Appendix B8. Intakes River Sediment Analysis – North Delta Intakes (Final Draft)

1. Introduction and Purpose

The purpose of this technical memorandum (TM) is to document the data sources and methodology used to analyze the suspended sediment in the Sacramento River at the Delta Conveyance Project (Project) intake locations. This TM also presents the suspended sediment settling velocity analysis for the particles at the intake locations using various state-of-the-art approaches. Further, the data and methodologies used to analyze Project-specific sediment quantities and off-site disposal estimates are discussed in this TM.

1.1 Organization

This TM is organized in the following main sections:

- Introduction and Purpose
- Background
- Methodology
- Analysis and Evaluation
- Particle Settling Velocity Analysis
- Sediment Capture and Disposal
- Results and Conclusions
- References
- Attachment 1 - Monthly Sediment and Sediment Disposal Calculations

2. Background

The Project includes two intake structures, C-E-3 and C-E-5, located at river mile (RM) 39.4 and RM 36.8 on the Sacramento River, respectively. Each intake is capable of conveying up to 3,000 cubic feet per second (cfs) for a total Project flow capacity of 6,000 cfs.

The intakes would include sedimentation basins to remove suspended sediment from the diverted river water. Each intake sedimentation basin would be sized, at a minimum, to capture 100 percent of the sand sized suspended sediment which includes a size greater than or equal to 0.0625 millimeter (mm) prior to the diverted flows entering the outlet channel into the tunnel conveyance system. Depending on a sediment particle's position in the water column as it begins the sedimentation process, smaller particles would also be captured. Captured sediment would be dredged annually, dewatered, dried, and disposed of at a permitted offsite disposal location. In an effort to appropriately size the intake facilities and estimate the number of annual truck trips required to transport the sediment, a suspended solids particle analysis was performed using data from two stream gauges located in proximity to the potential intakes on the Sacramento River. Generally, metal fish screens are used to prevent fish from entering the intake facility. The screens have 1.75-mm openings that allow water and sediment to enter the facility.

It is important to understand the fate and transport of particles within the intake structures. The particle fall velocity, along with the potential deposition of suspended sediments, are important design parameters because they determine the sedimentation management facilities size and therefore the overall site footprint.

The settling rate of suspended sediment it is related to the particle size. Capture efficiency of the sediment particles is related to the sedimentation basin length. In this study, the potential settling rate of particles is estimated based on five different methods, as presented in Section 5.

2.1 Data Collection and Information Sources

Data used for the Sacramento River suspended solids analysis were collected from the U.S. Geological Survey (USGS) *National Water Information System* (NWIS) (2020). USGS maintains gauges along the Sacramento River and publishes the available data online for each gauge. For this analysis, two gauges were used: the Sacramento stream gauge and the Freeport stream gauge.

Data collected from March 1957 to September 1979 were based on laboratory sampling and testing results from samples collected from USGS stream gauge 11447500, Sacramento. This gauge was located at Latitude 38 degrees (°) 35 minutes (’) 12 seconds (”), Longitude 121°30’16” using North American Datum of 1927 (NAD27) datum. Locally, this gauge was located along the river near I Street in downtown Sacramento. Available data for this location include the following particle size distribution analysis for suspended solids:

- By sieve analysis for larger-diameter particles (greater than or equal to 0.0625 mm)
- By fall diameter (deionized [DI] water) for smaller particles (less than 0.0625 mm)

Data collected from September 1979 to May 2019 were based on laboratory sampling and testing results from samples collected from USGS stream gauge 11447650, Freeport. This gauge was located at Latitude 38°27’22”, Longitude 121°30’01” using NAD27 datum. Locally, this gauge is located along the river near the Freeport Bridge over the river south of downtown Sacramento. Available data for this location include the following particle size distribution analysis for suspended solids:

- By sieve analysis for larger-diameter particles (greater than or equal to 0.0625 mm)
- By fall diameter (DI water) for smaller particles (less than 0.0625 mm)

Data collected for the Sacramento stream gauge were also available through the Freeport stream gauge, but redundant data were allocated to the corresponding stream gauge reference point.

Estimates of total sediment load and capture quantities at the Project intakes were developed using simulated data for river flow and diversion rates based on CalSim 3 analyses conducted by DCO and provided to DCA on March 25, 2021. The CalSim 3 results included the average monthly Sacramento River flow (in cfs) at the Freeport gauge and the average monthly total Project diversion rate for each month of the 94-year CalSim simulation period. The values provided does not include the effects of climate change.

3. Methodology

The following methodology was used to evaluate the suspended sediment concentration and particle size distributions within the Sacramento River:

- Retrieved suspended sediment and particle size distribution data from two USGS stream gauges near the proposed intake sites.
- Separated and organized data by sieve size, fall diameter, and river concentration.

- Confirmed information complies with the number of samples required for determining a statistical value for a range of data points.
- Applied statistical equations for the 98th percentile, 95th percentile, median, and mean for the applicable data available.

The following methodology was used to determine the sediment characteristics:

- Analyzed suspended sediment data from previous reports (CH2M, 2003) as a basis for settling velocity estimates.
- Reviewed the American Society of Civil Engineers' (ASCE's) Manuals and Reports on Engineering Practice No. 110 – Sedimentation Engineering: Processes, Measurements, Modelling and Practice (2007) and the ASCE's Manuals and Reports on Engineering Practice No. 54, Sedimentation Engineering (2006) about the settling velocity of suspended particles.
- Compared several settling velocity equations (e.g., from G.G. Stokes (1851) and Chakraborti et al. [2007]) and modified the Stokes law equation and two equations derived from the empirical relationships, as described in ASCE's Manuals and Reports on Engineering Practice No. 110 — Sedimentation Engineering: Processes, Measurements, Modeling and Practice (Manual 110) (2007).
- Estimated particle settling velocities for various sizes, densities, and porosities.

The information developed according to the methodology described above would be applied to estimates of water diversions by month at each Project intake. That analysis results in estimates of sediment loading and capture by particle size at each intake. Sediment loading and capture methodology included the following:

- Applied the median river concentration to the river flow to determine the total river sediment load for each month of the CalSim 3 simulation period.
- Conducted statistical analysis of CalSim 3 results to determine the minimum, median, and maximum flow diversion years based on water year type.
- Applied the median river concentration to the water diversions by month, distributed to each Project intake, for the minimum, median, and maximum flow diversion years based on water year type.
- Determined the total sediment diverted and the amount captured at each intake.
- Determined the work duration and the truck trips required to dredge, dry, haul, and dispose of the captured sediment for minimum, median, and maximum diversion years based on water year type.

4. Analysis and Evaluation

4.1 Particle Size Distribution

For each stream gauge location, the particle size distribution data were downloaded from the USGS NWIS (2020) and combined into a single Microsoft Excel data table. Valid data were separated by size and month and then sorted in ascending order. While data are available for particles up to 2 mm, particles larger than 1.75 mm were not assessed, because fish screen openings are generally no larger than 1.75 mm. Therefore, it is assumed for this analysis that no particle equal to or larger than 1.75 mm in diameter would enter the system.

Once data were organized and analyzed, the total available particle size distribution for each month ranged from 0–35 samples per month. Figure 1 shows the test values available for each particle size range.

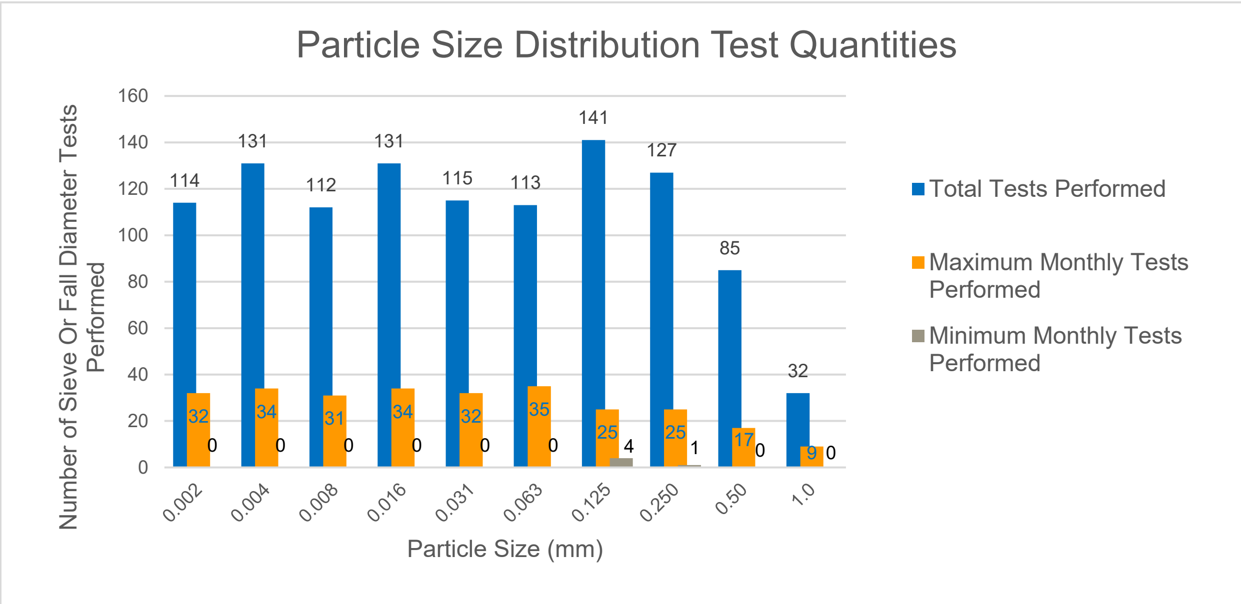


Figure 1. Particle Size Distribution Test Quantities

Based on an article written for the journal *Biometrika* by William Gosset under the pseudonym Student (1908), a minimum of 30 samples appears to be required to develop a valid statistical conclusion for the value of a sample series. Since many months do not have 30 samples, a by-month particle distribution analysis could not be used, so each value for a particular particle size range was based on the total collected data for that range. Table 1 summarizes the values used for each statistical method and particle size.

Table 1. Particle Size Distribution Percent Retained

Particle Size (mm)	98th Percentile for % Retained	95th Percentile for % Retained	Median for % Retained	Mean for % Retained
0.002	11	11	8	9
0.004	8	10	9	9
0.008	12	12	9	7
0.016	34	10	9	9
0.031	76	12	8	10
0.0625	2	3	12	9
0.125	0	0	7	9
0.25	0	0	3	5
0.5	0	0	0	1
1	0	0	0	0

Notes:
% = percent

4.2 Suspended Sediment Analysis

For the analysis of the suspended sediment concentration in the Sacramento River, a similar approach was used as for the particle size distribution. After the available data were collected from USGS (2020), the data were sorted by month and placed in ascending order for that month. In terms of distribution, year over year, August and November had the lowest number of samples reported (156 and 158 samples, respectively). May and December had the highest number of samples reported (315 and 296, respectively).

Figure 2 shows the number of samples collected by USGC for each month from February 1, 1973, to May 9, 2019.

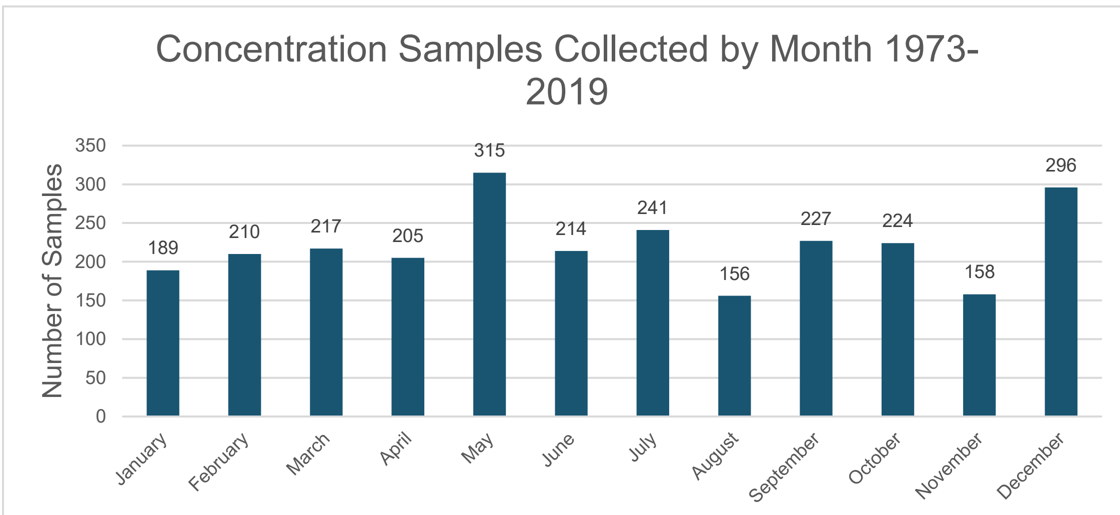


Figure 2. Monthly Suspended Sediment Concentration Sample Quantities

For each month, statistical values were assessed for 98th percentile, 95th percentile, median, and mean values (Figure 3). Upon comparison with individual values for Sacramento River concentrations, it was determined that the highest and average sediment loading values for each month was most closely represented by the 95th percentile and mean statistical values, respectively. However, using this approach assumes that the highest or average loading values would occur consistently in each month for a given year. This scenario is highly unlikely. However, using a less conservative percentile could reduce the sediment loading rate to a level that could lead to an under-designed facility.

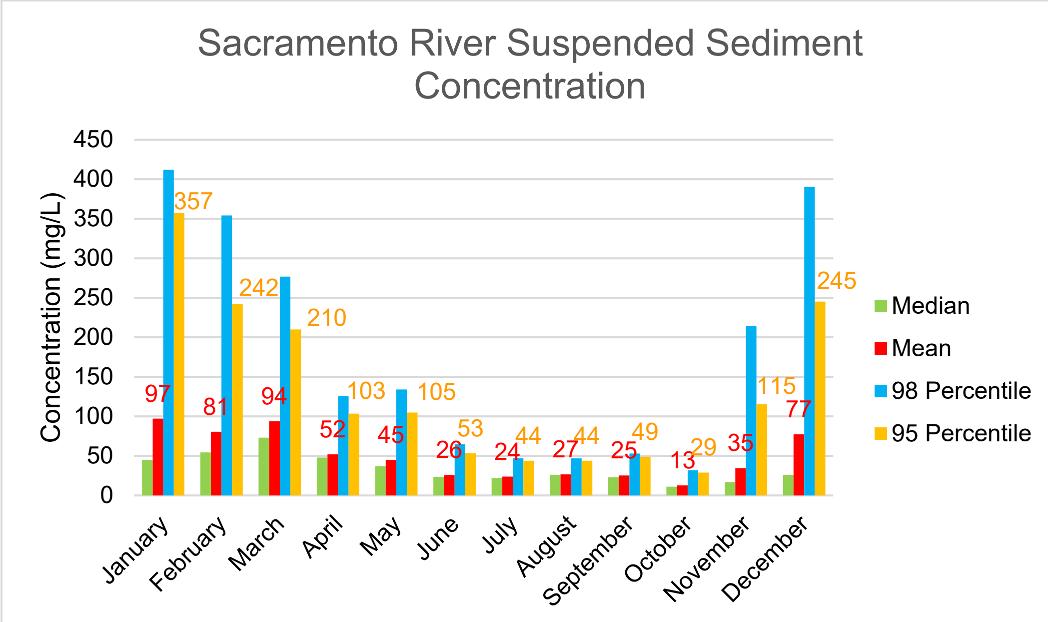


Figure 3. Monthly Suspended Sediment Concentration Values

4.3 Suspended Sediment Loading Recommendations

As previously discussed, each sedimentation basin would be sized to capture 100 percent of sediment particles greater than or equal to 0.0625 mm in diameter, but a percentage of smaller particles would also be captured. The percentage captured was calculated based on the settling velocity of each particle size (per Method 4 as discussed in Section 5), the flow velocity through each basin, and the length of the sedimentation basin. The flow velocity and the length of the sedimentation basin would vary based upon the intake layout for each site and the assumed operational flow diversion patterns. Project-specific suspended sediment loading is discussed further in Section 6.

5. Particle Settling Velocity Analysis

The settling of suspended particulate material depends on a variety of environmental factors, including organic or inorganic particle origin, shear flow (mixing), and other factors (Gregory, 1989). These factors affect aggregation (size and shape) kinetics. Due to variable porosity, size and shape, and uncertainty in the estimation of floc density, it is difficult to predict the settling rate of aggregates, which are often fragile, porous, wispy, and nonspherical (Chakraborti and Kaur, 2014; Guérin et al., 2019).

The determination of particle settling rate is a key factor for predicting the path of transport for suspended particles in a reservoir or sedimentation basin. Settling velocities often are calculated on the basis of Stokes law (Thomann and Mueller, 1987), which assumes particles to be solid spheres. Stokes law has many limitations. Therefore, there are many expressions that have been derived to estimate particle settling behavior based on shape, size, density, and porosity. Most of these approaches are modifications of Stokes law.

The suspended sediment data presented by CH2M (2003) were used in this analysis to estimate the settling velocity of the suspended sediment for the Project. These data were then used to estimate the settling characteristics of the particles at each of the intake sedimentation basins.

For this analysis, the settling velocity of particles (Thomann and Mueller, 1987) was estimated using the following approaches:

- Method 1: Stokes law settling velocity estimate
- Method 2: Chakraborti et al. (2007) settling velocity estimate
- Method 3: Particle shape factor settling velocity estimate – Stokes law (Thomann and Mueller, 1987) and Manual 110, page 40–41 (ASCE, 2012)
- Method 4: Manual 110 settling velocity estimate, page 41, Equation 2-46g (ASCE, 2012)
- Method 5: Manual 110 settling velocity estimate with shape factor, page 41, Equation 2-46h (ASCE, 2012)

5.1 Particle Data

The sediment data used in the settling velocity analysis were collected from the Suspended Sediment Loading and Transport in the Freeport Regional Water Project TM (CH2M, 2003). The suspended sediment data from the Sacramento River at or near Freeport were collected from largely from the NWIS [USGS, 2020]).

Median suspended sediment values were used rather than mean for this analysis, because the median value is based upon the "middle" value and the "mean" is based upon the "average" value (sum of all values divided by the number of values). Due to the calculation method for the "mean" value, a few very large or very small numbers can make the value very different than the "median" value. The median value would be more representative of a large number of sediment samples.

The suspended sediment concentration in the Sacramento River is three to four times higher in the winter than in the summer (CH2M, 2003). The median suspended sediment particle concentration from the 1973–2001 period measured by the USGS gauge 11447650 at Freeport ranged between 19 and 114 milligrams per liter (mg/L) from November through April and between 17 and 35 mg/L from May through October. Sieve analysis particle sizes were not available for the USGS Freeport station but were available for the USGS Sacramento station approximately 15 miles upriver from the Project, just downstream of the American River confluence and in the relative same Sacramento River reach as the intake locations for this analysis (CH2M, 2003).

Figure 4 shows particle size distribution of the noncolloidal fraction of particles suspended in water. The noncolloidal particles (greater than 0.002 mm or 0.00008 inch) represent clay, fine sand, and medium sand. Figure 5 shows the percent fines of various particle sizes. About 40 percent of particles are less than 0.0625 mm, 0.0025 inch). For practical purposes, this fine fraction of particles is considered as near-colloidal, and the settling of those fractions within the intake basin would be insignificant. In essence, those particles would be in suspension within the intake basin area. Some of those small fractions could collide as a result of mixing caused by flow conditions and form larger flocs that could settle by gravity.

Larger sized particles (greater than 0.0625 mm or 0.0025 inch) are the size of interest in terms of potential sedimentation settling prior to reaching the back of the sedimentation basin. Therefore, the focus of this study was to characterize settling behavior of this larger fraction of particles, which is 60 percent of the suspended sediment particle load (Figure 5).

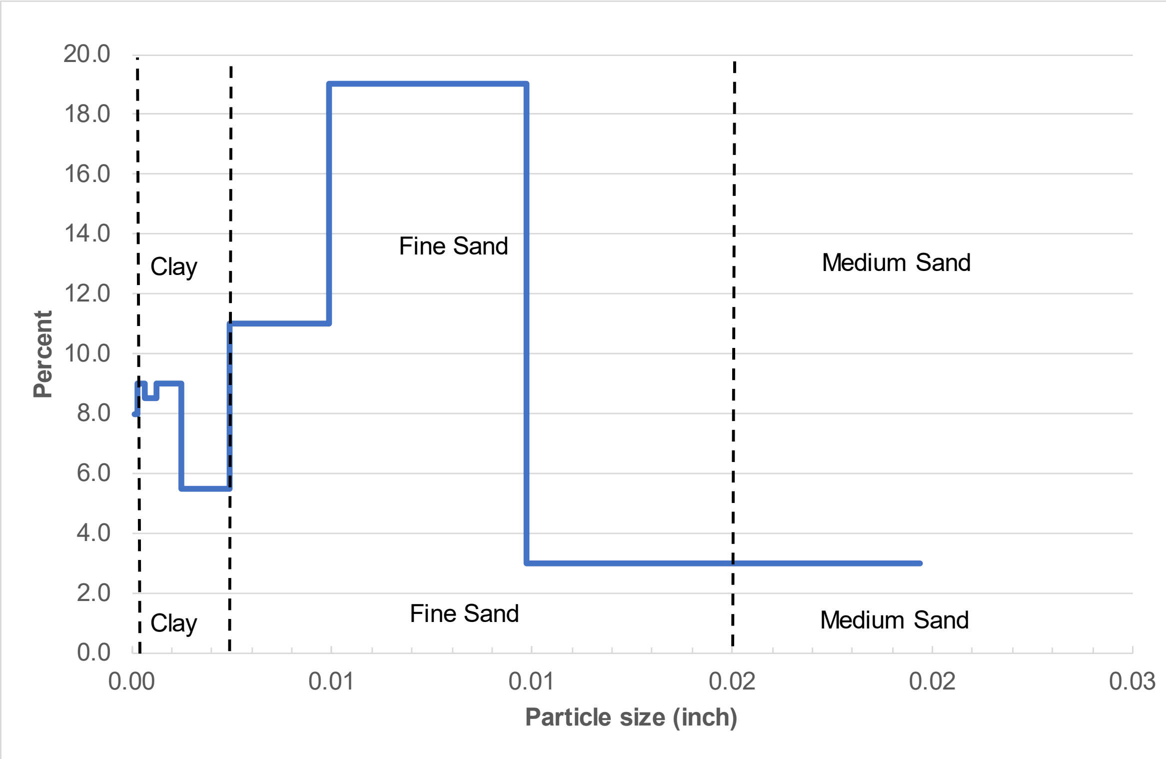


Figure 4. Particle Size Distribution of Noncolloidal Sediment Particles Greater Than 0.00008 inch

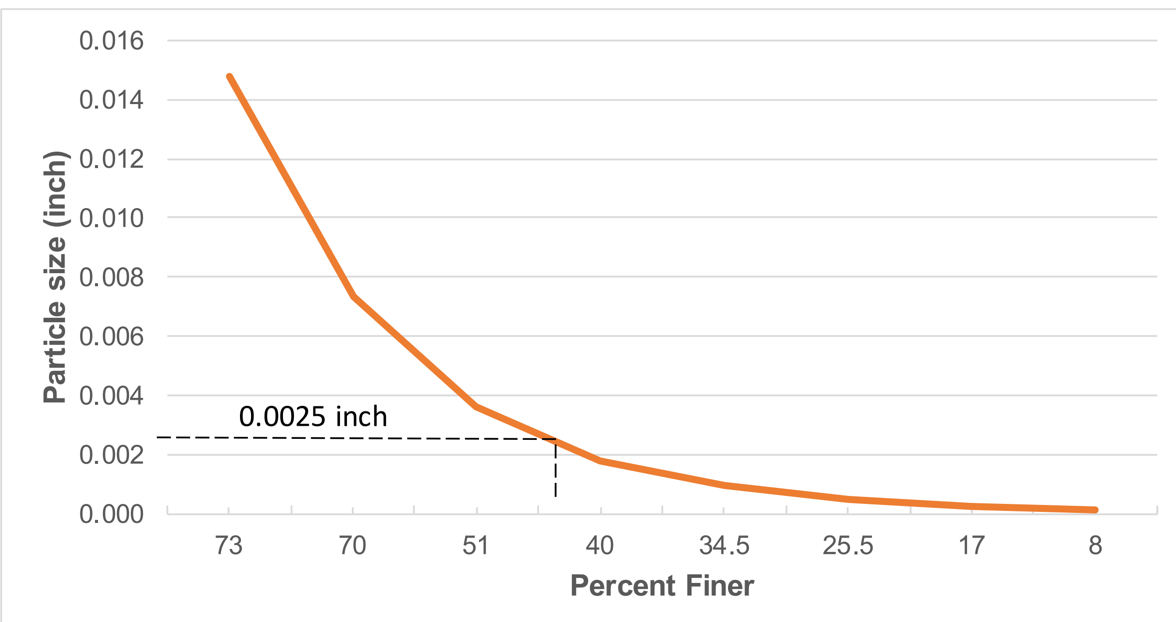


Figure 5. Percent Fines of Noncolloidal Sediment Particles Greater Than 0.00008 inch

5.2 Settling Velocity Analysis Using Various Approaches

This section discusses the settling velocity of suspended sediment particles, using various methods reported in the literature. Five methods developed from various concepts of particle shape and size were used to estimate potential settling of suspended particles. The estimate methods evolved from the consideration of particles as spherical or irregular shapes that are expressed by some form of shape factor. Because neither shape nor density was measured in this study, various approaches were used to estimate the spectrum of settling velocities.

5.2.1 Method 1: Settling Velocity Estimate Using Stokes Law

The settling velocities for suspended sediment particles of various sizes were estimated using Stokes law. The velocities determined from Stokes law provide the theoretical settling velocity of a spherical particle in motionless fluid. This is only an approximation of the real-world settling characteristics of sediment particles. Stokes law has been widely used to estimate settling velocities for many years, although this rule is developed for conditions with (1) a low particle Reynolds number (ASCE, 2012), (2) solid spherical particles, and (3) under laminar flow conditions. These conditions rarely exist in natural settings. In spite of these limitations, historically, the theoretical settling velocities have been used extensively to estimate particle settling velocity (Graf, 1971; Thomann and Mueller, 1987).

Stokes law is derived from the following equation (Thomann and Mueller, 1987):

$$V_p = \frac{g(\rho_w - \rho_p)d_p^2}{18\mu_w} \qquad \textbf{[1]}$$

Where:

- V_p = particle settling velocity, meters per second (m/s)
- d_p = particle diameter, meter (m)
- g = gravity constant = 9.81 meters per square second (m/s^2)
- ρ_w = density of water = 998 kilograms per cubic meter (kg/m^3) (62.3 lb/ft^3)
- ρ_p = particle density = 1,600 kg/m^3 (99.9 lb/ft^3)
- μ_w = viscosity of water = 1.408 x 10^{-3} kilograms per meter per second (kg/m/s) (3.4 lb/ft-h) at 7.5 degrees Celsius (°C)

Figure 6 shows the settling velocities derived from Stokes law for various particle sizes greater than 0.00008 inch using these parameters. Applicable values are also listed in Table 8 (Section 7).

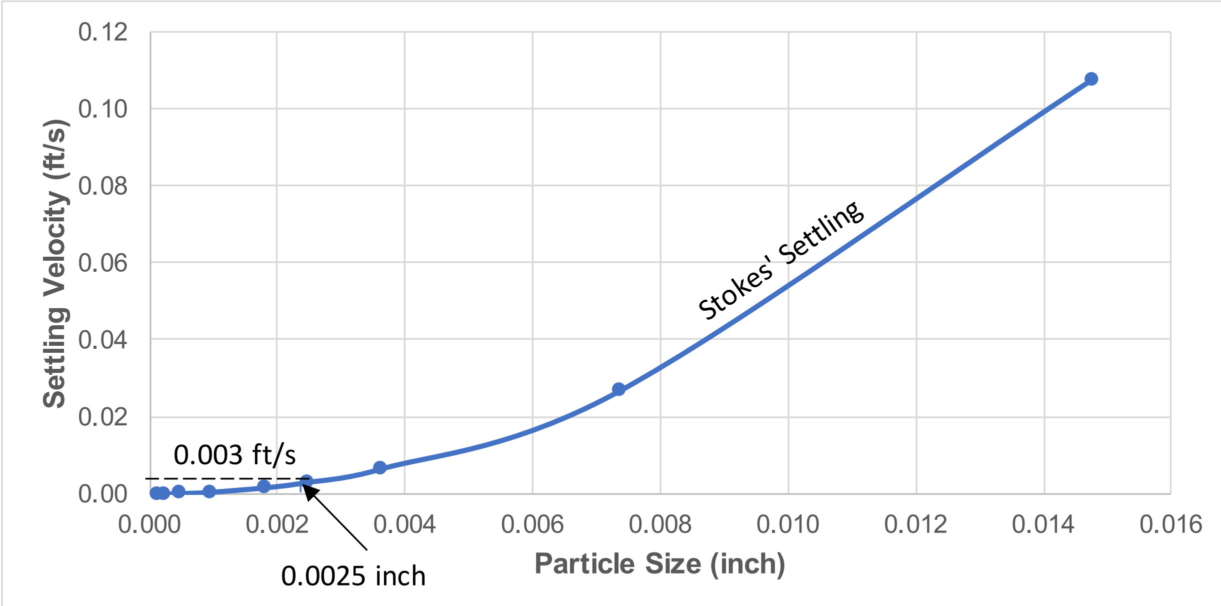


Figure 6. Method 1 Noncolloidal Sediment Particle Settling Velocity

Notes: Particles depicted on the figure are greater than 0.00008 inch.
Velocity was determine using Stokes law using a particle density of 1,600 kg/m3. (99.9 lb/ft3)

With a setting velocity of only approximately 0.0001 centimeter per second (cm/s) (0.5 centimeter per hour [cm/h], or 0.2 inch per hour [in/h]) for particles smaller than 0.00008 inch and a very low shear velocity requirement for resuspension, these particles have been considered nonsettling.

For comparison, the Stokes law equation was used to determine the settling velocity using a different set of values for the particle density and viscosity than the values shown underneath Equation 1. The complete set of parameters used for the Stokes law settling estimate includes the following:

V_p = particle settling velocity, m/s
d_p = particle diameter, m
g = gravity constant = 9.81 m/s^2 (32.2 ft/s^2)
ρ_w = density of water = 998 kg/m^3 (62.3 lb/ft^3)
ρ_p = particle density = 2,650 kg/m^3 (165.4 lb/ft^3)
μ_w = viscosity of water = 0.0014084 kg/m/s (3.41 lb/ft-h) at 7.5°C

Figure 7 shows the settling velocity estimated for various particle sizes for noncolloidal particles with higher particle density and lower temperature than the previous analysis. The settling velocity values are higher than the values presented on Figure 6. For example, the settling estimate for the largest particle (0.015 inch) presented on Figure 7 is double the value presented on Figure 6. For comparison, both estimates are plotted on Figure 8. The separation of the values increases as particle size increases, and the difference in particle density is more important than the smaller size range.

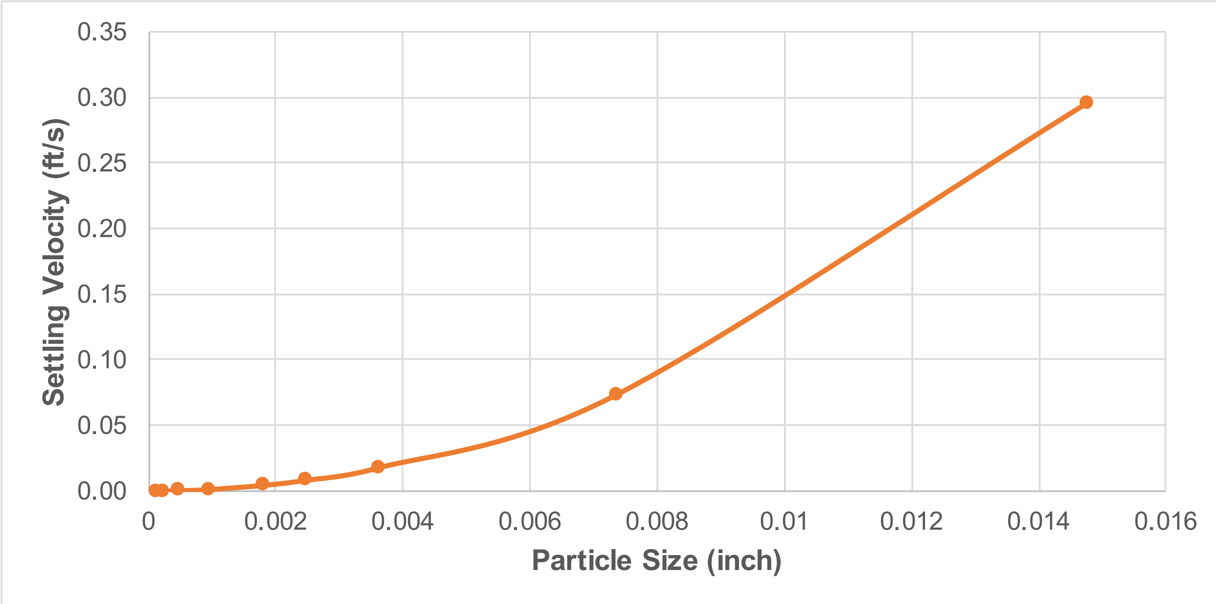


Figure 7. Method 1 Noncolloidal Higher-Density Sediment Particle Settling Velocity

Notes: Particles depicted on the figure are greater than 0.00002 inch.
Velocity was determined using Stokes law using a particle density of 165.4 lb/ft3.

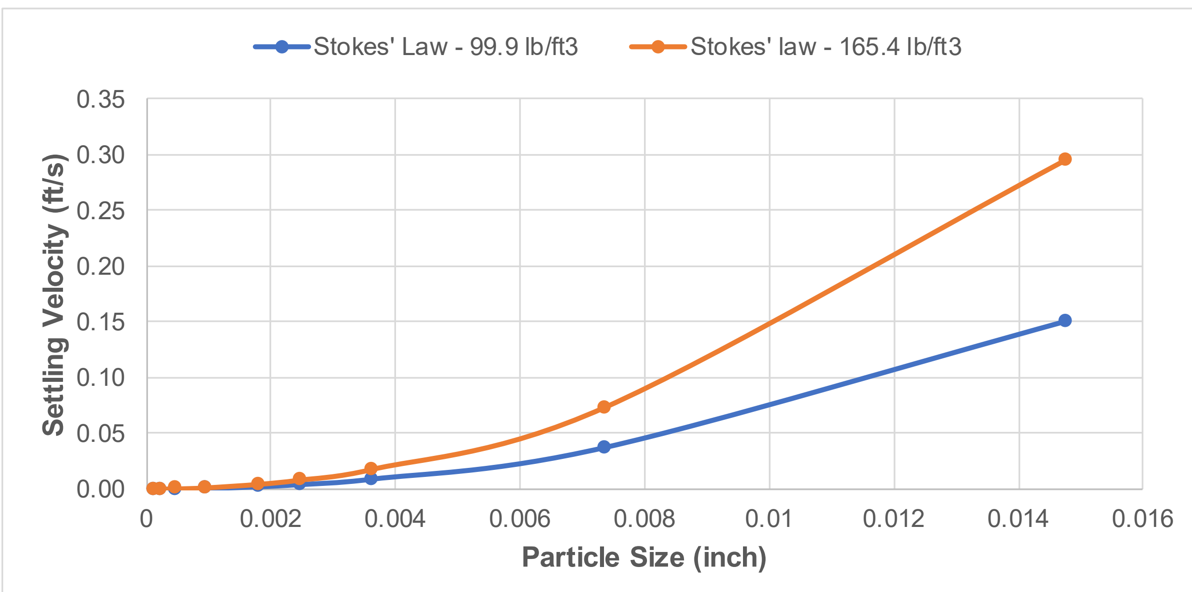


Figure 8. Method 1 Noncolloidal Variable-Density Sediment Particle Settling Velocity

Notes: Particles depicted on the figure are greater than 0.00002 inch.
Velocity was determine using Stokes law and a variable particle density, viscosity of water, and temperature.

5.2.2 Method 2: Settling Velocity Estimate by Chakraborti et al. (2007)

Stokes law is commonly used to determine particle settling velocity estimates; however, there are several limitations:

- There is a relatively small range of particle Reynolds numbers (less than 0.1) that the laminar drag assumption is valid for.
- Stokes law assumes that particles are spherical.
- The Stokes law influence of the floc's structure on the floc's density and permeability.

Significant prior research has been conducted on these topics. For instance, Graf (1971) reported the experimental work to extend the drag relationship for spheres to Reynolds numbers up to 800. McNown and Malaika (1950) conducted experimental work investigating the effects of shape and orientation of slowly settling particles and developed corrections to the drag relationship for these effects. Fractal geometry concepts for floc characterization have also been addressed by research (Chakraborti et al., 2003). Kranenburg (1994) described and derived relationships for the influence of fractal geometry on floc density and strength. Winterwerp (1998, 2002) extended fractal concepts to settling velocity, which includes the Schiller-Naumann drag expression, a shape factor, and the fractal geometry effects on particle density. Settling velocity estimates based on particle structure are a realistic assumption because particles as found in nature are often nonspherical, irregular-shaped, and porous. The Sacramento River's suspended sediments potentially have each of these qualities, so the particles cannot be expressed as spherical particles with constant density. Also, the flow and wind-induced mixing in a shallow waterbody like a river may prevent particles from floc formation as large flocs normally found in lake water. Suspended sediments in the Sacramento River are more like fine and medium sand (Figure 4) with relatively larger specific gravities than flocs of same mass observed in large lakes (Chakraborti et al 2007; Chakraborti and Kaur 2014).

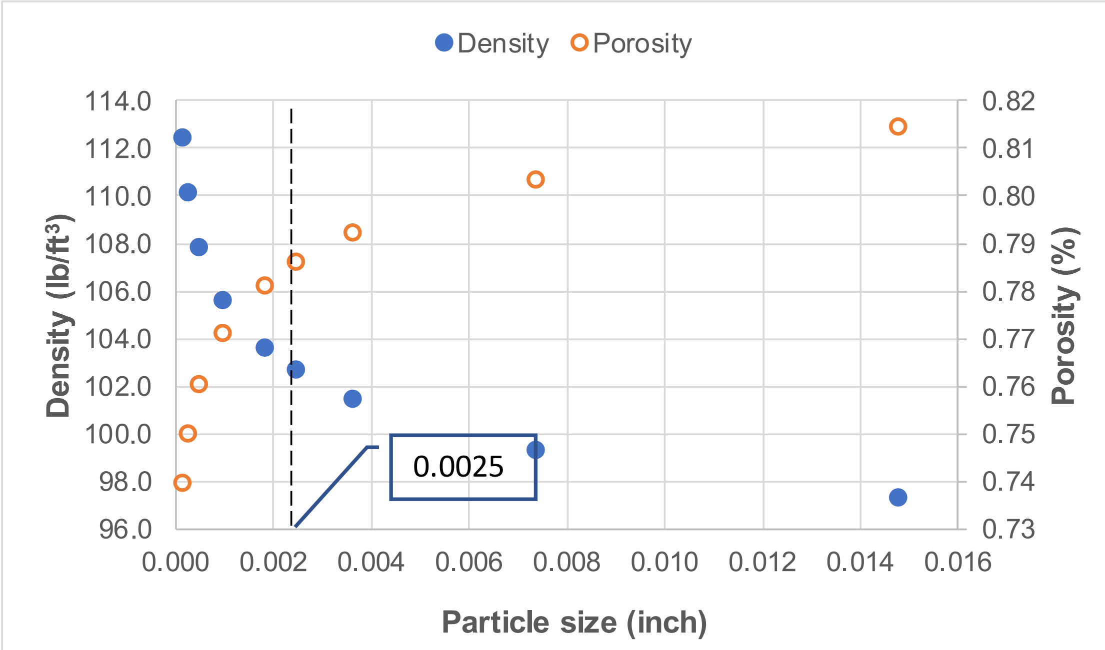
Particle density is not constant; rather, it changes with particle shape and size. Chakraborti et al. (2007) developed a relationship between density and porosity as a function of particle size, as shown in the following equation:

$$\rho = 1.23 * l^{-0.03} \text{ and } \phi = 0.87 * l^{0.02} \qquad \textbf{[2]}$$

Where:

l = the particle size
ρ = particle density
ϕ = porosity

Figure 9 shows the density and porosity of noncolloidal particles, using the Chakraborti et al. (2007) method.

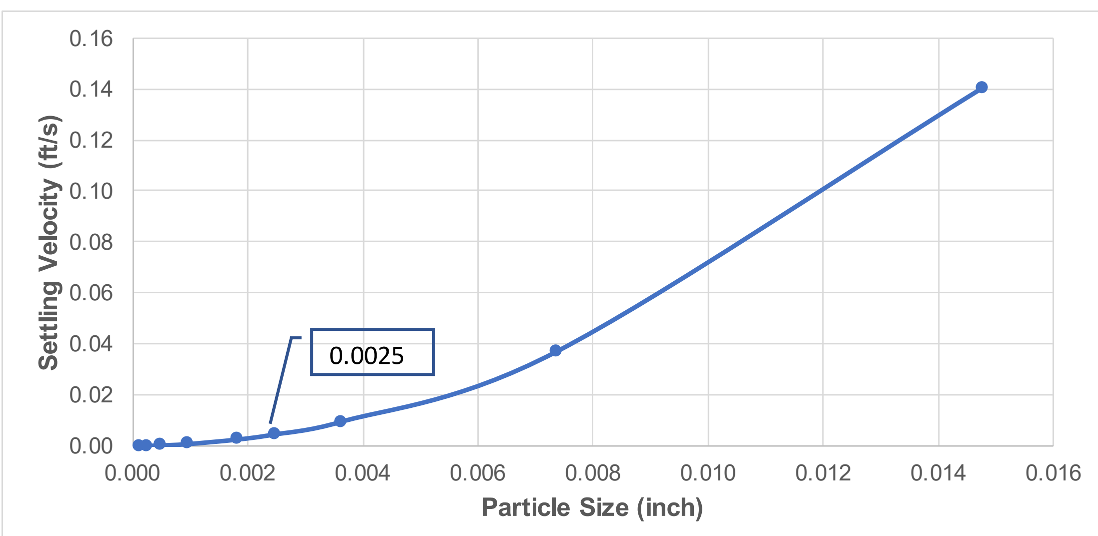


Source: Chakraborti et al., 2007

Figure 9. Method 2 Noncolloidal Sediment Particle Density and Porosity

Notes: Particles depicted on the figure are greater than 0.00008 inch.

The revised density and porosity of particles illustrated on Figure 6 were substituted for density and porosity in the Stokes law settling velocity equation. The resulting estimated settling velocity distribution for various particle sizes is presented on Figure 10. Applicable values are also listed in Table 8. In comparison with Method 1, the density of particles in this estimate varied with the particle size per Equation 2, and the settling velocity for particles less than 0.0025 inch is very low.



Source: Chakraborti et al., 2007

Figure 10. Method 2 Noncolloidal Sediment Particle Settling Velocity

Notes: Particles depicted on the figure are greater than 0.00008 inch.

5.2.3 Method 3: Settling Velocity Estimate Using Particle Shape Factor

Under the Method 3 approach, the Stokes law settling velocity was modified with a Corey shape factor of 0.7 from the Manual 110 [ASCE, 2012]. In this estimate, the viscosity of water was assumed as 3.41 lb/ft-h at 7.5°C, with a particle density of 136 lb/ft^3). Figure 11 shows the resulting particle settling velocity for various sizes. Applicable values are also listed in Table 8.

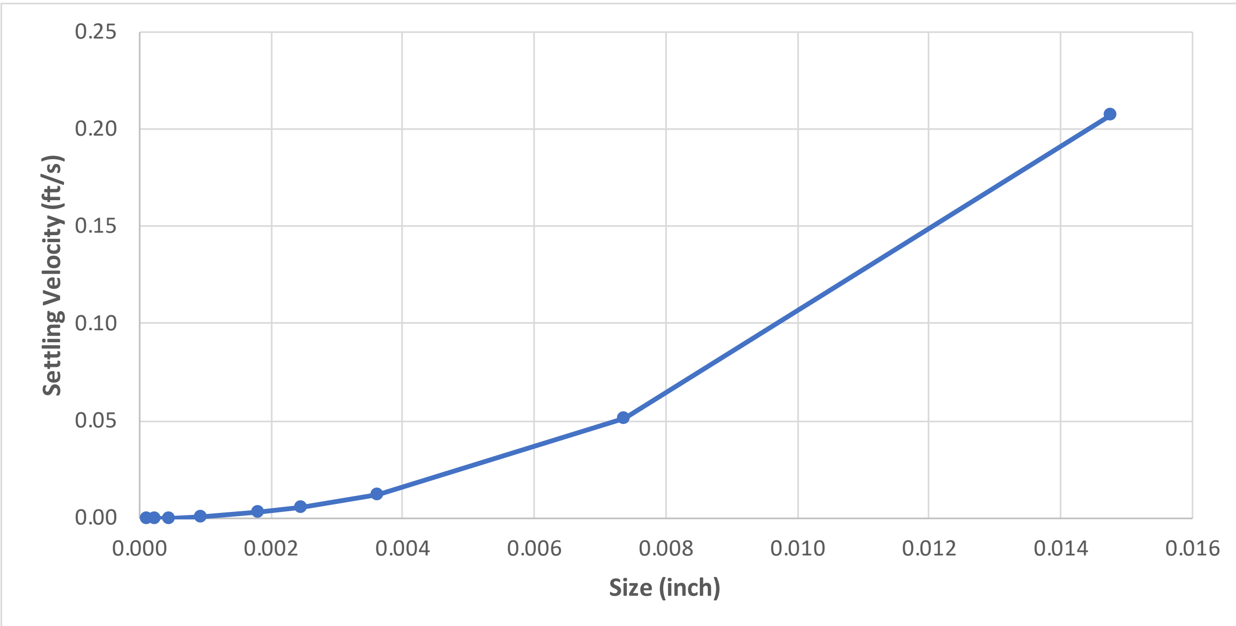


Figure 11. Method 3 Noncolloidal Sediment Particle Settling Velocity

Notes: Particles depicted on the figure are greater than 0.00008 inch with a Corey shape factor.

5.2.4 Method 4: Settling Velocity Estimate per ASCE Manual 110

Under the Method 4 approach, the settling velocity of particles is estimated using Equation 2-46g in ASCE's Manual 110 (2012).

Equation 2-46g $v_s = (gRD^2)/(18v)$ **[3]**

Where:

R = submerged specific gravity (SG) of quartz = 1.65

v = kinematic viscosity = 1.41568E-06 square meters per second (m^2/s) at 7.5°C per Equation 2-46h (ASCE, 2012)

Equation 2-46h $v = (1.79\ 10^{-6})/(1 + 0.03368T + 0.00021T^2)$ **[4]**

V as square meters/second

T = Temperature in Celsius

The settling velocity plot and values are shown on Figure 12 and listed in Table 8, respectively.

5.2.5 Method 5: Settling Velocity Estimate per ASCE Manual 110, with Shape Factor

Dietrich (1982) performed dimensional analysis to analyze sediment settling velocity data for natural particles. Later, Jimenez and Madsen (2003) fitted Dietrich's formula to an expression that was used for Method 5.

Under the Method 5 approach, particle settling velocity is estimated using Equations 2-48a and 2-48b in Manual 110 (ASCE, 2012), as follows:

$$W_* = (v_s)/[(gRD_N)^{1/2}] = [A + (B/S_*)]^{-1} \text{ with } S_* = [(D/4v)*(gRD_N)^{1/2} \quad \textbf{[5]}$$

Where:

R = submerged SG of quartz = 1.65
v = kinematic viscosity= 1.41568E-06 m^2/s at 7.5°C per Equation 2-46h (ASCE, 2012)

D_N varies with particle size as D/0.9.

Where:

A = 0.954
B = 5.12

The settling velocity plot and values are shown on Figure 12 and listed in Table 8, respectively.

5.3 Risk and Accuracy

This study is based on certain factors that can substantially impact the settling velocity estimates. These factors would be weighed against the final size of the basin relative to its theoretical minimum length. The basins included in the engineering concept drawings are sized for an on-site earth balance and therefore have a conservative safety factor relative to theoretical settling length. If future revisions to the basin length results in a significant reduction in the safety factor, additional analyses would be considered to help account for some the accuracy and risk factors presented in this section. The results of this study depend on the accuracy of the data, which can be influenced by many geomorphological and physical-chemical-biological factors, such as the following:

- Environmental impacts, such as global warming and sea-level rise, can affect particle shape and size, which can impact the settling velocity estimates. In situ measurements of particle characteristics can improve the estimates.
- The assumptions about a sample's constant sediment loading and constant density have serious flaws because geomorphic changes could impact particle concentration and density. In practice, sediment loading is a variable caused by settling and resuspension events. Wind velocity and mixing contribute to the suspended sediment particle concentration and floc density. Filamentous algae floating in the water column often develop flocs of various structures that can be different from the shape and size of primary particles.
- The porous structure of sediment flocs was not considered in the estimates. Flow through the floc structure and around the particle could have impacted the drag; therefore, settling characteristics could be different than estimated.
- The assumption of using the constant rate of sediment resuspension in the form of single particle size distribution consideration for settling velocity estimates has limitations because sediment

control plays a big part in sediment erosion, which could eventually result in time varying sediment loading, which was not considered in this study.

6. Sediment Capture and Disposal

6.1 Project-Specific Sediment Quantity Analysis

A Project-specific sediment quantity analysis was performed to estimate the total sediment in the river, diverted sediment, and captured and dewatered sediment disposed using CalSim 3 results provided by DCO on March 25, 2021. The CalSim 3 results includes the average monthly Sacramento River flow (in cfs) at the Freeport gauge and the average monthly total DCP diversion for each month of the 94-year simulation period. The data provided does not include the effects of climate change.

To calculate the sediment quantities in the analysis, the following key assumptions were used:

- Statistical analysis of CalSim 3 results was conducted to determine the minimum, median, and maximum flow diversion years.
- Suspended sediment quantities were determined by applying the median monthly sediment concentration in the river to the CalSim 3 flowrate.
  - The median concentration values were applied to the river flow predicted by CalSim 3 for the for every month of the simulation period. The resulting total river sediment load data was provided to DCO for other analyses by the environmental team and is not described further in this TM.
  - The median concentration values were applied to the diversion flows predicted by CalSim 3 for the for each month of the minimum, median, and maximum year of simulation period. The median suspended sediment concentration in the river was selected for the analysis due to sample size limitations as described in Section 4.1.
- The particle size distribution analysis could not be performed monthly due statistical limitations as described in Section 4.1. The median particle size distribution was selected for the analysis as the most representative of the particle distribution based on the information available.
- Particle settling velocities within the sedimentation basins at each intake were determined using Method 4 as described in Sections 5 and 7.
- The monthly CalSim 3 flows were provided as total Project diversions, so these flows were distributed to each intake to develop an assumed flow distribution for determining sediment quantities at each intake. Flows were generally assigned in 500 cfs increments, except the minimum flow of 300 cfs per intake required special distribution for lower flows. Flow were assigned to the intakes as follows:
  - 0- to 800 cfs CalSim 3 flows: full flow distributed to the furthest downstream intake (example: 600 cfs all to intake C-E-5)
  - 800 to 1300 cfs CalSim 3 flows: first 500 cfs distributed to furthest downstream intake; next 300 to 500 cfs distributed to upstream intake, flows 1000 to 1300 cfs distributed to further downstream intake (examples: for 900 cfs—500 cfs to intake C-E-5 and 400 cfs to Intake C-E-3; for 1200 cfs—700 to Intake C-E-5 and 500 to Intake C-E-3)
  - Flows greater than 1300 cfs:
    - Alternatives with two intakes: first 500 cfs distributed to furthest downstream intake; next 500 cfs distributed to upstream intake, flows above 1000 cfs distributed alternatively to

each intake in 500 cfs increments (example: for 2900 cfs—1500 cfs to intake C-E-5 and 1400 cfs to Intake C-E-3)

The flow distribution scheme described above is not intended to reflect actual flow distribution patterns that may be developed by the operations and permitting teams. It is simply an even distribution to each active intake that accounts for a 300 cfs minimum flow accommodation at each intake. A different flow distribution is likely to be developed prior to actual operations, but it would not be expected to have a significant impact on the sediment capture quantities.

- The analysis was performed using the cylindrical tee screen intake configurations for the sedimentation basin at each intake.
- Sediment accumulation and disposal years mirror CalSim 3 simulation year runs from October through September.

6.2 Sediment Capture – Design Flow

The sediment capture at each intake is a function of geometry of the intakes, settling velocity, depth, and diversion flow rate. The capture percentage is independent of river level since the lateral velocity and the depth to settle mathematically compensate for each other. Using the design flows, the sediment capture percentages based on particle size were calculated at each intake using the following equations:

$$T_s = \frac{d}{V_{settling}} \quad \textbf{[6]}$$

Where:

T_s = Time to settle particle (s)
d = 200-year depth (ft)
$V_{settling}$ = particle settling velocity (fps)

The calculated time to settle the particle is used to determine the theoretical length required to settle the particle.

$$L_T = V_{200} \times T_s \quad \textbf{[7]}$$

Where:

L_T = Theoretical length required to settle the particle (ft)
V_{200} = sedimentation basin velocity based on 200 year (fps)
T_s = Time to settle particle (s)

The theoretical length required to settle the particle is compared to the actual sedimentation basin length to determine the percent of sediment captured in the basin.

$$SC_{\%} = \frac{L_T}{L_A} \times 100 \quad \textbf{[8]}$$

Where:

$SC_{\%}$ = Percent sediment captured (%), design flow
L_T = Theoretical length required to settle the particle (ft)
L_A = Actual length of the basin minus 50 feet (ft)

The captured sediment percentages by particle size for design flows at each intake are shown in Table 2.

Table 2. Maximum Percent of Sediment Captured at Intake Design Flow Capacity (6,000 cfs Project Capacity)

Particle Size (mm)	Percent Captured Intake C-E-3 (3,000 cfs)	Percent Captured Intake C-E-5 (3,000 cfs)
2	100	100
1	100	100
0.5	100	100
0.25	100	100
0.125	100	100
0.0625	100	100
0.031	67.9	49.9
0.016	18.1	13.3
0.008	4.5	3.3
0.004	1.1	0.8
0.002	0.3	0.2
0.001	0.1	0.1

6.3 Total Diverted Sediment

The maximum, median, and minimum flow diversion years were determined using the 94 years of data for representative sediment quantities during varying flow conditions. The maximum, median, and minimum years were 1993, 2007, and 1983 respectively.

Using the CalSim 3 results diversion flows and the median monthly sediment concentrations, the total suspended sediment diverted per intake was calculated at minimum, median, and maximum flow diversion years using the following equation:

$$S_{DT} = \sum_{M=1\text{-}12} C_M \times Q_{DM} \times CF \quad \textbf{[9]}$$

Where:

S_{DT} = Total diverted sediment per year (tons), summed for months (M) 1 through 12
C_M = Median monthly sediment concentration in the river (mg/l)
Q_{DM} = Monthly diversion rate (cfs)
CF = unit conversion factor (0.0027 multiplied by days in the month)

The annual diverted sediment is summarized in Table 3. Monthly data is shown for minimum, median, and maximum flow diversion years for each intake in Attachment 1.

Table 3. Diverted Sediment – Total Annual Sediment Diverted at each Intake for 6,000 cfs Project Design Capacity

Intake C-E-3 Flow Diversion Year Min (tons)	Intake C-E-3 Flow Diversion Year Median (tons)	Intake C-E-3 Flow Diversion Year Max (tons)	Intake C-E-5 Flow Diversion Year Min (tons)	Intake C-E-5 Flow Diversion Year Median (tons)	Intake C-E-5 Flow Diversion Year Max (tons)
1,087	17,263	57,312	1,635	24,011	63,147

Notes: Based on CalSim 3 runs without climate change provided by DCO March 25, 2021.

6.4 Captured Sediment

The amount of captured sediment at each intake varies by diverted flow. For example, if the actual flow rate (represented by the CalSim 3 flow rate data results) were half of the design flow rate, then twice as much sediment in each size fraction would settle relative to design flow conditions.

Therefore, the ratio of the design flow rate to the actual (CalSim 3) flow rate establishes a flow factor for each month analyzed. The monthly flow factor can be multiplied by the sediment capture percentages by particle size per Table 2, to establish a flow-specific capture ratio for that particle size for that same month. Then, the average of the flow specific capture ratio for the upper and lower end of each size range defines the amount of sediment captured in that range.

The annual tons of sediment captured in each intake sedimentation basin was calculated by multiplying the total month diverted sediment (Attachment 1) by the percent of the total sediment in each fraction (Table 1, median data) and by the average flow-specific capture ratio for each size fraction and summed overall size fractions and all months as represented by the following equation:

$$S_{CT} = \sum_{\mathrm{M=1\text{-}12}} \left(\sum_{\mathrm{Fs}} (\mathrm{S_{DM}} \times \mathrm{X_{50}} \times \overline{\mathrm{X}}_{\mathrm{Fs}}) \right) \quad [10]$$

Where:

- S_{CT} = Total captured (settled) sediment per year (tons), summed for months (M) 1 to 12
- S_{DM} = Total diverted sediment per month for lower end of size fraction (tons), per Attachment 1
- X_{50} = Particle size percent retained for lower end of size fraction, using median values per Table 1, (%, input as decimal ratio)
- $\overline{X}_{Fs}$ = Average of flow-specific percent capture ratio between upper and lower end of size range (decimal ratio),
- Fs = Size fractions of particles, using upper and lower limits defined in Table 1

The annual captured tons of sediment per intake, and minimum, median, and maximum flow diversion years is summarized in Table 4. Monthly data is summarized in Attachment 1.

Table 4. Captured Sediment – Total Captured Sediment at each Intake Sedimentation Basin for 6,000 cfs Project Design Capacity

Intake C-E-3 Flow Diversion Year Min (tons)	Intake C-E-3 Flow Diversion Year Median (tons)	Intake C-E-3 Flow Diversion Year Max (tons)	Intake C-E-5 Flow Diversion Year Min (tons)	Intake C-E-5 Flow Diversion Year Median (tons)	Intake C-E-5 Flow Diversion Year Max (tons)
496	6,689	19,932	650	8,646	20,248

Notes: Based on CalSim 3 runs without climate change provided by DCO March 25, 2021.

6.5 Sediment Management and Disposal

6.5.1 Sedimentation Basin Operation and Maintenance

The sedimentation basins at each intake would operate passively and sediment would naturally settle from the water column to the bottom of the basin during flow diversions. A turbidity curtain would be provided in the sedimentation basin so that about half of the basin could be dredged while the other half of the basin would remain in service.

Once a year, during the warm summer months (assumed to be May through September), the sediment would be dredged from the sedimentation basins using a portable floating hydraulic suction dredge. The sediment basin dredge would discharge a sediment slurry into the sediment drying lagoons using a combination of portable (floating) piping in the basin and permanently installed piping leading to the lagoons. The operation of the lagoons is described below. The sediment would be removed during the summer to maximize natural drying in the sediment drying lagoons.

The suction dredge would be maneuvered around the sedimentation basin until manual soundings demonstrate that the accumulated sediment has been removed. The dredging operation would be coordinated with the operation of the drying lagoons to maximize dredging and drying efficiency. Once the dredging operation on one side of the sedimentation basin was completed, the dredge would be moved to the other side and the process repeated. If excess sediment builds up before the summer dredging season, the dredge would be mobilized earlier in the year and used to fill one or more of the four drying lagoons in order to make room for additional sediment.

Depending on season, the presence of regulated fish species in the river, and the Project diversion requirements, the operating portion of the intake would potentially be operated up to 0.33 fps approach velocity during dredging to preserve most of the intake diversion capacity during the dredging operation.

Dredging equipment would require maintenance on an annual basis.

6.5.2 Sediment Drying Lagoon Operation and Maintenance

Sediment dredged from the sedimentation basin would be separated from the dredged water and dried in the sediment drying lagoons for removal off-site by trucks. The sediment is anticipated to be large silt and sand particles with minimal organic material. Therefore, no substantial odors are anticipated from the sediment drying lagoon operations.

Sediment dredged from the sedimentation basin would be conveyed to the drying lagoons using piping installed from the basins to the lagoons. The lagoons would be equipped with several inlet valves such that the dredged slurry would be distributed around the full lagoon area. The lagoons would include an outlet structure with an adjustable weir to decant water off the top of the sediment slurry and underdrains to transport water from beneath the dredged sediment.

The suction dredge would operate to fill each lagoon up to the level of the top of the adjustable weir in its full up position. Once the first lagoon is full, the dredge would begin to fill a second lagoon. It would be expected to take up to about 2 days to fill each lagoon. Therefore, it would take about 6 to 8 days to fill all four lagoons.

After the lagoon is filled, the weir gate would be gradually lowered to decant the water off the top of the sediment. The decanting process would take about a day. After decanting, the remaining water would be allowed to drain into the outlet structure through the underdrains. Decant and underdrain water would flow to a central return flow pump station and be pumped back into the sedimentation basin. Each time the lagoons are filled, about 1 foot of sediment would be expected to settle to the bottom of the lagoon. Once the sediment was collected and most of the water removed by decanting and underdrains, the basin would be allowed to dry for 2 to 3 days while being mixed with agricultural or municipal style mixing implements. Over the next two days, the basin would be cleaned using front end loaders and dozers. The sediment would be loaded into trucks and hauled off site for disposal at a permitted disposal site or used for beneficial uses off site. For the purposes of this analysis, it was assumed the sediment would be hauled to Florin Perkins landfill in Sacramento County.

Each lagoon would be filled and drained for about 3 days, then the sediment would be dried and removed in about 4-5 days. Therefore, the fill and drain/dry sequence would be about 7 to 8 days, which would approximately match the dredged material filling rate so continuous operation would be possible. The full 7-8 period is defined as one dredge cycle, as further considered in Section 6.5.3.

Other sediment drying lagoon maintenance would include periodic cleaning of the underdrains using conventional agricultural drain cleaning equipment. Replacement of the underdrains and the gravel envelope surrounding the lines. would be required on an infrequent basis, possibly every five to ten years or more.

Return flow pumping equipment, adjustable weir gates, and mixing and loading equipment would require typical mechanical equipment maintenance on an annual basis. Minor debris collection would be conducted on a continuous basis.

6.5.3 Sediment Disposal

As described above, the total captured sediment would be removed from the basin annually, dewatered, and trucked to an off-site disposal facility using one or more dredge cycles per intake. The captured sediment and water year type, as described in Table 4, was assumed to all be dried and disposed. Therefore, the values in Table 4 were used to estimate truck trips required to transport dried sediment off-site. The Florin Perkins landfill in Sacramento was assumed as the location for disposal for the purposes of this analysis. The dried sediment was assumed to weigh 112.5 pounds per cubic yard and the truck size was assumed to carry an average of 15 cubic yards per load. Using the dried sediment volume and the truck size, the annual truck trips for each intake was estimated. The total number of truck trips per year for each intake are shown in Table 5 for minimum, median, and maximum flow diversion years.

Table 5. Number of Truck Trips per Year for 6,000 cfs Project Design Capacity

Intake C-E-3 Flow Diversion Year Min	Intake C-E-3 Flow Diversion Year Median	Intake C-E-3 Flow Diversion Year Max	Intake C-E-5 Flow Diversion Year Min	Intake C-E-5 Flow Diversion Year Median	Intake C-E-5 Flow Diversion Year Max
22	294	875	29	380	889

Notes: Based on CalSim 3 runs without climate change provided by DCO March 25, 2021.

In order to fully clean out the sedimentation basin at each intake, the captured sediment would be moved to the drying lagoons by repeating the dredge cycle described above as many times as needed until the sediment was all removed, dried, and hauled offsite. The number of dredge cycles required per year per year helps establish the number of truck trips per day and the duration of the dredging, drying, and disposal operation at each intake.

To determine the yearly number of dredge cycles per intake required to remove the sediment, a 1-foot depth of dried sediment, (about 2,074 cubic yards) in each drying lagoon was assumed to be removed per dredging cycle. This value is consistent with the duration of the activities described for each dredge cycle. The number of dredge cycles was estimated by determining the number of drying lagoon volumes (at the unit weight of dried sediment defined above) would be required to remove the full quantity of capture sediment defined in Table 4. The yearly number of dredge cycles of the sediment disposal is shown in Table 6 for minimum, median, and maximum flow diversion years.

Assuming a sequential application of the dredge cycle activities, the trucking component would be continuous once the first cycle reaches the trucking component. In other words, the send dredge cycle would reach the trucking component as soon as trucking was completed for the first cycle, and so on throughout all the required cycles. Therefore, the number of work days to conduct the sediment cleanout operation can be estimate by assuming three days of trucking for each cycle, plus the initial 5 days for dredging and drying. About 3-5 days would be required at each site once the work is complete to clean up and get the sediment facilities ready to sit idle until the following year.

In accordance with the description of the dredge cycle above, the number of trucking days is assumed to be three days per dredge cycles. The corresponding number of truck trips per day as estimated for minimum, median, and maximum flow diversion years for each intake are shown in Table 7.

Table 6. Number of Dredge Cycles Per Year at each Intake for 6,000 cfs Project Design Capacity

Intake C-E-3 Flow Diversion Year Min	Intake C-E-3 Flow Diversion Year Median	Intake C-E-3 Flow Diversion Year Max	Intake C-E-5 Flow Diversion Year Min	Intake C-E-5 Flow Diversion Year Median	Intake C-E-5 Flow Diversion Year Max
1	3	7	1	3	7

Notes: Based on CalSim 3 runs without climate change provided by DCO March 25, 2021.

Table 7. Number of Truck Trips per Day at each Intake for 6,000 cfs Project Design Capacity

Intake C-E-3 Flow Diversion Year Min	Intake C-E-3 Flow Diversion Year Median	Intake C-E-3 Flow Diversion Year Max	Intake C-E-5 Flow Diversion Year Min	Intake C-E-5 Flow Diversion Year Median	Intake C-E-5 Flow Diversion Year Max
8	33	42	10	43	43

Notes: Based on CalSim 3 runs without climate change provided by DCO March 25, 2021.

Review of Table 7 shows that sediment disposal could be conducted at each intake in 24 days, or less, with a maximum of 46 of trucks per day over a 10-hour period. A fleet of about 6 trucks would be required assuming a 1 hr. total cycle time. The total work period to conduct annual cleaning would be about 34 days, or less, at each intake when the initial 5 day dredging period and the 5 day cleanup period at the end are considered. These results demonstrate that a single dredging, sediment drying, disposal crew, equipment and truck fleet can clean out all intakes in a single summer dry season. The durations demonstrate that a buffer for up to double the sediment accumulation would be available for anomalously extreme sediment buildup years.

7. Results and Conclusions

The settling velocity distribution for various particle sizes using various methods is shown in Figure 12. Table 8 provides settling velocity values for various noncolloidal particle sizes.

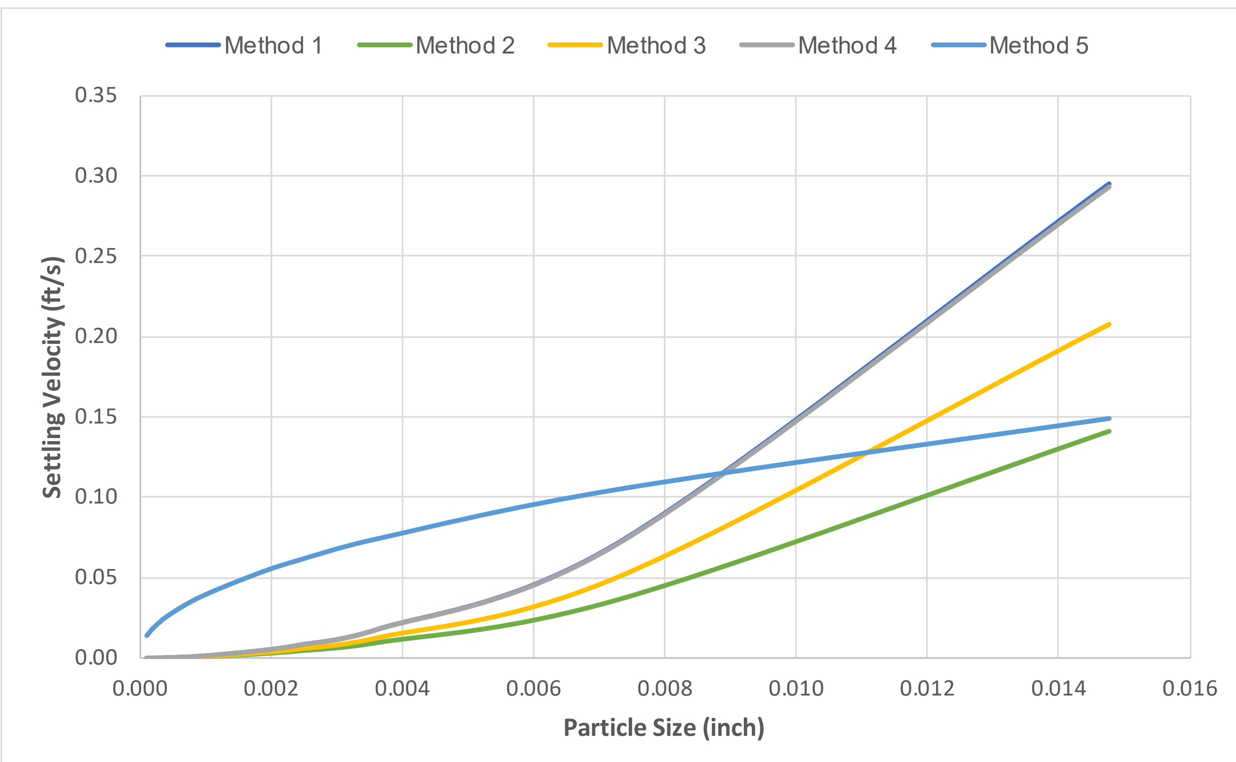


Figure 12. Settling Velocity Distribution for Various Particle Sizes Using Various Methods

Notes: Particles depicted on the figure are greater than 0.00008 inch.

Table 8. Particle Settling Velocity Estimate (ft/s) Using Various Methods

Particle Class	Size (inch)	Method 1	Method 2	Method 3	Method 4	Method 5
Sand	0.015	0.29	0.14	0.21	0.29	0.15
	0.007	0.073	0.037	0.052	0.073	0.106
	0.004	0.018	0.009	0.012	0.018	0.074
	0.002	0.0082	0.0045	0.0058	0.0081	0.0610
Silt	0.002	0.0044	0.0025	0.0031	0.0044	0.0524
	0.001	0.00121	0.00071	0.00085	0.00120	0.0378
	0.0005	0.00030	0.00019	0.00021	0.00030	0.0268
	0.0002	0.00008	0.00005	0.00005	0.00008	0.0189
	0.0001	0.00002	0.00001	0.00001	0.00002	0.0134

Notes:

ft/s = foot (feet) per second

In reality, natural suspended particles have variable shapes, sizes, effective density, pore structures, and surface areas, which can each influence drag on the particle surface and, therefore, also influence the settling velocities. General physicochemical conditions prevailing in the system also impact settling; for example:

- Fluid shear
- Organic content
- Particle concentration
- Location of particle with reference to the settling area
- Depth of the water column

A variety of attempts have been made to characterize the settling velocity. Initial efforts were focused on Stokes law, followed by many modifications through empirical relationships with settling velocity data and considering particle shape characteristics experiencing variable drag. Basically, the particle density expression in Stokes law varied with particle size, and as natural particles are not spherical, various shape factors were considered to define the particle size and modify the Stokes law equation.

As a result of this analysis, the settling velocity of particles based on Method 4 would be used to size the intake area. The results derived from Method 1 are based on Stokes law, which does not consider the irregular shape of particles, variable density, and porosity. Method 3 is a modification of Method 1 with a constant shape factor for all particle size classes. Method 2 is based on the direct measurement method and illustrates the impact of variable density with particle size, but it also assumes particles are too fluffy, highly irregular, and porous. The drag effect considered in Method 2 may not be appropriate for Sacramento River sediment suspensions, which are relatively rounded and heavier sand particles (Figure 4) and less floc compared with aggregates present in a quieter environment like a lake. The coefficient drag for sand particles would be much less than flocs with high organic content (Chakraborti and Kaur 2014). Method 5 is heavily dependent on the appropriateness of various empirical values used in the model, including a constant shape factor in terms of the nominal diameter of particles. The trend of this plot is different from the trend determined by the other four methods. Method 4 considers the SG of quartz, which is the most appropriate settling estimate for coarse sediment particles. Note that it is difficult to predict the settling velocity of particles accurately without a settling column experiment and use of noninvasive measurement methods such as the coulter counter method to precisely determine particle size distribution.

In summary, particle sizes of 0.002 inch are estimated to settle at a rate of 0.008 ft/s. In perspective, a 0.002 inch particle would travel 15 feet downward in 31 minutes with a 0.008-ft/s settling speed.

In accordance with the goal to capture all sediment with particle size greater than 0.002 inch, the minimum settling basin length, assuming a 1.25 safety factor for sediment settling velocity and a 50 foot inlet mixing buffer zone, would be as listed in Table 9 for the cylindrical tee screen configuration being considered as part of the Environmental Impact Report (EIR) (DWR, 2023).

Table 9. Minimum Sedimentation Basin Bottom Length

Intake (Capacity)	Minimum Sedimentation Basin Bottom Length (Feet)
C-E-3 (3,000 cfs)	464
C-E-5 (3,000 cfs)	464

Note: Length based on configuration shown in the DCA Volume 2 – Drawings (2024a)

The intake sedimentation basin would capture between 500 and 20,200 tons of sediment each year, depending on the intake location and Project design capacity over minimum, median, and maximum flow diversion years. This sediment would be dredged and dried in less than 61 days. Review of the estimates of captured sediment presented in this TM suggested that considerable variability exists relative to the flow diversion quantities during that year. In some years, illustrated by the estimates for minimum diversion years, the accumulation could be so low that no dredging, drying, and disposal operation is needed. During the maximum diversion years, the estimated accumulated sediment would be orders of magnitude higher than minimal years, but still within the quantity that could be hauled off-site for disposal using less than about 2,000 truck trips per year with about 46 truck trips per day during the peak operation. During median diversion years, sediment quantities would about midway between minimum and maximum years. For those years, the accumulated sediment would be hauled off-site for disposal using less than about 725 truck trips per year with about 43 truck trips per day during the peak operation.

The results of the sediment management analyses demonstrate that a single dredging, sediment drying, disposal crew, equipment and truck fleet can clean out all intakes in a single summer dry season. Also, the analysis shows that a seasonal buffer would be available to manage about double the amount of sediment produced for the maximum diversion year in the case of an anomalous set of circumstances.

8. References

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Attachment 1
Monthly Sediment and Sediment Disposal Calculations

Attachment 1.A

EIR Alternative 5 – 6000 cfs Bethany – Max Year

6000 cfs Bethany - Max Year Flow Diversion	
River Sediment Concentration	Median
Particle Size Distribution Analysis Method	Median

INTAKE C-E-3

Month	Flow Rate (cfs)	Total Diverted Sediment (tons)	Total Settled Sediment (tons)	Sediment Captured Based on Particle Size Distribution									
				Settled > 1.00 mm	Settled 1.00-0.500 mm	Settled 0.500-0.250 mm (tons)	Settled 0.250-0.125 mm (tons)	Settled 0.125-0.0625 mm (tons)	Settled 0.0625-0.031 mm (tons)	Settled 0.031-0.016 mm (tons)	Settled 0.016-0.008 mm (tons)	Settled 0.008-0.004 mm (tons)	Settled 0.004-0.002 mm (tons)
January	2819	10607	3545	0	0	318	689	1220	731	437	115	29	6
February	3000	12349	4064	0	0	370	803	1420	829	478	126	31	7
March	2159	13179	4744	0	0	395	857	1516	1024	708	186	47	10
April	2000	7768	2852	0	0	233	505	893	621	444	119	30	7
May	2500	7735	2668	0	0	232	503	889	561	359	94	24	5
June	2500	4754	1640	0	0	143	309	547	345	221	58	15	3
July	500	920	419	0	0	28	60	106	74	83	53	14	3
August	0	0	0	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual		57312	19932	0	0	1719	3725	6591	4186	2730	750	188	42

Notes: Based on CalSim3 runs without climate change provided by DCO March 25, 2021.

Sediment Disposal Calculations

pounds	39,864,133.46
yards	13,123.99
truck trips/year	874.93
cy/cleanout	2,074.00
Dredge cycles	7.00
Trucking Days	21.00
Total Work Days	26.00
truck trips/day	42.00
hours/day	10.00
truck trips/hour	4.20
cycle time (mins)	14.29

6000 cfs Bethany - Max Year Flow Diversion	
River Sediment Concentration	Median
Particle Size Distribution Analysis Method	Median

INTAKE C-E-5

Month	Flow Rate (cfs)	Total Diverted Sediment (tons)	Total Settled Sediment (tons)	Sediment Captured Based on Particle Size Distribution									
				Settled > 1.00 mm	Settled 1.00-0.500 mm	Settled 0.500-0.250 mm (tons)	Settled 0.250-0.125 mm (tons)	Settled 0.125-0.0625 mm (tons)	Settled 0.0625-0.031 mm (tons)	Settled 0.031-0.016 mm (tons)	Settled 0.016-0.008 mm (tons)	Settled 0.008-0.004 mm (tons)	Settled 0.004-0.002 mm (tons)
January	3000	11288	3478	0	0	339	734	1298	677	321	84	21	5
February	3000	12349	3805	0	0	370	803	1420	740	351	92	23	5
March	2500	15260	4880	0	0	458	992	1755	976	521	137	34	8
April	2030	7885	2649	0	0	237	513	907	548	331	87	22	5
May	2649	8196	2589	0	0	246	533	943	513	264	69	17	4
June	2544	4838	1541	0	0	145	314	556	307	162	43	11	2
July	902	1659	643	0	0	50	108	191	133	108	41	10	2
August	0	0	0	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	0	0	0
December	769	1672	663	0	0	50	109	192	134	114	49	12	3
Annual		63147	20248	0	0	1894	4105	7262	4028	2172	603	151	33

Notes: Based on CalSim3 runs without climate change provided by DCO March 25, 2021.

Sediment Disposal Calculations

pounds	40,495,092.46
yards	13,331.72
truck trips/year	888.78
cy/cleanout	2,074.00
Dredge cycles	7.00
Trucking Days	21.00
Total Work Days	26.00
truck trips/day	43.00
hours/day	10.00
truck trips/hour	4.30
cycle time (mins)	13.95

Attachment 1.B

EIR Alternative 5 – 6000 cfs Bethany – Medium Year

6000 cfs Bethany - Median Year Flow Diversion	
River Sediment Concentration	Median
Particle Size Distribution Analysis Method	Median

INTAKE C-E-3

Month	Flow Rate (cfs)	Total Diverted Sediment (tons)	Total Settled Sediment (tons)	Sediment Captured Based on Particle Size Distribution									
				Settled > 1.00 mm	Settled 1.00-0.500 mm	Settled 0.500-0.250 mm (tons)	Settled 0.250-0.125 mm (tons)	Settled 0.125-0.0625 mm (tons)	Settled 0.0625-0.031 mm (tons)	Settled 0.031-0.016 mm (tons)	Settled 0.016-0.008 mm (tons)	Settled 0.008-0.004 mm (tons)	Settled 0.004-0.002 mm (tons)
January	0	0	0	0	0	0	0	0	0	0	0	0	0
February	2000	8232	3022	0	0	247	535	947	659	471	126	31	7
March	1000	6104	2437	0	0	183	397	702	488	424	186	47	10
April	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0	0	0	0
July	1000	1840	734	0	0	55	120	212	147	128	56	14	3
August	0	0	0	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	0	0	0
December	500	1087	496	0	0	33	71	125	87	98	62	17	4
Annual		17263	6689	0	0	518	1122	1985	1381	1120	430	109	24

Notes: Based on CalSim3 runs without climate change provided by DCO March 25, 2021.

Sediment Disposal Calculations

pounds	13,378,777.74
yards	4,404.54
truck trips/year	293.64
cy/cleanout	2,074.00
Dredge cycles	3.00
Trucking Days	9.00
Total Work Days	14.00
truck trips/day	33.00
hours/day	10.00
truck trips/hour	3.30
cycle time (mins)	18.18

6000 cfs Bethany - Median Year Flow Diversion	
River Sediment Concentration	Median
Particle Size Distribution Analysis Method	Median

INTAKE C-E-5

Month	Flow Rate (cfs)	Total Diverted Sediment (tons)	Total Settled Sediment (tons)	Sediment Captured Based on Particle Size Distribution									
				Settled > 1.00 mm	Settled 1.00-0.500 mm	Settled 0.500-0.250 mm (tons)	Settled 0.250-0.125 mm (tons)	Settled 0.125-0.0625 mm (tons)	Settled 0.0625-0.031 mm (tons)	Settled 0.031-0.016 mm (tons)	Settled 0.016-0.008 mm (tons)	Settled 0.008-0.004 mm (tons)	Settled 0.004-0.002 mm (tons)
January	675	2540	1029	0	0	76	165	292	203	182	84	21	5
February	2204	9072	2986	0	0	272	590	1043	609	351	92	23	5
March	1380	8424	3110	0	0	253	548	969	674	489	137	34	8
April	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0	0	0	0
July	1472	2708	994	0	0	81	176	311	217	155	41	10	2
August	0	0	0	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	0	0	0
December	583	1267	527	0	0	38	82	146	101	96	49	12	3
Annual		24011	8646	0	0	720	1561	2761	1804	1272	404	101	22

Notes: Based on CalSim3 runs without climate change provided by DCO March 25, 2021.

Sediment Disposal Calculations

pounds	17,292,096.08
yards	5,692.87
truck trips/year	379.52
cy/cleanout	2,074.00
Dredge cycles	3.00
Trucking Days	9.00
Total Work Days	14.00
truck trips/day	43.00
hours/day	10.00
truck trips/hour	4.30
cycle time (mins)	13.95

Attachment 1.C

EIR Alternative 5 – 6000 cfs Bethany – Min Year

6000 cfs Bethany - Min Year Flow Diversion	
River Sediment Concentration	Median
Particle Size Distribution Analysis Method	Median

INTAKE C-E-3

Month	Flow Rate (cfs)	Total Diverted Sediment (tons)	Total Settled Sediment (tons)	Sediment Captured Based on Particle Size Distribution									
				Settled > 1.00 mm	Settled 1.00-0.500 mm	Settled 0.500-0.250 mm (tons)	Settled 0.250-0.125 mm (tons)	Settled 0.125-0.0625 mm (tons)	Settled 0.0625-0.031 mm (tons)	Settled 0.031-0.016 mm (tons)	Settled 0.016-0.008 mm (tons)	Settled 0.008-0.004 mm (tons)	Settled 0.004-0.002 mm (tons)
January	0	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	0	0	0
August	500	1087	496	0	0	33	71	125	87	98	62	17	4
September	0	0	0	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual		1087	496	0	0	33	71	125	87	98	62	17	4

Notes: Based on CalSim3 runs without climate change provided by DCO March 25, 2021.

Sediment Disposal Calculations

pounds	991,062.51
yards	326.28
truck trips/year	21.75
cy/cleanout	2,074.00
Dredge cycles	1.00
Trucking Days	3.00
Total Work Days	8.00
truck trips/day	8.00
hours/day	10.00
truck trips/hour	0.80
cycle time (mins)	75.00

6000 cfs Bethany - Min Year Flow Diversion	
River Sediment Concentration	Median
Particle Size Distribution Analysis Method	Median

INTAKE C-E-5

Month	Flow Rate (cfs)	Total Diverted Sediment (tons)	Total Settled Sediment (tons)	Sediment Captured Based on Particle Size Distribution									
				Settled > 1.00 mm	Settled 1.00-0.500 mm	Settled 0.500-0.250 mm (tons)	Settled 0.250-0.125 mm (tons)	Settled 0.125-0.0625 mm (tons)	Settled 0.0625-0.031 mm (tons)	Settled 0.031-0.016 mm (tons)	Settled 0.016-0.008 mm (tons)	Settled 0.008-0.004 mm (tons)	Settled 0.004-0.002 mm (tons)
January	0	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	0	0	0
August	752	1635	650	0	0	49	106	188	131	113	49	12	3
September	0	0	0	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual		1635	650	0	0	49	106	188	131	113	49	12	3

Notes: Based on CalSim3 runs without climate change provided by DCO March 25, 2021.

Sediment Disposal Calculations

pounds	1,300,709.14
yards	428.22
truck trips/year	28.55
cy/cleanout	2,074.00
Dredge cycles	1.00
Trucking Days	3.00
Total Work Days	8.00
truck trips/day	10.00
hours/day	10.00
truck trips/hour	1.00
cycle time (mins)	60.00