Study 51

Sand Accumulation in Spawning Gravels

Final
2015 Monitoring and Analysis Plan

SAN JOAQUIN RIVER
RESTORATION PROGRAM

January 2015

1.0 Sand Accumulation in Spawning Gravels

Themes:

- 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-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-009c: Does sedimentation negatively impact spawning in Reach 1? If so, are there strategies available to reduce its impacts (e.g., sedimentation basins, sediment removal, watershed rehabilitation)?

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 contains and is expected to maintain each of these attributes in high quality must be used to quantify the amount of suitable spawning habitat. The degree to which sand accumulates within the gravel interstices will directly affect the hyporheic water exchange and its quality, and the potential for adverse effects caused by fine grains (e.g., entombment of fry). Therefore, understanding the flow conditions under which sand will accumulate over the immobile gravel bed and redds is necessary for managing salmon spawning and incubation habitat in a river system prone to transport sand while gravels remain immobile.

1.2 Background

The completion of Friant Dam in the 1940s resulted in a coarsened bed texture downstream. However, in addition to bed erosion, other processes such as erosion of stored bank deposits and floodplains, aggregate mining waste, 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, U.S. Department of the Interior, Bureau of Reclamation (Reclamation) has proposed quantifying the spawnable area based on a layered approach of the above compilation of characteristics (see Reclamation 2013, and Monitoring and Analysis Plan (MAP) Study 40).

Considering that the purpose of this scope of work is to investigate and predict sand accumulation within spawning gravels, the relevant previous and ongoing studies include:

- Gravel mobility (see MAP Study 28)
- Sand storage and sources (see 2011 Annual Technical Report (SJRRP, 2012))
- Sand accumulation in artificial redds (see MAP Study 27)
- Egg survival in artificial redds (see MAP Study 8)

- Tributary sediment supply rates (see MAP Study 22)
- Bedload transport rates (see MAP Study 28)
- Hyporheic flow
- Fry emergence (see MAP Study 8)

The following describes these relevant efforts in more detail.

Reach 1A Spawning Area Bed Mobility (MAP Study 28): 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 dimensionless critical shear stress 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 Program of gravel replenishment to spawning loci, degradation of pools by sediment filling, and channel adjustment under the altered flow regime.

Sand Storage in Reach 1(Refer to 2011 Final Annual Technical Report (SJRRP, 2012)): Between 2008 and 2011, Tetra Tech (2011) mapped 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.

Effect of Scour and Deposition on Incubation Habitat in Reach 1A (MAP Study 27) and Egg Survival and Emergence in Reaches 1A and 1B of the San Joaquin River (MAP Study 8): In 2011, DWR began a spawning gravel sand accumulation study in collaboration with the USFWS egg survival study. Results indicate variable egg survival that correlates inversely 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, the amount of sand being transported and deposited is sufficient to inhibit egg survival.

USGS San Joaquin River Tributary Sediment and Geomorphology Study (MAP Study 22): 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.

Reach 1A Spawning Area Bed Mobility (MAP Study 28): In 2013, DWR proposed monitoring bed load transport in Reach 1A (SJRRP, 2014). The data produced from this study will be used to quantify fractional transport rates as a function of discharge and location. The results from bed load transport studies on the reach are intended to provide insight on the sediment budget proximal to spawning gravels.

Hyporheic Flow: In 2013, Reclamation proposed monitoring hyporheic flow at sites where trapped-and-hauled salmon constructed redds in Water Year (WY) 2014 (SJRRP, 2014). Included with the permeability measurements will be bulk samples of the bed from the vicinity of the redds and permeability measurements locations. The results from this study will include a change in permeability with time assessment and assumptions can be made as to the original sediment composition post redd construction. Therefore, sand accumulation over the redd surface can be quantified, compared with change in permeability, and related to egg survival and emergence success.

Egg Survival and Emergence in Reaches 1A and 1B of the San Joaquin River (MAP Study 8): In 2013, USFWS proposed monitoring fry emergence from trapped-and-hauled salmon constructed redds in WY 2014 (SJRRP, 2014). The results of this study in tandem with the Reclamation study should produce relevant correlations of relationships of hyporheic flow, sediment composition, and egg survival and fry emergence success. In addition, the results should provide a means of validating the layered approach's (MAP Study 40) predicted salmonid spawning gravel locations.

1.3 Anticipated Outcomes

There are three objectives to this scope of work:

1) Field measure the cumulative distribution of grain scale relief, known as the “roughness geometry function (RGF).”

2) Test a method of predicting sand accumulation within the gravel bed for a range of different flows.

3) Extend the method to sites across the reach and develop predicted sand accumulation as a function of discharge, sediment transport, and location.

The overall outcome will be a predicted sand accumulation depth within the gravel bed interstices as a function of discharge. Relating the predictions to changes in rates of down-welling, permeability, and egg survival and fry emergence will allow flow managers the ability to make decisions based on quantified effects. For example, fall pulse flow levels may be tuned so as to prevent burial of spring-run Chinook salmon redds based on their location. Additionally, results will be used to define sand prone sites. In doing so, the results can be used as part of the layered approach to quantifying spawning habitat (see MAP Study 40).

1.4 Methods

Type of Study: combination of modeling and field studies.

Reach(es): Upper Reach 1A

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

1) Plan data collection effort

a) DWR will collaborate with fisheries scientists to identify primary spring-run spawning locations at which to focus data collection efforts. There is potential for fall-run spawning to be segregated from or otherwise downstream of the spring-run spawning reach where sand supply is known to be greater. Therefore, additional consideration will include investigating the upstream limits of the anticipated fall-run spawning areas where sand supply is likely to be more limited and as a result more controllable. The SJRRP SRH-2D calibrated hydraulic model output will be used to delineate areas with suitable flow velocity and depth at anticipated spawning season flows. In addition, USFWS performed trap-and-haul of adult fall-run Chinook salmon in 2013. Their redd locations will be used as well to select sites that are more likely to be used as spawning and incubation habitat. Reclamation and USFWS have already provided the model output information and 2013 trap-and-hauled redd locations, respectively.

b) DWR will also assemble data collection plans that outline schedule and resource needs so that data collection assistance (e.g., local bedload sampling, local hydraulic monitoring for model calibration and validation, RGF measurements) can be identified and duplication of efforts will be avoided. Additionally, DWR will provide materials and labor to fabricate necessary equipment for quantifying the RGF.

c) The Reclamation has already provided 2D hydraulic model output for a range of flows within those expected to occur during the fall pulse. Additional model runs may be requested from Reclamation at specific flows and across other parts of the reach than provided thus far. These 2D model results are necessary for providing the local flow velocity and shear stress for each flow for use as analytical input.

2) Implement RGF data collection effort

a) DWR will provide equipment, supplies, and labor for photographing the submerged bed surface as part of the RGF measurement effort. A frame will be used to define and confine sand to an area approximately a meter square. Sand will be added at known volumes incrementally with photographs taken at each increment. The amount of area covered by the sand will be determined from each increment until 100% coverage is reached. If necessary, DWR will purchase software capable of quantifying the grain size statistics from the bed photographs. From the measured percent sand coverage per volume of sand added a cumulative distribution curve will be generated. The curve will define the RGF. Up to 5 areas at a site will be measured for its RGF to assess for variance.

b) If necessary, DWR will characterize the bed's surface texture in the vicinity of test locations. The bed's surface grain size compositions may be necessary for (1) determination of the upper limit of the prediction (i.e., when the bed's framework becomes mobile) or (2) validating the photographically determined grain size statistics with pebble count produced statistics.

3) Implement sand accumulation calculation.

To help meet objectives 2 and 3, DWR will measure channel hydraulic characteristics at a range of flows less than 700 cfs using the following techniques:

a) Survey water surface elevation using a Real Time Kinematic (RTK) GPS with a vertical accuracy of approximately 2 centimeter. DWR will use this data to provide a quantitative means of assessing the calibrated the 2D hydraulic model simulation results at the study sites at the monitored flow levels. The calibrated model will produce a prediction of the local hydraulics. If necessary, the model runs will be further calibrated by adjusting the roughness parameter so as to produce flow depths similar to those observed.

b) Measure flow velocity and depth using either an Acoustic Doppler Current Profiler (ADCP) or Acoustic Doppler Velocimeter (ADV) along channel-spanning transects and at points local to RGF test areas. DWR will provide the measured water column depth and mean water column velocity to validate the calibrated hydraulic model's predictions.

c) U.C. Santa Barbara will parameterize a pre-defined model framework (Pellachini et al., in review) to predict the quantity of sand accumulated between the bed's surface framework grains. Necessary parameters include the field measured RGF and the validated 2D model's predicted shear stress which will be adjusted with the relationship of shear stress with sand content.

4) **Predict sand accumulation with respect to flow level and location.**

a) DWR developed a 2D hydraulic model of Reach 1A in 2009 (DWR, 2010). Since then Reclamation has continued to develop flow simulations throughout the study reach. Existing simulation results will be obtained from Reclamation and compared to hydraulics as measured in the field as per 3.a-b. The existing mesh for this model will be evaluated for appropriateness and any abnormalities will be brought to Reclamation's attention. In doing so, the 2D model shall be updated with the most current topographic data thereby making future hydraulic simulations more accurate.

b) U.C. Santa Barbara will use the 2D hydraulic model's calculated shear stress, and ultimately predict the sand accumulated at each grid node. The key metric will be the shear or depth average flow velocity. Model nodes will be binned according to accumulated sand at each flow and the resulting histograms displaying proportion of bed containing different thicknesses sand will be presented.

c) Accumulated sand will then be mapped into polygons. Spawning areas will then be compared for effect of flow level on the accumulation of sand at each site, and rehabilitation potential of flows (e.g., flushing effect). Furthermore, these polygons can be overlain onto the other spawning habitat parameter layers to assist in quantifying suitable spawning area (MAP Study 40).

1.5 Deliverables and Schedule

Deliverables for this effort will consist of two preliminary Technical Memoranda (TM) and a final TM. The preliminary TMs will document methods used and the preliminary test results including the uncertainty of the prediction. A final TM will include the appropriate calibrated and validated sand accumulation predictions for up to five sites spanning Reach 1A. GIS shape files will be provided that delineate area's predicted sand accumulation for each flow scenario.

The proposed work will be implemented based on the following timeline:

- Identify priority reach boundaries and target areas with collaborators and fish specialists from readily available model predictions of suitable flow depth and velocity, and from 2013 trap-and-hauled fall-run Chinook redds by September 2014.

- In Fall 2014, DWR will focus RGF test activities around an area (e.g., Riffle 38 or 40) most likely to experience sand transport in appreciable quantities, salmon spawning, and where the measurement may be useful for other studies.

- Results from the RGF field measurement test will be reported by DWR and reviewed by U.C. Santa Barbara in a TM by March 2015.

- DWR will perform ADCP and water surface elevation flow monitoring activities beginning in WY 2014 and conclude by Spring 2015.
- Sand accumulation predictions as a function of discharge at test sites will be completed by U.C. Santa Barbara after the Spring 2015 high flows.
- Model test and calibration results will be reported by U.C. Santa Barbara in a TM by October 2015.
- DWR will perform additional RGF measurements and flow velocity, sand content, and bedload monitoring at test sites spanning Reach 1A, will be concluded by Summer 2015.
- Prediction of sand accumulation as a function of discharge and location will be reported by U.C. Santa Barbara in a final TM by October 2015.

1.6 Budget

The total cost estimate is $100,000 for 2015.

Table 1. Proposed 2015 Budget

Task	Cost
Planning	$5,000
Roughness Geometry Function (RGF) data collection	$15,000
Sand Accumulation Calculations	$30,000
Sand Accumulation Prediction	$30,000
Reporting	$20,000
Total	**$100,000**

1.7 Point of Contact / Agency Principal Investigator

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1.8 References

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