a preferred alternative and further investigations were recommended to more fully evaluate the feasibility of the identified alternatives. It was also agreed that a better understanding of the river dynamics and sediment transport and deposition was key to meeting the objectives of the project. The following investigations were identified and approved:

1. Determine the physical feasibility of extracting 150 cfs of groundwater from the study area.
2. Develop preliminary cost estimates for the installation of an additional "tee" fish screen, groundwater extraction with production wells and groundwater extraction with Ranney Collector Wells.
3. Evaluate the economic and legal aspects of the above-listed alternatives.
4. Evaluate the water supply and water demands.
5. Consider impacts to the City of Chico Wastewater Treatment Plant outfall.
6. Conduct a river meander and sediment-transport analysis for the project site.



### 2.2.2. Workshop #2 (March 2004)

MWH Americas staff presented the results of their groundwater model investigation and the potential for an alternative supply of water for the stakeholders to the Steering Committee (The specific reports are located on the DU project website). Additionally, preliminary cost estimates were presented for the alternatives and legal issues (surface water vs. groundwater rights) and economic (cost of water) issues were discussed by the Expert Panel. Water supply and demand (150 cfs) for the M&T project was discussed. The potential for changing the fish screens and for relaxing fish screen criteria were also discussed. The results of four investigative studies conducted by the members of the Expert Panel were presented to the Steering Committee (Harvey et al., 2004).

After reviewing the technical reports, the Expert Panel listed all of the possible alternatives and then evaluated the likelihood that each alternative would meet fish screen criteria, pumping capacity and river meander goals. Advantages, disadvantages, risks, uncertainties and fatal flaws were identified in the review process. Alternatives evaluated included:

1. Collector basin (infiltration gallery)
2. Extended intakes—down river
3. Extended intakes—across river
4. In-conduit fish screen
5. Dredging with modified fish screen
6. Rock dikes/groins
7. Multiple groundwater production wells
8. Ranney Collector wells
9. Combination of 1 Ranney Collector well and dredging

**Table 1** provides a summary of the alternatives evaluation. Because of significant uncertainties and un-solvable flaws a number of alternatives were rejected. These included:

- Extended intakes down and across the river
- In-conduit fish screens
- Collector basin/infiltration gallery
- Multiple production wells

The alternatives carried forward from the screening process included:

- Dredging with modified fish screens
- Spur dikes/groins
- Ranney Collector wells

After extensive review and discussion of the alternatives, the Expert Panel concluded that there were too many unknowns and uncertainties to make a recommendation to CBDA. The principal uncertainties were the likely future behavior of the river, the hydraulic capacity of the subsurface water-bearing strata and the potential impact of river meandering on groundwater yield. To address these issues the Expert Panel recommended the following investigations:

Table 1. Summary of Expert Panel evaluation of alternatives.

| Alternative                           | Criteria    |                |                           |                                 |                                                                                                | Uncertainties                                                                                                                                                                                                 | Flaws                                                                                                                                                                                                      |
|---------------------------------------|-------------|----------------|---------------------------|---------------------------------|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                       | Fish Screen | Allows Meander | Provides Pumping Capacity | Provides for City Outfall Needs | Other                                                                                          |                                                                                                                                                                                                               |                                                                                                                                                                                                            |
| Extended Intake - Down the River      | Yes         | Yes            | Maybe                     | No                              | Maintains existing facility                                                                    | River meander<br>City of Chico selection of alternatives<br>Head loss / affects on pump                                                                                                                       | Project life                                                                                                                                                                                               |
| Extended Intake - Across the River    | Yes         | Yes            | Maybe                     | No                              | Maintains existing facility                                                                    | Flood flows at the new location<br>Air burst<br>Scour depth<br>River meander                                                                                                                                  | River shift<br>Accessibility                                                                                                                                                                               |
| In-conduit Fish Screen                | Yes         | Yes            | Yes                       | No                              | Maintains existing facility<br>Pumping costs remain the same<br>Known technology               | Pipe extensions--cost/permitting/ long-term maintenance<br>Capacity variables<br>Pumping costs<br>Meet State criteria                                                                                         | Bypass pipe/predation at point of discharge<br>Intake--chase meander                                                                                                                                       |
| Dredging / Deadend Screen             | Yes         | Yes            | Yes                       | No                              | Maintains existing pumping plant<br>Low initial cost (new screens)                             | How much dredging to maintain capacity<br>Dredging costs<br>Where do the spoils get deposited?<br>Screen costs (flat plate?)                                                                                  | Frequency of dredging<br>Permit process<br>Dredging when endangered species are present<br>Other ownership issues - State Parks<br>As river moves west, channel would need to increase in width and length |
| Collector Basin/ Infiltration Gallery | Yes         | Yes            | Yes                       | No                              | Low cost for initial construction<br>Compatible with present facility                          | Permeability of gravels<br>Impact on drawdown<br>Estimated size of basin<br>Site selection<br>River movement<br>Economics<br>Groundwater impacts                                                              | Requires loss of farmland<br>Public safety<br>Levee breach liability<br>River meander impacts<br>Maintenance issue - siltation (no backflush ability)                                                      |
| Multiple Production Wells             | Yes         | Yes            | Yes                       | No                              | Wider distribution of drought risks                                                            | Power availability<br>Pumping costs<br>Water distribution system<br>Groundwater impacts<br>Impacts to farmland<br>Water rights and legal issues                                                               | Loss of farmland<br>Higher maintenance costs                                                                                                                                                               |
| Groins/Dikes                          | Yes         | No             | Yes                       | Yes                             | Maintains current operations<br>Improves current situation<br>Reasonable confidence in utility | Off-site impacts<br>Mitigation costs<br>Mitigation possibilities (trading)<br>Authorities / maintenance                                                                                                       | Public safety / navigation<br>Environmental impact to river meander<br>Institutional constraints                                                                                                           |
| Ranney Collectors                     | Yes         | Yes            | Yes                       | No                              | Minimal environmental impacts<br>Possible use of existing large pumps                          | Permeability of gravels and water yield (number of wells)<br>Cost for pumping and long-term maintenance<br>Impacts of river meander and aging on yield<br>Capacity / cost<br>Life cycle costs<br>Water rights | Additional pumping expense (\$32/AF v \$8/AF)<br>Highest capital cost idea                                                                                                                                 |

1. Two-dimensional (2-D) hydraulic modeling of the river to evaluate how sediment is transported through the M&T reach, develop a better understanding of the effects of upstream bank revetments on the flow patterns at the M&T site, and evaluate the necessary length and locations of the spur dikes/groins (Mussetter Engineering, Inc.)
2. Meander modeling of the river from Pine Creek to Stony Creek to evaluate upstream and downstream effects of spur dikes/groins, effects of potential cutoff of Pine Creek bend on M&T reach, and compute the area of floodplain reworked (ecological benefits) under a range of possible scenarios (Larsen).
3. Drilling of test and monitoring wells to develop the aquifer capacity information required to evaluate the potential for groundwater replacement of current surface-water supplies (MWH Americas).

### **2.2.3. Workshop #3 (February 2005)**

The results of the two-dimensional hydraulic and sediment transport modeling (Mussetter Engineering, Inc), meander modeling (Larsen) and groundwater monitoring and analyses (MWH Americas) were presented to the Steering Committee. Peer reviews of the reports for these studies were conducted by Dr. Cui. Additionally, the Director of the City of Chico Public Works Department (Mr. Fritz McKinley) and their consultants (Corrollo Engineers) gave a presentation on the issues associated with the City of Chico's requirements to expand their wastewater discharge from 9 mgd to 12 mgd by 2010. The following provides a summary of the City of Chico's issues, requirements and preferences:

1. City needs to increase the outfall capacity and the size of the diffuser located about 300 feet downstream of the M&T pumps and fish screens, but the growth of the gravel bar and migration of the river to the west will prevent them meeting the required dilution standards.
2. The City would like to maintain the outfall in the same location if possible and would be a willing cost-share partner in a joint project with M&T.
3. The City needs to move forward for an EIS/EIR, and through its consultants has identified six alternatives:
  - a. Dredging of the river, as was done in 2001,
  - b. Construction of spur dikes on the west bank of the river,
  - c. Relocation of the gravel bar to the west side of the river,
  - d. Dredging of a pilot channel through Bidwell State Park,
  - e. Develop a moveable diffuser design, and
  - f. Relocate the outfall about 1,200 feet downstream of its present location with the expectation that this would meet the design life of the new diffuser (15 to 20 years).
4. City has decided to advance the relocation of the outfall as the preferred alternative to move the EIS/EIR process forward, but would prefer a joint project with M&T that involved construction of spur dikes on the west bank of the river.

Based on the findings from the various investigations, the Expert Panel identified three alternatives and a No-Action alternative for further evaluation. The No-Action alternative was considered to be unacceptable. The Expert Panel concluded that the three alternatives identified would meet the requirements of providing a reliable source of water for the M&T

Ranch, Llano Seco Ranch, U.S. Fish and Wildlife Service and California Dept. of Fish and Game Refuges and with varying success meet the other project goals. The three alternatives in order of preference were:

1. Ranney Collector Wells
2. Spur dikes/groins on the west bank of the Sacramento River opposite the existing pumping plant, and
3. Dredging of the river to provide both short- and long-term water access to the existing pumps while meeting required fish screen criteria.

The Expert Panel concluded that a recommendation for a preferred alternative could not be made and recommended that comprehensive concurrent investigations be conducted on the three alternatives to assess the feasibility of individual alternatives and combinations of alternatives to meet the goals and objectives for a 40-year project life based on the projected life of the stainless steel fish screens. Because of uncertainties about the operation and maintenance costs, water yields, long-term maintenance and efficiencies, project life expectancy and water rights issues associated with the Ranney Collector Wells, it was decided that simultaneous further evaluations of the other two alternatives (spur dikes/groins and dredging) should be conducted to ensure the on-going operation and protection of the fish screen facility in the event that the Ranney Collector wells alternative failed to meet Economic Feasibility (capital expenditure and O&M costs) criteria.

In addition, due to the on-going erosion of the west bank, the Expert Panel recommended an interim action to maintain the viability of the three alternatives. Because the ability to use spur dikes/groins to rectify the hydraulic conditions at the fish screens and pumps is limited by further erosion of the right bank of the river opposite the pumps, it was further recommended that a temporary revetment be evaluated along the right bank of the river to prevent further erosion thereby preserving the existing bank line during the alternative selection and NEPA/CEQA process. A partial or entire excavation of the encroaching gravel bar was considered to be necessary to eliminate the current threat to the operations and function of the M&T/Llano Seco Fish Screen facility and City of Chico outfall. Ongoing monitoring has been conducted each year to trigger the need to execute this task. As a result of the 2004 diver assessment at the fish screens, the Expert Panel recommended that, due to the sediment deposition that has occurred to date, Ducks Unlimited request CBDA's approval to proceed immediately with the permitting process to implement the gravel bar reduction action. This action would allow the owners/stakeholders additional time to assure water supply with the existing pumping and fish screen facility while a permanent solution was developed.

The Expert Panel recommended the following actions:

1. Conduct four feasibility studies to investigate and prioritize identified risks and uncertainties associated with Ranney Collector wells, spur dikes/groins, and dredging and fish screen modification
2. Perform a refined river meander migration analysis to simulate upstream and downstream effects of proposed alternatives at 5-year intervals up to 50 years
3. Immediately begin environmental documentation for gravel bar extraction.

4. Conduct a feasibility study of temporary revetment with the goal of preserving the feasibility of the spur dike/groins option.
5. Commence discussions with key agency representatives (USFWS, NMFS, DF&G) to discuss relaxation of fish screen criteria due to the current stringent sweeping flow velocity requirements at the face of the screens. Relaxing fish screen criteria based on more informed science would provide the basis for salvaging a portion of the initial CALFED investment by finding a solution that maintains the existing pumping facility and installs a redesigned fish screen.

#### **2.2.4. Workshop # 4 (April 2006)**

The goals of the Fourth Workshop were to:

1. Review and evaluate the results of the four technical studies recommended by the Expert Panel at Workshop 3. These included; 1) meander modeling (Larsen), 2) two-dimensional modeling of the spur dikes (MEI), 3) further analysis of Ranney Collector Wells and 4) evaluation of dredging and fish screens (MWH Americas),
2. Develop a technical recommendation from the Expert Panel for a Preferred Alternative (PA), and
3. Move the process forward to Phase II that will include pre-construction engineering design and environmental documentation (CEQA, NEPA).

Following extensive discussion of the pros and cons of the various alternatives developed from the results of the four studies, and a reminder that the Senate Bill (SB)1086 process acknowledged the need to protect existing infrastructure (bridges, buildings, pumping plants, flood management control structures and levees) along the river when other alternatives for allowing river meandering processes to continue had been considered and were found to be infeasible, the Expert Panel evaluated the alternatives through the Decision Matrix identified in the Project Conceptual Model (Figure 3). Alternatives evaluated by the committee through this process included three spur dike alternatives, three dredging alternatives, four Ranney Collector Well alternatives and a No- Action alternative. Uncertainties, or issues requiring clarification, were identified for each of the alternatives. Additionally, an O&M cost per acre-foot of water was computed for each alternative, except the No-Action alternative, to permit non-capital cost economic comparisons between the alternatives. **Table 2** provides a summary of the evaluation conducted through the decision matrix by the Expert Panel.

#### **No Action Alternative**

The No-Action alternative failed to meet the Fish Screen, Water Supply and Benefit to the City of Chico criteria, but did permit continued river meandering. However, no feasible alternative water supply to replace the existing in-river water supply was identified, and thus the No-Action alternative was rejected.

#### **Ranney Collector Well Alternatives**

In terms of the primary criteria (Fish Screens, River Meander, Water Supply), only the 3 and 4 Ranney Collector Well alternatives that are capable of delivering 30,000 to 40,000 AF/year meet all the project goals, and thus rank as the preferred alternatives. The alternatives meet the

Table 2. Decision matrix for alternatives reviewed by the Expert Panel.

| Alternatives       | Fish Screen<br>(Y, N, ?) | Pumping<br>Requirements<br>(Y, N, ?) | River<br>Meander<br>(Y, N, ?) | Engineering<br>Feasibility<br>(Y, N) | Economic Feasibility<br>(x\$1,000)<br>(2006 dollars) |          | Benefits City of Chico<br>(Y, N) | Uncertainties/Clarifications                                                                                                                                                                      | O & M Cost<br>(\$ per Ac-ft) |
|--------------------|--------------------------|--------------------------------------|-------------------------------|--------------------------------------|------------------------------------------------------|----------|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|
|                    |                          |                                      |                               |                                      | Capital                                              | O&M      |                                  |                                                                                                                                                                                                   |                              |
| Spur Dikes (8)     | Y                        | Y                                    | N                             | Y                                    | \$7,350                                              | \$784    | Y                                | Number and design of dikes depends on results of physical modeling; bio-remediation not included in costs                                                                                         | \$0.65                       |
| Spur Dikes (9)     | Y                        | Y                                    | N                             | Y                                    | \$8,050                                              | \$884    | Y                                | Number and design of dikes depends on results of physical modeling; bio-remediation not included in costs                                                                                         | \$0.74                       |
| Spur Dikes (9x)    | Y                        | Y                                    | N                             | Y                                    | \$11,610                                             | \$2,024  | Y                                | Number and design of dikes depends on results of physical modeling; bio-remediation not included in costs                                                                                         | \$1.69                       |
| Dredging (1)       | Y                        | Y ?                                  | Y                             | Y                                    | \$8,650                                              | \$4,108  | N                                | Permits (costs), state parks, schedule of removal, frequency of removal, access to remove material near screen; screen cost included (\$3,000,000); no mitigation cost included                   | \$3.42                       |
| Dredging (3)       | Y ?                      | Y ?                                  | Y                             | Y                                    | \$8,650                                              | \$2,263  | N                                | Permits (costs), screen modifications, capacity?schedule of removal, frequency of removal, access to remove material near screen; screen cost included (\$3,000,000); no mitigation cost included | \$1.89                       |
| Dredging (GB)      | Y?                       | Y?                                   | Y                             | Y                                    | \$9,400                                              | \$12,000 | N                                | Permits (costs), Impact of river migration, rate of channel fill, response of other cases, assumes dropping gravel in river; screen cost included (\$3,000,000); no mitigation cost included      | \$10.00                      |
| Collector Well (1) | Y                        | N                                    | Y                             | Y                                    | \$6,637                                              | \$12,120 | N                                | Assumes yield of 10,000AF/y                                                                                                                                                                       | \$30.30                      |
| Collector Well (2) | Y                        | N                                    | Y                             | Y                                    | \$13,274                                             | \$24,249 | N                                | Assumes yield of 20,000AF/y                                                                                                                                                                       | \$30.31                      |
| Collector Well (3) | Y                        | Y ?                                  | Y                             | Y                                    | \$19,911                                             | \$33,627 | N                                | Assumes yield of 30,000AF/y                                                                                                                                                                       | \$28.02                      |
| Collector Well (4) | Y                        | Y                                    | Y                             | Y                                    | \$26,548                                             | \$43,024 | N                                | Assumes yield of 40,000AF/y                                                                                                                                                                       | \$26.89                      |
| No Action          | N                        | N                                    | Y                             | Y                                    |                                                      |          | N                                | Where/How would we get replacement water??                                                                                                                                                        |                              |

Engineering Feasibility criterion as well. However, the alternatives failed the Economic Feasibility criterion. Capital costs were on the order of \$20 M to \$26.5 M, which exceeded the \$12 M non-stakeholder capital limit that was assumed to be available for the project. From a stakeholder perspective, the 3 and 4 Ranney Collector Well alternatives also failed to meet the Economic Feasibility criterion. An additional cost of \$28 to \$27/AF on top of the existing water cost of approximately \$8/AF created a water cost of about \$36 to \$35/AF, which was beyond the ability of the stakeholders (ranches and refuges) to absorb. The Ranney Collector Wells alternatives provided no benefit to the City of Chico. The 3 and 4 Ranney Collector Wells alternatives were, therefore, rejected.

Since the 3 and 4 Ranney Collector Wells alternatives failed to meet the Economic Feasibility criterion, it was necessary to evaluate non-goal alternatives in the matrix. Ranney Collector Well alternatives that deliver less than 30,000 AF/year (1 and 2 Ranney Collector Wells) fail to meet the Water Supply criterion and fail to meet the Economic criterion for O&M costs (\$38/AF) and were, therefore, rejected.

### **Spur Dikes/Groins**

Three spur dike/groins non-goal alternatives were evaluated through the matrix. These included 8-, 9-, and 9-extended dike alternatives. All the dike alternatives met the Fish Screen and Water Supply criteria. Dike alternatives failed to meet the River Meander criterion due to their local prevention of westward migration of the river, but meander modeling indicated that there were unlikely to be significant impacts on upstream or downstream meander processes over the next 50 years. All the dike alternatives meet the Engineering Feasibility criterion, but the final configuration of the dike field will be dependent on the results of Phase II modeling and engineering analysis. All of the dike alternatives met the Capital Cost Economic criterion (\$7.4 M to \$11.6 M) including the full cost of 1:1 mitigation for the project (assuming full-bank rock protection), but the costs associated with an interim solution bio-remediation project (\$620,000 that was unknown at the time) that was required to preserve the dike alternatives prior to project implementation in 2010, were not included in the economic analysis. Costs associated with physical modeling (\$400,000) and an Adaptive Management Experiment (\$345,000) were included in the capital costs. From an O&M costs perspective, the spur dike alternatives increased the existing cost of water (\$8/AF) by between \$0.7 and \$1.7/AF and thus met the O&M cost Economic criterion. All the spur dike alternatives will provide benefits to the City of Chico in terms of either maintaining the existing location of the wastewater outfall, or by eliminating or postponing the need for a further downriver move of the outfall in the future. Based on the matrix evaluation, and taking into account the uncertainty regarding the final configuration of the spur dikes, and the potential for downstream rock removal as mitigation, the Expert Panel recommended that a non-goal spur dike alternative be advanced as a Technical Recommendation.

### **2.2.5. Dredging Alternatives**

Three dredging in-river alternatives that preserve the existing M&T pumping facilities were evaluated through the decision matrix. These included Alternative 1 that involved dredging a 400-cfs inlet channel and a 250-cfs bypass channel and modifying the existing fish screens to flat-plate screens; Alternative 3 that involved dredging a dead-end channel with a flow velocity of less than 0.33 fps with flat-plate fish screens; and Alternative GB that involved continued dredging of the gravel bar and replacement of the existing screens with flat-plate screens. The purpose of the flat-plate fish screens was to permit sediment removal in front of the fish screens which is impossible with the existing cylindrical screens.

Dredging Alternative 1 met the Fish Screen and River Meander criteria, but there is considerable uncertainty as to whether it meets the Water Supply criterion at all times because of the inability to dredge under high flow conditions. The alternative met the Engineering Feasibility criterion, provided that it is only necessary to dredge under low flow conditions. Access to remove material from near the existing screens will be difficult and addition of the flat-plate screens improved the reliability of supplying the required amount of water. Alternative 1 provided no benefit to the City of Chico, but it did meet both Capital cost and O&M cost criteria. Capital costs were about \$8.6 M, and the alternative increased the existing cost of water (\$8/AF) by about \$3.40/AF. Based on the matrix evaluation, and taking into account the uncertainties regarding permitting, access, and frequency and volume of sand and gravel deposition, the Expert Panel recommended that this dredging alternative be advanced as a Technical Recommendation.

Because of the considerable uncertainties regarding the ability to meet Fish Screen and Water Supply criteria, dredging Alternative 3 was rejected as an alternative by the Expert Panel. Similarly, even though dredging Alternative GB appeared to meet all the primary criteria (Fish Screen, River Meander, Water Supply) as well as the Engineering and Capital Cost Economic Feasibility criteria, there is such a high level of uncertainty regarding the impacts of river migration, the effects of point bar dredging on river meandering processes, long-term permitting, gravel disposal and O&M costs that the Expert Panel rejected the alternative.

Because of existing uncertainties with the two Technical Alternatives, additional studies and actions were recommended by the Expert Panel. These additional analyses to be conducted in Phase II included:

1. Meander modeling to evaluate the long-term (50 years) behavior of the river and environmental benefits with and without existing revetments (Larsen),
2. Two-dimensional (2-D) hydrodynamic modeling to evaluate the hydraulic consequences of removing revetments on the overflows at the M&T Flood Relief Structure and any upstream hydraulic impacts of the spur dike/groins alternative (Mussetter Engineering, Inc),
3. Physical modeling (1:75 scale) of the M&T reach to evaluate spur dike/groins and dredging alternatives (Colorado State University), and
4. Engineering analyses and development of preliminary alternative designs and costs (MWH Global).

Additionally, interim toe bank protection was recommended for the west bank of the Sacramento River to maintain the status quo until a preferred alternative could be identified, permitted and implemented. To maintain the ability to supply water from the existing pumps until uncertainties with the Technical Alternatives were resolved dredging of the gravel bar was recommended. The interim toe protection (1,500 feet) and bar dredging (100,000 tons) were completed in October 2007.

### **2.3. Phase II Technical Studies**

The results of the Phase II technical studies were presented. These included:

1. Modeling revetment removal and implications for meander migration of selected bends River Miles 222 to 179 of the Sacramento River, January 10, 2008 (Larsen) (**Appendix A.3**)



2. Channel migration 2007-2057 Final Technical Memorandum – Simulated channel migration (2007-2057) near River Miles 197 to 191 of the Sacramento River, September 25, 2008 (Larsen) (**Appendix A.4**)
3. Phase II Two-dimensional modeling to evaluate the potential river training works at M&T pumping plant Sacramento River, RM 192.5, California, October 2, 2008 (Mussetter Engineering, Inc.) (**Appendix A.5**)
4. M&T pump station intake Physical Model report, August 2008 (Colorado State University) (**Appendix A.6**)
5. Draft Engineering Analysis, Technical Memorandum, M&T Ranch/Llano Seco Intake project, Final Alternatives, September 2008 (MWH) (**Appendix A.7**)

### **2.3.1. Modeling Revetment Removal and Implications for Meander Migration of Selected Bends RM 222 to RM 179 of the Sacramento River, January 10, 2008 (Eric Larsen)**

Meander migration patterns 50 years into the future in 5-year increments, as a result of removal of existing revetments at nine locations between RM 179 and RM 222 were evaluated with a meander migration model. The baseline for the modeling was the 2004 river planform. Meander modeling at each of the 9 sites was conducted with and without the revetment in order to provide a basis for determining the ecological benefit (channel migration and area reworked) of revetment removal. The sites were located within 3 general reaches of the river: Woodson Bridge (RM 220-222R, RM 216-217L), Hamilton City (RM 197-198R, RM 191-192R, 186R, 186,5L, 191.5L, 197.5R) and Ord Ferry (RM 179R). The modeled migration was performed from simulated Water Year (WY) 2005 to WY2054, which were based on the recorded flows from WY 1939 to WY 1988 from three different gauges on the Sacramento River.

In the Woodson Bridge Reach, there is increased area reworked of the bends for both bends 221R and 216R when the revetment is removed. For bend 221R, the model shows that removing the revetment also changes the migration patterns directly downstream and decreases the total area reworked (in the downstream bend) when the upstream revetment is removed. For bend 216R, removing revetment increases the local area reworked as well as increases the area reworked for the bend immediately downstream.

In the Hamilton City Reach, six bends were modeled. At RM 197-8R the model shows that removing revetment increases the migration to the south near River Mile 197 in the area where the revetment is removed. At RM 196L the model shows that the increase in migration when the revetment is removed is limited by the natural restraint that occurs because of the erosion-resistant material near River Mile 196. The total change in area reworked is comparatively small. At RM 191-2R the model shows that the migration increases toward the western side when the revetment is removed in that location. In addition, there is a slight change in the pattern of area reworked in the bend immediately downstream. At RM 191L the model shows that the migration increases toward the south (right bank looking downstream) where the revetment is removed. At RM 186L the model shows that there is increased migration to the south when the revetment is removed and no effect on the bend immediately downstream. At RM 186R the model shows that there is no change in the migration pattern at this location when the revetment is removed. The pattern of migration is to the south away from the revetment that is located to the north of the channel.

In the Ord Ferry Reach, at RM 179R the model shows that when the revetment is removed at this location, a cut-off occurs. The length of abandoned channel created by that cutoff was

about 2500 meters. Channel migration rates decreased subsequent to cutoff due to decreased channel length and decreased sinuosity.

When the nine sites are compared with each other, two of the sites have limited increase in migration when revetment is removed, and one site experiences cutoff. Migration of the bend at RM 196L is limited by the natural restraint to the east. Migration of the bend at RM 186R is modeled to move away from the revetment. The bend at RM 179R cuts off when the revetment is removed. At the remaining six sites, including the RM 192.2R (Phelan Island) and RM 191L (Golden State Island) revetment removal results in significant, but unquantified, increases in area reworked. At some sites, there is also some change in the pattern and quantity of area reworked in the bend immediately downstream.

### **2.3.2. Channel Migration 2007-2057 Final Technical Memorandum – Simulated Channel Migration (2007-2057) near RM 197 to RM 191 of the Sacramento River, September 25, 2008 (Eric Larsen)**

2004 to 2054 meander simulations were conducted for the RM 191 to RM 197 reach to evaluate the impacts of the west bank spur dikes/groins on channel migration. The 50-year meander analysis was conducted for existing conditions and with the spur dikes/groins in place. The comparative analysis showed that under both simulations the west bank of the river downstream of the spur dikes/groins migrated westward to some extent, but that the spur dikes/groins had no additional impact on the downstream migration. The simulations also showed that the spur dikes/groins had no detectable impacts on river meandering upstream or downstream of the site.

### **2.3.3. Phase II Two-dimensional Modeling to Evaluate the Potential River Training Works at M&T Pumping Plant Sacramento River, RM 192.5, California, October 2, 2008 (Bob Mussetter, Mussetter Engineering, Inc.)**

At the conclusion of Phase I of the project (Workshop #4) additional two-dimensional (2-D) hydraulic modeling of the M&T reach was recommended by the Expert Panel for Phase II of the M&T Pumping Plant project to address the following issues:

1. The downstream boundary of the model used for the spur dike/groin evaluations in Phase I of the project (MEI, 2006) may be located sufficiently close to the M&T pumps that the downstream boundary effects could influence the hydrodynamic results in the vicinity of the pumps.
2. Incorporation of the 8- and 9-dike configurations into the Corps of Engineers coarser scale 2-D Butte Basin Model that extends from RM174 to RM212 (USACE, 1997) to evaluate the hydrodynamic impacts of the proposed spur dikes/groins on flood-flow distributions between the river and the overbanks.
3. Modification of the 2-D Butte Basin model to incorporate likely future channel conditions (50 years) following removal of existing revetments at Phelan Island (RM 192.2R) and Golden State Island (RM 191L) as predicted by meander modeling (Larsen, 2008) to evaluate the effects of river meandering on the stage-discharge relations at the M&T overflow weir (Flood Relief Structure).

To address the objectives of the investigation, the following 2-D models were developed for each specific objective:

1. The original MEI 2-D models (MEI, 2006) for the without dikes, and 8- and 9-dike configurations were extended 5,500 feet downstream. The models were re-run at the bankfull flow of 90,000 cfs, and the hydraulic results from the extended models were compared to the original models in the overlapping areas.
2. The without-dikes and 9-dike configurations were incorporated into the Corps of Engineers coarser-scale 2-D Butte Basin Model that extends from RM174 to RM212 (USACE, 1997) to evaluate the hydrodynamic impacts of the proposed spur dikes on flood flow distributions at the 100-year peak flow event, between the river and the Butte Basin, respectively.
3. Two-dimensional models were developed to represent the predicted channel alignments 50 years after removal of revetments at Golden State Island (191L), Phelan Island (192R) and both Golden State Island and Phelan Island (191L-192R) (Larsen, 2008). The 50- and 100-year peak flow events were simulated to evaluate the effects of river meandering on the stage-discharge relations at the M&T overflow weir.

Comparison of the hydraulic results of the extended models with the original models for the without-dikes and 8- and 9-dike conditions, indicated that the boundary effects of the original models are negligible; thus, the downstream boundary of the original models is suitably located to minimize boundary effects, and the results of the original models are not affected by the length of the models.

Comparison of the hydraulic results between the without-dikes and 9-Dike configuration at the 100-year peak flow (370,000 cfs) indicated that the 9-Dike conditions will increase the velocities over the gravel bar upstream of the pump station inlets by approximately 0.5 ft/s and increase the water-surface elevations upstream of the dikes by approximately 0.15 feet for a distance of 3,200 feet.

Comparison of the hydraulic results of the three channel migration scenarios with the original conditions indicates that removal of the revetments at both Phelan Island and Golden State Island (Scenario 3) will have the largest effect on stage and discharge at the M&T weir. The stage at the weir is predicted to increase by 0.2 feet for both the 50- and 100-year peak flow events, and the discharge will increase by 5,800 (4-percent increase) and 8,300 cfs (5-percent increase) for the 50- and 100-year peak flow events, respectively. Removal of the Golden State Island revetment (RM 191L) (Scenario 1) will increase the stage at the weir by 0.1 feet for both the 50- and 100-year peak flows, and the discharge over the weir will increase by about 3,800 cfs. Removal of the Phelan Island revetment (RM 192R) (Scenario 2) will increase the stage at the weir by about 0.06 feet for both the 50- and 100-year peak flows, and the discharge over the weir will increase by about 2,250 cfs.

#### **2.3.4. M&T Pump Station Intake Physical Model Report, August 2008 (Amanda Cox, Colorado State University)**

In order to evaluate a series of options for mitigation of the current problems affecting the M&T/Llano Seco Pumping and Fish Screen Facility, a physical model of a 6,975-ft section of the Sacramento River was constructed at the Colorado State University Engineering Research Center. The 1:75-scale model maintained Froude similitude, and approximate Shields parameter and critical velocity ratio similitude. Three different sediment types were incorporated in the physical model to simulate: 1) the gravel bar, 2) the slightly erodible sections along the west bank, and 3) the highly erodible section of the west bank.

Once constructed, the model was used to evaluate three unique mitigation options:

1. Option 1 – structural solutions incorporating spur dikes;
2. Option 2 – maintenance solutions utilizing dredge channels; and
3. Option 3 – relocation of the pump intake.

The scope of the test program focused on velocity distributions and channel-bed migration for each proposed control configuration. Flow conditions within the channel were modeled based on three discharges: 1) a 145,000 cubic feet per second (cfs) high discharge, 2) a bankfull discharge of 90,000 cfs, and 3) a lower discharge of 10,000 cfs. The 145,000-cfs discharge was used to develop the initial bed equilibrium, examine dredge-channel options, and investigate Extended Baseline Conditions. Each dike configuration or dredge-channel option was tested with the 90,000-cfs discharge, and velocity and elevation data throughout the river channel were obtained. In addition, all the dike configurations and one of the dredge-channel options were tested with the low-discharge condition (10,000 cfs) and velocity fields were quantified. Continuous and uniform sediment supply to the model was maintained in order to facilitate accurate simulation of gravel-bed morphology.

Data collected to quantify each option included velocity distributions for 10,000- and 90,000-cfs discharges, and topographic bed-elevation data to evaluate erosion and deposition patterns. In addition to mitigation options, the model was used to evaluate gravel-bar migration under Extended Baseline Conditions. **Table 3** provides the test matrix for the research program. The following sections summarize the hydraulic modeling and accompanying results.

| Option | Test Configuration | Discharge (cfs) |        |         | Velocity (ft/s) |            | Elevation (ft) |       |
|--------|--------------------|-----------------|--------|---------|-----------------|------------|----------------|-------|
|        |                    | 10,000          | 90,000 | 145,000 | 10,000 cfs      | 90,000 cfs | Point-gage     | LIDAR |
|        | Baseline           | X               | X      | X       | X               | X          | X              | X     |
| 1      | 8-Dike             | X               | X      |         | X               | X          | X              |       |
|        | Modified 8-Dike    | X               | X      |         | X               | X          | X              | X     |
|        | 9-Dike             | X               | X      |         | X               | X          | X              | X     |
|        | Extended 8-Dike    | X               | X      |         | X               | X          | X              | X     |
| 2      | Dredge Channel 1   | X               | X      | X       | X               | X          | X              | X     |
|        | Dredge Channel 2   |                 | X      | X       |                 |            | X              | X     |
| 3      | Intake Relocation  | X               | X      |         | X               | X          |                |       |
|        | Extended Baseline  |                 | X      | X       |                 |            | X              | X     |

### Option 1 – Structural Solutions Incorporating Spur Dikes

Four configurations of dike fields were installed along the west bank of the channel in order to protect the bank from erosive forces, redirect the largest velocities into the central area of the channel, and prevent downstream migration of the gravel bar. All dike fields achieved these goals to varying degrees of success, although three of four developed an area of increased

velocities during the 10,000-cfs flow along the west bank opposite of the pump facility. The 9-Dike Configuration provided bank stabilization to this area at low and high flows and was shown to be the most suitable dike configuration in accomplishing the project goals.

### **8-Dike Configuration**

West-bank stabilization and increased velocities within the gravel-bar reach and at the pump intake for both the 10,000- and 90,000-cfs flow rates were observed. Increase in flow velocity was observed along the west bank opposite the pumping facility at 10,000 cfs. Velocity recorded at the pump intake showed no difference in comparison to Baseline Conditions at 10,000 cfs. However, at 90,000 cfs, a local velocity of 5.64 ft/s was recorded at the intake, representing approximately a 17-percent increase from Baseline Conditions. Bed deposition occurred within the dike field and aggradation was not observed at the facility intake.

### **Modified 8-Dike Configuration**

The Modified 8-Dike Configuration incorporated the initial 8-Dike Configuration with the two upstream-most dikes having reduced lengths by approximately 100 feet. Implementing the Modified 8-Dike Configuration resulted in stabilization of the west bank, and increased velocities at the pump intake and along the gravel-bar reach for both flow conditions. Compared to Baseline Conditions, decreases in velocity along the west bank within the dike field and increases in velocity within the gravel-bar region were observed for both flow rates. Increase in flow velocity was observed along the downstream west bank for the 10,000-cfs flow. No significant deviation in velocity compared to Baseline Conditions occurred at the pump intake for the 10,000-cfs flow. However, at 90,000 cfs, a local velocity of 4.63 ft/s was recorded at the intake, representing a reduction of approximately 4 percent compared to Baseline Conditions. Comparative elevation changes from the baseline datum indicated deposition occurring within the dike field and immediately downstream of the pump intake.

### **9-Dike Configuration**

The 9-Dike Configuration incorporated the Modified 8-Dike Configuration with an additional dike located downstream. Implementing the 9-Dike Configuration resulted in stabilization of the west bank within and downstream of the dike field for both flow conditions. Compared to Baseline Conditions, increases in velocity at the pump intake and along the gravel-bar reach were also observed for both flow conditions. At 90,000 cfs, a local velocity of 5.63 ft/s was recorded at the intake, representing approximately a 17-percent increase from Baseline Conditions. Comparative elevation changes from the baseline datum indicated deposition occurring immediately downstream of the pump intake.

### **Extended 8-Dike Configuration**

The Extended 8-Dike Configuration incorporated the five upstream-most dikes from the Modified 8-Dike Configuration, while extending the three downstream dikes to meet the 1996 bankline. Implementing the Extended 8-Dike Configuration resulted in west-bank stabilization and increased velocities at the pump intake and along the gravel-bar reach for both flow conditions. Increase in flow velocity was observed along the downstream west bank for the 10,000-cfs flow. However, at 90,000 cfs, a local velocity of 5.04 ft/s was recorded at the intake, representing an increase of approximately 4 percent compared to Baseline Conditions. Comparative elevation

changes from the baseline datum indicated deposition occurring immediately downstream of the pump intake.

## **Option 2 – Maintenance Solutions Utilizing Dredge Channels**

Two trapezoidal dredge channels were formed within the study reach to evaluate their ability to maintain the designed conveyance for the intake. Dredge Channel 1 consisted of a dredged trapezoidal channel aligned along the eastern bank extending to just upstream of the pump intake. Dredge Channel 2 was designed to simulate a channel placed directly in front of the pump intake after downstream migration of the gravel bar had already occurred. Sedimentation within the channels was evaluated for a range of discharges. Performance of each configuration was evaluated over a range of discharges. Both dredge designs were observed to fill with sediment during testing and, therefore, were inadequate in meeting the objectives of the design.

### **Dredge Channel 1 Configuration**

Dredge Channel 1, which consisted of a dredged trapezoidal channel aligned along the eastern bank, rapidly filled with sediment returning the channel to Baseline Conditions. Initially, the velocity reading recorded at the pump intake during 90,000-cfs testing was greater than Baseline Conditions. However, monitoring the velocity at the intake over a 12-hour period indicated that the velocity at the intake was decreasing with time, a direct result of sedimentation within the dredge channel.

### **Dredge Channel 2 Configuration**

Set perpendicular to flow across the upstream gravel bar, Dredge Channel 2 was a surrogate for a channel placed directly in front of the pump intake once gravel-bar migration had occurred. Dredge Channel 2 proved incapable of handling the sediment load during the 145,000-cfs flow condition. Following testing, the channel had filled with sediment thereby restricting the discharge capacity to the intake.

## **Option 3 – Relocation of the Pump Intake**

An alternative location for the pump intake, located about 670 feet downstream of the current pump intake location investigated. The velocity at the relocation site was observed to be 8.66 ft/s, which was greater than the 4.83 ft/s velocity recorded at the current intake location. However, relocation to this site would require an evaluation of the stability of the west bank opposite this current pump location in order to determine long-term operation sustainability due to gravel-bar migration.

## **Extended Baseline Testing**

In addition to evaluating the different mitigation options, the physical model was used to investigate gravel-bar migration associated with the Extended Baseline Conditions. This was accomplished by testing a 90,000-cfs event followed by a 145,000-cfs event and finally a second 90,000-cfs event. The gravel bar was observed to migrate downstream towards the pump intake during the 145,000-cfs event and continued to migrate downstream during the second 90,000-cfs event.

## **Summary**

Of all Option 1 configurations, the 9-Dike Configuration produced conditions best suited for accomplishing the study objectives with the largest decreases in velocity along the erodible west bank and second highest velocity increase (16.6 percent) at the pump intake. For the 10,000-cfs flow, only the 9-Dike Configuration reduced velocities along the west bank downstream of the dike field. Option 1 bed-elevation analyses revealed a trend of scour upstream of the pump intake and an area of deposition directly downstream of the intake for each dike configuration. Zones of deposition occurred within the interior of each dike field and scour was observed along the instream boundary of the dike fields.

Both dredge channels in Option 2 did not adequately meet the outlined objectives. Dredge Channel 1 and Dredge Channel 2 were observed to fill completely with sediment and could not provide the capacity to the intake for which they were designed. Analysis of Dredge Channel 1 velocity data determined that the velocity distribution did not deviate significantly from Baseline Conditions other than slight time-dependent velocity increases at the pump intake and near the filled-in dredge channel.

Testing of the pump-intake relocation site, Option 3 identified the suitability of the location to provide conditions favorable to pumping under current river conditions. However, it should be noted that future morphological changes in the system could result in problems at the proposed location similar to those currently affecting facility operation. The scope of this project did not allow for evaluation of this potential condition during testing.

In conclusion, the 9-Dike Configuration is recommended as a solution meeting the outlined objectives. Additionally, testing of Option 3 suggests further investigation of alternate pump-intake locations is warranted. Results from the physical modeling indicate that the dredge-channel configurations only provide a short-term solution rapidly filling with sediment thus requiring continuous maintenance. Extended baseline testing of existing conditions resulted in sediment deposition near the pump intake, indicating a potential for the gravel bar to migrate downstream from its current location.

### **2.3.5. Engineering Analyses and Development of Preliminary Alternative Designs and Costs (Dennis Dorratcague, MWH Global)**

MWH Americas conducted an engineering analysis of the spur dike/groin alternative as well as two potential pump relocation alternatives, 2,200 and 3,500 feet, downstream of the current pump intakes. Consideration of an approximately 600 feet downstream relocation that would have allowed the existing pump station to be used was eliminated by the Expert Panel because of the high risk (4 to 10 years of project life) associated with downstream migration of the gravel bar. Preliminary cost opinions for construction and operation for both spur dike/groin and pump relocation alternatives were developed.

#### **1. Spur Dikes/Groins**

##### **Design and Construction Considerations**

The 9 dikes are spaced approximately 250 to 350 feet apart. They are approximately 150 to 250 feet long, including the dike root (30 feet) and nose. The tops of the dikes are 5 feet wide and flat along the center line of the dikes. The upstream and downstream sides of the dikes slope down to the existing bed at a 1V:2H slope. The elevation of the top of the dikes at the bank are set at the 35,000-cfs water-surface elevation, which occurs annually. At this height water will overtop the full length of the dikes approximately 7 percent of the time. The dikes slope downward longitudinally into the river at a 5-percent grade. The height at the nose of the dikes is approximately 10 feet above the bed. To

size the rocks for the dikes, a design flood of 100-year recurrence interval was used. Based on the results of the 2-D numerical and physical modeling, a velocity of 11 ft/s with a corresponding depth of 19 feet over the top of the dike was selected for rock sizing. Based on the application of various methods for sizing rock and historic performance of the different methods, a gradation of  $D_{15} = 2.0$  feet,  $D_{50} = 2.6$  feet, and  $D_{85} = 3.0$  feet was selected for design. A filter layer with a gradation of  $D_{15} = 0.3$  feet,  $D_{50} = 0.6$  feet, and  $D_{85} = 0.9$  feet was calculated based on the design rock size and riverbed gradation using a method recommended by the Corps of Engineers (ASCE, 2007). A rock thickness of 2 times the  $D_{50}$  was selected. Therefore, the thickness of the rock layer is 5.2 feet. To prevent erosion under the dike and failure, a filter layer is to be located between the riverbed and dike. The filter layer will be greater than 12-inch thick as recommended by the Corps (ASCE, 2007). The dike has a filter rock fill core, which has the same size characteristics as the filter material.

Construction will require an excavator(s) capable of lifting a one-ton rock or greater and placing it at least 15 feet away. Construction of the dikes will likely occur during the winter low-flow season. The following is a possible approach to construction. The dike root will be excavated first. Next, the filter rock and fill core will be placed from the root outward. The tracked excavator will place the rock on the filter to a level above the water surface. The excavator will then operate from the top of the partially constructed dike to build the dike out into the river and up to an elevation, which is wide enough to support the excavator. The excavator will place the launchable toe from the end of the dike. Then the excavator will build the dike up to its design height from the end back to the root.

### **Probable Construction Costs**

The opinion of probable construction cost is \$6.6 million. The estimated cost is considered to be a Class 4 cost opinion as defined by the Association for the Advancement of Cost Engineering. Class 4 cost opinions are for projects in which design is generally developed to between 10 and 40 percent of completion. They are typically used for project screening, determination of feasibility, concept evaluation and preliminary budget approval. The expected accuracy of a Class 4 cost opinion ranges from -15 to -30 percent on the low side and +20 to +50 percent on the high side. In this estimate, the primary costs are for rock and excavation. A lump sum allowance has been included for off-site mitigation. We have assumed that about half the rock volume of the spur dikes/groins would have to be removed from another section of the river, and this removal would cost the same as dike installation on a per-ton basis.

### **Operation and Maintenance Costs**

Maintenance costs will include rock replacement and repair for the dikes, which is estimated to occur on an infrequent basis, generally after large storm events. Maintenance will include adjusting and replacing washed-out rock and reshaping of the dikes such that river training effects are maintained. The annual operations and maintenance for the project is estimated as 1.5 percent of the overall cost, or approximately \$100,000 per year.

2. Intake and Pump Station Relocation (3,600 feet)



Selection of the relocation site was based on results of the 50-year meander modeling (Larsen, 2008) and an evaluation of the potential rate of downstream migration of the gravel bar (26 to 60 years).

### **Design and Construction Considerations**

The intake structure for the existing pump station is located in a natural deep pool where Big Chico Creek confluences with the Sacramento River and uses cylindrical tee fish screens. At the new location, based on 2005 bathymetry, the river is not deep enough for the use of cylindrical tee screens. As a result, an intake structure with vertical flat plate screens is required at this location. The Sacramento River bends to the west at the proposed intake structure location, and a small pool exists with a minimum depth of approximately 10 feet.

The intake structure will have a footprint that is 76 feet long and 27 feet wide and will have six vertical flat-plate screens, each 10 feet long by 8 feet high, along the front face that will provide fish screening that meets fish agency screening criteria. The screens will have a maximum approach velocity of 0.31 fps. The top of the screens will be at elevation 111.0 feet, or approximately 0.5 feet below the estimated minimum water-surface elevation in the Sacramento River. The screens will be kept clean by a water jet system that will also act to re-suspend sediment at the intake structure. It is assumed that the natural sweeping velocity of the river combined with the minimal approach velocity will be able to keep the screens clear of large debris.

A 72-inch diameter reinforced concrete cylinder pipe (RCCP) approximately 345 feet in length will connect the intake structure and the new pump station on the land side of the levee. The pipe will have an invert elevation of 102.0 feet and run beneath the levee to the pump station. It is allowable to bury the pipe through the levee because this is not a state project levee. A gate structure with a 72- by 72-inch sluice gate will be constructed on the river side of the levee to provide the ability to shut off and dewater the pipeline and pump station. At the maximum flow rate, the pipe will carry 150 cfs to the pump station with a velocity of approximately 5.3 fps. The pipeline will be installed by an open cut through the levee, which will involve excavation of approximately 29,000 cubic yards of earth.

The intake and pump station are designed to withdraw water from the Sacramento River and deliver it to the headworks of the Phelan Canal. The station will have three pumps, each designed with a maximum capacity of approximately 50 cfs. Water-surface elevations in the Sacramento river can vary by up to 21.5 feet. The minimum estimated water-surface elevation is 111.5 feet and the maximum design water elevation is 133.0 feet at the 100-year event. Water discharged from the pumps will be conveyed through approximately 3,500 feet of 72-inch diameter concrete pipe to the connection with the existing pipe north of the existing pump station. From the connection to the canal the flow will be conveyed in the existing 72-inch diameter pipe. In total, there is 8,300 feet of pipe from the river to the canal. Water reaching the outlet structure flows over a weir with a crest elevation of 134.5 feet and into a free surface chamber, from which water is drawn through two 42-inch pipes into the canal. At minimum water elevation and maximum flow, the pumps will be required to produce 38 feet of head to deliver water to the canal outlet structure. At a high water level, the pumps will operate at 16.5 feet of head. The head loss in this system is too great to route the flow from the new intake to the existing pump station. Each pump will require a 300-hp electric motor and will draw approximately

350 kW at the maximum flow and head combination. This system will require about 22 percent more energy to pump the same amount of flow than in the existing pump station.

The transmission pipeline from the new pump station will run along the east edge of the existing farm road at the base of the levee for about 1,800 feet to where it passes over the new City of Chico outfall pipe. Then, it will continue along the edge of the farm road until reaching the existing pump station. It will tee into the existing discharge line just north of the present pump station. The pipe will be 72-inch diameter reinforced concrete cylinder pipe and will be buried at least 3 feet beneath the surface. The slope of the pipe will be essentially horizontal for the first 2,100 feet until passing the Chico outfall pipe, then slope downward at a grade of 0.2 percent for the last 1,500 feet, to connect with the existing transmission line at an invert elevation of approximately 116.0 feet. It is estimated that 3,600 lineal feet of pipe will be required. The City of Chico Outfall pipe is anticipated to have a top elevation of 118.0 feet, which will give approximately 1 foot of clearance between the top of the outfall pipe and the invert of the new transmission pipeline. Special fill will be required around the two pipes at this location. Total earth excavation for the transmission pipe is estimated to be 35,000 cubic yards. A clearing width of approximately 100 feet wide will be necessary along the 3,600 feet pipe for construction and future maintenance access. At the point of intersection between the new and existing transmission pipelines, a segment of the old pipeline will be removed and a tee connection will be installed. To block off flow back to the existing pump station, two blind flanges will be installed, one on the end of the existing pipeline and the other at the end of the tee facing the old pump station. By using blind flanges, this will allow the pipeline to be connected and re-activated more easily if future conditions require switching operation back to the existing pump station.

An existing rock revetment is located along the east river bank just south of the proposed City of Chico outfall location. In order to prevent erosion of the bank upstream of the new intake location, this existing rock revetment will be removed, realigned, and extended. The new revetment will cover the sloping face of the bank and run approximately 1,600 feet along the river to the new intake location. No calculations were made to size the rock. Sizes were assumed based on observations of the revetment on the levee at the existing pump station. The revetment will be approximately 40 feet wide, with a 15-foot toe in the channel bottom. The rock will be 24 inches thick with a  $D_{50} = 1.0$  feet. Additional rock will be placed on the downstream side of the intake structure to prevent scouring and undermining of the structure. In total, approximately 14,400 tons of the rock will be placed.

A cofferdam, probably consisting of sheet piles, will be constructed in the river around the intake and back into the bank to provide dewatering for the intake and pipeline back into the levee. The intake and pipeline will be constructed in the dry behind the cofferdam.

In-water work will be necessary for construction of the revetment. An excavator(s) will lift the rock and place it at least 30 feet away such that the excavator will not have to enter the water. Installation of the rock revetment will likely occur during the low-flow season.

### **Probable Construction Costs**

The Class 4 opinion of construction costs is \$13.2 million. In this estimate, the primary costs are for the pipe and excavation. An allowance for off-site mitigation equal to the cost of placement of the revetment has been included. Operations and maintenance of

the structure should be similar to the costs incurred at the existing structure, but with an approximately 22-percent increase in power costs due to additional pumping head.

### **Operation and Maintenance Costs**

Annual operations and maintenance (O&M) costs for the pump station will include electricity for pumping, lights and other appurtenances, general maintenance and repair and labor. Moving the pump station 3,600 feet downstream is estimated to increase the energy requirements by 22 percent. In addition to these annual costs, we have assumed that the pumps will be replaced every 15 years at a present-value cost of \$130,000, and pump motors will be replaced every 25 years at a cost of \$70,000. Assuming other electrical costs and general maintenance and repairs are similar to the existing pump station, annual O&M costs for the new pump station are estimated to be about \$332,000 per year in 2008 dollars, or \$8.20 per acre-ft.

### 3. Intake and Pump Station Relocation (2,200 feet)

Selection of this site was based on the proposed location of the City of Chico's new wastewater outfall (1,500 feet downstream of existing pump intakes), the minimum distance required for wastewater mixing and dilution that would permit use of the water on the ranches and refuges, the desire to remain within the existing east bank rock revetment and the need to remain a reasonable distance upstream of the downstream end of the revetment that is currently unraveling. Depending on the assumed rate of downstream bar migration (60 to 140 ft/yr) the site would be viable for between 16 and 36 years. Extension of the project life and reduction of the risk might be achievable by the addition of driven sheetpile Iowa vanes (Nakato and Ogden, 1998) at the upstream end of the intakes. Additional physical and numerical modeling will be required to assess the utility of the vanes.

### **Design and Construction Considerations**

The intake structure for the existing pump station is located in a natural deep pool where Big Chico Creek conflues with the Sacramento River and uses cylindrical tee fish screens. At the new location, the river is not deep enough for the use of cylindrical tee screens. As a result, an intake structure with vertical flat plate screens is required at this location. An existing rock revetment would surround the proposed intake location and project slightly into the Sacramento River at this location. The intake was placed in the revetment area and about 200 feet upstream from the southern end of the revetment at a small pool area near the bank. This area provides a minimum depth of approximately 10 feet.

The intake structure will have a footprint that is 76 feet long and 27 feet wide and will have six vertical flat-plate screens, each 10 feet long by 8 feet high, along the front face that will provide fish screening that meets fish agency screening criteria. See Figure 4-2. The screens will have a maximum approach velocity of 0.31 fps. The top of the screens will be at elevation 111.0 feet, or approximately 0.5 feet below the estimated minimum water surface elevation in the Sacramento River. The screens will be kept clean by a water jet system that will also act to re-suspend sediment at the intake structure. It is assumed that the natural sweeping velocity of the river combined with the minimal approach velocity will be able to keep the screens clear of large debris.

A 72-inch diameter reinforced concrete cylinder pipe (RCCP) approximately 255 feet in length will connect the intake structure and the new pump station on the land side of the levee. The pipe will have an invert elevation of 102.0 feet and run beneath the levee to the pump station. At this location, it is allowable to bury the pipe through the levee because it is not a state project levee. A gate structure with a 72- by 72-inch sluice gate will be constructed on the river side of the levee to provide the ability to shut off and dewater the pipeline and pump station. At the maximum flow rate, the pipe will carry 150 cfs to the pump station with a velocity of approximately 5.3 fps. The pipeline will be installed by an open cut through the levee, which will involve excavation of approximately 36,000 cubic yards of earth.

The intake and pump station are designed to withdraw water from the Sacramento River and deliver it to the headworks of the Phelan Canal. The station will have 3 pumps, each designed with a maximum capacity of approximately 50 cfs. Water surface elevations in the Sacramento river can vary by up to 21.5 feet. The minimum estimated water surface elevation is 112.0 feet and the maximum design water elevation is 133.5 feet at the 100-year event. Water discharged from the pumps will be conveyed through approximately 2,200 feet of 72-inch diameter concrete pipe to the connection with the existing pipe north of the existing pump station. From the connection to the canal the flow will be conveyed in the existing 72-inch diameter pipe. In total, there is 6,900 feet of pipe from the river to the canal. Water reaching the outlet structure flows over a weir with a crest elevation of 134.5 feet and into a free surface chamber, from which water is drawn through two 42-inch pipes into the canal. At minimum water elevation and maximum pumped flow, the pumps will be required to produce about 36 feet of head to deliver water to the canal outlet structure. At a high water level, the pumps will operate at 14.7 feet of head. The head loss in this system is too great to route the flow from the new intake to the existing pump station.

The pump station layout will be similar to that of the existing structure. The 72-inch pipe from the intake structure will expand into a 120-inch pipe. The 30 feet of 120-inch pipe will enter a manifold structure at an invert elevation at approximately 98.75 feet. The manifold structure will consist of four branches to the three pumps and a spare pump bay. An above-ground building will house the pump motors and electrical equipment. Four pump barrels constructed of 54-inch RCP will rise to an above-ground elevation of 131.0 feet. The existing grade at the pump station is about 128.0 feet. Each pump will require a 300 hp electric motor and will draw approximately 300 kW at the maximum flow and head combination. This system will require about 12 percent more energy to pump the same amount of flow than in the existing pump station.

The transmission pipeline from the new pump station will run along the east edge of the existing farm road at the base of the levee for about 360 feet to where it passes over the new City of Chico outfall pipe. Then, it will continue along the edge of the farm road until reaching the existing pump station. It will tee into the existing discharge line just north of the present pump station. The pipe will be 72-inch diameter reinforced concrete cylinder pipe and will be buried at least 3 feet beneath the surface. The slope of the pipe will be essentially horizontal for the first 700 feet, then slope downward at a grade of 0.2 percent for the last 1,500 feet, to connect with the existing transmission line at an invert elevation of approximately 116.0 feet. It is estimated that 2,200 lineal feet of pipe will be required. The City of Chico Outfall pipe is anticipated to have a top elevation of 118.0 feet, which will give approximately 1 foot of clearance between the top of the outfall pipe and the invert of the new transmission pipeline. Special fill will be required around the two pipes at this location. Total earth excavation for the transmission pipe is estimated to be 27,000

cubic yards. A clearing width of approximately 100 feet wide will be necessary along the 2,200 feet pipe for construction and future maintenance access. At the point of intersection between the new and existing transmission pipelines, a segment of the old pipeline will be removed and a tee connection will be installed. To block off flow back to the existing pump station, two blind flanges will be installed, one on the end of the existing pipeline and the other at the end of the tee facing the old pump station. By using blind flanges, this will allow the pipeline to be connected and re-activated more easily if future conditions require switching operation back to the existing pump station.

An existing rock revetment is located along the east river bank. The new intake structure will be located in this revetment, approximately 200 feet upstream of the downstream end. The rock will need to be removed in order to excavate and construct the intake structure and connection pipeline. Some of the rock may be replaced to reinforce the upstream and downstream toes of the structure to prevent scouring and undermining. In total, approximately 475 cubic yards of the rock will be removed and relocated. After removing the rock revetment at the intake area, a cofferdam, probably consisting of sheet piles, will be constructed in the river around the intake and back into the bank to provide dewatering for the intake and pipeline back into the levee. The intake and pipeline will be constructed in the dry behind the cofferdam. In-water work will be necessary for replacement of the revetment. An excavator(s) will lift the rock and place it at least 30 feet away such that the excavator will not have to enter the water. Installation of the rock revetment will likely occur during the low-flow season.

#### **Probable Construction Costs**

The Class 4 opinion of construction costs is \$9.5 million. In this estimate, the primary costs are for the pipe and excavation. An allowance for off-site mitigation equal to the cost of placement of the revetment has been included. Operations and maintenance of the structure should be similar to the costs incurred at the existing structure, but with an approximately 12-percent increase in power costs due to additional pumping head.

#### **Operation and Maintenance Costs**

Annual operations and maintenance (O&M) costs for the pump station will include electricity for pumping, lights and other appurtenances, general maintenance and repair and labor. Moving the pump station 2,200 feet downstream is estimated to increase the energy requirements by 12 percent. In addition to these annual costs, we have assumed that the pumps will be replaced every 15 years at a present-value cost of \$130,000, and pump motors will be replaced every 25 years at a cost of \$70,000. Assuming other electrical costs and general maintenance and repairs are similar to the existing pump station, annual O&M costs for the new pump station are estimated to be about \$316,000 per year in 2008 dollars, or \$7.80 per acre-ft.

### **2.4. City of Chico Wastewater Treatment Plant Relocation Update (Tamara Miller, P.E., City of Chico)**

The City of Chico needs to increase their wastewater discharge capacity from the present 9 to 12 mgd and has to deal with two issues, the downstream migration of the gravel bar and replacement and upgrading of the diffuser. Based on their analysis of the situation they have made a decision to move the wastewater outfall 1,200 feet downstream from its current location that was first utilized in 1961. The current outfall is located 300 feet downstream of the M&T

pumping plant and the new location will be 1,500 feet downstream of the pumping plant. The City, based on advice from its engineering consultants, is concerned that continued gravel bar migration could limit the life of the outfall to 15-20 years. They have concluded that the spur dike/groin alternative for the M&T pumps is the only one that would benefit their project. It is possible and if it fits within their required timeframe, the City would like a conjunctive solution with the M&T pumps project.

The City commenced their project in fiscal year 2003-2004 that included a geomorphic assessment, diffusion analysis and environmental documentation. By 2005, the project was defined and the EIR was completed. In 2006 additional design was conducted for both the water treatment control plant expansion and the diffuser, but at the request of the M&T ranch, the diffuser design process was delayed to see if a compatible solution with the M&T project could be found. In 2007, the wastewater plant design was completed and construction commenced, but the final design for the outfall was delayed pending decisions from the M&T project. In 2008, when it became apparent that the two projects were on very different schedules, the City decided to complete design of the outfall at the new location. Permitting for the outfall is ongoing and construction is scheduled for 2009, but will probably be delayed until 2010. Construction cost is \$4.9 million. The City would like to reserve the ability to return to its original outfall location if the bar moves downstream and conditions are such that there will be sufficient flows to provided for the required level of dilution, but that is unlikely to occur. The City can only afford a short delay in implementing their project because of the requirement to redo their EIR for the State Water Control Board if they are to receive finding from the Board. Ms. Miller reminded the participants that it will take the City about 5 to 6 years to get their project designed, permitted and constructed.

The City has looked at the possibility of tertiary treatment of the effluent, but the costs of upgrading the Treatment Plant (about \$50M) and the lack of a buyer or user for the treated water make this a non-viable alternative. Even at a 12mgd capacity the City would not be able to supply enough water to the M&T and Llano Seco Ranches and Refuges and provide it on the required schedule.

## **2.5. Comments from Mr. Howard Ellman, Esq., Attorney for Llano Seco Ranch**

Mr. Ellman stated that the initial movement of the M&T pumping Plant from Big Chico Creek to the Sacramento River was supposed to provide a guaranteed supply of water in perpetuity, but that the solution failed within 5 years. He pointed out that it probably was unrealistic to expect that a new solution would be implemented within the next 3 years even if an alternative was selected immediately. After 5 years of studies and investigations it should be possible to select a solution while recognizing that no solution is totally risk free. "Paralysis by Analysis" is not an acceptable situation to the stakeholders.

## **2.6. Evaluation of Alternatives by Expert Panel**

After extensive discussion of the alternatives and the results of the Phase II studies by members of the Expert Panel and the Steering Committee, and recognizing that TNC is unlikely to amend the conservation easement on the Shaw property (Letter from TNC to Mr. Les Heringer, September 29, 2008), Mike Harvey provided a summary of alternatives that had been agreed upon by the Expert Panel members. It is fully recognized by the Expert Panel that the alternatives do not meet all the project goals (Figure 3) and that each of the alternatives carries some level of risk that will be borne by the stakeholders. The Alternatives include:

1. No Action alternative
2. 9 dike spur dike/groin alternative
3. 2,200 feet Pumping Plant relocation alternative
4. 3,600 feet Pumping Plant relocation alternative

Taking into account the length of time it is likely to take to get a project selected, funded, permitted and constructed it is highly likely that a further dredging of the gravel bar will be required to maintain the ability to pump in the intervening period. Because of relatively high flows and the need to work within containment berms, the gravel bar in the vicinity of the pump inlets and fish screens was not dredged in the Fall of 2007. Under current conditions, the subaqueous portion of the bar has extended downstream to a point that is opposite the pump inlets and fish screens. The Expert Panel, therefore, included maintenance dredging as a short-term solution.

Each member of the Expert Panel was asked to comment on the alternatives.

### **Mike Harvey**

The No-Action alternative is unacceptable to all stakeholders. The 9 dike spur dike groin alternative as the best technical solution with the lowest level of risk and uncertainty, but recognized that implementation may not be possible if TNC is unwilling to amend the Conservation Easement on the Shaw property. As an alternative solution, the 3,600 feet pump relocation is most likely to provide an assured water supply for the next 30 to 40 years, but will require the addition of 1,600 feet of additional bank protection. The 2,200-foot relocation alternative, while not requiring any additional bank protection, may not provide a long enough project life (16 to 36 years) and, therefore, is a higher risk alternative. Preliminary analyses have been conducted for the pump relocation alternatives and further analysis is required. Dredging as a long-term solution is not a viable alternative.

### **Bob Mussetter**

Bob basically agreed with Mike Harvey's assessment but pointed out that the risk associated with the spur dike/groins option is less than that for the other alternatives. Pump relocation alternatives are promising enough to warrant further investigation. Pump relocation alternatives will require maintaining the existing short-term bank stabilization on the west bank of the river. Removal of this revetment will effectively eliminate the pump relocation alternatives. Dredging has retarded the downstream migration of the bar but it has not prevented it, and therefore, dredging is not a viable long-term solution.

### **Yantao Cui**

All three alternatives are possible solutions. Moving the pumping plant and intakes will have a higher uncertainty, but it is doable. The stakeholders and agencies have to assess the level of risk that they are prepared to accept, the level of investment they are prepared to make and whether from an ecological viewpoint you are prepared to trade this reach of the river which has relatively a low ecological value in terms of river meandering with a reach elsewhere that has a higher value.

### **Eric Larsen**

Eric has uncertainties about the spur dike/groin alternative and doesn't agree that his meander modeling showed that this alternative will have minimal impacts on larger scale geomorphology and environmental impacts. Although the 3,600 feet pump relocation alternative will require the addition of 1,600 feet of bank protection that may not be a significant problem because geologic controls in that portion of the floodplain are likely to limit meander migration. Concerned that other potential locations for pump relocations may have been dismissed with too little information and that previously rejected alternatives may require further investigation. Would like to revisit extension of the existing pump inlets and dredging as possible alternatives. Believes that some of his concerns can be revisited in the EIR/EIS process.

## **2.7. Findings and Recommendations**

During the course of the Workshop a considerable amount of discussion addressed the question of risk and uncertainty associated with the various alternatives and the level of analysis that was applied to each of the considered alternatives during the 5-year investigation. A large number of alternatives were identified in Workshop #1 and these were evaluated after further information was acquired at Workshop #2. A number of potential alternatives were eliminated on technical grounds by the Expert Panel. More promising alternatives were carried forward for evaluation in Workshops #3 and #4 following additional studies. In the main, cost information was only developed for alternatives that were carried forward by the Expert Panel to Workshops 3 and 4. Some alternatives (e.g., 8 spur dike alternative) were eliminated from further assessment for technical reasons, while other alternatives (e.g., Ranney Wells) were eliminated on the basis of capital costs and O&M costs even though they were technically feasible and met all of the project objectives. Non-goal alternatives that did not meet all the project goals, but were technically feasible, and also met capital and O&M cost criteria, were eventually selected as alternatives. These included, spur dikes/groins and two pump station relocation alternatives.

The majority of the Expert Panel members (Harvey, Mussetter, Cui) have concluded on the basis of the extensive analyses that have been conducted that the lowest risk and uncertainty is associated with the 9 dike spur dike/groins alternative. Higher levels of uncertainty and risk are associated with the two pump relocation alternatives. The sources of the risk and uncertainty are twofold: the lesser degree of analysis and investigation that has been expended on the alternatives due to their recent development, and estimates of the rate of bar migration that could adversely affect the new pump intakes and fish screens. The level of uncertainty regarding the former can be reduced through further studies and investigation. Site-specific empirical data indicate that the rates of bar migration range from 60 to 140 ft/yr, and the range of values is related to the period of estimation of the data and the incidence of geomorphically effective flows within the time frame. The highest estimate of bar migration rate (140 ft/yr) provides the shortest potential period before the relocated pump intake would be adversely affected by sedimentation. Conversely, the lowest estimate of bar migration rate (60 ft/yr) provides the longest potential period before the relocated pump intake would be adversely affected by sedimentation. Based on these estimated bar migration rates, the 3,600 feet relocation of the pump intake and fish screen will have 26 to 60 years before it is adversely affected, and the 2,200 feet relocation will have 16 to 37 years. To have the relocated pumping intake and fish screen possibly affected in 16 years is clearly a high level of risk.

It is possible that addition of Iowa vanes at the 2,200 feet relocation site will be able to extend the unaffected period, thereby reducing the risk of implementing the alternative to an acceptable level. Clearly, the level of risk that is acceptable has to be determined by the stakeholders.

Members of the Steering Committee were asked to identify which alternatives they would be willing to carry forward to the EIS/EIR process.



**Kevin Foerster, USFWS**

1. No-Action alternative that includes the removal of the interim rock toe
2. 9 spur dike/groin alternative, recognizing that TNC approval will be required
3. Two pump-relocation alternatives
4. Long-term dredging alternative with relaxed fish screen criteria with a mechanism for returning the gravel to the river

Previously eliminated alternatives will be re-visited in the EIS/EIR process, and an interim dredging program will be required to maintain the existing pumping ability. An EIS will be required for the project.

**Howard Brown, NOAA Fisheries**

1. No-Action alternative
2. 9 spur dike/groins alternative
3. Two pump-relocation alternatives
4. Long-term dredging alternative with modified fish screen criteria

An interim dredging program will be required while the EIS/EIR process is being developed. NOAA Fisheries is the federal lead agency for threatened and endangered anadromous fish.

**Bruce Ross, CDWR**

1. No-Action alternative
2. 9 spur dike/groins alternative, with some reservations
3. Two pump-relocation alternatives

An interim dredging program will be required while the EIS/EIR process is being developed.

**Carl Wilcox, CDFG**

Move the identified alternatives forward, but must consider the temporary nature of the existing toe structure on the west bank of the river and how it will be incorporated into the alternatives and start working on required permits.

**Tracy McReynolds, CDFG**

Need to deal with the issues of the interim toe protection, maintenance dredging and disposal of gravel stockpile from the two previous dredging. Need to add long-term dredging as an alternative. State will be lead agency on the EIR/EIS process. Joint EIS/EIR with the federal agencies to meet requirements of CEQA and NEPA. Need to get funding to move the EIS/EIR process forward.

**Dave Zezulak, CDFG**

Need to get all the agencies together, USFWS, DFG and NOAA Fisheries to talk about the regulatory issues.

## **2.8. Post-Workshop #5 Conference Call**

On October 16, 2008, members of the Expert Panel discussed the potential for reducing the risk at the pump relocation sites by adding driven sheetpile Iowa Vanes to the design. The 2- to 5-foot high vanes have been used successfully on both sand-bed and gravel-cobble bed rivers to increase local shear stresses on the bed immediately upstream of pump intakes in order to move the bed-load around the inlets. A technical paper (Nakato and Ogden, 1998) was provided to the Panel members that showed the concept as it was applied to intakes on the Missouri River. Panel members concluded that the vanes are unlikely to be effective at the current pump intake location, but have potential to work at the intake relocation sites on the Sacramento River. They concluded that additional investigation and analysis was required. A preliminary estimate to add the vanes to the relocated intakes was \$1M, and it appears that installation at the same time as the intakes and fish screens are built would be the most appropriate timing. To investigate the feasibility of adding the vanes to the pump station relocation designs, it will be necessary to conduct both physical and numerical (2-D) modeling. The physical modeling will also have to address the issue of erosion of the west bank of the river opposite the relocation sites. The existing physical model at Colorado State University will have to be reconfigured to model the proposed pump station and inlet relocation sites. Additional bathymetric data should probably be acquired for the additional numerical and physical modeling to more accurately reflect existing conditions in the reach. Panel members reiterated their concern that the pump station relocation alternatives were only viable if the current alignment of the river was maintained by the interim bank protection project. For a long-term solution, the interim protection is most likely going to need upgrading.

An additional potential alternative was also addressed during the conference call. An octagonal, velocity-cap-type of intake structure that was designed and built to permit sediment-free water to be withdrawn from the Chattahoochee River was discussed. A cylindrical support structure, much like a circular bridge pier, acts as a bed scouring agent and maintains the riverbed at a much lower elevation than the overlying screened intake. The advantage of the mid-channel structure would be that it could be built in the center of the river opposite the existing pump station or at the proposed relocation sites. Disadvantages identified during the conference call included construction cost, navigation issues, and the total inability to meet fish screening criteria. Panel members eliminated this potential alternative from further consideration.

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**Appendix A.1**

**M & T / Llano Seco Fish Screen Facility  
Short-Term/Long-Term Protection Project**

**Workshop #5  
Transcripts of Workshop  
September 30, 2008**

To be provided

## **Appendix A.2**

### **M & T / Llano Seco Fish Screen Facility Short-Term/Long-Term Protection Project**

#### **Workshop #5 Technical Team Recommended Alternatives**

**September 30, 2008**

Llano Seco Ranch Headquarters  
Chico, CA

#### **Attendees:**

- Beverly Anderson-Abbs, Executive Director, Sacramento Conservation Area Forum
- Koll Buer, Consultant to the California Department of Water Resources
- Howard Brown, Fishery Biologist, National Marine Fisheries Service
- Josh Brown, Administrative Associate, Sacramento Conservation Area Forum
- Stacy Cepello, Environmental Scientist, California Dept. of Water Resources
- Amanda Cox, Hydraulic Engineer, Colorado State University
- Yantao Cui, Research Scientist, Hydrology/Geomorphology
- Dennis Dorratcague, Principal Engineer, MWH Global
- Sandy Dunn, Attorney, Somach, Simmons & Dunn
- Howard Elman, Esq., Attorney, representing Dick Thieriot, Llano Seco Rancho
- Woody Elliott, District Resource Ecologist, Calif. Dept. of Parks & Recreation-Northern Buttes District
- Kevin Foerster, Project Leader, Sacramento National Wildlife Refuge Complex
- Jim Gaumer, Engineer, M&T Chico Ranch
- Greg Golet, Project Ecologist, The Nature Conservancy
- Quene Hansen, Engineer, City of Chico
- Michael Harvey, Principal Geomorphologist, Mussetter Engineering, Inc.
- Les Heringer, Manager, M&T Chico Ranch
- Mark Hoover, Deputy Assistant Field Supervisor, Ecosystem Restoration Program, U.S. Fish & Wildlife Service
- Eric Larsen, Research Scientist, Geology, U.C. Davis
- Chris Leininger, Project Development Consultant, Ducks Unlimited, Inc.
- Tracy McReynolds, Assoc. Fishery Biologist, Region 2, Calif. Dept. of Fish & Game
- Tamara Miller, Principal Engineer, MPM/Engineering, for the City of Chico
- Kelley Moroney, Refuge Manager, Sacramento Valley National Wildlife Refuge Complex

- Robert Mussetter, Principal Engineer, Mussetter Engineering, Inc.
- Bruce Ross, Engineering Geologist, California Dept. of Water Resources
- Neil Schild, Principal Engineer, MWH Americas
- David Sieperda, Manager, Rancho Llano Seco
- Richard Thieriot, Shareholder, Rancho Llano Seco
- Chris Thornton, Hydraulic Engineer, Colorado State University
- Paul Ward, Retired, Associate Fishery Biologist, Region 2, Calif. Dept. of Fish and Game
- Greg Werner, Project Ecologist, The Nature Conservancy
- Carl Wilcox, Chief-Water Branch, Bay Delta Conservation Plan, Calif. Dept. of Fish and Game
- Kathy Wood, Assistant Field Supervisor, Ecosystem Restoration Program, U.S. Fish & Wildlife Service
- Dave Zezulak, Environ. Program Mgr. I, Water Branch-Bay Delta Conservation Plan, Calif. Dept. of Fish & Game

**From:** Gregg Werner [mailto:gwerner@TNC.ORG]

**Sent:** Thursday, September 11, 2008 3:34 PM

**To:** Basia Trout;; Dan Gover;; Dan Silva;; Don Anderson;; Frank Piccola;; Gary Evans;; Glen Pearson;; Glen Hawes;; Jan Knight;; Jane Dolan;; Jim McKeivitt;; Keith Hansen;; Knute Myers;; Lady Bug Doherty;; Lynnel Pollock;; Marc Faye;; Ron Warner;; Sandy Morey;; Shirley Lewis:

**Cc:** banderso@water.ca.gov; Kent Smith; Kevin\_Foerster@fws.gov; Les Heringer; Jim Well; Richard Theriot; Dawit Zeleke; Sam Lawson; Greg Golet; Cathy Norlie

**Subject:** Concerns Related to the M&T / Llano Seco Pumping Plant

Good Afternoon,

We wanted let you know in advance about some important issues regarding the M&T / Llano Seco Pumping Plant Project that may arise at your upcoming SRCAF Board meeting.

A CALFED grant has been ongoing for several years, looking for the best way to resolve the Pumping Plant's problem with siltation that threatens the operation of the fish screens. The grant project is coming to an end and the stakeholders will meet to discuss the findings of the analysis on September 30. Prior to that meeting we understand that Les Heringer of M&T Ranch is scheduled to give a presentation on the project at the September 18 SRCAF Board meeting. From our discussions with Les it is also our understanding that the project proponent's (M&T Ranch and Llano Seco Ranch) preferred alternative will be to install nine, large spur dikes across the river to hold the river in place and limit the siltation near the plant intake.

The proposed dikes raise major concerns for The Nature Conservancy and other conservation interests. Also, the installation of the 8th and 9th dikes, which the project engineers have said are critical to this alternative, is precluded by the provisions of a conservation easement that The Nature Conservancy owns on the land across the river from the pumping plant. The easement dates back to 1991 some 6 years before the pumping plant was constructed on the current site. Therefore, this is a situation where the plant owners may be proposing a resolution that directly conflicts with our existing private property rights. We have discussed this problem with the owners of the pumping plant on several occasions and asked that they pursue other alternatives. We have also offered to help find an acceptable method to resolve this dilemma.

There are major issues with the proposed spur dike solution:

First, and most important, the spur dikes would stop the meander of the river for the long term. As detailed in the SRCAF Handbook, river meander is essential for the creation and renewal of the riparian habitat that supports the many special status species in the area. River meander in the area supports wildlife habitat owned by several public agencies as well as our easement property. The project proponents provided us with a brief analysis of the effect of the spur dikes on riparian habitat but the analysis fails to consider the importance of habitat reworking and vegetation succession that is supported by natural river meander. There is a clear scientific consensus as to the need for continued river meander in order to sustain the vegetation communities and animal species along the Sacramento River.

Second, the proposed spur dikes would violate the terms of our easement and the basic conservation purpose of the easement, the long term preservation and health of the riparian habitat. The Nature Conservancy has the ability to amend conservation easements when appropriate but we do not do so when it would violate the basic

purpose of the easement. We believe that this is a question of organizational integrity where our direction is clear.

Finally, we believe that a solution that does not have the severe environmental consequences of the spur dikes must be found. We understand that the moving of the plant has recently been evaluated as an alternative although limited effort has been directed toward that option. We are also aware that other alternatives such as developing a way to extend the pumping plant intake to follow the river were given relatively little consideration in the planning process. We believe that these kind of alternatives need to be given full consideration in view of the infeasibility of the spur dike alternative.

The existence of TNC's conservation easement and its prohibition of bank protection has been common knowledge among project stakeholders since at least 2006. At that time we became aware of a proposal to place interim rock revetment on our conservation easement and we contacted project partners. We have discussed the matter several times with the project proponents and made our position clear. Unfortunately, it appears that the spur dike proposal has been advanced in the hope that TNC will change its standards, agree to amend our easement and permit the spur dikes on the property. Thus, we are near the end of the grant process with a key alternative that is infeasible.

We agree that finding an acceptable way to maintain the pumping plant capacity and the related water rights is important for agriculture, for the managed wetlands at Llano Seco and for a portion of fish flows in Butte Creek. We are committed to finding the best appropriate way to maintain pumping plant capacity for those uses. As reflected in the Basic Principles of the SRCAF Handbook, "Decisions on the location of bank protection should be made on a site-specific basis in cooperation with participating landowners." As a directly affected landowner we are anxious to continue to work with M&T Ranch, Llano Seco Ranch, the US Fish and Wildlife Service and other landowners in the area come to an acceptable solution. However, we must request a solution that protects our preexisting private property rights,

We have not yet had an opportunity to review the latest results of the M&T / Llano Seco Pumping Plant study as they have not yet been released. We are looking forward to the stakeholders meeting on September 30 and subsequent discussions at your Technical Advisory Committee and Board meetings. The Nature Conservancy has a long history of working cooperatively with other landowners along the Sacramento River to address mutual concerns and we will continue to do so in this situation. We want to be a part of the process and we are willing to help identify funding to move toward a solution that is acceptable to all concerned.

If we can provide any further information or any clarification please contact me. We will also be attending the SRCAF Board meeting on September 28 and will be available to speak to this important matter.

**Gregg Werner, Project Director**  
**The Nature Conservancy**  
Northern Central Valley Office - Sacramento River  
500 Main Street  
Chico, CA 95928  
530-897-6370 x216 (Chico office)  
530-244-3162 (home office)  
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September 29, 2008

Les Heringer, Manager  
M&T Ranch  
3964 Chico River Road  
Chico, CA 95928

Subject: M&T Ranch / Llano Seco Ranch Pumping Plant

Dear Les,

The Nature Conservancy wishes to help develop a long term solution for your pumping plant operations. However, as we have indicated, placing the large spur dikes on Shaw Ranch, a property on which the Conservancy holds a conservation easement, is not a suitable way to resolve this particular siltation issue. The spur dikes pose major, long-term negative impacts to the riparian habitat the property as well as the surrounding public and private lands.

The Great Valley mixed-riparian forest habitat along the Sacramento River and on the property is rare and supports more than 250 species, many of which are listed threatened or endangered, including tropical migrant songbirds, raptors and Chinook salmon. The natural meander of the river is critical in maintaining the long-term health this habitat. This fact was acknowledged in the Primary Project Goal of your CALFED grant, which specified the identification of a long-term solution, "to adapt the fish-friendly pumping facility to the lateral migration of the Sacramento River.

Scientific evidence is well established that revetment, like the proposed spur dikes, block river meander and stop the natural renewal of this habitat over time. Therefore, the conservation easement on the property, established in 1991, specifically precludes revetment like the spur dikes.

The question of whether or not The Nature Conservancy would consider an amendment to our conservation easement was addressed by key decision makers and counsel at the regional, state and worldwide offices of the Nature Conservancy. And, as we have indicated to you, we have determined that we must uphold the integrity of our conservation easement and the important habitat it protects. Therefore, we will not amend our conservation easement to permit the spur dikes.

The Nature Conservancy is absolutely willing and anxious to work with the two ranches, the US Fish and Wildlife Service and other stakeholders to find a mutually acceptable solution to

this complex dilemma. We are also willing to help find funding sources if such are needed to permit further evaluation of alternatives for making the pumping plant usable into the future.

Accordingly, we urge you to continue to pursue options to maintain pumping operations that do not involve stopping the river's natural process.

We would be happy to meet following the September 30<sup>th</sup>, SRCAF Board meeting to explore ways to resolve this challenging situation.

Sincerely,

A handwritten signature in black ink, appearing to read "Dawit Zeleke".

Dawit Zeleke

Cc: Mike Sweeney,  
Gregg Werner,  
SRCAF Board Members,  
Chico City Manager David Burkland

## Appendix A.3

### **Modeling revetment removal and implications for meander migration of selected bends River Miles 222 to 179 of the Sacramento River, January 10, 2008 (Larsen)**

To be provided

## Appendix A.4

**Channel migration 2007-2057 Final Technical Memorandum – Simulated channel migration (2007-2057) near River Miles 197 to 191 of the Sacramento River, September 25, 2008  
(Larsen)**

To be provided

## **Appendix A.5**

**Phase II Two-dimensional modeling to evaluate the potential river training works  
at M&T pumping plant Sacramento River, RM 192.5, California, October 2, 2008  
(Mussetter Engineering, Inc.)**

To be provided

## **Appendix A.6**

### **M&T pump station intake Physical Model report, August 2008 (Colorado State University)**

To be provided

**Appendix A.7**

**Draft Engineering Analysis, Technical Memorandum, M&T Ranch/Llano Seco  
Intake project, Final Alternatives, September 2008 (MWH)**

To be provided