Study 47

Spring Run Spawning Habitat Assessment – Sediment Mobility

Final
2015 Monitoring and Analysis Plan

SAN JOAQUIN RIVER
RESTORATION PROGRAM

January 2015

1.0 Spring Run Spawning Habitat Assessment – Sediment Mobility

Theme(s):

- Flow management
- Spawning and incubation

Related Question(s):

- SI-001a: Is spawning habitat quality in Reach 1A sufficient to support adequate egg survival and healthy emergent fry for both spring- and fall-run Chinook salmon?

- SI-001c: Will fine sediment accumulation during incubation impair egg survival and/or alevin emergence in fall-run and spring-run Chinook salmon redds?

- SI-001d: Are gravel surfaces in Reach 1 capable of being mobilized, or are they sufficiently reinforced or embedded, in such a way that a loose and permeable stream bed is insufficient for spawning habitat?

- SI-003b: Is gravel recruitment sufficient for spawning habitat in Reach 1A?

- SI-005: Will releasing pulse flows to attract fall-run Chinook salmon increase sand accumulation in spring-run redds?

- SI-008: If new spawning habitat is created, or existing spawning habitat rehabilitated, will future sand (fine bedload) quickly infiltrate spawning habitat and reduce the quality (longevity) of spawning habitat? How frequently would gravel improvements be needed?

- SI-009a: Is existing sand storage contributing to the infiltration into gravels in Reach 1, thereby negatively affecting the health and survival of fry?

- SI-009b: Will future Restoration Flows alter the fine sediment budget in Reach 1? Will this increase or reduce sand storage and fine sediment infiltration into redds?

- SI-015: What are the bed transport rates at various flows? How would this change with the addition of new spawning habitat or rehabilitation of existing habitat? How would you schedule gravel augmentation with different flows and quantities of gravel in the system?

- SI-015c: At what flows do spawning gravels begin to mobilize in riffles in Reach 1?

1.1 Statement of Need

The San Joaquin River Restoration Program's (SJRRP) Restoration Goal is to "restore and maintain fish populations in good condition in the main stem of the San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally-reproducing and self-sustaining populations of salmon and other fish." The SJRRP Fisheries Management Plan (SJRRP, 2010) identifies spawning and incubation as a life stage to be supported for successful completion of the salmon life cycle. The SJRRP Spawning and Incubation Small Interdisciplinary Group agreed on a process for ensuring adequate spawning habitat is available to support fish populations, and a central effort in that process involves identifying the quality and quantity of spawning habitat. Several uncertainties exist as to the suitability for successful spawning in the existing stream bed within Reach 1A, which include adequate (1) hyporheic and surface water exchange, (2) flow depth and velocity, (3) sediment attributes, and (4) hyporheic water quality. The channel area that currently contain and is expected to maintain each of these attributes in high quality should be used to quantify the amount of suitable spawning habitat. Most of these attributes and their contribution to spawning and incubation habitat quality are dependent on the maintenance of the bed's surface texture. This maintenance is performed by occasional flows that are capable of dislodging the coarse grains (i.e., gravel and cobble) and flushing the finer particles (e.g., sand and silt).

1.2 Background

After the completion of Friant Dam in the 1940s the reduced instream flow that ensued downstream resulted in a coarsened bed texture as finer grains were typically the only grains capable of being eroded. However, in addition to bed erosion, other processes such as erosion of stored bank deposits and floodplains, and fine sediment contributions during tributary flow events have, to some extent, maintained a supply of mobile sand in Reach 1A. It is generally accepted that the proportion of fine sediment (e.g., sand and finer) is inversely related to egg survival.

Multiple studies are currently underway or have been completed to help identify the quality of the hyporheic environment as it relates to successful spawning, incubation, and fry emergence (see SJRRP, 2013). These include efforts to evaluate water quality within the hyporheic zone (dissolved oxygen, water temperature, fine sediment accumulation), egg survival, spawning habitat use by trapped-and-hauled fall-run Chinook, bed material size and mobility, scour and deposition, and channel morphology changes associated with alteration to the flow regime. Recently, Reclamation has proposed quantifying the spawnable area based on a layered approach of the above compilation of characteristics (see Reclamation, 2013).

In 2009, DWR began a study designed to evaluate bed mobility within Reach 1A at two riffles approximately midway between Friant Dam and Highway 41. The result of this study is a measured and validated critical shear stress (preliminary Shield's numbers of 0.020$\pm$0.003 at Riffle 38 and 40) for incipient entrainment of coarse bed material (i.e., gravel and cobble). With this primary input parameter for sediment transport formulae, the sediment transport rate for specified discharges can be predicted and, aided by a two-dimensional (2D) hydraulic model, the area of mobilization can be delineated and quantified. Additional information is gained from transport distance and storage loci of mobilized particles. These characteristics can be used to determine continuity of transport within the geomorphic unit (i.e., from bar to bar) or the lack thereof. Understanding this process will inform the SJRRP of gravel replenishment to spawning loci, degradation of pools by sediment filling, and channel adjustment under the adjusted flow regime.

Between 2008 and 2011, Tetra Tech (2011) assessed sand storage and sources within Reach 1A. The amount of sand within the channel and the location of other sources are useful for understanding which areas are more susceptible to its deposition. Sand transported on the bed surface is much more likely to deposit between larger particles where it is sheltered from the force exerted by the flowing water. Such transport and resulting deposition can clog gravel interstices, reducing hyporheic ventilation, as observed during the egg survival/sand accumulation study. Several sand source areas were noted in Tetra Tech (2012), including eroding banks, bluffs, floodplain, and side channels. However, flows capable of accessing and eroding these storage sites are not known, and therefore, the change in sand storage and the rate of contribution to the channel from these sources are also presently unknown.

In 2011, DWR began a spawning gravel sand accumulation study (Monitoring and Analysis Plan (MAP) Study 27) in collaboration with the USFWS Egg Survival and Emergence in Reaches 1A and 1B of the San Joaquin River Study (MAP Study 8). Results indicate variable egg survival that correlates well with sand accumulation. Sand transport was observed to vary across the five study sites, which were evenly spaced between Friant Dam and Highway 41. The upstream-most site (at River Mile (RM) 266.7) experienced the least sediment transport and deposition, while these attributes generally increased with distance downstream. The greatest transport and deposition occurred at the fourth site downstream (RM 258.6). Transport and deposition of sand decreased at the fifth site (RM 255.5) relative to the fourth site. These results suggest local sources supplying sand, a translating sand pulse, and/or differential sand storage within the channel and are supported by sand mapping efforts by Tetra Tech (2011) and bed sample results collected by DWR (SJRRP, 2012). Furthermore, results of this study demonstrate that the amount of sand being transported and deposited within the artificial redds is sufficient to inhibit egg survival.

In 2012, the USGS began monitoring the contribution of sediment provided by two intermittent tributaries within upper Reach 1A called Cottonwood Creek and Little Dry Creek. Though little, if any, coarse sediment is likely being supplied by these ephemeral streams, it is possible that they are providing sand-sized sediment to the main-stem San Joaquin River. Future monitoring results will provide information to quantify their contribution.

1.3 Anticipated Outcomes

The objective will be to characterize gravel and sand mobility in potential spring-run spawning habitat, and to map mobility characteristics at each site. These maps will be used as layers that will be joined with other habitat characterizing efforts (see MAP Study 40) to provide a habitat suitability index (HSI) throughout the Spring-run Chinook salmon spawning habitat. With the HSI maps the amount of spawning habitat deemed to fall within suitable characteristics will be delineated, quantified, and compared to the study's goals. In addition, the mobility characteristics will be used to consider methods of expanding spawning habitat through enhancement strategies if it is determined that there is a deficit in spawning habitat.

Specific outcomes will include the following:

- Shape files delineating extent of active layer depths as a function of flow level.
- Sand transport rate as a function of flow at three sites.
- Preliminary gravel transport rates as a function of flow at the same three sites.
- An appropriate sediment transport formula as determined by comparison with the bedload samples at varying discharges.

1.4 Methods

Type of Study: Predominantly a field study with some minor hydraulic modeling support.

Reach(es): Upper five miles of Reach 1A

The following is a list of tasks necessary to achieve the goals and objectives of this scope:

1. **Plan data collection effort**
   a. DWR collaborated with fisheries scientists to identify primary spring-run spawning locations at which to focus data collection efforts. The SJRRP SRH-2D calibrated hydraulic model output was used to delineate areas with suitable flow velocity and depth at anticipated spawning season flows. Suitable areas are targeted for each of the proposed investigations (i.e., gravel mobility and sand-gravel transport rates).
   b. Areas where the flow model suggests suitable flow depth and velocities for spawning salmon were used to determine best sites for force gauge surveys.
   c. Areas with predicted heightened shear stress were delineated and the transport rate investigation targeted these areas so as to monitor localized bed mobility during higher return interval flow events. As best as possible, based on field

limitations, channel traversing cross-sections were selected immediately downstream of these zones. These cross-sections will be used to monitor sand and gravel transport at anticipated managed flow releases. They are also accessible for bedload sampling equipment at non-wade-able flow levels.

2. **Implement gravel mobility data collection effort**
   a. DWR will deploy and survey radio frequency identification tags (RFID)-tagged tracer particles to determine movement during pulse flows. The attributes of each tracer will be recorded with its associated RFID tag code. Tracer placement at each site will bracket the areas anticipated to have the highest potential for transport at low return interval flow levels. Deployment will occur immediately prior to anticipated 1,200 cfs or greater flow releases. Post pulse flow surveys will be conducted to relocate non-mobilized tracers. Each tracer's diameter and mass will be compared to the shear stress exerted on it during the peak flow as predicted from the 2D hydraulic model.
   b. DWR, with the assistance of other SJRRP agency personnel, will characterize the bed's surface texture in the vicinity of placed tracers. The bed's surface grain size compositions are necessary for applying measurements of critical shear stress with respect to particle size and each size's proportion of the bed surface. This effort can be coordinated with Reclamation to supply information to the facies mapping.
   c. DWR will perform a force gauge survey of particles larger than 32 millimeter by selecting representative areas on each riffle and pool tail near tracer cross-sections to measure *in-situ* bed surface particles' resistance to motion. The results of this survey will produce trends of the thresholds of mobility (incipient and fully mobile thresholds as measured using the dimensionless shear stress) as a function of particle diameter (see Mobility journal article, in preparation). The midpoint between these thresholds for a given particle diameter will be used to determine the 50 percent mobile trend for each site at a given flow. This 50 percent mobile particle size will be used to approximate the bed's active layer depth.
   d. DWR, with the assistance of other SJRRP agency personnel, will measure channel hydraulic characteristics at key flows using the following three techniques:
      i. Survey water surface elevation using a Real Time Kinematic (RTK) GPS with a vertical accuracy of approximately 2 centimeters. DWR will use this data to calibrate the 2D hydraulic model at the selected locations and observed flow levels.
      ii. Measure flow velocity and depth using an Acoustic Doppler Current Profiler (ADCP) along channel-spanning transects. DWR will use the measured water column depth and mean water column velocity to validate the calibrated hydraulic model's prediction.
      iii. Add additional pressure transducers to provide a continuous record of stage during the pulse flow release, if needed.

3. **Implement sand supply data collection effort.**

   a. Tetra Tech will survey sand supply from channel, bank, and floodplain sources to determine change in volume from previous measurements and to keep downstream sand transport measurements in the proper context of sand supply (i.e. bed material, pool, channel margin supply, or other). Two types of data collection will be needed:
      i. Tetra Tech will position stations for repeat channel spanning bedload measurements immediately downstream of spawning habitat as determined in 1.a. A hand-held Helley-Smith bedload sampler with a 0.250 mm mesh bag will be used to collect samples during the inclining limb of flow pulses at a range of wade-able flow levels. Three non-wade-able flow levels will be monitored for bedload transport using a cataraft and TR-2 bedload sampler with a 0.250 mm mesh sample bag. Efforts will be made to coordinate bedload sampling activities and locations with the needs of other agencies (Reclamation and USGS).
      ii. Bedload samples will be integrated at each location to determine the transport rate corresponding to the monitored flow. A sediment rating curve will be developed from the results at each site in the context of availability of sand for transport (i.e., upstream source is only bed material, pools and/or margins have an estimated volume of sand).

4. **Analyze data to provide the information for relative habitat suitability of each site**
   a. DWR developed a 2D hydraulic model of Reach 1A in 2009 (DWR, 2010) and has since passed on the model to Reclamation for further development. The existing mesh for this model will be evaluated for appropriateness and applied where possible to eliminate duplication of previous efforts.
   b. If necessary, DWR/Tetra Tech will provide updated elevations for creating a mesh with the most recent topography and project horizontal and vertical datum.
   c. DWR will request Reclamation to supply results from the existing calibrated model for flow simulations at levels experienced during monitored events. DWR/Tetra Tech will use these simulations and compare with calibration and validation data for the model using water surface elevation and ADCP survey data, respectively, to quantitatively assess its predictive capability.
   d. DWR will use the model results to compare the simulated hydraulics experienced at each tracer's initial location with the tracer's size. This comparison will provide a means of validating of the force-gauge-measured critical shear stress.
   e. DWR will calibrate gravel transport rate equations using the measured critical shear stress, bed grain size, and all appropriate bedload transport measurements available. The most accurate and appropriate sediment transport formula as determined by comparison with the bedload samples at varying discharges will be an end product.
   f. DWR will use the hydraulic model to run flushing flow scenarios to predict the mobile area of spawning areas. The metric will be the shear stress capable of mobilizing 50 percent of a particle diameter as determined from the function developed in 2.c. Each of the model nodes predicted shear stress will be used to

compute the 50 percent mobile grain diameter and delineate into polygons (i.e., shape files).

g. The sand transport rates will be used with results from the sand accumulation study to quantify the longevity of clean spawning gravels. Transport rates will be applied to measured trap efficiency of cleaned gravel surfaces. Accumulated sand can then be mapped into polygons or gradationally. Spawning areas can then be compared for expected longevity and rehabilitation potential.

1.5 Deliverables and Schedule

Deliverables for this effort will consist of a preliminary technical memorandum (TM) and final TM as well as SJRRP Data Reporting updates. The preliminary TM will document methods used and the preliminary, non-validated critical shear stress for each location for use in interim calculations. A final TM will include the appropriate calibrated and validated sediment transport formulae, monitored sand storage and sand supply rates, and gravel depletion rate based on several flow scenarios and grain sizes. GIS shape files will be provided that delineate areas predicted to be maintained via gravel flushing using the active depth and areas at risk of degradation due to sand accumulation (i.e., high supply rate as bedload and absence of gravel mobility).

The work is being implemented based on the following timeline.

1) Identified priority reach boundaries and targeted areas from readily available model predictions of suitable flow depth and velocity with collaborators and fish specialists in Spring 2014.
2) Performed a site reconnaissance to locate monitoring sites based on field conditions in May 2014.
3) Performed force gauge surveys activities at sites with suitable spawning hydraulics as of Spring 2014.
4) Preliminary critical shear stresses from force gauge survey results will be reported in the Preliminary TM by December 2014.
5) Bedload sampling at three sites will be performed during wade-able flow levels and during three bankfull (~1,300 cfs) and greater flows that are sufficiently different and of sufficient duration beginning in 2014.
6) ADCP and water surface elevation flow monitoring activities will coincide with bedload sampling events in Water Year 2014 and conclude after the third sampling event.
7) Sand influx and storage surveying will commence in November 2014 through Winter 2015.
8) The 2D hydraulic model will be calibrated and validated using monitored flows in after the bed load monitoring has completed.
9) Sediment transport equations and monitored rates will be provided approximately four months after the final bankfull bedload sampling event. If tracers have been sufficiently monitored the validated entrainment thresholds will also be included in this final TM anticipated by December 2015.

1.6 Budget

The total cost estimate is $130,000 for 2015.

Table 1-1. Proposed 2015 Budget

Task	Cost
Field Data Collection	$80,000
Analysis	$45,000
Reporting	$5,000
Total	**$130,000**

1.7 Point of Contact / Agency Principal Investigator

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1.8 References

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