US Army Corps of Engineers
Hydrologic Engineering Center

Truckee River at McCarran Ranch Ecosystem Functions Model Application

October 2005

PR-61

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
October 2005	Project Report	

4. TITLE AND SUBTITLE
Truckee River at McCarran Ranch Ecosystem Functions Model Application

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5F. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER
PR-61

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Environmental Laboratory
US Army Engineer Research and Development Center
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

10. SPONSOR/ MONITOR'S ACRONYM(S)
ERDC

11. SPONSOR/ MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
.

14. ABSTRACT

This report describes the analysis, input data, and results of the Hydrologic Engineering Center's Ecosystem Functions Model (HEC-EFM) application on the Truckee River at McCarran Ranch. The Nature Conservancy is overseeing a pilot restoration project at McCarran Ranch, where local, regional, and national agencies are trying to restore the channel to a more natural condition and improve conditions for natural habitat. The objective of this HEC-EFM application was to predict how ecosystem habitat would change (increase or decrease) with the proposed channel modifications to the McCarran Ranch study area.

15. SUBJECT TERMS
Ecosystem Functions Model, HEC-EFM, HEC-RAS, HEC-GeoRAS, McCarran Ranch, flood control, river restoration, Truckee River, hydraulic metrics, modeling tools, ecological relationships, habitat change, The Nature Conservancy, UFDP, arid, semi-arid

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
U	U	U	UU	26	19b. TELEPHONE NUMBER

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October 2005

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Engineering Research and Development Center
Environmental Lab

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PR-61

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Preface

This report describes the analysis, input data, and results of the USACE Hydrologic Engineering Center's Ecosystem Functions Model (HEC-EFM) application on the Truckee River at McCarran Ranch, Nevada. This HEC-EFM application was performed in cooperation with the Desert Research Institute (DRI), a nonprofit research campus of the Nevada System of Higher Education. Project funding was provided by the Environmental Lab at the US Army Engineer Development and Research Center (ERDC).

Jason Needham (HEC) collected and prepared data for HEC-EFM execution, completed the model runs, post-processed the output, analyzed the results, and authored this report. John Hickey (HEC) assisted with data collection and provided technical guidance on application of the HEC-EFM program and processing of HEC-EFM results. He also authored portions of this report. Cameron Ackerman (HEC) provided technical assistance on the application of HEC-RAS and HEC-GeoRAS for this analysis. Stanford Gibson (HEC) assisted with HEC-RAS model validation and application. He also provided technical guidance on sediment issues encountered during this analysis.

Scott Bassett (DRI) was project manager for the DRI portion of this project. Jim Brock (DRI) and Don Sada (DRI) provided data on cottonwood and mayfly habitat for the development of the HEC-EFM relationships used in this study. Jamie Trammell (DRI) collected and delivered data, organized meetings, and took the lead role in the transfer of the HEC-EFM and HEC-RAS models of McCarran Ranch from HEC to DRI for further application.

Chris Dunn, Chief of HEC's Water Resource Systems Division, was project manager. He provided general guidance on project direction, and provided in-depth review and suggestions throughout the study. Darryl Davis was Director of HEC during this project.

Introduction

The Ecosystems Function Model (HEC-EFM) for McCarran Ranch was developed by the U. S. Army Corps of Engineers Hydrologic Engineering Center (HEC) in collaboration with the Desert Research Institute (DRI). Together, HEC and DRI are applying and evaluating innovative approaches to assess the impact of flood control and river restoration activities on the Truckee River. This report describes the HEC-EFM analysis, input data, and results of the HEC-EFM application on the Truckee River at McCarran Ranch.

A key component of the overall effort is to learn whether it is possible to use results from the intensively studied McCarran Ranch reach to later make decisions for the entire river. The goal is to use hydraulic metrics and innovative USACE and DRI developed modeling tools to study ecological relationships and habitat change caused by restoration and flood control activities.

The application of HEC-EFM for the Truckee River restoration project was funded through multiple sources. The first was the Urban and Channel Restoration Demonstration Program for Arid and Semi-Arid Regions or Urban Flood Restoration Program (UFDP) for short. UFDP is a regional program that is tailored for arid and semi-arid regions. This research and development program is a congressional add-on that has several purposes. Primarily, it encourages collaboration between the U.S. Army Corps of Engineers and the Desert Research Institute (DRI). In this case, collaboration was initiated through application of HEC-EFM. HEC engineers worked with DRI engineers and biologists to apply HEC-EFM to the Truckee River.

The Corps' System-wide Modeling Assessment and Restoration Technologies R&D program (SMART) also contributed to this EFM application. One of the purposes of the SMART program was to demonstrate new or emerging ecological or restoration technology in the field. In 2005, the SMART program was discontinued and its research units, including this HEC-EFM demonstration, were included in a new program, termed System-wide Water Resources Research Program (SWWRP). With SWWRP funding in fiscal year 2005, the demonstration was completed and this final report was prepared.

Overview

Study Area

As illustrated in Figure 1, McCarran Ranch is located approximately 15 miles east of Reno, Nevada on the Truckee River. The 305 acre property runs along both sides of the Truckee River for five miles. The headwaters of the Truckee River are in the Sierra Nevada Mountains and encompass the Lake Tahoe region in northeastern California and western Nevada. Originating at Lake Tahoe, the Truckee River flows about 140 miles eastward through the cities of Reno and Sparks, Nevada. It continues into the high desert of the Great Basin, where it terminates at Pyramid Lake.

In 1962, as part of a flood control project, the channel at McCarran Ranch was straightened to allow flow to pass through the area and limit flood damage. Because of this straightening, the channel has entrenched downward by roughly three feet. This cutting has caused the groundwater to drop beyond the reach of river-side vegetation. The entrenched channel also caused a disconnect between the stream and the natural floodplain, which means the overbank areas along the McCarran Ranch do not receive flood waters as frequently as they had in the past. These factors contributed to a severe degradation of riparian vegetation and natural ecosystem habitat.

The goal of the McCarran Ranch Pilot Restoration Project, overseen by The Nature Conservancy, is to reconnect the Truckee River to its floodplain, increase the frequency of flooding in the overbank areas, and replenish the vegetation in the area. Restoration plans will reduce the width of the channel from approximately 200 feet to 120 feet, reintroduce meanders in the channel, and raise the bed of the channel by constructing a grade control structure at the downstream end of the study area.

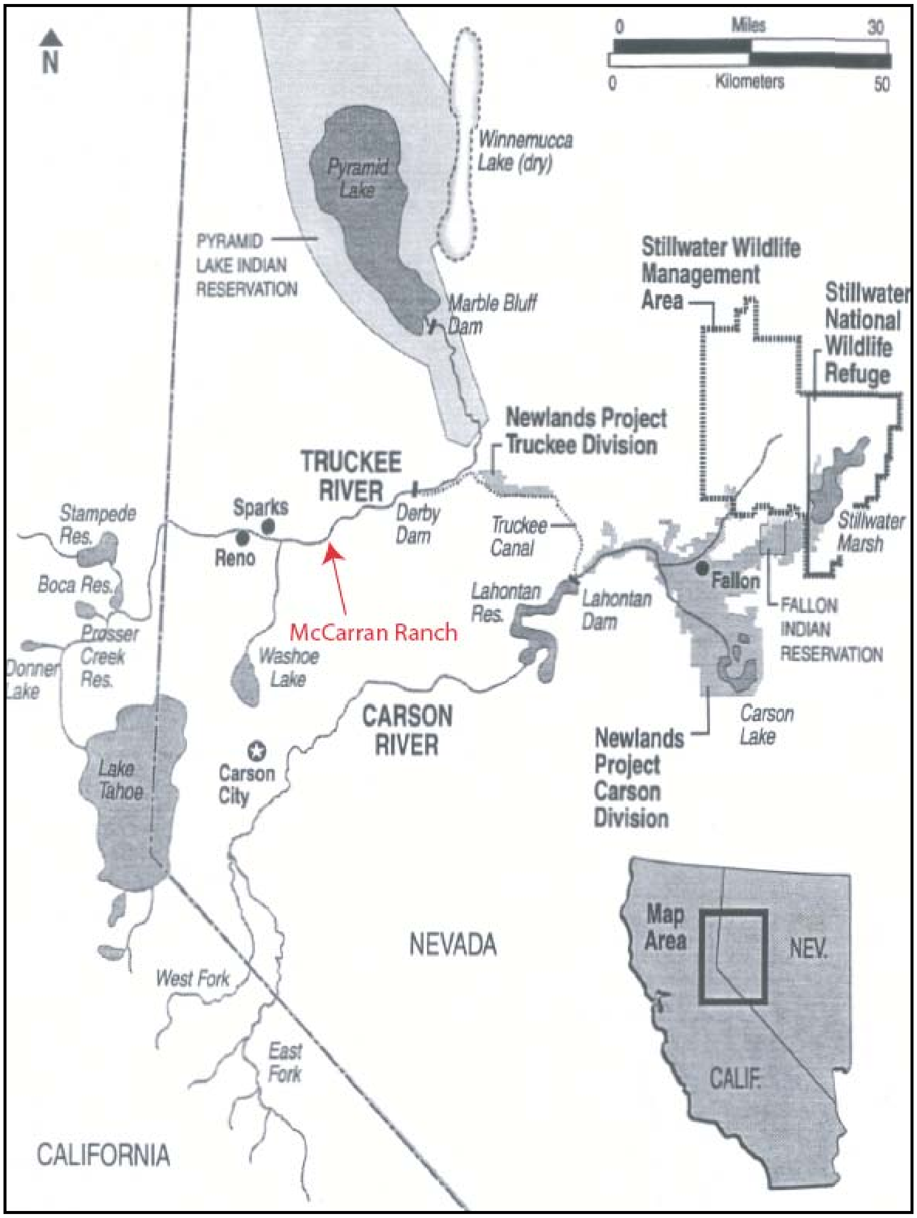

Figure 1. Study area location.

Analysis Approach

This analysis consisted of the following components:

1. Applied HEC-EFM to identify flows and stages that meet various biological and hydraulic relationships for the existing channel conditions and proposed channel modifications at McCarran Ranch. To do so, it was necessary to gather and develop supporting data necessary for running HEC-EFM, which includes flow and stage time series for the area and eco-hydro relationships.

2. Ran a steady-state HEC-RAS (River Analysis System) model and then HEC-GeoRAS to produce inundation maps of those flows identified by HEC-EFM.
3. Processed inundation maps in GIS software to illustrate and quantify the effects of channel restoration on various ecosystem habitats.

What is HEC-EFM?

The Ecosystem Functions Model (HEC, 2003) is a planning tool that aids in analyzing ecosystem response to changes in flow regime. The Hydrologic Engineering Center is developing HEC-EFM and envisions environmental planners, biologists, and engineers using the model to help determine whether proposed alternatives (e.g., reservoir operations or levee alignments) would maintain, enhance, or diminish ecosystem health. Project teams can use HEC-EFM to visualize existing ecologic conditions, highlight promising restoration sites, and assess and rank alternatives according to the relative enhancement (or decline) of ecosystem aspects.

An HEC-EFM analysis typically involves: 1) statistical analyses of relationships between hydrology, hydraulics, and ecology, 2) hydraulic modeling, and 3) GIS programs to display results and other relevant spatial data. HEC-EFM is a computer program that consists of a user interface and an ArcGIS extension. Hydraulic modeling for the HEC-EFM application process is performed by existing independent software such as HEC-RAS (HEC, 2002a).

Data requirements of HEC-EFM are related to the level of detail desired by the modeler. If only statistical results are desired, then required data consist only of flow and stage time series and eco-hydro relationships. If the user intends to visualize statistical results spatially (GIS), data (and software) requirements increase significantly and include flow and stage time series, eco-hydro relationships, digital topography, a geo-referenced hydraulic model, and any other spatial data relevant to the ecosystem investigations.

A fundamental use of HEC-EFM is to execute statistical analyses of flow and stage time series in accordance with criteria specified by the user. Central to HEC-EFM analyses are "functional relationships." These relationships link characteristics of hydrologic and hydraulic time series (flow and stage) to elements of the ecosystem through combinations of four basic criteria – 1) season, 2) flow frequency, 3) duration, and 4) rate of change – that determine the statistical analysis to be performed for each relationship. These relationships are developed jointly by biologists and engineers for a specific application. No limit exists to the number or genre of relationships that may be developed and the HEC-EFM user interface facilitates entry and inventory of criteria. During formulation of relationships, it is important for study teams to hypothesize about the effects that changes in flow would have on the ecosystem elements being characterized through each relationship.

After relationships are developed, the computational engine analyzes flow and stage time series for the specified criteria and produces a single flow and stage value for each relationship. This process is repeated to assess each alternative flow regime, and the resulting values for with- and without-project conditions are compared to indicate the direction of change of ecosystem health for each relationship (in accordance with the hypotheses discussed above).

Steady-state hydraulic modeling (flow held constant through a section of river) allows the statistical results (single flow values for each relationship) to be translated into water surface profiles. HEC-RAS was the hydraulic model used for this analysis and is discussed later in this report. If using a geo-referenced hydraulics model, the water surface profiles produced by HEC-RAS can then be translated into GIS layers representing inundated area, flood depths, and velocities using HEC-GeoRAS (HEC, 2002b), a pre- and postprocessor for HEC-RAS.

GIS allows HEC-EFM users to display generated layers (water depths, velocities, and inundated area) as well as other relevant spatial data (e.g., soils, vegetation, and land-use maps). The ability to assess results spatially is a strength of HEC-EFM. GIS (and hydraulic modeling) improves HEC-EFM applications by: 1) helping project teams to visualize existing ecologic conditions and highlight promising restoration sites, 2) computing depth and velocity data that can be used as criteria to further define relationships, and 3) making it possible to assess multiple alternatives incrementally - through GIS, inundated areas for individual relationships can be compared and ranked as a measure of the relative enhancement (or decline) of that ecosystem element for any number of alternatives.

All steps in this process (entering criteria, executing statistical computations, and viewing results) are performed by the user via the program interface.

Data Sources and Development

Flow and Stage Data

A time series of flow is required by HEC-EFM. If the relationships entered by the user also include criteria for change in stage, a matching stage time series must also be supplied. For this study, historical flow data were obtained from USACE Sacramento District for gages on the Truckee River near McCarran Ranch. Flow data from 1972 through 2002 at the Truckee River below Tracy gage was selected as the most relevant data for this analysis for the following reasons:

1. The Tracy gage is located downstream of McCarran Ranch and the nearest upstream gage (Vista) did not include significant local inflows that would be present at McCarran Ranch. No significant local inflows arrive between McCarran Ranch and the Tracy gage.

2. Flow data prior to 1972 existed for many of the gages on the Truckee River. However, in 1972, Martis Creek Dam was completed upstream of McCarran Ranch. Martis Creek Dam was the last significant control structure added to the Truckee River system upstream of McCarran Ranch, so all flows after 1972 happened under consistent structural storage capacities on the river. Using flows prior to 1972 could introduce discrepancies that would affect the statistical output results of HEC-EFM.

To run HEC-EFM for this analysis, flow and stage time-series were required for both the existing and restored condition of the channel. The stage and flow time-series for the existing condition are illustrated in Figure 2. Historical flow values would not change with the new channel geometry being proposed for the restored condition, but the associated stages would. To develop the stage time-series for both the existing and restored conditions, HEC-RAS was used to compute a new rating curve for a representative cross-section of the channel. DSS-Math (HEC Data Storage System math package) was then used to compute stage time-series based on the rating curves from HEC-RAS.

A representative cross-section was selected to reflect how stage changes with a change in flow throughout the study area. If the slopes of the channel vary greatly within the study area, a representative cross-section would be difficult to identify, and it may be necessary to break the study area into separate reaches and compute different stage time-series for each reach.

Cross-sections 239904.1 and 243440 were chosen for this analysis from the HEC-RAS model for the existing and restored channel geometries, respectively. After the analysis, a sensitivity analysis was performed to measure how HEC-EFM results would change depending on the cross-section that was chosen to represent the study area. The sensitivity analysis showed that the cross-section chosen in this case had minimal impact on the results.

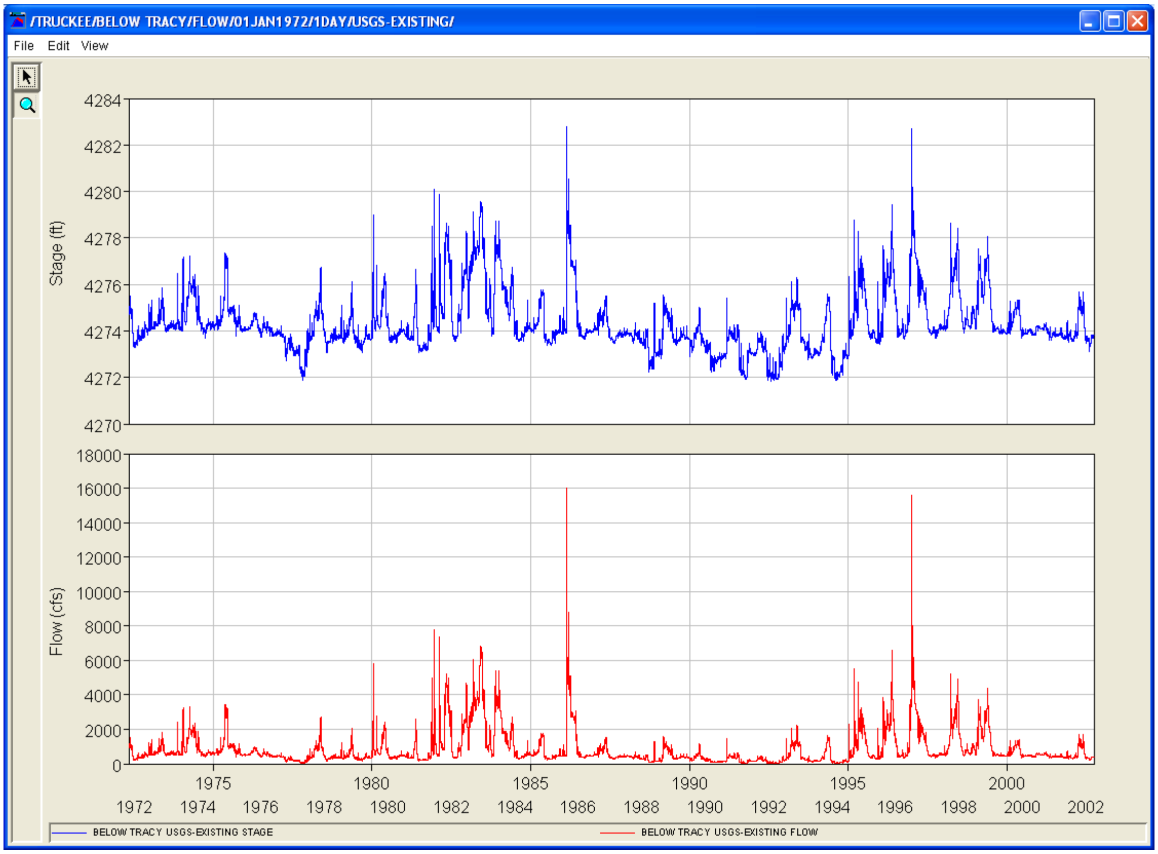

Figure 2. Stage and flow time-series for the existing condition – Truckee River below Tracy.

HEC-EFM Relationships

Two relationships were selected to demonstrate how the channel restoration would affect ecosystem habitat in the McCarran Ranch study area: cottonwood and mayfly (Baetis). Cottonwoods were chosen because of their importance, visibility, and popularity in the area. Mayfly were chosen to represent how macroinverts habitat could be studied using HEC-EFM. Another factor that went into choosing these relationships was the fact that both had enough supporting data to develop a reasonably defensible eco-hydro relationship.

Cottonwood Habitat

In this analysis, cottonwood habitat was identified for both the existing and restored channel conditions by determining the areas suitable for cottonwood seedling establishment and then removing from that area the inundated area that would not allow established cottonwood seedlings to survive. GIS maps for both conditions were created showing the cottonwood establishment areas and the inundated areas. The actual cottonwood habitat was quantified by intersecting the map of establishment with inundation and computing the habitat area.

A relationship for cottonwood establishment was derived using information provided by DRI scientists (Rood et al., 2003). The HEC-EFM screen showing the cottonwood establishment relationship is shown in Figure 3. It contains the following parameters:

- Season – Mid June through the end of July. This is the time of year when cottonwoods along the Truckee River release their seeds.
- Rate of change – Stage decline must be less than 1 inch/day. This rate of stage decline will allow seeds and new roots access to water. If the stage declines faster than 1 inch/day, the root growth will not be able to keep up with the stage recession and they will die before becoming established.
- Return period – 10 years. Studies of established cottonwoods along the Truckee River show that, on average, the major recruitments have happened about every 10 years.

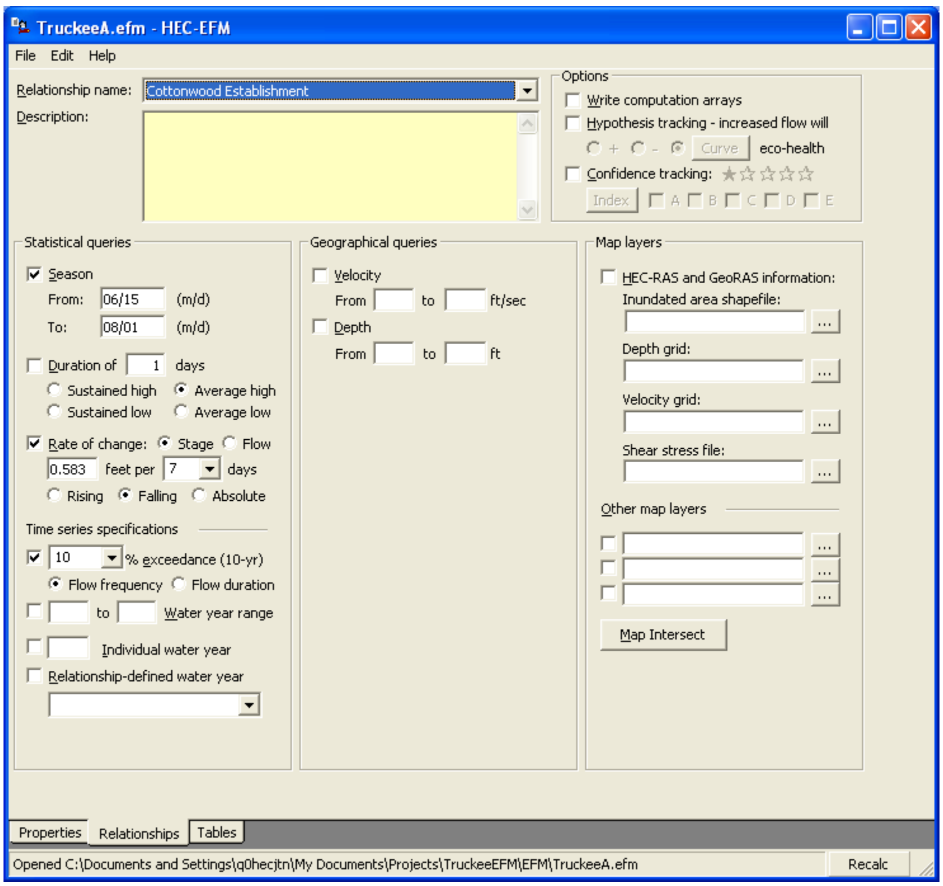

Figure 3. Cottonwood establishment relationship in HEC-EFM.

Cottonwoods cannot establish in standing water. The above relationship for cottonwood establishment identifies areas that are regularly and permanently under water as areas supporting cottonwood establishment. In order to remove areas not suitable as cottonwood habitat, a relationship was derived that would identify inundated area. This relationship was based on season, duration, and return period:

- Season – Beginning of August through mid September. This represents the time period immediately following the establishment season, where cottonwood seeds would most likely drown if they were inundated for an extended length of time.
- Duration – 21 days. The estimated length of time that a seed or sapling could be inundated before it died.
- Return period – 2 year. This would identify the median annual flow during the inundation season, which is a simple estimation of what would likely follow any given establishment season.

The inundation relationship is illustrated in Figure 4.

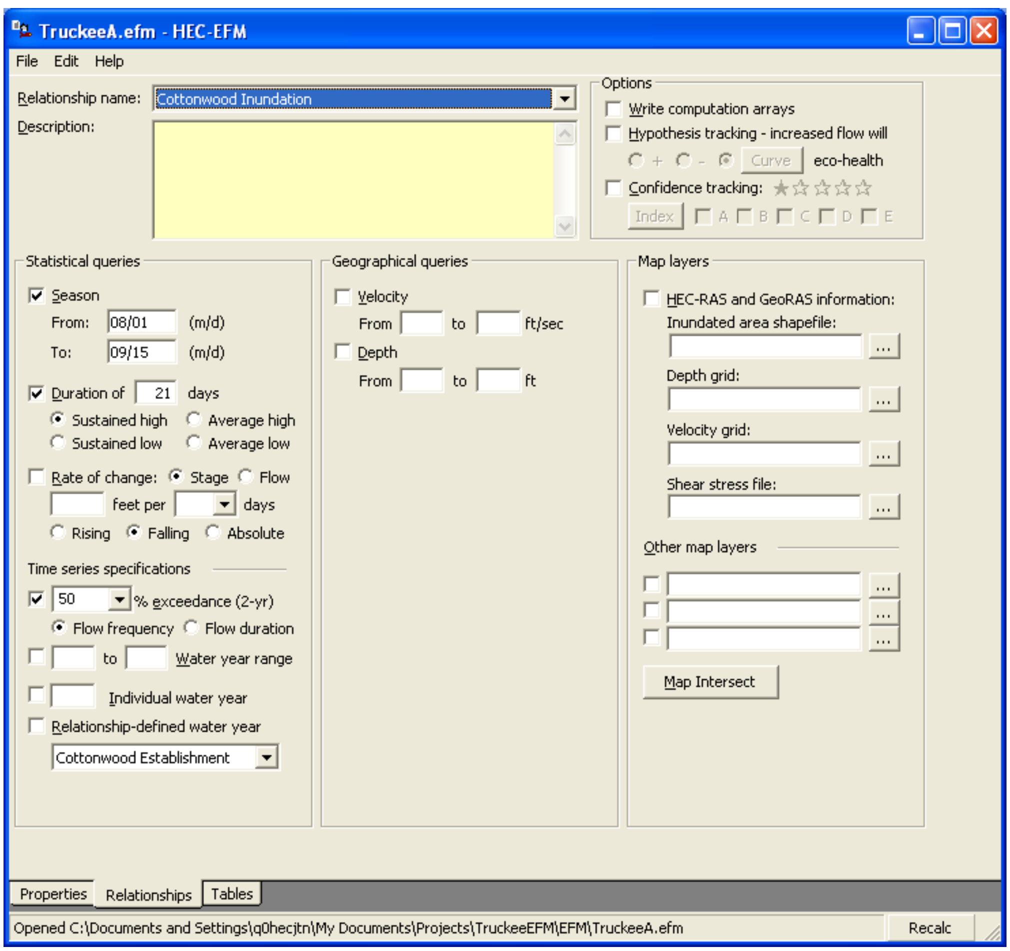

Figure 4. Cottonwood inundation relationship in HEC-EFM.

Mayfly Habitat

Mayfly habitat was determined by first identifying the areas that contained substrate where field samples indicate mayfly prefer to live, then identifying the flow that would be available during the time period that mayfly are most active. The actual habitat was identified and computed by overlaying the floodplain map (that showed the inundation boundary) on the substrate map and computing the area where substrate and flow combined to create mayfly habitat.

A substrate map of the study area was developed by computing the channel forming flow in HEC-EFM. The channel forming flow for a river is usually accepted to be the 2-year flow (highest flow that, on average, occurs every two years). So a relationship was added to HEC-EFM for substrate that contained the following seasonal, durational, and return period parameters:

- Season – all year.
- Duration – 1 day average high flow.
- Return period – 2 years.

The relationship used to identify channel forming flow in HEC-EFM is illustrated in Figure 5.

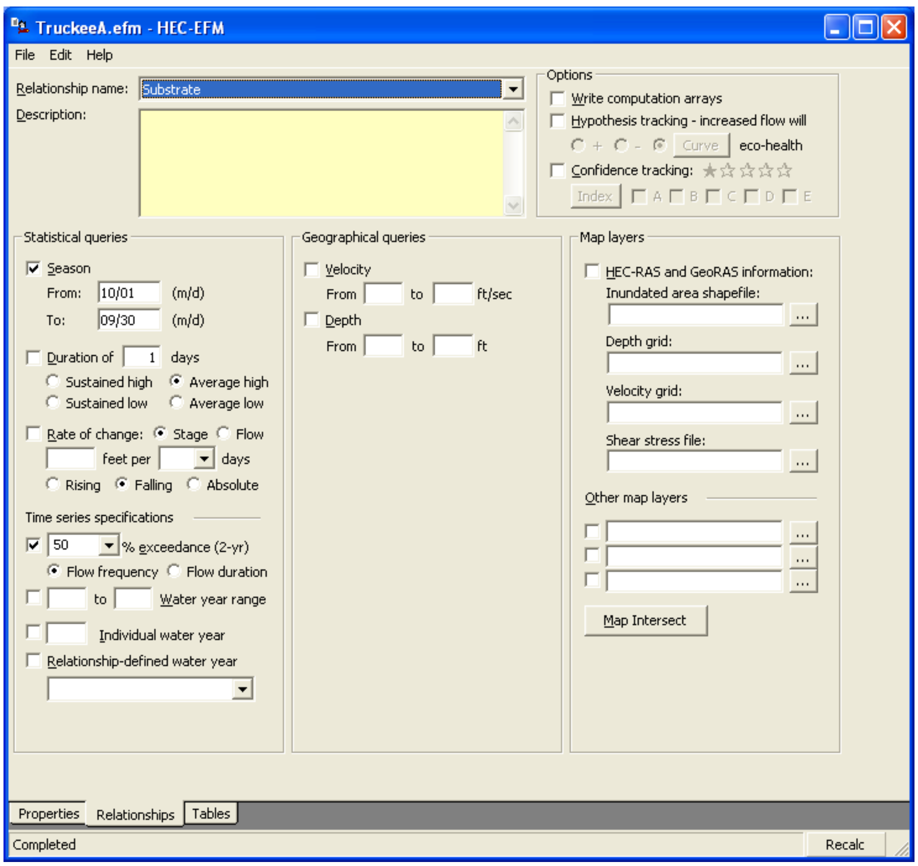

Figure 5. Flow relationship for computing channel substrate in HEC-EFM.

To determine the flow that would be available for mayfly habitat, the following relationship was used in HEC-EFM:

- Season – mid-August through mid-September, which is the time period, identified by DRI scientists, when mayfly are most active in the Truckee River.
- Duration – 1 year average high.
- Return period – 2 years.

The mayfly (Baetis) flow relationships used to determine mayfly habitat is illustrated in Figure 6.

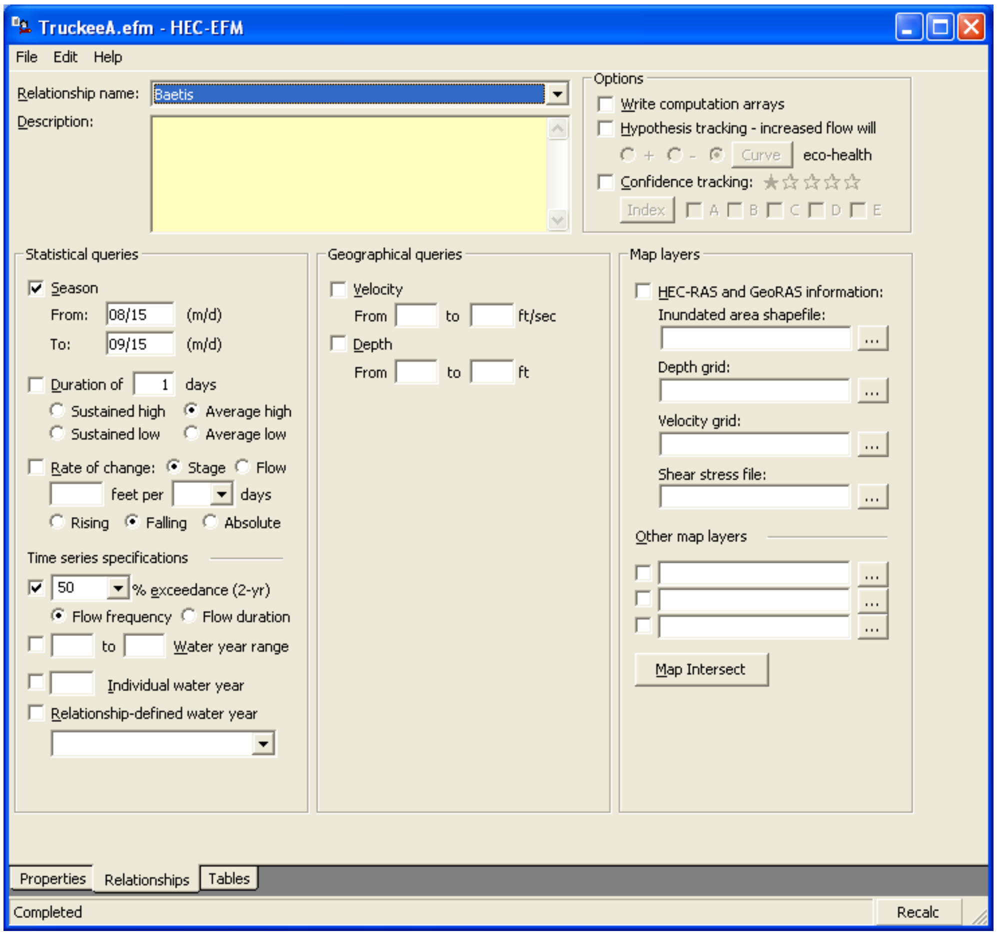

Figure 6. Mayfly (Baetis) flow relationship in HEC-EFM

HEC-RAS and HEC-GeoRAS Application

The HEC-RAS model used in this analysis was obtained from the Corps of Engineers Sacramento District. The HEC-RAS model contained both the existing and restored geometries for McCarran Ranch. Flow results from HEC-EFM were used as input to HEC-RAS. HEC-RAS was used to compute water surface profiles and velocity arrays, where necessary, for the flows from HEC-EFM.

HEC-GeoRAS was used to produce depth grids and velocity grids for analysis and display in GIS. In order to create depth grids using water surface profile results from HEC-RAS, HEC-GeoRAS requires a digital terrain model. The Sacramento District provided a digital terrain model of the existing stream channel and over bank area. A terrain model of the restored channel geometry was created by “cutting” the stream channel out of the existing terrain model and imposing the cross-sections from the HEC-RAS model of the restored condition onto the existing terrain model (with stream cut out). This process, in effect, removed the existing stream channel and added in the restored stream channel to the terrain in the study area. The restored digital terrain model was created using tools available in ArcView 3.2. HEC-GeoRAS computed depth grids for the existing and restored conditions by taking the water surface profiles from HEC-RAS, which contain water elevations for a given flow at each cross-section in the study, and projecting those over the terrain elevation map to find the difference in elevation between the ground and water surface.

For cottonwood establishment and inundation, flow results from HEC-EFM were run in HEC-RAS. Water surface profile results from HEC-RAS were imported into HEC-GeoRAS, which was then used to create floodplain boundary maps in the form of depth grids for each flow and each condition. Then, using map calculation tools available in ArcView, a new map (cottonwood habitat) was created that contained only grid cells that were in the establishment zone but outside the inundation zone. The number of cottonwood habitat grid cells was then computed for both conditions, existing and restored, to show if cottonwood habitat increased or decreased with the channel restoration.

Actual mayfly habitat depends on three characteristics: substrate, depth, and velocity. To develop a map of substrate for the McCarran Ranch reach, flows computed by HEC-EFM for the substrate relationship (channel forming flow computation) were used as input to the HEC-RAS model for both the existing and restored conditions. HEC-RAS was used to compute water surface elevations and velocities for the channel forming flow. These values were imported into HEC-GeoRAS, which was then used to create depth and velocity grids for the channel forming flows. Next, Laursen’s equation was applied to compute the average particle size diameter for each grid cell based on the depth and velocity of flow in that grid cell.

Laursen's equation, rearranged to solve for average particle diameter size, is:

$$D_{50} = \left(\frac{V_c}{K_u y_1^{1/6}} \right)^3$$

Where: D_{50} = bed material particle size (ft)
V_c = critical velocity above which material of size D_{50} and smaller will be transported (ft/s)
K_u = 11.17
y_1 = average depth of flow

Using map computation tools in ArcView, a new layer containing particle size (substrate) by grid cell was created. The grid cell size used in this analysis was 10 feet by 10 feet. Figure 7 shows the velocity grid computed by GeoRAS for the channel forming flow of 2,155 cfs on a segment of the existing channel. Figure 8 shows the depth grid for the channel forming flow along the same segment of the stream. Finally, Figure 9 shows the computed stubstrate by category for the same segment of the stream using the Laursen's equation approach.

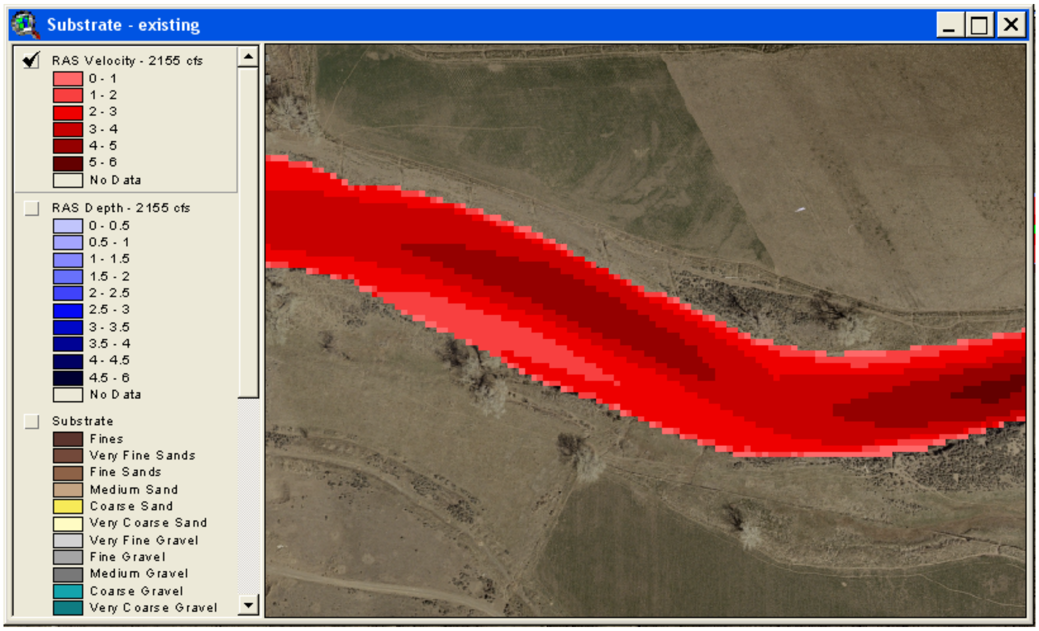

Figure 7. Velocity grid for channel forming flow of 2,155 cfs.

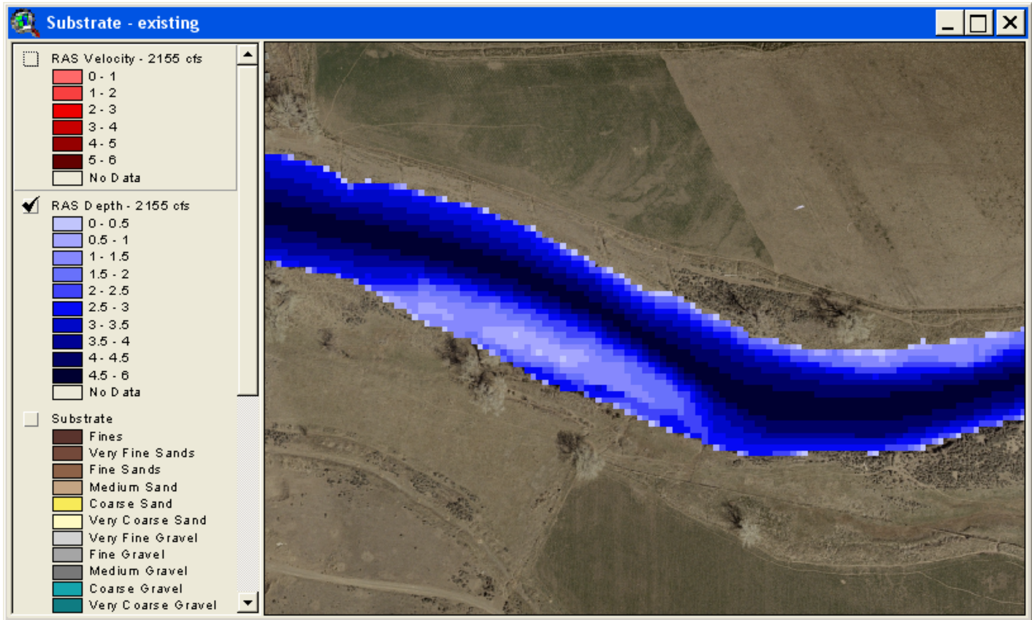

Figure 8. Depth grid for channel forming flow of 2,155 cfs.

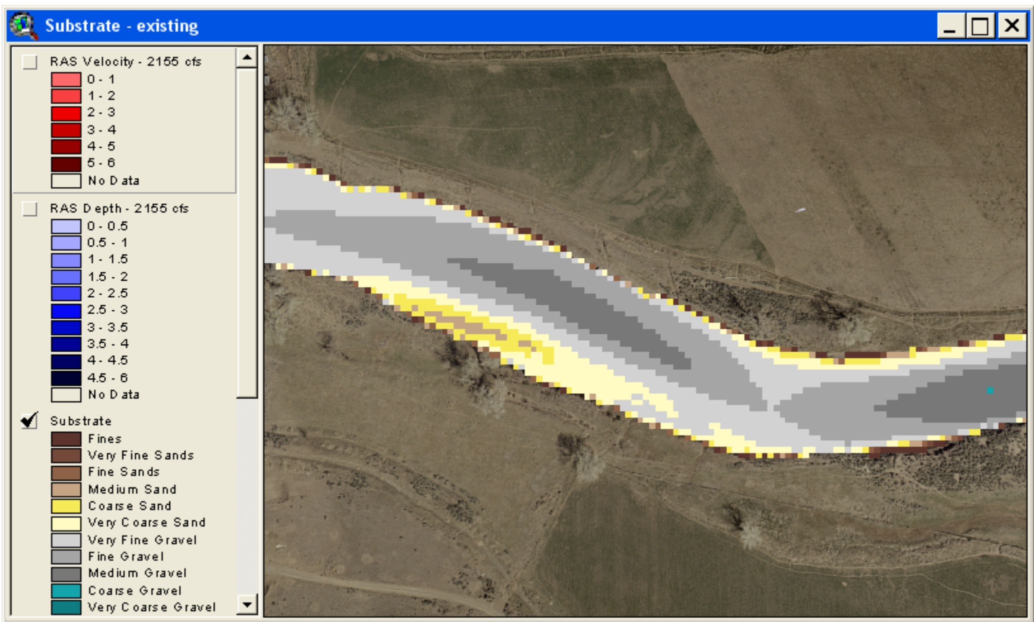

Figure 9. Computed substrate grid.

Substrate results for the existing conditions were spot checked using field survey data provided by DRI. In many locations, the substrate sizes recorded in the field match closely with the substrate computed using the results from HEC-EFM and Laursen's equation. However, most of the comparisons showed the DRI field data had much larger sample sizes than those computed using EFM results. DRI's sampling technique could be one of the reasons for the difference.

Their technique consisted of moving away from the bank a specified distance, and then looking straight down and recording the size of the substrate at that exact location. This technique will not necessarily lead to recording the average particulate size in an area, where as the computation using EFM results and Laursen's equation was aimed at determining average substrate size.

Depth and velocity grids for the flow available during the mayfly active season were then generated in HEC-GeoRAS using the flows from the HEC-EFM relationship for mayfly habitat. Mayfly field sample data provided by DRI scientists showed that mayfly nymphs are found in water where bed particle size is between 0.5 mm and 4 mm diameter, depths were between 1.85 ft. and 2.35 ft. and flow velocities were between 2.5 ft/s and 5 ft/s. So a grid layer was generated using grid computation tools available in ArcView that only contained grids that met the conditions specified by the DRI scientists for mayfly habitat.

Results

EFM Results

HEC-EFM results for this analysis are shown in Table 1. For all relationships other than cottonwood establishment, the resultant flow computed by HEC-EFM is the same for both the existing and restored conditions because those relationships did not contain a parameter for change in stage (and historical flow did not change between existing and restored conditions). For the cottonwood establishment relationship, HEC-EFM results are based on both flow and change in stage. Since the channel geometry is different between the two conditions, the elevation of the water will recede at different rates even though the flow recedes at the same rate.

Table 1. HEC-EFM Results

	Existing		Restored	
Relationship	**Elevation (ft)**	**Flow (cfs)**	**Elevation (ft)**	**Flow (cfs)**
Cottonwood establishment	4,275.2	1,256	4,278.1	1,059
Cottonwood inundation	4,278.8	385	4,276.6	385
Substrate	4,276.2	2,155	4,280.0	2,155
Mayfly	4,273.9	451	4,276.8	451

GIS Results

Cottonwood

GIS results illustrating cottonwood establishment and inundation for the existing and restored condition of the McCarran Reach study area are displayed in Figure 10 and Figure 11, respectively. The lighter polygon layer represents the establishment area and the darker polygon layer represents the inundated area. The areas where the darker polygon does not cover the lighter polygon are where the HEC-EFM results suggest conditions would be suitable for cottonwood habitat. Grid cell computations show that the area of cottonwood habitat decreases from approximately 11.1 acres under the existing conditions to approximately 6.5 acres under the restored condition.

The reason for the decrease is that the main channel under the restored condition is deeper and narrower and the resultant flow from the cottonwood establishment relationship does not get out of the channel in either the existing or restored cases. Therefore, the actual affect of the restored channel is reducing the area of cottonwood habitat.

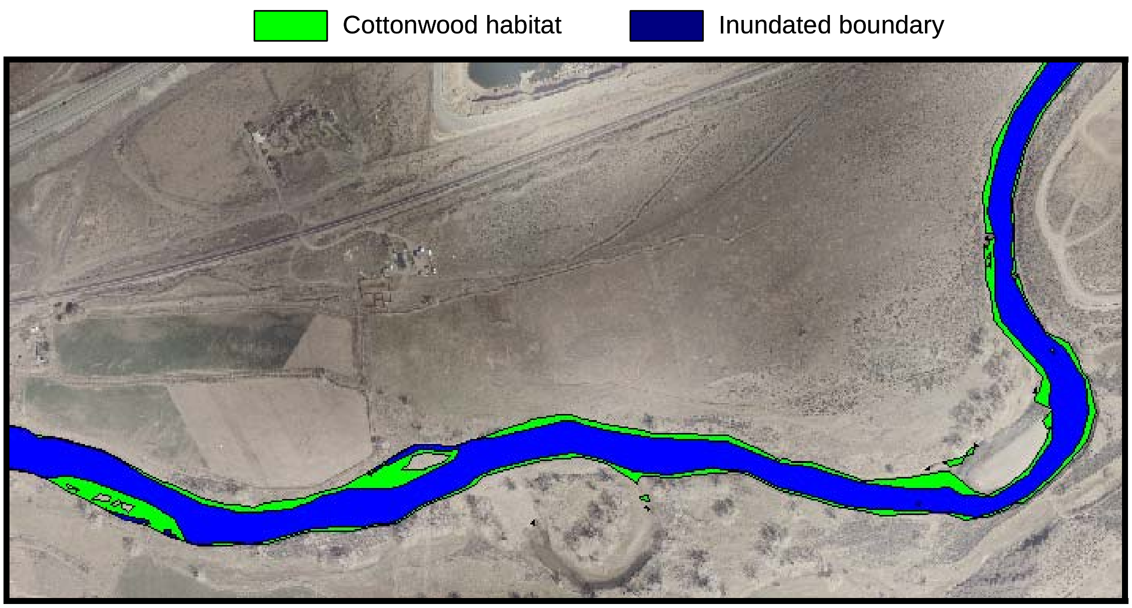

Figure 10. Cottonwood establishment and inundation – Existing condition.

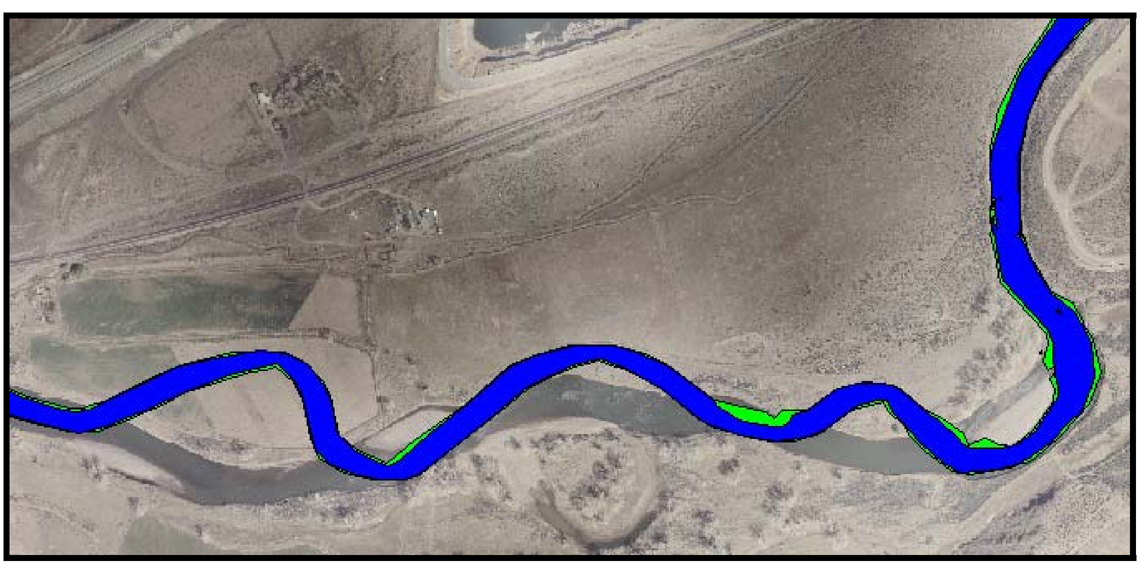

Figure 11. Cottonwood establishment and inundation – Restored condition.

Mayfly

Mayfly habitat for the existing and restored conditions is show in Figure 12 and Figure 13, respectively. The dark area is the flood inundation boundary polygon for the mayfly flow computed by HEC-EFM: 451 cfs. The light areas within the inundation boundary polygon are the grid cells that contain the correct substrate size, depth, and velocity as specified by DRI scientists and described in the previous section.

Like cottonwood habitat, results from this EFM analysis show that the mayfly habitat decreases under the restored McCarran Ranch condition. The total mayfly habitat area goes from 5.4 acres under the existing condition to 4.2 acres under the restored condition. This is explained by the fact that the restored condition has more of a riffle/pool setup, which leads to deeper, slower flow than the existing channel in many areas. Since mayfly prefer faster flow velocities, their habitat is reduced under the restored condition.

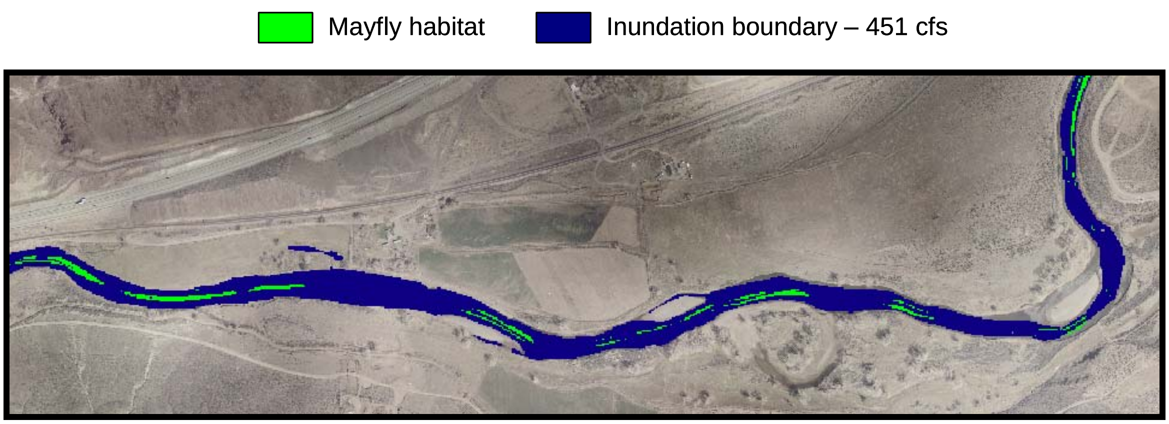

Figure 12. Mayfly habitat – Existing condition.

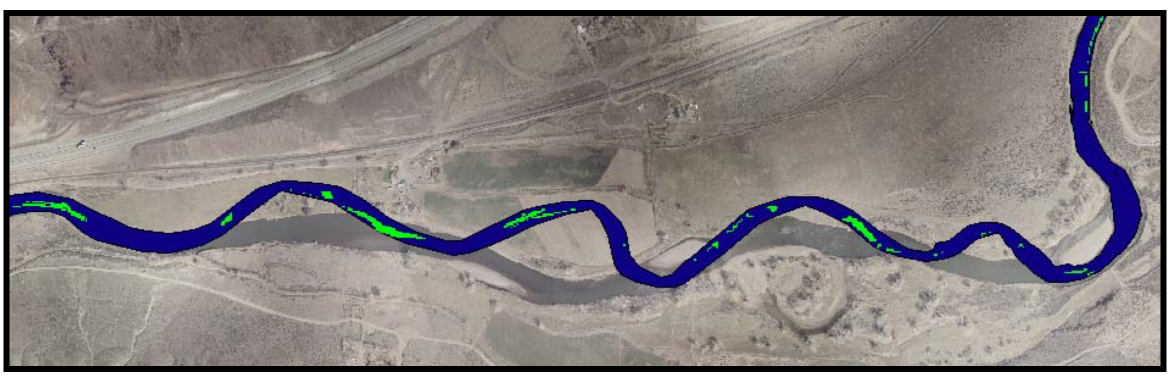

Figure 13. Mayfly habitat – Restored condition.

Conclusions and Recommendations

This analysis indicates that mayfly and cottonwood habitat will be reduced by the modifications made to the channel geometry along the Truckee River at McCarran Ranch. While the restoration effort is aimed at restoring the channel to a more natural state and not specifically at improving mayfly and cottonwood habitat, these results still warrant further discussion.

This analysis is based on gaged flows for the Truckee River at Tracy from 1972 through 2004. Truckee flows at Tracy have been altered by multiple upstream reservoirs and municipalities. It is likely that these alterations have muted the river's natural ability to perform flow-driven processes such as cottonwood recruitment. The alterations, however, do not preclude a viable ecosystem. It simply means that some processes are not as likely to occur or will continue at a reduced state in a managed system.

As with many restoration projects in the western United States, efforts to restore riparian vegetation at McCarran Ranch include planting and irrigation of cottonwood seedlings. Riparian habitat will be created through a human process in lieu of natural recruitment. HEC-EFM results indicate that the channel restoration reduces cottonwood recruitment with the current flow regime, which actually supports the decision to use plantings. An interesting continuation of this application would be to analyze changes to the flow regime designed to promote natural establishment of cottonwoods.

True validation of HEC-EFM results will be provided through field observations of how mayfly and cottonwood dynamics change in response to the channel modifications. By continuing to monitor and compare actual habitat change with modeling results, information can be learned about the relationships used in this application as well as the applicability of HEC-EFM to these types of restoration projects.

The following recommendations should be considered for expanding this analysis:

1) Additional eco-hydro relationships. This analysis looked at how cottonwood and mayfly habitat would change given the proposed modifications to the Truckee River channel. Additional relationships, including trout, beneficial diatoms (algae), the endangered Cui-ui (suckerfish), and other macroinverts, could be analyzed with HEC-EFM to get a broader picture of the effects the restored channel will have on ecosystem habitat.

2) One-dimensional vs. two-dimensional hydraulic modeling. Results presented in this paper are based on one-dimensional hydraulic modeling, which does not account for

lateral or vertical velocities. A parallel modeling effort by the Corps' Engineer and Research Development Center (ERDC) is underway to develop a two-dimensional hydraulic model for the McCarran Ranch area. Two-dimensional models account for longitudinal and lateral velocities and tend to be more expensive to develop and calibrate than one-dimensional models. The process of applying HEC-EFM is indifferent to which type of hydraulic model is used. A comparison of the results from HEC-EFM using the one- and two-dimensional models would be valuable. This comparison would provide insight into whether the more detailed hydraulic modeling affects conclusions reached and to whether or not the more costly two-dimensional modeling effort is necessary for HEC-EFM studies similar in scale to the one presented here for the McCarran Ranch.

3) Use HEC-EFM in conjunction with Riverware. This report detailed an HEC-EFM analysis of changes in channel geometry. HEC-EFM is also useful in analyzing alternative flow regimes. A Riverware model of the Truckee already exists that can simulate different reservoir operation scenarios, each generating a different flow regime at McCarran Ranch. HEC-EFM could be used to test the ecological value of each scenario for each of the established relationships (for both the existing and restored channel geometries).

4) This analysis focused on a five mile stretch of the Truckee River, which travels between Lake Tahoe and Pyramid Lake. This application could be expanded to other sections on the Truckee River, with the goal of making HEC-EFM a stronger support tool for water management decision making on the Truckee River.

Additional information on the McCarran Ranch Pilot Restoration project can be found on The Nature Conservancy's website: http://nature.org/wherewework/northamerica/states/nevada/preserves/art11683.html.

References

Hydrologic Engineering Center (2002a). *HEC-RAS (Version 3.1), River Analysis System*, User's Manual, U.S. Army Corps of Engineers, Davis, CA.

Hydrologic Engineering Center (2002b). *HEC-GeoRAS, An extension for support of HEC-RAS using ArcView*, User's Manual, U.S. Army Corps of Engineers, Davis, CA.

Hydrologic Engineering Center (2003). *HEC-EFM, Ecosystem Functions Model*, User's Manual, U.S. Army Corps of Engineers, Davis, CA.

Rood, S.B., Gourly, C.R., Ammon, E.M., Heki, L.G., Klotz, J.R., Morrison, M.L., Mosley, D., Scoppenttone, G.G., Swanson, S, Wagner, P.L. (2003). *Flows for Floodplain Forests: A Successful Riparian Restoration*, BioScience, Vol 53 No. 7.