Improving riparian wetland conditions through evaluation of infiltration and drainage behavior during and after a controlled flood event

T. A. Russo1; A. T. Fisher1; J. W. Roche2
1 Earth and Planetary Sciences Department, University of California, Santa Cruz, CA. 2 Yosemite National Park, CA

Abstract

We have conducted an observational and modeling study of a riparian wetland system adjacent to the Tuolumne River, downstream of the Hetch Hetchy Reservoir in Yosemite National Park (YNP). The study area is located along the bottom of Poopenaut Valley, a 25 hectare region comprising a diverse mixture of soil, vegetation, and wetland types (Figure 1). Instruments were deployed within wetlands, and along and adjacent to a 300-m stretch of the Tuolumne River in Poopenaut Valley, to assess soil, ground water, and wetland response to a controlled flood in Spring 2009. Instruments included stream stage recorders, piezometers, water content sensors, and vertical probe arrays to assess stranded seepage. The controlled flood lasted for 60 days, and increased channel discharge from about 30 cms to a peak near 225 cms. Water content sensors show the influence of soil inundation and penetration of a wetting front within the upper 1 m of soil. Piezometers show a water table response to ground water recharge. We have completed numerical models of unsaturated-saturated conditions to assess controls on infiltration and ground water response to controlled flooding in a transect perpendicular to the river channel (Figure 1). One metric for wetland functionality is maintenance of saturated conditions to a depth of 30 cm for 14 consecutive days once each year. Our model will be used to assess how controlled flooding can be managed (drainage hydrograph, integrated volume of release) to satisfy this requirement.

Figure 1. Poopenaut Valley is a 25 hectare region surrounding the Tuolumne River three kilometers downstream of the Hetch Hetchy Reservoir. The focus of this study is in the two upland wetlands on Transect 2, defined by Wells 3 (closest to the river), 2, and 1 (farthest from the river).

Field methods

We used three primary methods for collecting information on the passage of the flood wave through the shallow wetlands. Pressure gauges were used to monitor stream stage and water table height in shallow piezometers along profiles oriented perpendicular and parallel to the river channel. Water content sensors were collocated with two of the shallow piezometers. Water temperature loggers were installed in vertical thermal probe arrays used to assess streamed seepage. Soil samples were collected after the flood adjacent to Wells 1, 2, and 3 down to 180 cm below ground surface (bgs). Infiltration tests were performed at the same locations using a double ring infiltrometer.

Figure 4. 4. Grain size distribution indicates a mode at medium silt (60 µm) and a maximum size of fine sand (180 µm). The curves from (Figure 4A) generally show a unimodal particle size distribution, whereas discrete samples (Figure 4B) tended to be bimodal. The observed change in particle size distribution with depth is consistent with soil moisture data, which suggest a slower rate of drainage at depth. Saturated hydraulic conductivity was estimated from grain size data using the Hazen method (Hazen, 1911), suggesting values of 10⁻⁸ to 10⁻⁷ m/s. Infiltration testing during flood experiments was initially 10⁻⁹ m/s, but decreased to 10⁻⁸ m/s after several minutes of infiltration. These values of conductivity are consistent with the calculated conductivities using the Hazen method and the modeling results.

Discussion and Conclusions

The hydrograph produced by the 2009 controlled flood was highly dynamic but saturation was maintained at 40 cm depth for 14 consecutive days in Well 2. Soil moisture content measured at 40, 70 and 100 cm-bgs near Well 2. River discharge corresponding to Well 2 ground elevation is shown with a gray line on the hydrograph. The hydrograph of the controlled flood was highly dynamic, but saturation near Well 2 was maintained at 40 cm depth for 14 consecutive days, longer than the cumulative period of inundation at this location.

Citations

We constructed a hydrologic model of soil water response using V3DDH (Figure 6), which simulates flow in a variably saturated, two-dimensional system. We modeled one profile in the lower meadows oriented perpendicular to the river channel, along Transect 2. The modeling geometry assumed symmetry across the river. The model included three distinct soil layers. Using V3DDH, we tested two sets of relations between pressure, water content, and hydraulic conductivity for unsaturated meadow soils, and found that parameters needed to fit field data during the controlled drainage were generally higher than the pre-flood condition but were consistent with pre-flood values during the dry period. This suggests that modeled soil hydraulic conductivities increase with depth, but are all within the range of 10⁻⁸ to 10⁻⁷ m/s.

Figure 6. The model represents 400 m long by 240 m deep transect perpendicular to the river channel. The hydraulic conductivity and Brooks-Corey parameters used in the model are shown in the table above. Figure 7. Soil moisture content at three periods during the flood: pre-flood (WD 201), 14 days into the flood (WD 225), and 40 days after the flood (WD 265) with river inundation at Wells 1 and 2. Figure 8. Moisture content shown at the end of the flood. Observed moisture content values were used to calibrate the model. Observed values are shown as solid traces, modeled values are shown as -X-s. We conducted a hydrologic model of wetland conditions through evaluation of infiltration and drainage behavior during and after a controlled flood event

Hydrograph and soil moisture content

Water content sensors show the influence of soil inundation and penetration of a wetting front within the upper 1 m of soil. Piezometers show a water table response to ground water recharge. We have completed numerical models of unsaturated-saturated conditions to assess controls on infiltration and ground water response to controlled flooding in a transect perpendicular to the river channel (Figure 1). One metric for wetland functionality is maintenance of saturated conditions to a depth of 30 cm for 14 consecutive days once each year. Our model will be used to assess how controlled flooding can be managed (drainage hydrograph, integrated volume of release) to satisfy this requirement.

Figure 2. River hydrograph during the 2009 controlled flood release in Poopenaut Valley.

Figure 3. Soil moisture content measured at 40, 70 and 100 cm-bgs near Well 2. River discharge corresponding to Well 2 ground elevation is shown with a gray line on the hydrograph. The hydrograph of the controlled flood was highly dynamic, but saturation near Well 2 was maintained at 40 cm depth for 14 consecutive days, longer than the cumulative period of inundation at this location.

Figure 4. 4. Grain size distribution indicates a mode at medium silt (60 µm) and a maximum size of fine sand (180 µm). The curves from (Figure 4A) generally show a unimodal particle size distribution, whereas discrete samples (Figure 4B) tended to be bimodal. The observed change in particle size distribution with depth is consistent with soil moisture data, which suggest a slower rate of drainage at depth. Saturated hydraulic conductivity was estimated from grain size data using the Hazen method (Hazen, 1911), suggesting values of 10⁻⁸ to 10⁻⁷ m/s. Infiltration testing during flood experiments was initially 10⁻⁹ m/s, but decreased to 10⁻⁸ m/s after several minutes of infiltration. These values of conductivity are consistent with the calculated conductivities using the Hazen method and the modeling results.

Figure 5. Infiltration test.

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Figure 7. Soil moisture content at three periods during the flood: pre-flood (WD 201), 14 days into the flood (WD 225), and 40 days after the flood (WD 265) with river inundation at Wells 1 and 2. The model results suggest that controlled floods could be optimized for wetland benefit, and could help to maintain wetland conditions in Poopenaut Valley even during years that are drier than 2009.