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File 50514

16 April 2009

Matt Gause
Senior Ecologist
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Sacramento, CA 95834

RE: Sedimentation Screening Analysis for Cosumnes Floodplain Mitigation Bank

Dear Mr. Gause:

As requested, Northwest Hydraulic Consultants (**nhc**) has completed a reconnaissance-level sedimentation screening analysis of the Cosumnes Floodplain Mitigation Bank site using available hydrologic and sediment data from the California Data Exchange Center (CDEC) and US Geological Service (USGS). The analysis presented here considered sedimentation rates at the levee breach inlet as well as in the mitigation site assuming typical monthly and annual hydrologic conditions on the Cosumnes and Mokelumne Rivers. For all the locations and sediment transport scenarios considered, calculated deposition rates were low or near zero; which are considered insignificant. This technical letter describes the methods used for quantifying deposition rates at each location and discusses the implications of the results.

Background and Existing Data

The study site lies in the North Sacramento-San Joaquin Delta in an unincorporated section Sacramento County. Westervelt Ecological Services (Westervelt) has proposed to develop the 493-acre property for wetland and riparian mitigation banking by breaching the existing northern levee along the Cosumnes River. The site is bordered by the Mokelumne River to the West and Grizzly Slough to the East and New Hope Road and agricultural fields to the South. A project location map is shown in Figure 1.

The Cosumnes River is largely unregulated and produces flow hydrographs similar to pre-settlement conditions (Booth et al. 2006). The Cosumnes River passes through the Granlee Dam downstream of Michigan Bar, which acts as a bed load trap. However, studies have shown that the suspended sediment load of the river is about the same downstream of the dam as at Michigan Bar (nhc, 2003). The Mokelumne River is a controlled river regulated by flow releases from Camanche Dam. The Camanche Dam is responsible for the far lower suspended sediment concentrations observed on the Mokelumne in comparison to Cosumnes River sediment levels.

In order to better understand the long-term response of the site to the proposed levee breach, a sedimentation analysis was performed to quantify local deposition and erosion rates. The hydrologic and sedimentation characteristics of the site were analyzed from existing data for the area. Hydrologic and sediment data for the reach were acquired from three gages:

CDEC's Benson Ferry Gage on the Mokelumne River and the USGS's McConnell (ID #11336000) and Michigan Bar (ID # 11335000) gages on the Cosumnes River. The data collection sites' locations relative to the project site are given in Figure 2.

The Benson Ferry CDEC gage provided hourly water surface elevation data from 1984 to the present. The gage is located immediately downstream from the Cosumnes River Mitigation Bank site at the confluence with the Mokelumne River and was used to define tidal stages in the Cosumnes River at the breach location. Two USGS stream gages upstream of the project site on the Cosumnes River were used to establish discharge and suspended sediment concentrations. The Michigan Bar gage has daily discharge data from 1907 to the present as well as selected sediment data from 1965-1971. McConnell Gage has daily discharge data from 1941-1982 and selected suspended sediment data from 1965-1967.

Methods

Hydrology and Tidal Hydraulics

Approximate mean high and low tide levels were computed from the two most recent water years on record in the CDEC data. The 2007 and 2008 water years rank as the 21st and 13th driest years, respectively, based on daily mean discharge data in the Michigan Bar gage's 101 year history. Mean Tide Level was calculated to be 2.0 ft at the Benson's Ferry gage, and Mean Higher High Water and Mean Lower Low Water were calculated to be 3.5ft and 0.6ft, respectively.

Tidal prism volumes at the mitigation site were calculated on an hourly basis using the proposed project grading plan provided by Westervelt. The significant project site features are shown in Figure 1. Discharge fluxes and velocities at the breach opening were calculated assuming a 30-foot wide breach base width with side slopes cut at a 3:1 slope. Tidal prism volumes in the proposed mitigation area were computed at ¼ foot increments. For the purposes of this analysis, it was assumed that full tidal exchange occurred through the levee breach, such that tide elevations in the site were equal to those in the Cosumnes River. For the two years of data used in this study, peak velocities through the breach were estimated to be about 3.0 feet per second with typical velocity magnitudes between 0.0 and 1.5 feet per second from tidal effects.

Sedimentation

Suspended sediment concentrations from the Cosumnes River as reported at the McConnell and Michigan Bar gages were plotted against river discharge, as shown in Figure 3. The data sets had similar scatter with some differences at the low flow condition. A linear relationship based on the McConnell record was ultimately used for this study because of the proximity of the gage to the mitigation site. As presented in the figure, a best fit line was relating concentration to discharge was defined as:

$$C\ (\text{mg/l}) = 0.11\ Q\ (\text{cfs})$$

Where the concentration, C, is in milligrams per liter and the river discharge, Q, is in cubic feet per second.

Previous studies of sediment transport in the Delta have estimated the average annual suspended load transport of the Cosumnes River to be 124,000 tons, of which 38% were silts and clays (less then 0.062mm) and 62% were sand (between 0.062 and 1mm) (**nhc**, 2003).

Most of the suspended sediment transport (59%) occurs during floods in excess of 10,000 cfs, which occur on average only 1 day per year (**nhc**, 2003). Suspended sediment gradation data were available from the USGS at the McConnell and Michigan Bar sites for the selected suspended sediment concentration data. This data failed to show a significant trend in gradation of sands to silts and clays related to discharge. Because this analysis considers generally low flow conditions in which sand transport is minor, it was assumed that 100% of the suspended sediment load consisted of fine material such as silts and clays. As such, it can be assumed that suspended sediment concentration does not vary dramatically with depth. This is a conservative assumption in the analysis since the proposed breach elevation is about 8 feet above the invert of the Cosumnes River bed and suspended sediment concentrations are typically lower at points above the channel bed.

Sediment aggradation rates in the proposed mitigation bank were computed by applying the law of conservation of mass and developing a simple mass balance model. Some significant assumptions used to develop the model include:

1. The fall velocity of particles was not influenced by fluid motion.
2. Sediment deposition away from breach was permanent and erosion of deposited sediments does not occur.
3. Shear stress at the breach can cause erosion of previously deposited sediments if the shear stress is higher than a critical level.
4. All of the suspended sediment in the water entering the site could be deposited given sufficient residence time.

These assumptions are commonly used in tidal deposition models as developed by Odell et al. (2008), Temmerman (2004) and Krone (1987). Sedimentation rates were calculated using a simplified form of the conservation of mass equation:

$$\Delta z = \frac{\int_t V_s C dt}{\rho_d}$$

where:

Δz = Change in Bed Elevation
V_s = Settling Velocity
C = Suspended Sediment Concentration
ρ_d = dry density of sediment
t =

Settling velocities for silts and clays depend on floc properties including size, density, and shape. Krone (1962) demonstrated that floc deposition in tidal environments could be related to concentration for C > 300 mg/l. Lower than this, he suggested using a fall velocity of 0.0022 meters per second. Stoke's law (ASCE, 2008) can also be used to estimate settling velocities of suspended sediment in low concentrations. Table 1 summaries the settling velocities calculated by these techniques. Based on the values in the table, the deposition model for the mitigation site considered settling velocities between 0.0022 m/s (0.007 ft/s) and $8E^{-5}$ m/s ($2.63E^{-4}$ ft/s). The concentrations calculated for the vicinity of the breach were under 300mg/l therefore the Krone (1962) free settling velocity of 0.0022 m/s was used.

Table 1. Summarizes the free settling velocities examined for suspended sediment in the mitigation bank.

Settling Velocity Method	ω_s (m/s)
Krone (1962)	0.0022
ASCE (2008) Stoke's Law (d=0.065mm)	0.0030
ASCE (2008) Stoke's Law (d=0.03mm)	7.2E-04
ASCE (2008) Stoke's Law (d=0.01mm)	8.0E-05

A dry density value of 1.3 g/cm^3 was used as a reasonable estimate for tidal deposits based on soil sampling in performed by Krone (1998) the San Francisco Bay region.

Modeled Scenarios

Two hydrologic conditions were considered to evaluate accretion rates at the proposed site. The first was looking at the 2007 and 2008 water years with the missing data filled in by interpolation. The second scenario was done to isolate the tidal effects. For this scenario a sampling of the last 1/5 of the 2008 water year was used to get a representative sample when discharges in the river are low.

Results

Hydrology
The approximate mean higher high water (MHHW) and mean lower low water (MLLW) tides calculated from the Benson Ferry data for 2007 and 2008 were 3.5ft and 0.6ft NGVD29 respectively. The daily maximum and minimum tidal data are shown in Figure 4. These data were compared to preliminary results from PWA (2004) for Grizzly Slough which had approximate mean higher high water of 3.6ft and mean lower low water of 1.7 ft NGVD29. The PWA levels were based on water year 1979 and the report noted that levels could vary substantially from tidal statistics of other years. The tidal data at Benson Ferry did not go back to 1979 so a direct comparison to the closest NOAA gage (New Hope Gage) could not be directly performed. Based on the proposed mitigation design, about 6.5% (31.5 acres) of the mitigation bank area would likely be inundated during Mean Higher High Water calculated in this study.

Sedimentation
Sedimentation rates in the mitigation Bank away from the breach are summarized by elevation in Table 2. The deposition rates do not include the effects of resuspension due to shear and turbulence. As indicated by the values in Table 2, deposition in the mitigation site is calculated to be a maximum of a small fraction of an inch per year to zero, based on very conservative assumptions that maximize computed sediment deposition. Based on a topographic survey of the mitigation Bank, almost the entire area is at an elevation greater than 3 feet NGVD29. Therefore, no significant sediment deposition is expected at the site under typical tidal and annual flooding conditions.

Table 2. Estimated average annual deposition rates at the mitigation site by elevation.

Site Elevation (ft NGVD29)	Average Annual Deposition Rate (in/yr)
0	0.22
1	0.10
2	0.007
3	0.000
>=4	0.000

Elevations below 3 feet NGVD 29 in the Mitigation Bank represent proposed excavated channel cuts at the site to convey tidal flows farther into the interior of the site. As shown for an elevation of 0 feet, deposition rates (without considering erosion) would accrete approximately 1 foot in elevation over a 50 year time period. In reality, erosion of sediment during peak tidal fluxes through the breach inlet would counteract this deposition over time. To evaluate the effect of erosion relative to deposition, a second model was developed to compute shear stress at the breach opening based on flow velocities. From shear stress, erosion rates were determined using the relationship:

$$E = M\frac{(\tau - \tau_{cr})}{\tau_{cr}}$$

where E = erosion rate
M = empirical coefficient
τ_{cr} = the critical shear stress for erosion to occur
τ = the observed shear at the site

Values for M and τ_{cr} vary based on soil type. For the San Francisco Bay and Delta region, typical values suggested by Odell et al. (2008) are: M=0.015 g/m^2/sec and τ_{cr} =0.015 lbs/ft^2. Using these values, the annual deposition rate at an elevation of 0 feet near the breach reduces from 0.22 inches per year to 0.09 inches per year.

Conclusions

The results of the suspended sediment deposition model for typical annual tidal cycles show very low deposition rates with a maximum rate of 0.22 inches per year over a limited portion of the Mitigation Bank based on very conservative assumptions. When expected erosion rates are included to account for normal tidal flow induced shear stress, the computed net deposition is reduced to 0.09 inches per year, indicating little or no net deposition in the excavated tidal channels in the Mitigation Bank.

Velocities up to 3 ft/s at the breach opening are expected for typical daily tidal conditions. These velocities are within the permissible velocity category for the native cover of short grasses or loam (Fischenich, 2001). The velocities for flood events would be greater than normal tidal velocities and may require bank protection if erosion at the breach is a design concern. The current design template of 1:1 slopes on the excavated interior channels will be prone to minor sloughing and erosion since this is higher than the lower bound recommended slope for excavated channels (TAC, 2004). Limited erosion from natural flooding events could be expected within the excavated channels may be an asset providing geometric diversity at the breach and in the interior branching channel network.

If you have any questions regarding the analysis or have a need for additional information, please call.

Sincerely,

NORTHWEST HYDRAULIC CONSULTANTS INC.

Brad Hall

Brad Hall

Principal

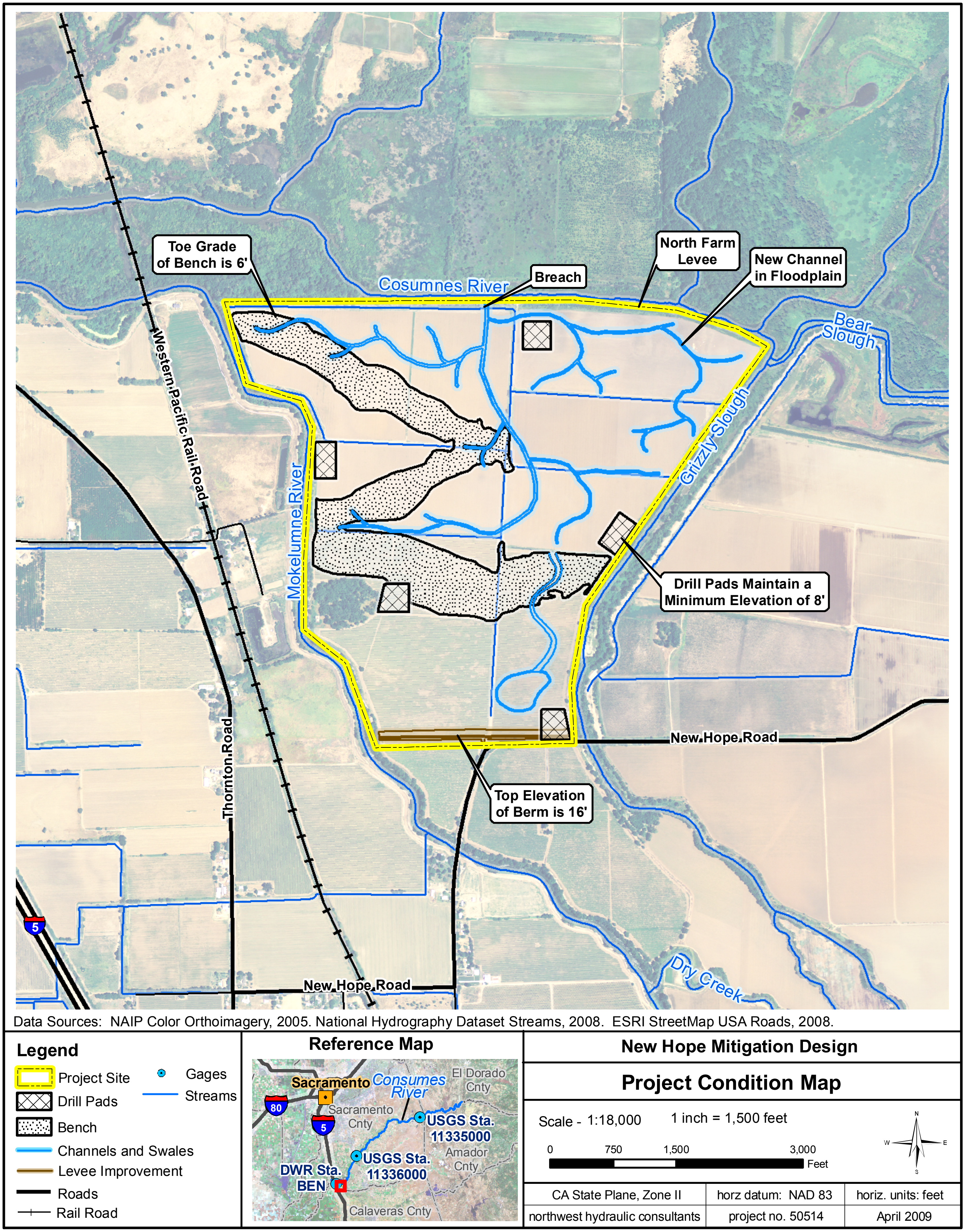
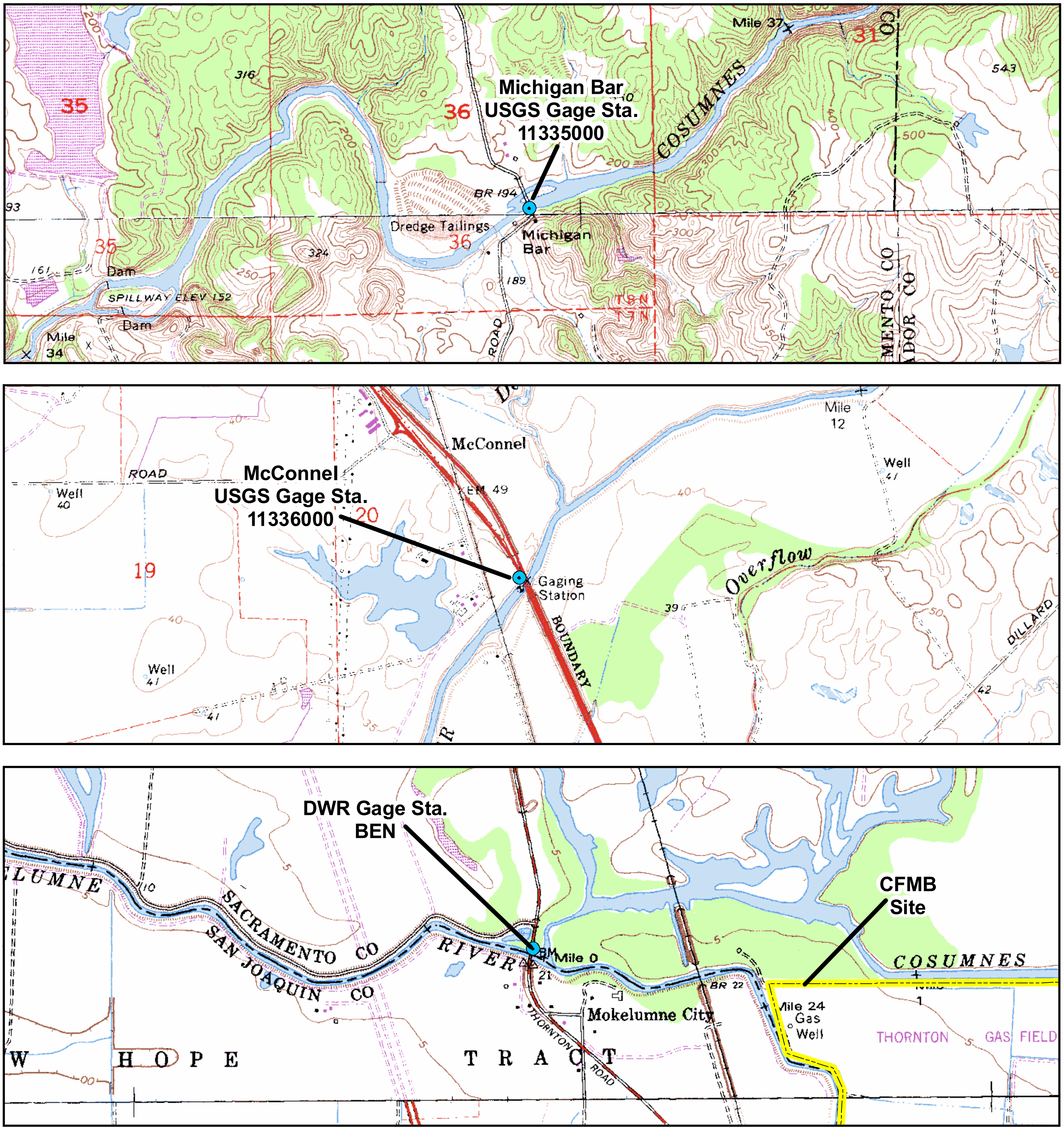


Figure 1: Site/Project Condition Map



Data Sources: USGS 24K Topographic Maps.

Legend

Project Site

Gages

Reference Map

New Hope Mitigation Design

Gage Location Map

Scale - 1:24,000   1 inch = 2,000 feet

0   1,000   2,000   4,000 Feet

CA State Plane, Zone II	horz datum: NAD 83	horiz. units: feet
northwest hydraulic consultants	project no. 50514	April 2009

Figure 2: Gage Location Map

Figure 3: Scatter Plot of Discharge vs. Suspended Sediment Concentration at the McConnell and Michigan Bar gages.

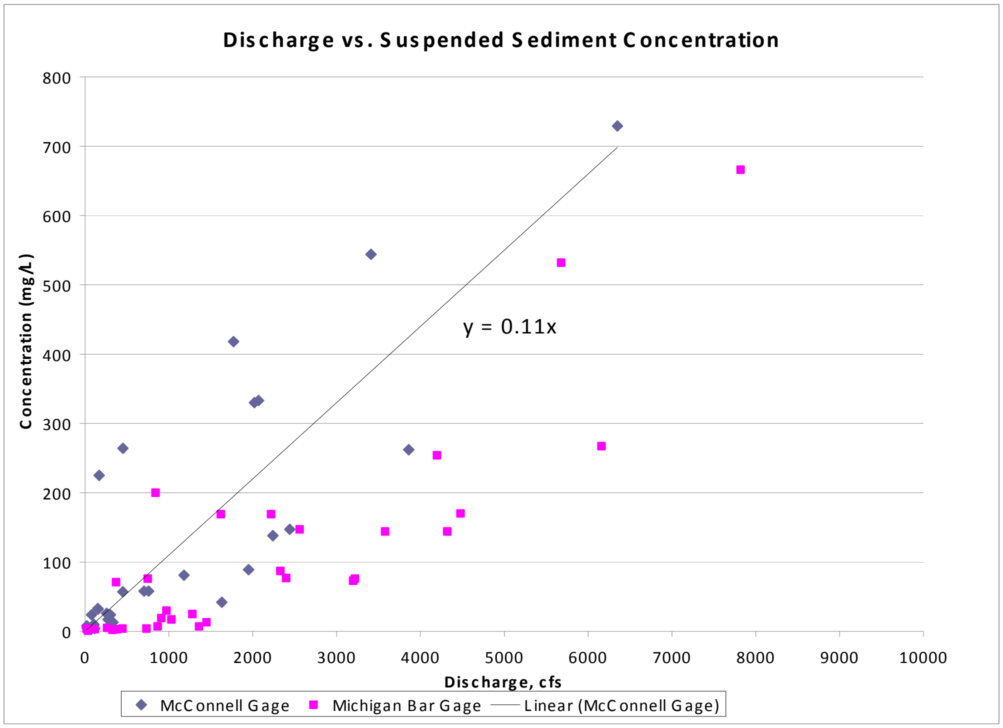
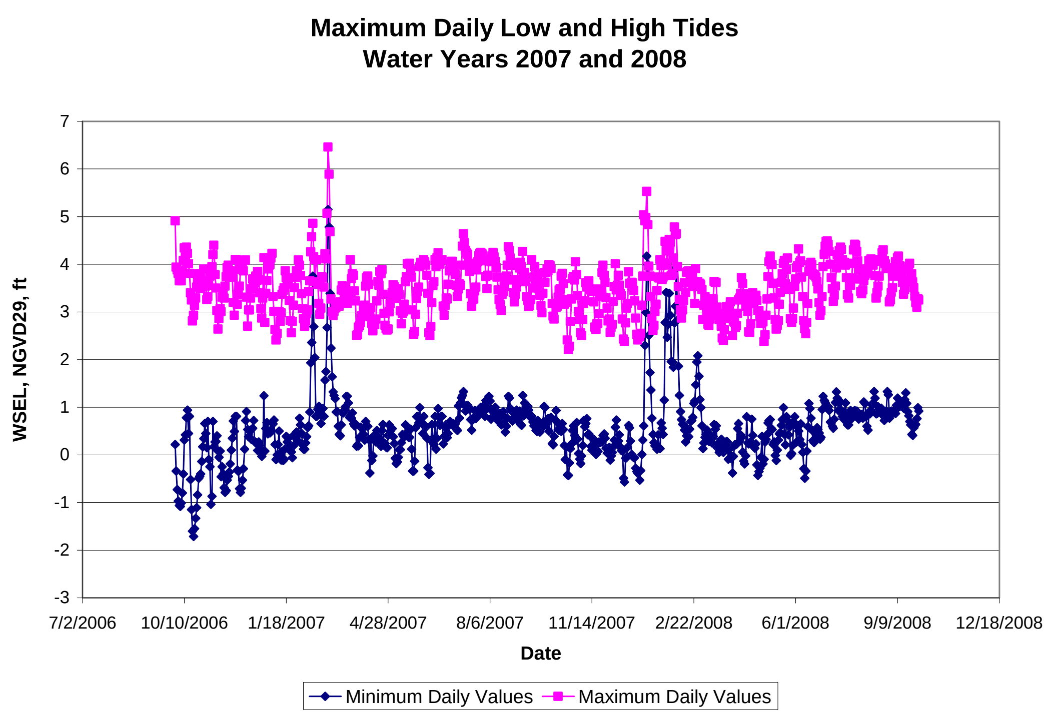


Figure 4: Scatter Plot of Maximum and Minimum Daily Tides used to find MHHW and MLLW for Benson Gage.



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