COSHOW ENVIRONMENTAL, INC.

MEANDER MIGRATION MODEL ASSESSMENT FOR THE 50- AND 100-YEAR STORMS, WHITMAN PROPERTY, SAN ANTONIO CREEK, VENTURA COUNTY, CALIFORNIA

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INTRODUCTION

David Magney Environmental Consulting (DMEC) was retained by Mr. John Whitman to assist with environmental analysis of project-related changes to San Antonio Creek on his property near Ojai, Ventura County, California (Figure 1). The need for this project arose when San Antonio Creek eroded a large portion of Mr. Whitman's property during the January 2005 storm. Following the storm, a straight pilot channel was excavated to convey low- to moderate-sized flows through this reach. Mr. Whitman lost a great deal of land, including road access between the upstream and downstream portions of his property. Mr. Whitman therefore would like to restore his eroded bank to the location just prior to the January 2005 storm.

Figure 1. Oblique photograph of the project area looking downstream just prior to the January 2005 storm.

The purpose of this analysis is to study the potential river migration dynamics on this reach if the river were to be left in the existing condition (i.e., a straight channel excavated to convey moderate-sized flows) or were to be restored to the pre-storm condition (i.e., the channel restored to the location just prior to the January 2005 storm). To do so, DMEC contracted Dr. Eric Larsen of the University of California, Davis and Dr. Mark Rains of Coshow Environmental, Inc. and the University of South Florida to employ a meander migration model (Larsen 1995). Field data documenting existing conditions were collected and used to model potential river migration dynamics under each of these scenarios during hypothetical 50- and 100-year flood events.

Two issues bear discussion. First, the model predicts trends in stream migration. The actual stream migration patterns will be similar to the predicted stream migration patterns. An exact match between the actual and predicted stream migration patterns would be, to a certain extent, fortuitous. Second, this model predicts stream migration patterns on generic time steps. However, stream migration can occur episodically so all or most of the predicted migration can occur in a short period of time. At the most extreme, most of the predicted stream migration could occur in a single storm event. Stream migration is a function of flow strength (e.g., stream power). If a great deal of stream power is experienced over a short period of time, or a small amount of stream power is experienced over a long period of time, then the actual trends in stream migration will be the same in both scenarios as long as the total excess stream power is the same in both scenarios.

SITE DESCRIPTION

The study reach is San Antonio Creek between Ojai and the U.S. Highway 33 crossing (Figure 2). In most naturally migrating rivers, local meander migration is related to the shape of the local meander bend and to the shape of the river upstream (Johannesson and Parker 1985, Johannesson and Parker 1989, Furbish 1991). Therefore, the analysis of local migration on the Whitman property requires the analysis of migration on a longer reach that includes sections of river both upstream and downstream from the Whitman property.

DATA COLLECTION

Most of the field data were collected on 18-19 July 2005 by Dr. Larsen, Dr. Rains, and Ms. Cher Batchelor of DMEC. Two typical cross-sections and a longitudinal profile were surveyed. The bankfull width and mean bankfull depth were calculated from the cross-section data, while channel slope was calculated from the longitudinal profile data. Stream bed material size class distributions are based upon a Wolman Pebble Count (Wolman 1954, Harrelson et al. 1994). The D_{50} is the median particle size, or the size that is greater than or equal to 50 percent of the particles. The D_{50} is typically taken to be the effective length scale of the bed-material load. Additional field data, such as additional GPS data on the locations of the stream centerline and bank constraints, were collected as necessary by DMEC personnel.

The Ventura County Flood Control District (VCFCD – now called Ventura County Watershed Protection District) provided annual peak discharge data and flood frequency analyses for San Antonio Creek at Casitas Springs (VCFCD Gage #605). Data were for water years 1950-1998. The flood frequency analyses were verified by using a lognormal distribution approach. The channel centerline was digitized from serial aerial photographs.

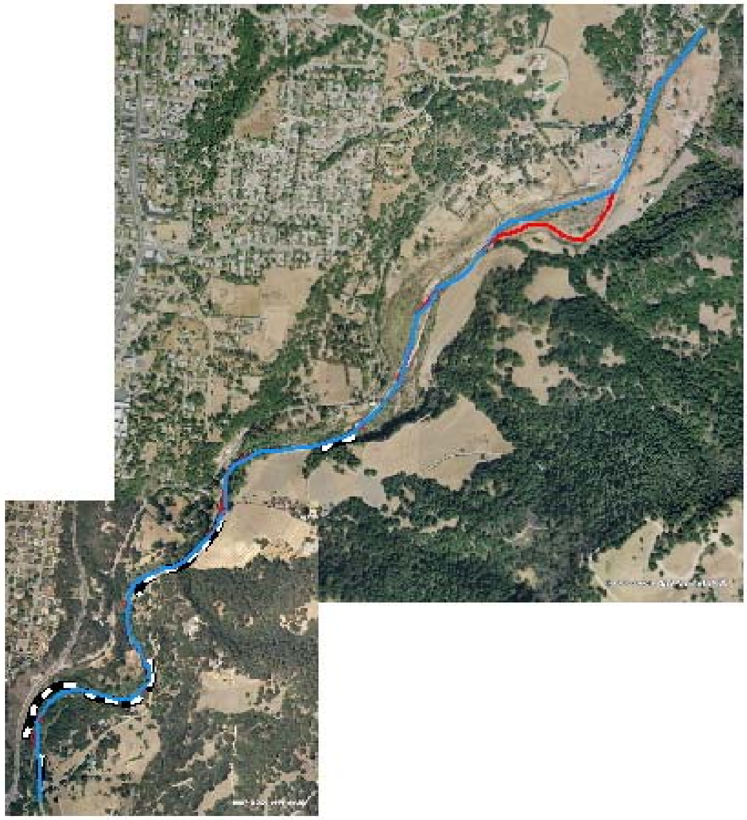

Figure 2. The entire study reach with bank restraints (black and white checked), the 2006 channel centerline including the pilot channel through the Whitman property (blue channel), and the channel centerline if it were relocated to the pre-2005 high-flow channel (red).

NUMERICAL SIMULATIONS

STREAM MEANDER MIGRATION MODELING

Unconstrained meander bends tend to migrate naturally across the landscape (Brice 1977, Hooke 1984). Bend migration tends to follow patterns that can be described by mechanical laws of fluid flow and by other methods (Brice 1974, Ikeda et al. 1981, Hooke 1984). When such meander bend migration occurs, an individual bend tends to move, unless constrained, both downstream and cross-stream. In other words, while a bend will tend to migrate continuously downstream, at the same time, because of the cross-stream component of migration, it will tend to migrate cross-stream. As the bend migrates, it also changes shape.

The stream meander migration model used in this report uses a linear theory for velocity distribution in meander bends to predict the velocity field (Johannesson and Parker 1989). This is coupled with a bank erosion theory (i.e., Ikeda et al. 1981) to predict the spatial and temporal patterns of stream migration. Bank erosion involves a variety of complicated processes, including fluvial entrainment of sediment, the influence of soil saturation, bank mass failure, and bank unraveling (Thorne 1982, Osman and Thorne 1988). The hydraulic algorithm for bank erosion was developed by Ikeda et al. (1981). Ikeda et al. (1981) do not explicitly model these processes; rather, they attempt to represent their integrated effects. The model assumes that a vertical bank experiences fluid shear forces due to the water flowing tangentially to the bank. In this view, local erosion occurs in linear proportion to the magnitude of the local shear stress and in inverse proportion to the magnitude of the bank resistive forces. One can visualize that the flowing water directly entrains the bank material. Although the conceptual model and the actual processes differ, the simple model adequately predicts bank erosion (Ikeda et al. 1981, Beck 1984, Johannesson and Parker 1989, Howard 1992, Larsen 1995).

The stream migration model used in this report was developed more than a decade ago (Larsen 1995), and recent versions have been employed in numerous locations (e.g., Larsen et al. 2006a, Larsen et al. 2006b), including previously on this reach of San Antonio Creek (David Magney Environmental Consulting 1999, Coshow Environmental, Inc. 2006).

HETEROGENEOUS ERODIBILITY SURFACE

A spatial erodibility surface was developed from site inspection, GPS coordinates, and calibration efforts (Figure 3). All surface types were assumed to be erodible, except for those shown in light tan which represent non-erodible areas based on their soil properties, sometimes called areas of geologic constraint. The more orange area is the high bank and is less erodible than the open ground.

MODELING THE 50- AND 100-YEAR STORMS

The magnitude of meander migration of a river in a time period is related to the cumulative stream power in the same time period (Larsen et al. 2006a, Larsen et al. 2006b). The stream power is proportional to the discharge times the slope. Because a single slope was used to model the migration, the total stream power is linearly proportional to the sum of the discharge. This model uses a single discharge, taken here to be the 5-year return discharge. The model can be run through enough time steps to essentially equal the stream power in any storm with a discharge equal to or greater than the 5-year return discharge. This model was calibrated to the January 2005 storm, which was a 50-year return discharge. An approximation of the total cumulative stream power is the area under the curve in a storm hydrograph. In order to estimate the cumulative stream power of a 100-year event, we took the ratio of the cumulative stream power of a hypothetical 100-year storm hydrograph to the cumulative stream power of a hypothetical 50-year storm hydrograph and multiplied it times the number of time steps required to calibrate to the 50-year return discharge.

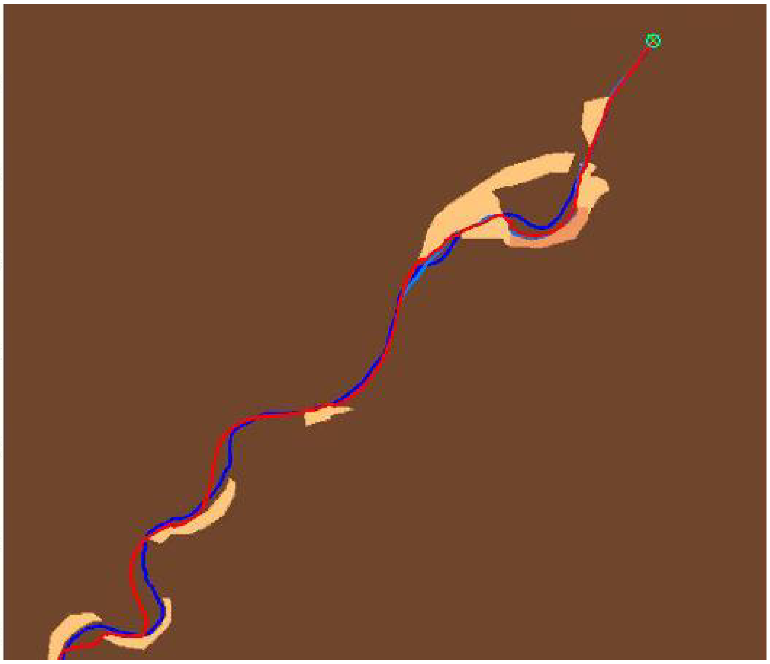

Figure 3. The entire study reach with various current and potential existing channel centerlines passing through the erosion field. Brown is highly erodible, orange is moderately erodible, and tan is non-erodible.

The 50-year return discharge was estimated to be 24,000 cfs, and the 100-year return discharge was estimated to be 32,000 cfs (Barry Rand, Hawkes and Associates, Inc., pers. comm.). Assuming that the storm hydrographs can be approximated as smoothed triangles of equal base length, then the ratio of the cumulative stream powers is 32,000/24,000, or 4/3 (Figure 4). Therefore, the total time steps used in calibrating to the 50-year event was multiplied by 4/3 to simulate the 100-year event.

RESULTS

CROSS-SECTIONS AND LONGITUDINAL PROFILES

The cross-sections and longitudinal profile are presented as Figures 5 and 6. Bankfull width is approximately 195 feet and mean bankfull depth is approximately 3.3 feet. Slope was measured along the thalweg (i.e., the deepest point of the channel). The channel slope is approximately 0.007 (i.e., 1 percent).

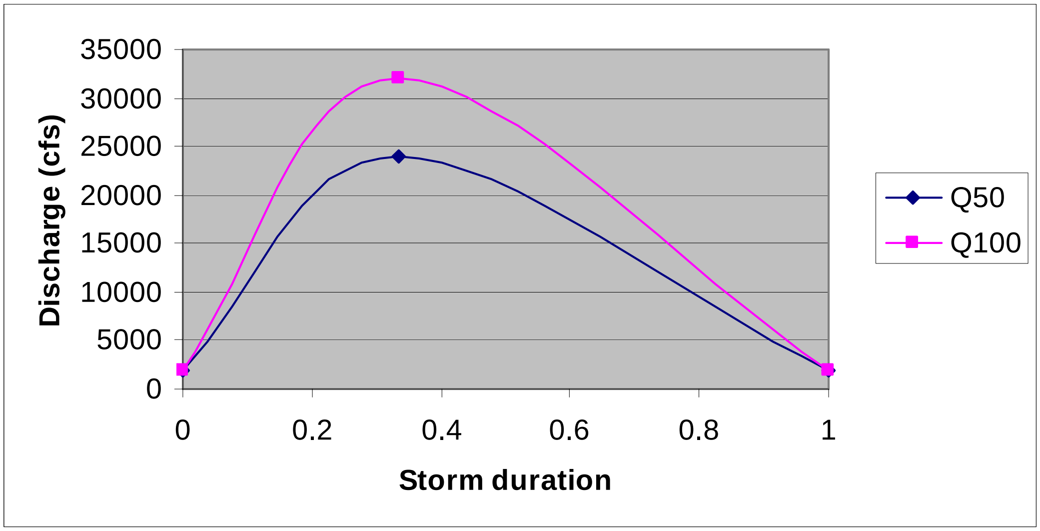

Figure 4. Hypothetical storm events with 50- and 100-year return discharges.

FLOOD FREQUENCY ANALYSIS

The VCFCD estimates that the 2-year and 5-year return discharges are 1,590 cfs and 4,750 cfs, respectively. Using a lognormal distribution approach, the 2-year and 5-year return discharges were computed independently to be 1,500 cfs and 5,100 cfs, respectively. The latter independently computed values are used herein.

The meander migration model used herein requires the estimation of a bankfull discharge. The bankfull discharge can be defined as the discharge that determines observed channel geometry (Wolman and Leopold 1957). Depending upon the physiographic characteristics of a region, the bankfull discharge can range from the 1- to 100-year return discharges (Williams 1978). The authors and others have found that the bankfull discharge in the Transverse Range, California is approximately the 5-year return discharge. Therefore, the independently computed 5-year return discharge is used herein.

CHANNEL MATERIALS

The characteristic channel bed material particle size is defined herein as the D_{50}. The D_{50} is the median particle size, or the size that is greater than or equal to 50 percent of the particles. The D_{50} of the channel bed materials at the project site is 23 mm.

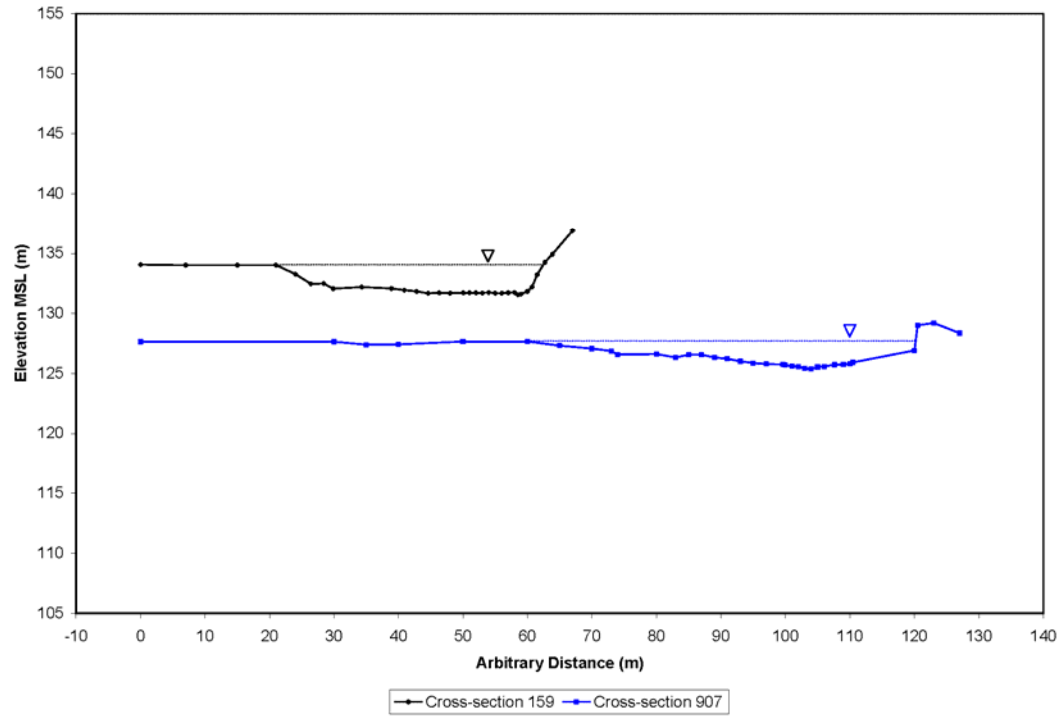

Figure 5. Typical cross-sections of San Antonio Creek.

Figure 6. Longitudinal profile of San Antonio Creek. Black points are thalweg measurements, while blue points are water surface measurements.

CALIBRATION MODEL RUN

This model was calibrated to the January 2005 storm, which was a 50-year return discharge (Figure 7). Prior to the January 2005 storm, fill was placed on the right bank of the floodway, and the main channel moved to the left bank of the floodway (Coshow Environmental, Inc. 2006). It was from this location that the bank eroded and the channel meandered during the course of the January 2005 storm. It also was from this location that the bank eroded and the channel meandered during the course of the calibration model run. As is typical, the channel migrated in cross- and downstream directions. The pre-storm channel is in dark blue, the post-storm channel is in light blue, and the modeled channel is in red. The agreement between the post-storm channel and the modeled channel indicates that the model is calibrated and can be used for additional predictions.

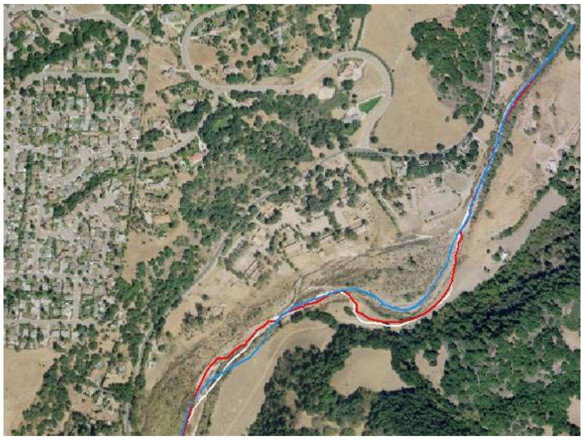

Figure 7. Calibration Model Run with the Pre-Storm Channel in Blue, the Post-Storm Channel in White, and the Modeled Channel in Red. (Note: In this model run, the pre-storm channel had been diverted to the left bank of the floodway by the placement of fill on the right bank of the floodway.)

PREDICTIVE MODEL RUNS

Simulations beginning from the existing condition for the 50- and 100-year floods are shown in Figure 8, while simulations beginning from the potentially restored condition for the 50- and 100-year floods are shown in Figure 9. The blue is the beginning channel centerline, the red line is the channel centerline for the 50-year flood prediction, and the yellow line is the channel centerline for 100-year flood prediction. In general, the channel centerlines for the 50- and 100-year floods are relatively similar for simulations beginning from the existing condition and from the potentially restored condition.

CONCLUSIONS

In this analysis, we present the results of a meander migration model that shows the potential river migration dynamics on this reach for the 50- and 100-year floods if the river were to be left in the existing condition (i.e., a straight channel excavated to convey moderate-sized flows) or were to be restored to the pre-storm condition (i.e., the channel restored to the location just prior to the January 2005 storm). The model results indicate that there would be no adverse consequences to neighboring properties under any of the modeled scenarios. In other words, the model results indicate that Mr. Whitman's proposal to restore his eroded bank would have no adverse consequences to neighboring properties.

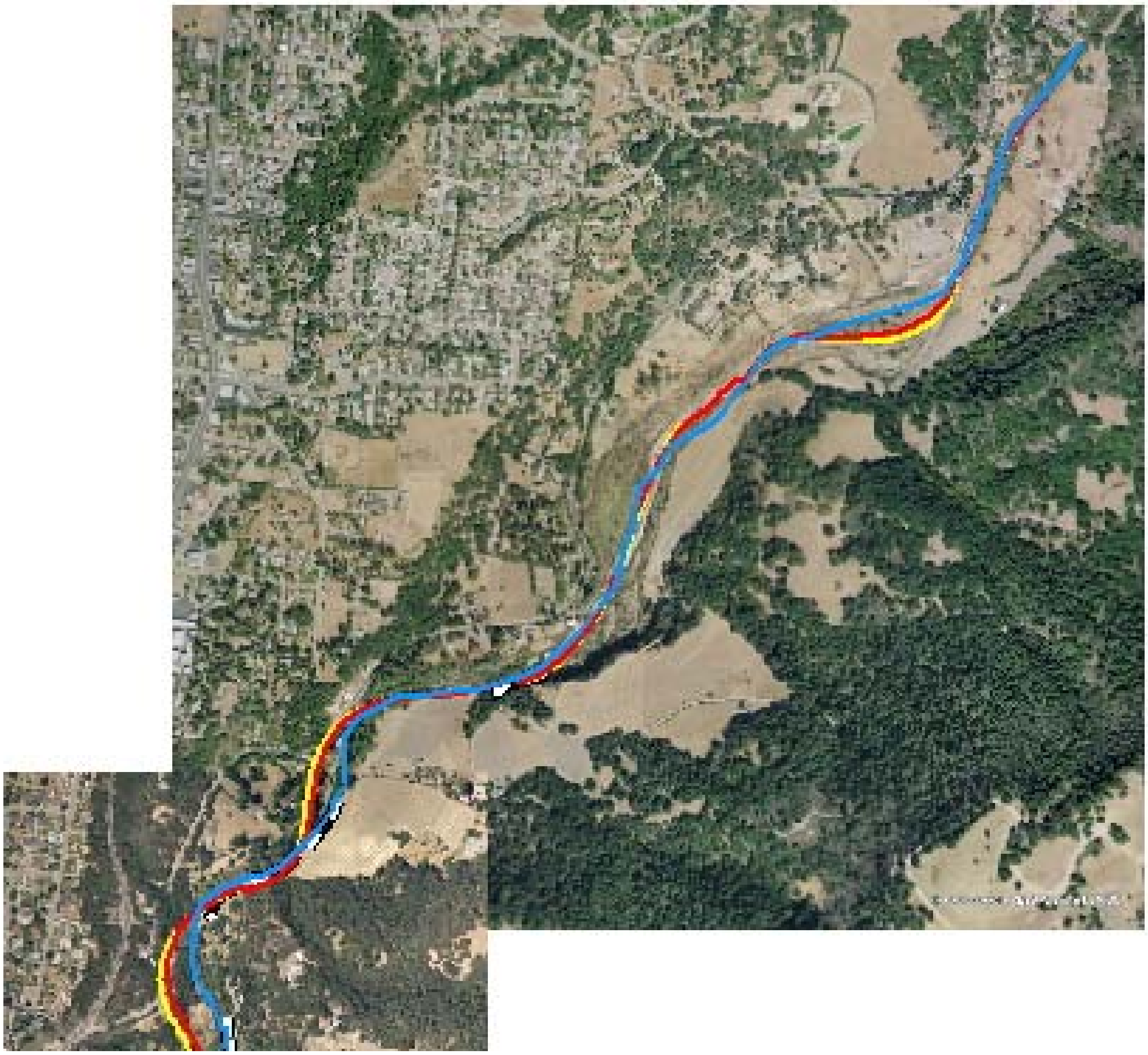

Figure 8. Simulations beginning from the existing condition. Blue is the beginning channel centerline, red is the channel centerline for the 50-year flood prediction, and yellow is the channel centerline for 100-year flood prediction.

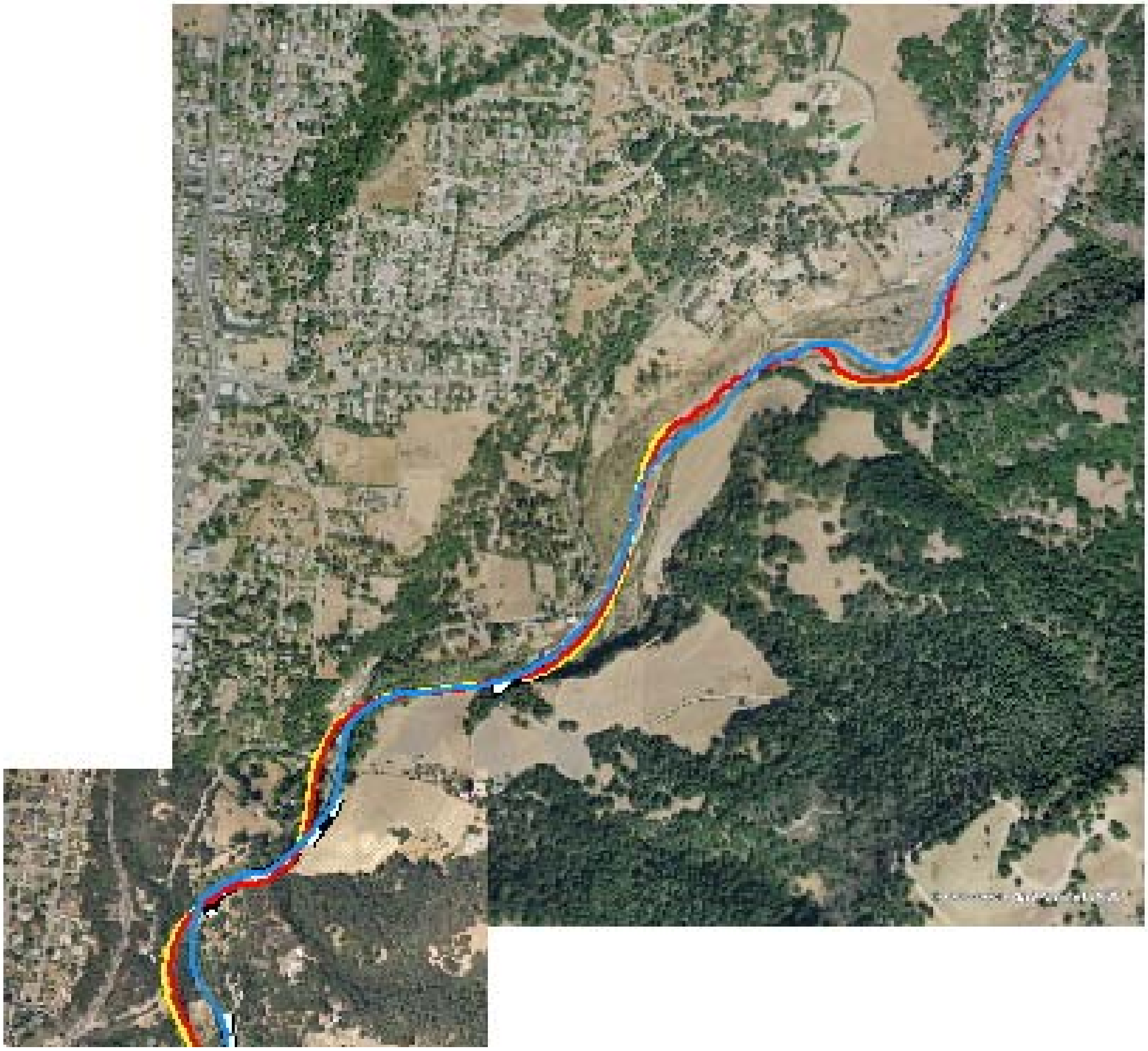

Figure 9. Simulations beginning from the potentially restored condition. Blue is the beginning channel centerline, red is the channel centerline for the 50-year flood prediction, and yellow is the channel centerline for 100-year flood prediction.

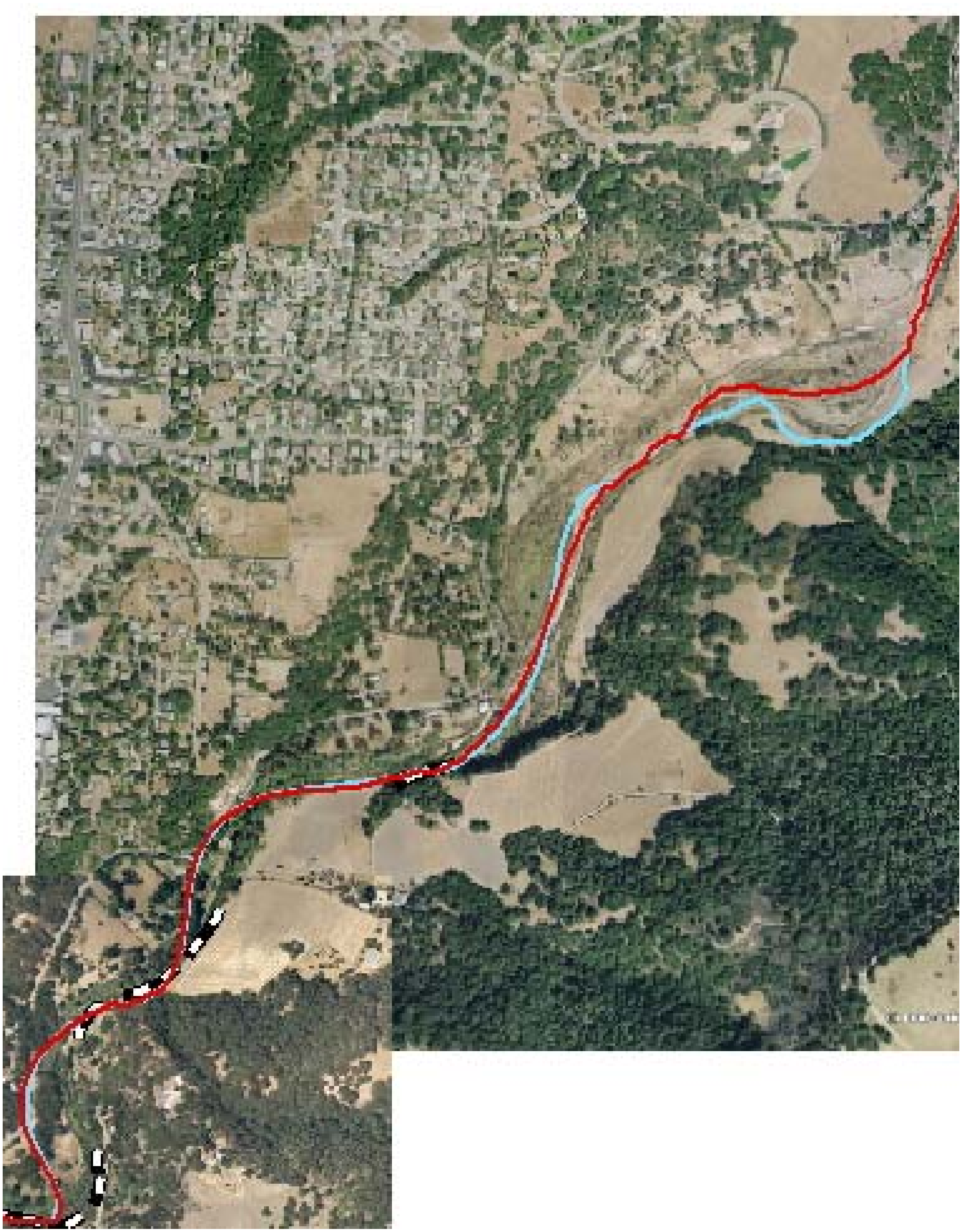

Figure 10. Simulations beginning from the existing (Red) and potentially restored (Blue) conditions for the 50-year flood prediction.

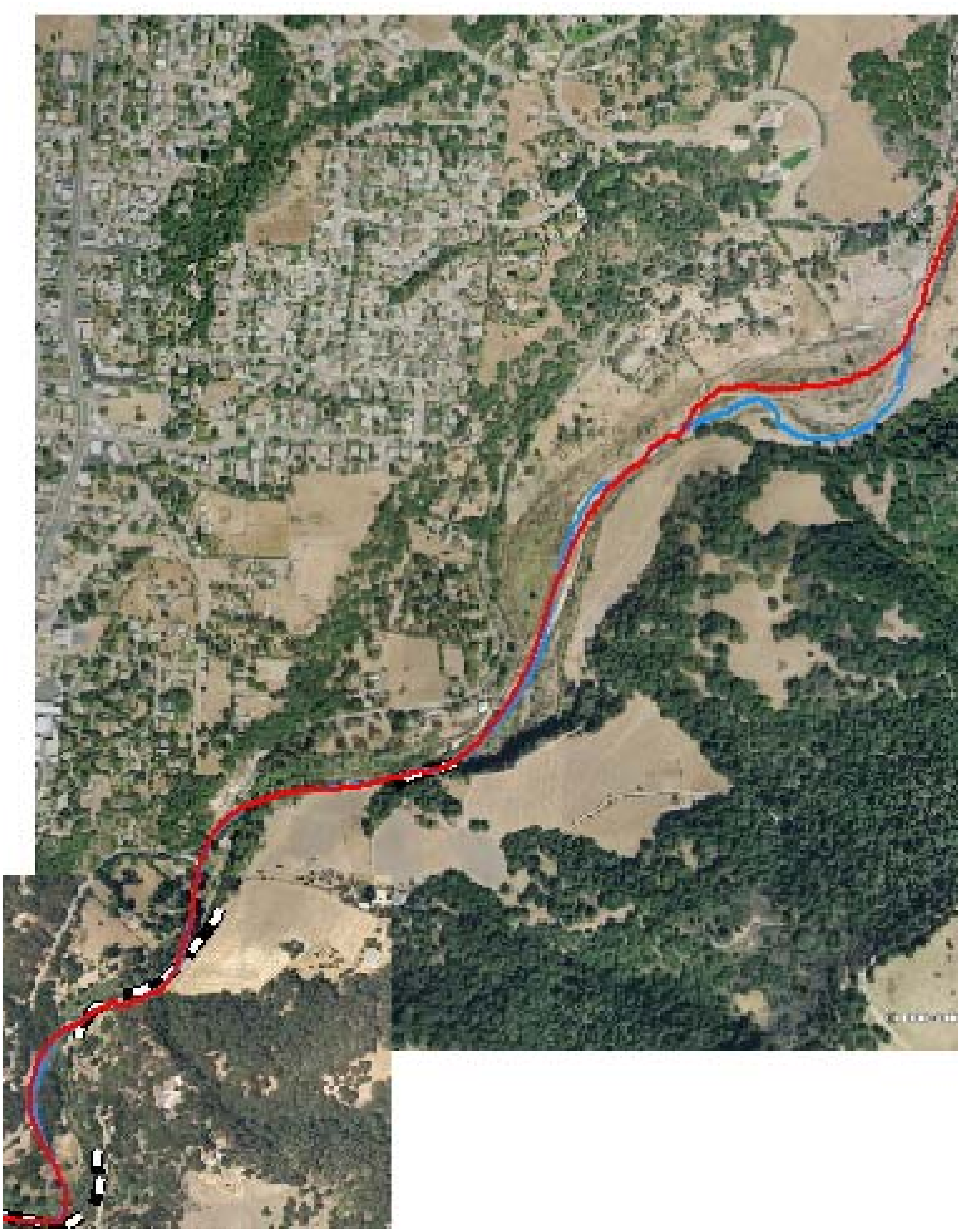

Figure 10. Simulations beginning from the existing (Red) and potentially restored (Blue) conditions for the 100-year flood prediction.

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