Appendix F
An Analysis of Potential Bedload Sediment Effects on Anadromous Fish in the Klamath Basin

F.1 Introduction

This appendix describes current habitat conditions and assesses the changes to bedload sediment within analysis areas described in Section 3.3 (Aquatic Resources) and under each Klamath Facilities Removal Environmental Impact Statement/Environmental Impact Report alternative described in Chapter 2 (Project Description).

F.2 Methods

The effects analysis relied upon output from the Sediment and River Hydraulics-1 Dimension (SRH-1D) model, Version 2.4 (Huang and Greimann 2010) to estimate the spatial and temporal patterns of dam released sediment and sediment resupply from upstream on bed elevation and bed substrate (percent composition of fines [more than 0.063 mm] sand [0.063 to 2 mm], gravel [2 to 64 mm], and cobble [64 to 256 mm; median substrate size [D50]). The model examined short-term (2-year) changes by month under scenarios of two consecutive wet, median, and dry years (i.e., wet-wet [wet simulation], median-median [median simulation], and dry-dry [dry simulation] years), and longer term changes (5, 10, 25, and 50 years) using a range of flows taken from historical hydrology. A long-term simulation was not conducted for the Klamath River upstream of Iron Gate Dam under the assumption that the gradations at the end of two years are representative and will persist through time, allowing for mild fluctuations as a function of hydrology (Bureau of Reclamation [Reclamation] 2011, David Varyu, personal communication January 4, 2011). The effects determination used conclusions from the analysis and knowledge of habitat requirements of affected fish species to determine how changes in bed elevation and substrate would potentially impact aquatic resources (e.g., pool habitat, spawning gravel, benthic habitat).

Dam released sediment and sediment resupply may affect riverine spawning habitat. Increased levels of fine sediment can also reduce median substrate size below that usable for salmonids. Excessive amounts of fine sediment occupying interstitial spaces within spawning gravel can impede intragravel flow, preventing exchange of nutrients and dissolved oxygen between the water column and salmonid embryos, and fill interstitial spaces that impede the emergence of alevins thereby reducing survival (Chapman 1988, Bjornn and Reiser 1991). Studies vary on the size of sediment impeding intragravel flow

and blocking emergence, but typically, the sizes vary between 1 and 10 mm (Kondolf 2000). A review by Kondolf (2000) found that 10 to 40 percent fine sediment (ranging in size from 2 to 10 mm) within spawning gravels corresponded to 50 percent survival to emergence of various salmonid species. For example, Bjornn and Reiser (1991) summarized the effects of increasing levels of sediment less than 6.35 mm in the bed on salmonid incubation and found embryo survival and survival to emergence largely unaffected at levels less than 20 percent (98 percent and 70 to 95 percent, respectively). Levels more than 30 percent showed minor effect on embryo survival (90 percent), but greater effects on survival to emergence (10 to 60 percent). The proportion (percent) of sand within the bed and median substrate size, as estimated by SRH-1D, was used to estimate the potential effect of the Proposed Action on salmonid spawning success in specific reaches under short-term and long-term simulations. Beds comprised of less than 20 percent sand and D50 within observed suitable ranges of spawning gravel sizes (e.g., 16 to 70 mm for Chinook salmon [Kondolf and Wolman 1993]), were assumed to provide suitable habitat for salmonid spawning, while more than 20 percent sand along with D50 outside observed ranges of spawning gravel sizes were assumed to provide unsuitable conditions. Changes in substrate composition occurring as a result of dam removal that changed habitat from suitable to unsuitable were assumed to have an adverse impact on salmonids.

F.3 Affected Environment

F.3.1 Upper Klamath River: upstream of the influence of J.C. Boyle Reservoir

Bedload conditions in this region of the area of analysis are not expected to be affected by the Klamath Hydroelectric Settlement Agreement. The existing dams (Link and Keno dams) would remain in place and continue to affect hydrology and sediment transport in much the way they do currently.

For practical purposes, no sediment is supplied to the Klamath River from the basin upstream of Keno Dam (Reclamation 2011). Upper Klamath Lake, with its large surface area, traps nearly all sediment delivered from upstream tributaries. All fluvial sediment supplied to reaches downstream of Iron Gate Dam is delivered to the Klamath River between Keno Dam and Iron Gate Dam. Sources within this reach supply 24,160 tons/yr of coarse sediment (1.3 percent of the cumulative average annual basin-wide coarse sediment delivery) (Stillwater Sciences 2010a).

F.3.2 Hydroelectric Reach from upstream end of J.C. Boyle Reservoir to Iron Gate Dam

The project reservoirs are the dominant feature in this 38 mile (River Mile [RM] 228.3 to RM 190.1) reach, with a 22-mile riverine section between J.C. Boyle Dam (RM 224.1 and the upstream end of Copco 1 Reservoir (203.1) and a 1.5-mile riverine reach between Copco 2 Dam (RM 198.3) and the upstream end of Iron Gate Reservoir (RM 196.9). The four project dams currently store 13,150,000 cubic yards of sediment (3,605,000 tons)

(Reclamation 2011), with Copco 1 Reservoir storing the largest amount and J.C. Boyle Reservoir storing the least (Table F-1). The sediment stored within dams has a high water content and 85 percent of the particles are silts and clays (less than 0.063 mm) while 15 percent are sand or coarser (>0.063 mm) (Gathard Engineering Consulting [GEC] 2006, Stillwater Sciences 2008, Reclamation 2011).

Table F-1. Estimated Volume (yd^3) and Mass (Tons) of Sediment Currently Stored within Hydroelectric Reach Reservoirs

Reservoir	Current Sediment Volume (yd^3)	Current Sediment Mass (tons)
J.C. Boyle	1,000,000	287,000
Copco 1	7,440,000	1,884,000
Copco 2	0	0
Iron Gate	4,710,000	1,434,000
Total	13,150,000	3,605,000

Source: Reclamation 2011

F.3.3 Lower Klamath River: Downstream of Iron Gate Dam

Downstream of Iron Gate Dam, channel conditions reflect the interruption of sediment flux from upstream by project dams and the eventual resupply of sediment from tributaries entering the mainstem Klamath River (PacifiCorp 2004, Reclamation 2011). The reach from Iron Gate Dam to Cottonwood Creek (RM 190.1 to RM 182.1) is characterized by coarse cobble-boulder bars immediately downstream of the dam transitioning to a cobble bed with pool-riffle morphology farther downstream near Cottonwood Creek (Montgomery and Buffington 1996, PacifiCorp 2004, Stillwater Sciences 2010a). Fine sediment input from tributaries locally decreases sediment size distribution in the mainstem Klamath River, but the effect is temporary, as the bed coarsens before the next tributary junction (PacifiCorp 2004). For example, median grain size at the confluence of Bogus Creek and the Klamath River is 47 mm, but downstream the bed coarsens to a median grain size of 96 mm (PacifiCorp 2004). Cottonwood Creek to the Scott River (RM 182.1 to RM 143.0) is a confined channel with a cobble-gravel bed and pool-riffle morphology (PacifiCorp 2004). The median bed material ranges from 45 to 50 mm, but bar substrates become finer in the downstream direction, with median sizes of 49 mm and 25 mm at the upstream and downstream ends, respectively. Downstream of the Scott River, including through the Seiad Valley, the Klamath River is cobble-gravel bedded with pool-riffle morphology (PacifiCorp 2004). PacifiCorp (2004) also noted increasing quantities of sand and fine gravel on the bed surface with distance downstream, likely reflecting the resupply of finer material from tributaries to the Klamath River.

The project dams trap most coarse sediment produced in the low sediment yield, young volcanic terrain, upstream of the dams. This results in coarsening of the channel bed downstream of the dams until tributaries re-supply the channel with finer sediment. However, most of the supply from the portion of the watershed upstream of J.C. Boyle Reservoir is trapped in Upper Klamath Lake, which is a natural lake. Most of the sediment supplied to the mainstem Klamath River (~98 percent; Stillwater Sciences 2010a) is delivered from tributaries downstream of Cottonwood Creek, limiting the

effects of interrupting upstream sediment supply. Analysis of the area and number of gravel bars and terraces downstream of Iron Gate Dam suggests that the influence of the project dams on these alluvial features, which are sources of salmonid spawning gravel, is limited to the reach from Iron Gate Dam to Cottonwood Creek (PacifiCorp 2004). This effect is almost entirely absent downstream of the Shasta River, and is undetectable as the Klamath River flows through the Seiad Valley (PacifiCorp 2004).

F.4 No Action/No Project Alternative

F.4.1 Hydroelectric Reach: from upstream end of J.C. Boyle Reservoir to Iron Gate Dam

Under the No Action/No Project Alternative, project dams would continue to trap fine and coarse sediment and reduce the storage capacity of the reservoirs. Stillwater Sciences (2010a) estimates that 100,600 yd^3/yr (151,000 tons/yr assuming 1.5 tons/yd) of sediment is delivered to the Klamath River between Keno and Iron Gate Dams. A portion of the fine (less than 0.063 mm; 84,560 yd^3/yr) and all of the coarse (>0.063 mm; sediment load (16,107 yd^3/yr) loads would deposit within the project reservoirs. Reclamation (2011) estimates project reservoirs would store 23,500,000 yd^3 of fine and coarse sediment by 2061. As reservoir capacities decrease (i.e., as they fill with sediment), trap efficiency may decrease, or sedimentation may cease, allowing sediment to pass through pools.

Under the No Action/No Project Alternative, anadromous fish would not have access to this reach, as is currently the case. Impacts would be confined to riverine (redband trout, shortnose and Lost River suckers), and nonnative reservoir fish.

F.4.1.1 Redband Trout

Redband trout are found within the Hydroelectric Reach, migrating between tributaries and reservoirs to complete their lifecycle (Hamilton et al. 2010). The No Action/No Project Alternative would decrease reservoir capacity, as dams within the Hydroelectric Reach would continue to interrupt downstream sediment transport and store sediment delivered from upstream. The decrease in reservoir volume is expected to have negative long-term impact on redband trout habitat within the Hydroelectric Reach.

F.4.1.2 Lost River and Shortnose Suckers

Federally endangered Lost River and shortnose suckers are found within the Hydroelectric Reach. Similar to redband trout above, the No Action/No Project Alternative is expected to reduce habitat area as dams continue to trap sediment transported from upstream. However, there is little or no successful reproduction of either sucker species downstream of Keno Dam and both contribute minimally to conservation goals or significantly to recovery (Hamilton et al. 2010). Thus, although reduction in habitat would have negative long-term impact on Lost River and shortnose

sucker habitat in the Hydroelectric Reach, the overall impact to the population would be less than significant.

F.4.1.3 Nonnative Reservoir Fish

As discussed above, the No Action/No Project Alternative would decrease the amount of reservoir habitat as dams continue to interrupt downstream sediment transport. This reduction in reservoir volume is expected to have a negative long-term impact on habitat for nonnative reservoir fish.

F.4.2 Lower Klamath River: Downstream of Iron Gate Dam

The channel directly downstream of Iron Gate Dam would continue to be starved of fine sediment, but the effect would gradually decrease in the downstream direction as coarse sediment is resupplied by tributary inputs (Hetrick et al. 2010, Stillwater Sciences 2010a). The downstream extent of the effect of project dams on sediment supply (and channel condition) would be substantially reduced at the Cottonwood Creek confluence (PacifiCorp 2004). The bed material just downstream of Iron Gate Dam is coarser than would be expected due to the interruption of fine and coarse sediment supply from upstream (Reclamation 2011). The coarser bed material is mobilized at higher flows that occur less frequently, resulting in channel features that are more stable.

F.4.2.1 Fall-Run Chinook Salmon

The distribution of fall-run Chinook salmon would continue to be limited by Iron Gate Dam. Under the No Action/No Project Alternative, the bed immediately below Iron Gate Dam would continue to coarsen, which would result in worsening conditions for spawning in this reach. There would be no change in bed elevation or in habitat composition. Because of the limited amount of habitat affected (Iron Gate Dam [RM 190.1] to Cottonwood Creek [RM 182.1]), the impact described above, taken by itself, would not be expected to substantially affect fall-run Chinook salmon populations.

F.4.2.2 Spring-Run Chinook Salmon

Habitat relating to bedload movement within the current distribution of spring-run Chinook salmon would not change under the No Action/No Project Alternative, and thus would not affect this species.

F.4.2.3 Coho Salmon

Coho salmon use the Klamath River upstream as far as Iron Gate Dam, but the vast majority of spawning occurs on the tributaries. For those coho that do use the mainstem for spawning bed coarsening under the No Action/No Project Alternative would further decrease the suitability of the mainstem for spawning. Given the small proportion of coho that use the mainstem, this effect, by itself, would be unlikely to substantially affect the population.

F.4.2.4 Summer Steelhead

The habitat changes relating to bedload movement under the No Action/No Project Alternative would not overlap with the habitat of summer steelhead. Therefore, this alternative would not affect this species.

F.4.2.5 Winter Steelhead

Winter steelhead are currently distributed throughout the Klamath River upstream to Iron Gate dam, but spawn and rear in the tributaries (Federal Energy Regulatory Commission [FERC] 2007). There is no record of winter steelhead spawning in the mainstem Klamath River, which is used mainly as a migration corridor for adults and juveniles (Stillwater Sciences 2010). Therefore, they would not be affected by the bed coarsening that would occur under the No Action/No Project Alternative.

F.4.2.6 Green Sturgeon

The habitat changes relating to bedload movement under the No Action/No Project Alternative would not overlap with the habitat of green sturgeon. Therefore, this alternative would not affect this species.

F.4.3 Klamath River Estuary

As discussed above, the downstream extent of the effect of dams in the Hydroelectric Reach on sediment supply (and channel condition) would be substantially reduced below the Cottonwood Creek confluence, and largely absent downstream of the Shasta River (RM 176.7) (PacifiCorp 2004). There would be no bedload related impacts to aquatic species in the Klamath River Estuary Reach under the No Action/No Project Alternative.

F.4.4 Pacific Ocean Near Shore Environment

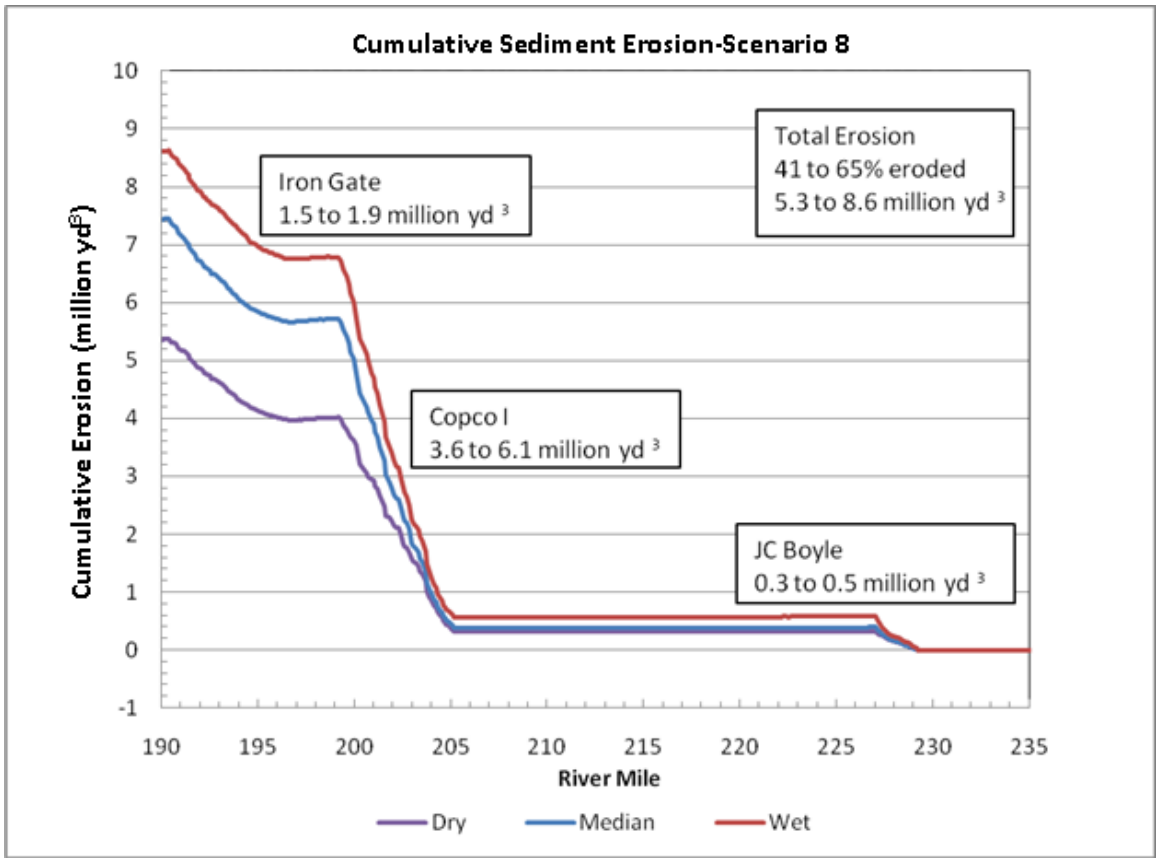
As discussed above, the downstream extent of the effect of dams in the Hydroelectric Reach on sediment supply (and channel condition) would be substantially reduced at the Cottonwood Creek confluence, and largely absent downstream of the Shasta River (PacifiCorp 2004). There would be no bedload related impacts to aquatic species in the Pacific Ocean near the shore environment under the No Action/No Project Alternative.

F.5 Proposed Action - Full Facilities Removal of Four Dams

F.5.1 Hydroelectric (Hydro) Reach: from upstream end of J.C. Boyle Reservoir to Iron Gate Dam

Dams in the Hydroelectric Reach currently store 13,150,000 y^3 (3,605,000 tons) of sediment (Table F-1) (Reclamation 2011). No sediment is stored within the Copco 2 Reservoir, but Copco 1 Reservoir stores the greatest amount, and J.C. Boyle Reservoir stores the least. The SRH-1D model estimated 41 to 65 percent (5,300,000 to 8,600,000

yd^3 [1,400,000 to 2,600,000 tons]) of dam stored sediment would be eroded the first year after dam removal depending on simulation type (wet, median or dry) (Figure F-1). Sediment not eroded from the reservoirs during the first year would be stored in gravel bars and terraces, and released more slowly through surficial and fluvial processes (Stillwater Sciences 2008).



Source: Reclamation 2011.

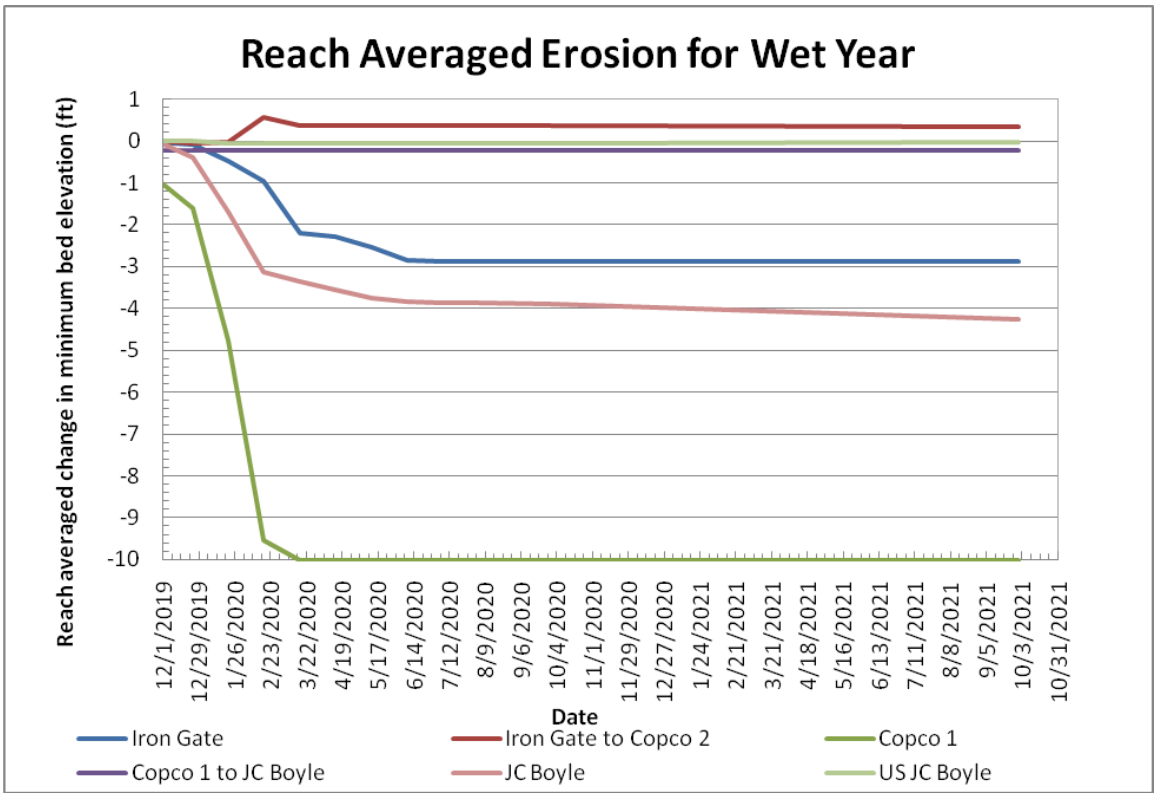
Figure F-1. Cumulative Sediment Erosion from Dams in the Hydroelectric Reach during Drawdown Beginning January 2020

F.5.1.1 Changes in Bed Elevation

SRH-1D data show substantial decreases in bed elevation within the reservoirs during drawdown (January 2020 to April 2020), which stabilizes as the bed within the historic river channel reaches pre-dam elevations (Reclamation 2011; Blair Greimann, personal communication 23 December 2010). In all simulations, the greatest decrease in bed elevation occurs through the Copco 1 Reservoir (10 ft of erosion), followed by J.C. Boyle Reservoir (3-4 ft), and Iron Gate Reservoir (3 ft) (Figure F-2 and Figure F-3). Draining J.C. Boyle, Copco 1, Copco 2, and Iron Gate Reservoirs and erosion of the accumulated sediment is expected to result in the river channels within reservoirs reaching their pre-dam elevations within 4 months. These sections of the river would

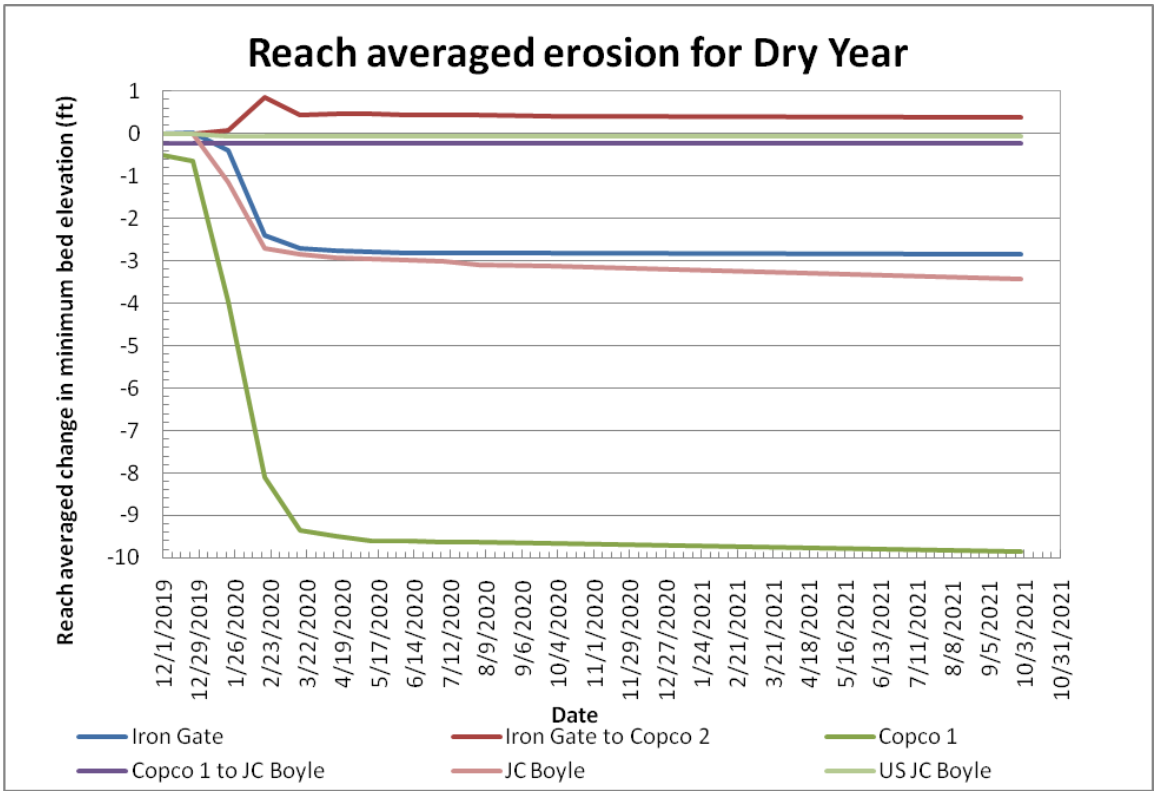
revert to and maintain a pool-riffle morphology, similar to that existing in reach downstream of Iron Gate Dam, due to restoration of fluvial geomorphic processes (PacifiCorp 2004).

The river reaches between the reservoirs from Copco 1 Reservoir to J.C. Boyle Dam and from Iron Gate Reservoir to Copco 2 Dam show little change during the wet and dry simulations (Figure F-2 and Figure F-3). Both simulations indicate some minimal deposition between Iron Gate Reservoir and Copco 2 Dam, but little change in the other two riverine reaches (Figure F-2 and Figure F-3). Upstream of J.C. Boyle Reservoir (US J.C. Boyle) is also shown in Figure F-2 and Figure F-3, but is part of the Upper Klamath Basin above J.C. Boyle Reservoir reach. Nonetheless, model simulations indicate little, if any change in this portion of the Klamath River.



Source: Reclamation 2011.

Figure F-2. Reach Averaged Erosion in the Hydroelectric Reach during Wet Year

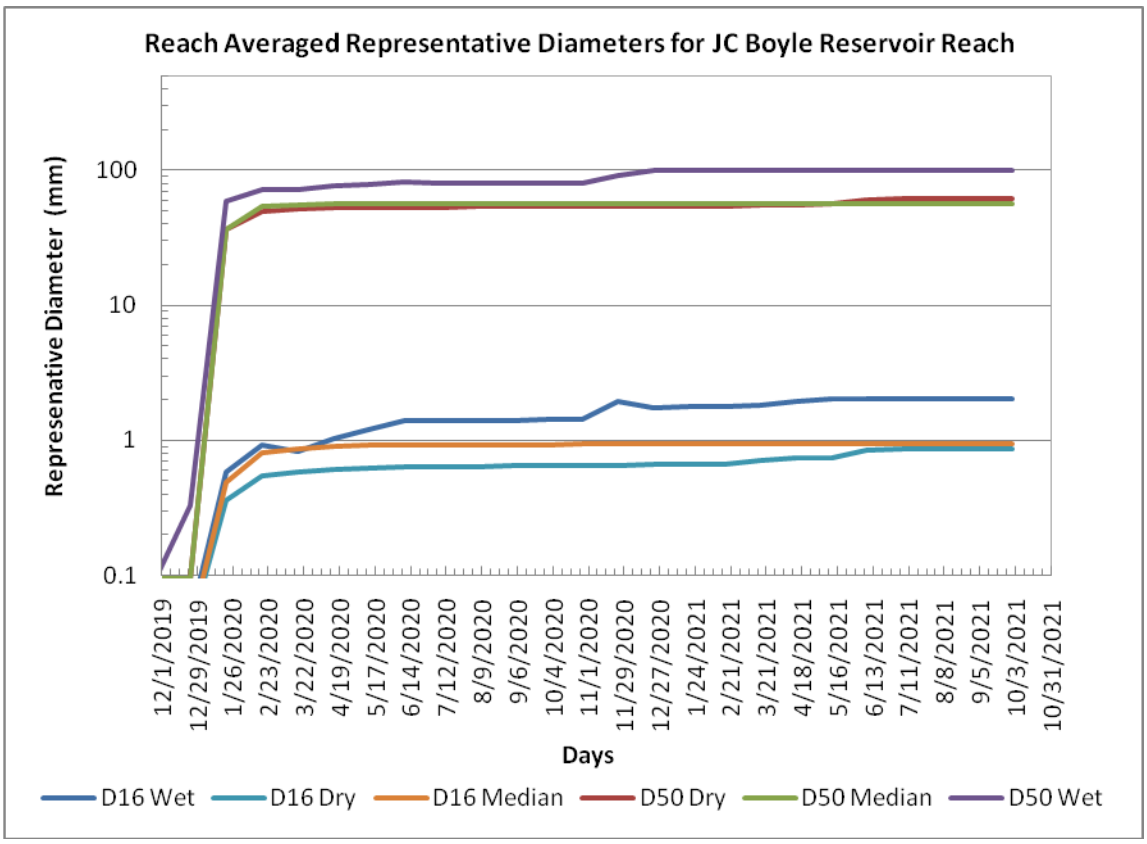


Source: Reclamation 2011.

Figure F-3. Reach Averaged Erosion in the Hydroelectric Reach during Dry Year

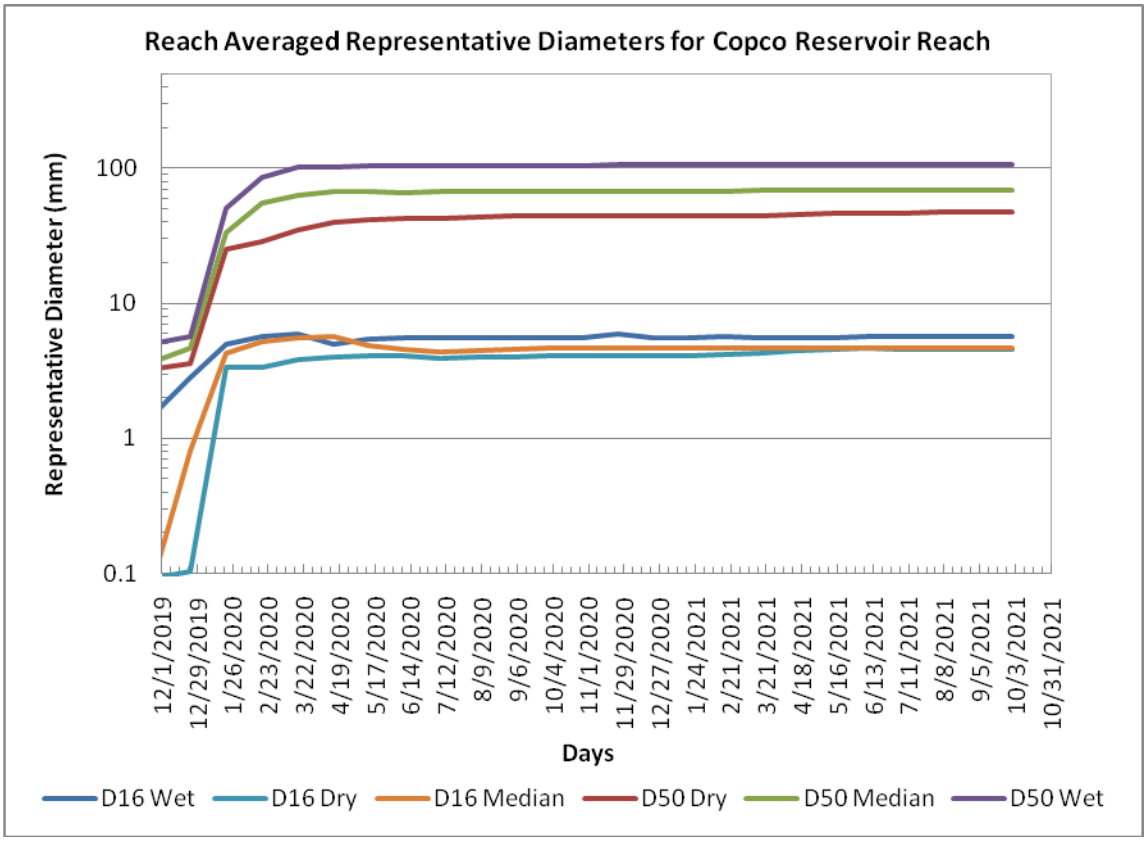
F.5.1.2 Changes in Bed Substrate

Within the reservoirs, SRH-1D modeling data for the first two years after dam removal show decreases in fine sediment and increases in median substrate size after drawdown that stabilize as the bed returns to pre-dam elevation. The proportion of fine sediment decreases from 50 to 80 percent to near zero within 2 months after drawdown, while the proportions of sand, gravel, and cobble increase to 20 to 40 percent, 20 to 30 percent, and 30 to 60 percent, respectively, depending on the reservoir and simulation type (i.e., wet, median, or dry) (Attachment F-1, Figures F1-1 to F1-9). D50s increase from less than 1 mm to sizes ranging from large gravel (32 to 64 mm) to small cobble (64 to 128 mm) (Figure F-4, Figure F-5, and Figure F-6) (Reclamation 2011). D50s may be slightly finer under the dry scenario, but are expected to approach wet and median scenario D50s over time (Reclamation 2011). The D16 (the size at which 16 percent of all particles are finer) shows similar patterns of increase and stabilization during drawdown, but remains sand or finer (less than 2 mm) under the dry and median simulations in the J.C. Boyle and Iron Gate Reservoir reaches (Figure F-4 and Figure F-6) (Reclamation 2011).



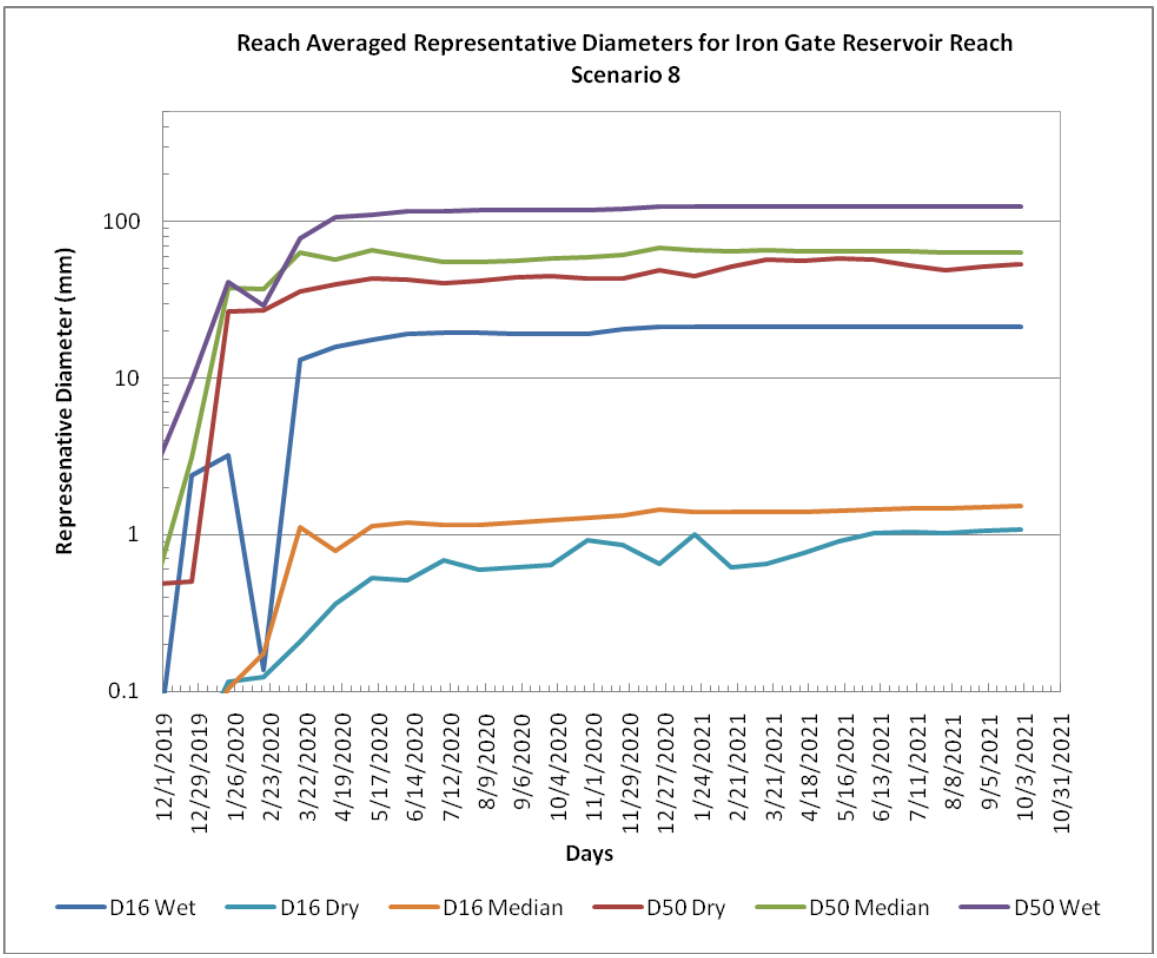
Source: Reclamation 2011.

Figure F-4. Reach Averaged D16 and D50 in J.C. Boyle Reservoir Reach Following Dam Removal



Source: Reclamation 2011.

Figure F-5. Reach Averaged D16 and D50 in Copco Reservoir Reach Following Dam Removal



Source: Reclamation 2011.

Figure F-6. Reach Averaged D16 and D50 in Iron Gate Reservoir Reach Following Dam Removal

The river reaches upstream of J.C. Boyle Reservoir and from Copco 1 Reservoir to J.C. Boyle Dam show little change in bed composition during drawdown. There is practically no temporal change in bed material in response to drawdown regardless of water year upstream of J.C. Boyle Reservoir and from J.C. Boyle Dam to Copco 1 Reservoir (Attachment F-1, Figures F1-10 to F1-15). These reaches are initially predominantly cobble (90 percent) with small fractions of gravel and sand and this composition is maintained throughout the 2-yr simulation.

The Copco 2 Dam to Iron Gate Reservoir reach shows increases in the proportion of sand to 35 to 45 percent shortly after drawdown (from January 2020 to February 2020) (Figure F-7, Figure F-8, and Figure F-9). The wet simulation shows decreases to less than 10 percent after February 2020 that continue through the end of two years, while the median simulation slowly decreases to 10 percent by July 2020 (Figure F-7 and Figure F-8). In the dry simulation, the percent sand decreases to 20 percent from

April 2020 to February 2021, then again to 10 percent from February 2021 to the end of the simulation (Figure F-9).

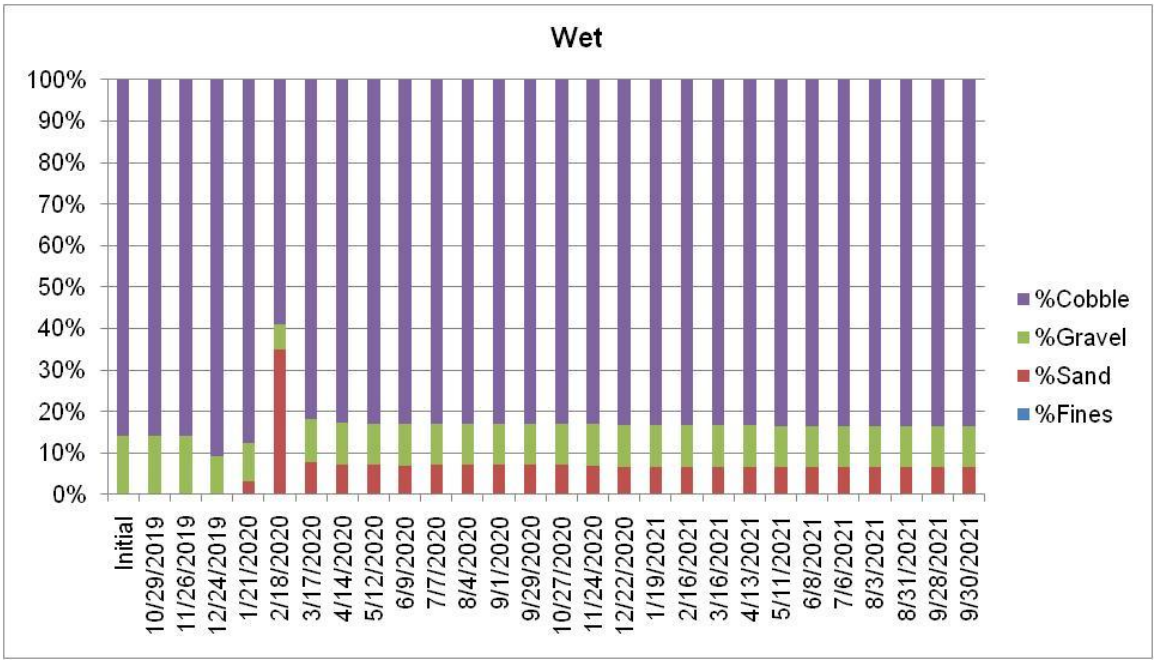
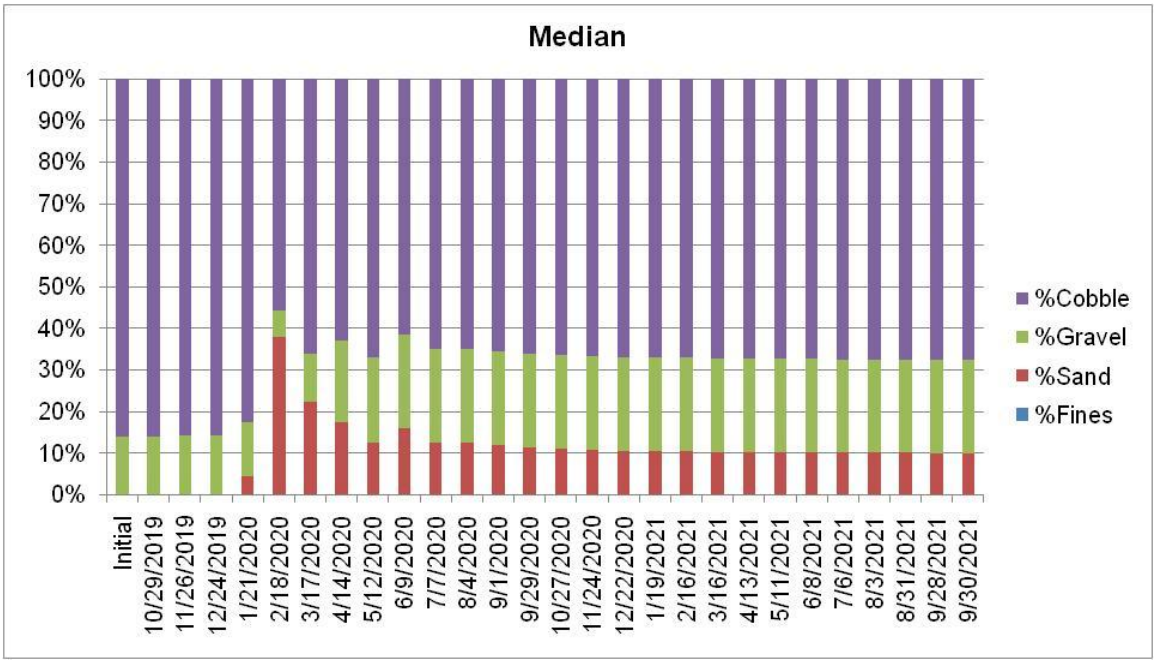


Figure F-7. Simulated Bed Composition from Iron Gate Reservoir to Copco 2 Dam during Two Successive Wet Water Years after Dam Removal



Source: Reclamation 2011.

Figure F-8. Simulated Bed Composition from Copco 2 to Iron Gate Reservoirs during Two Successive Median Water Years after Dam Removal

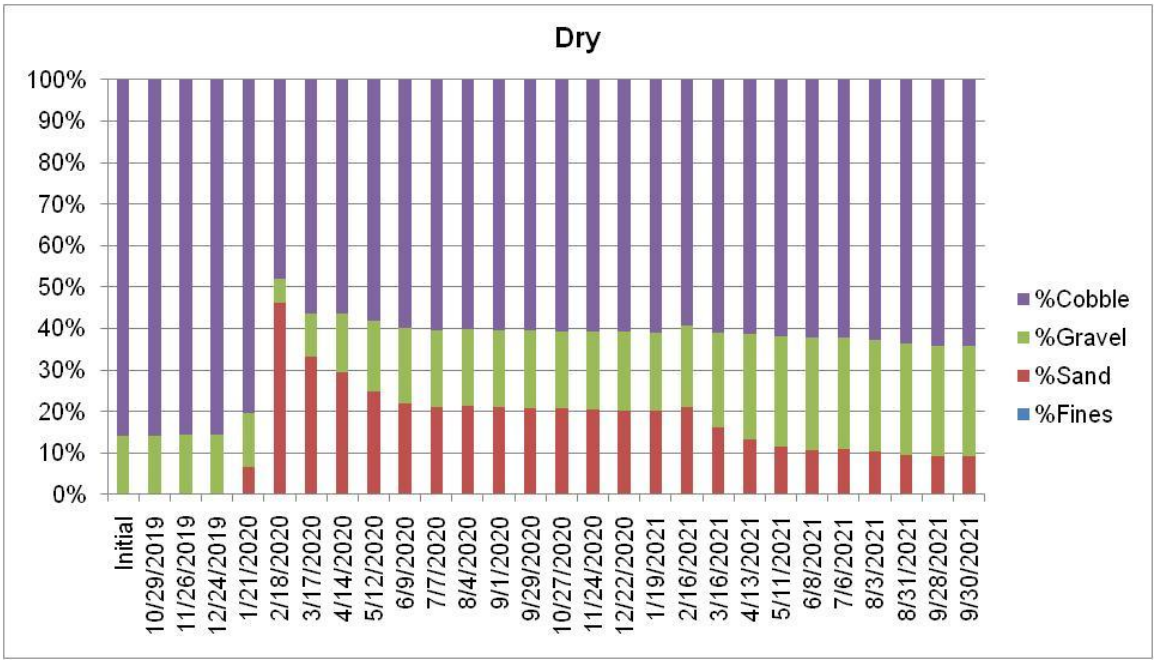


Figure F-9. Simulated Bed Composition from Copco 2 to Iron Gate Reservoirs during Two Successive Dry Water Years after Dam Removal

Fall-Run Chinook Salmon

The Proposed Action Could Have Impacts on Pool Habitat

The Proposed Action could erode sediment from reservoirs within the Hydroelectric Reach and, at most, cause minor (less than 0.5 ft) deposition in river reaches between reservoirs (Figure F-2 and Figure F-3). River channels within reservoir reaches could excavate to their pre-dam elevations within four months, and likely revert to and maintain a pool-riffle morphology, similar to the Downstream of Iron Gate Dam reach, due to restoration of riverine processes along the Hydroelectric Reach (PacifiCorp 2004). This could create holding and rearing habitat for anadromous salmonids. The removal of the dams would also create access to these habitats and habitats in reaches upstream. Fall-run Chinook salmon would first access the Hydroelectric Reach in fall 2020, at which time, the removal of the dam structures to stream elevation is expected to be complete. **Effects to pool habitat for fall-run Chinook salmon in the Hydroelectric Reach under the Proposed Action would be beneficial in the short- and long-term.**

The Proposed Action Could Have Impacts on Spawning Habitat

The Proposed Action could increase median substrate sizes in the Hydroelectric Reach. SRH-1D results show that during fall of 2020, when fall-run Chinook salmon first return to spawn after dam removal, D50s would range from coarse gravel (16 to 32 mm) to small cobble (64 to 128 mm) (Figure F-4, Figure F-5, and Figure F-6), which is within the preferred range for Chinook salmon spawning (16 to 70 mm [Kondolf and Wolman 1993]). As discussed above, the proportion of sand in the bed may be still be as high as 40 percent in former reservoir reaches and in the reach from Iron Gate Reservoir to

Copco 2 Dam (Figure F-9, Attachment F-1, Figures F1-1 to F1-9), which may impact spawning success (Chapman 1988), but would still provide spawning opportunities. River reaches between reservoirs would provide the preferred substrate size range for fall-run Chinook salmon, with very little sand (Attachment F-1, Figures F1-10 to F1-15), suggesting high quality spawning habitat. The removal of the dams would also create access to these habitats and habitats in reaches upstream. **Effects to spawning habitat for fall-run Chinook salmon in the Hydroelectric Reach under the Proposed Action would be beneficial in the short- and long-term.**

Spring-Run Chinook Salmon

Spring-run Chinook salmon distribution extends from the mouth of the Klamath River upstream to the Salmon River (Stillwater Sciences 2010b). Most spawning and rearing takes place within the Trinity and Salmon rivers. The current distribution of spring-run Chinook salmon does not extend as far as the Hydroelectric Reach. If spring-run Chinook salmon expand their range in response to dam removal, then they would benefit from this action in the same manner as fall-run Chinook salmon. Because spring-run Chinook salmon generally do not spawn on the mainstem, this benefit would be less than that for fall-run Chinook salmon. **Effects to spring-run Chinook salmon in the Hydroelectric Reach under the Proposed Action would be beneficial in the short- and long-term.**

Coho Salmon

Most coho salmon spawn and rear in the tributaries, but the mainstem Klamath River does contain habitat suitable for all lifestages (Stillwater Sciences 2010c). Iron Gate Dam currently blocks the upstream migration of coho salmon to upper reaches (Hamilton et al. 2005). Before construction of the dams in the Hydroelectric Reach, coho salmon distribution extended at least as far upstream as Spencer Creek, which enters the mainstem in J.C. Boyle Reservoir (Hamilton et al. 2005). The Proposed Action would restore access to the mainstem Klamath River and its tributaries upstream of Iron Gate Dam, increasing available rearing and spawning habitat. The changes to pool and spawning habitat described above for fall-run Chinook salmon may also provide suitable conditions for coho salmon spawning. Coho generally do not spawn in the mainstem, so the benefits to this species would not be as great, in terms of mainstem spawning. However, some coho do rear in the mainstem, and access to the cooler waters associated with tributaries entering the Hydroelectric Reach would be expected to benefit salmonids rearing in the mainstem (Hamilton et al. 2010). Access would also be provided to upstream tributaries where spawning and rearing would be expected to occur. Coho salmon are expected to use all tributaries upstream as far as Spencer Creek, including Jenny, Spring, and Fall Creeks. **Effects to coho salmon in the Hydroelectric Reach under the Proposed Action would be beneficial in the short- and long-term.**

Summer Steelhead

Summer steelhead distribution extends from the mouth of the Klamath River upstream to Empire Creek (RM 166.8) and may be rare above Seiad Creek (RM 130.9) due to water high water temperatures (Stillwater Sciences 2010c). The current distribution of summer steelhead does not extend as far as the Hydroelectric Reach, which begins at RM 190.

Like coho salmon, summer steelhead are expected to spawn and rear primarily in tributary streams. The Proposed Action may result in cooler water temperatures downstream of Iron Gate Dam that may increase the length of usable salmonid spawning and rearing habitat (Hamilton et al. 2010). The increase in usable length may extend summer steelhead distribution upstream to the Hydroelectric Reach. If this occurs, benefits to habitat described for fall-run Chinook and coho salmon (above) would occur to summer steelhead as well. **Effects to summer steelhead in the Hydroelectric Reach under the Proposed Action would be beneficial in the short- and long-term.**

Winter Steelhead

Winter steelhead are distributed throughout the Klamath River up to Iron Gate Dam, but spawn and generally rear in the tributaries (FERC 2007). There is no record of winter steelhead spawning in the mainstem Klamath River, which is used mainly as a migration corridor for adults and juveniles (Stillwater Sciences 2010c). With the removal of the dams, winter steelhead would be able to re-establish themselves throughout their much of their historic range, including the mainstem and tributaries within the hydroelectric reach and the Upper Basin (Hamilton et al. 2005). **Effects to winter steelhead in the Hydroelectric Reach under the Proposed Action would be beneficial in the short- and long-term.**

Green Sturgeon

Green sturgeon distribution extends from the mouth of the Klamath River upstream to the Salmon River (RM 66.5), with some observed migrating into the Salmon River, but do not ascend past Ishi Pishi Falls (Moyle 2002, FERC 2007), nor are they expected to do so if the dams were removed. Most spawning and rearing takes place within the lower mainstems of the Klamath and Trinity rivers. **There would be no impact to green sturgeon in the Hydroelectric Reach under the Proposed Action.**

Redband Trout

Within the Hydroelectric Reach, redband trout migrate between tributaries and reservoirs to complete their lifecycle (Hamilton et al. 2010). The Proposed Action would eliminate reservoir habitat as dams within the Hydroelectric Reach are removed and sediment moves downstream (Figure F-2 and Figure F-3). **The impacts to redband trout reservoir habitat would be significant in the short- and long-term under the Proposed Action**.

The Proposed Action would also create riverine habitat in sections of river formerly inundated by reservoirs. **As such, the Proposed Action would be a long-term benefit to redband trout riverine habitat.**

Lost River and Shortnose Suckers

Federally endangered Lost River and shortnose suckers occur within the Hydroelectric Reach. The Proposed Action would eliminate reservoir habitat as dams within the Hydroelectric Reach are removed and sediment is allowed to move downstream (Figure F-2 and Figure F-3). However, there is little or no successful reproduction of either sucker species downstream of Keno Dam and contributes minimally to conservation goals or significantly to recovery (Hamilton et al. 2010). **Thus, although the Proposed**

Action would have negative long-term impact on Lost River and shortnose sucker habitat in the Hydroelectric Reach, the overall impact to the population would be less than significant.

Nonnative Reservoir Fish

As discussed above, the Proposed Action would eliminate reservoir habitat as dams are removed. **Eliminating this habitat would have a negative impact on habitat for nonnative reservoir fish.**

F.5.2 Lower Klamath River: Downstream of Iron Gate Dam

The streambed downstream of Iron Gate Dam would be affected by dam released sediment and reconnection of natural sediment supply from upstream. The sediment stored within dams has a high water content and 85 percent of the particles are silts and clays (less than 0.063 mm) while 15 percent are sand or coarser (greater than 0.063 mm) (GEC 2006, Stillwater Sciences 2008, Reclamation 2011). As such, most sediment eroded from the dams would be silt and clay (less than 0.063 mm) with smaller fractions of sand (0.063 to 2 mm), gravel (2 to 64 mm), and cobble (64 to 256 mm) (GEC 2006, Stillwater Sciences 2010c, Reclamation 2011) (Table F-2). Silt and finer substrate, which comprise a large proportion of the volume of stored sediments, would likely be transported as suspended sediment and would travel to the ocean shortly after being eroded and mobilized (GEC 2006). Coarser (greater than 0.063 mm) sediment would travel downstream more slowly, attenuated by channel storage and the frequency and magnitude of mobilization flows. The amount of sand transported in suspension would vary with discharge, with greater proportions of sand in suspension at higher discharges.

Table F-2. Estimated Mass (Tons) of Reservoir Released Sediment by Size Under Wet, Median and Dry Water Years

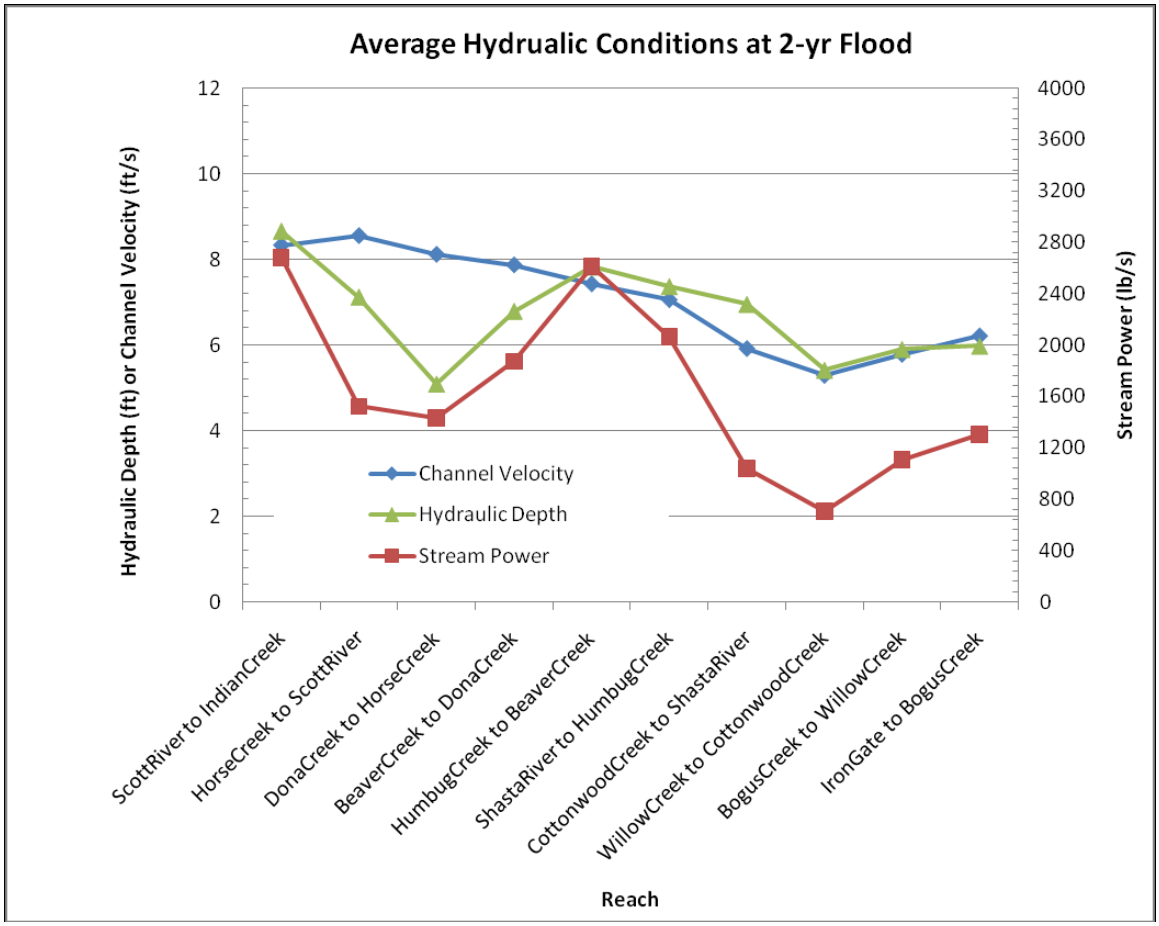
Substrate Size	Wet	Median	Dry
Silt (<0.063 mm)	2,352,233	1,808,719	1,238,525
Sand (0.063 to 2.0 mm)	185,797	276,558	124,371
Gravel (2 to 64 mm)	37,942	18,213	1,116
Cobble (64 to 256 mm)	5,889	1,513	76
Total	2,581,862	2,105,002	1,364,089

Source: Reclamation 2011

F.5.2.1 Downstream Extent of Effect

The effect of dam released sediment and sediment resupply likely extends from Iron Gate Dam to Cottonwood Creek (Reclamation 2011). Estimates of reach averaged stream power (based upon channel depth, width, and slope)) show a decrease from Iron Gate Dam to Cottonwood Creek, with stream power then increasing again downstream of Cottonwood Creek (Figure F-10). The increase suggests that short- or long-term sediment deposition, either from dam release or sediment resupply, is unlikely downstream of Cottonwood Creek. Using Cottonwood Creek as the downstream extent

of bedload related effects, 8 miles of channel could potential be affected by sediment release and resupply. The affected channel represents 4 percent of the total channel length of the mainstem Klamath River downstream of Iron Gate Dam (190 miles).



Source: Reclamation 2011.

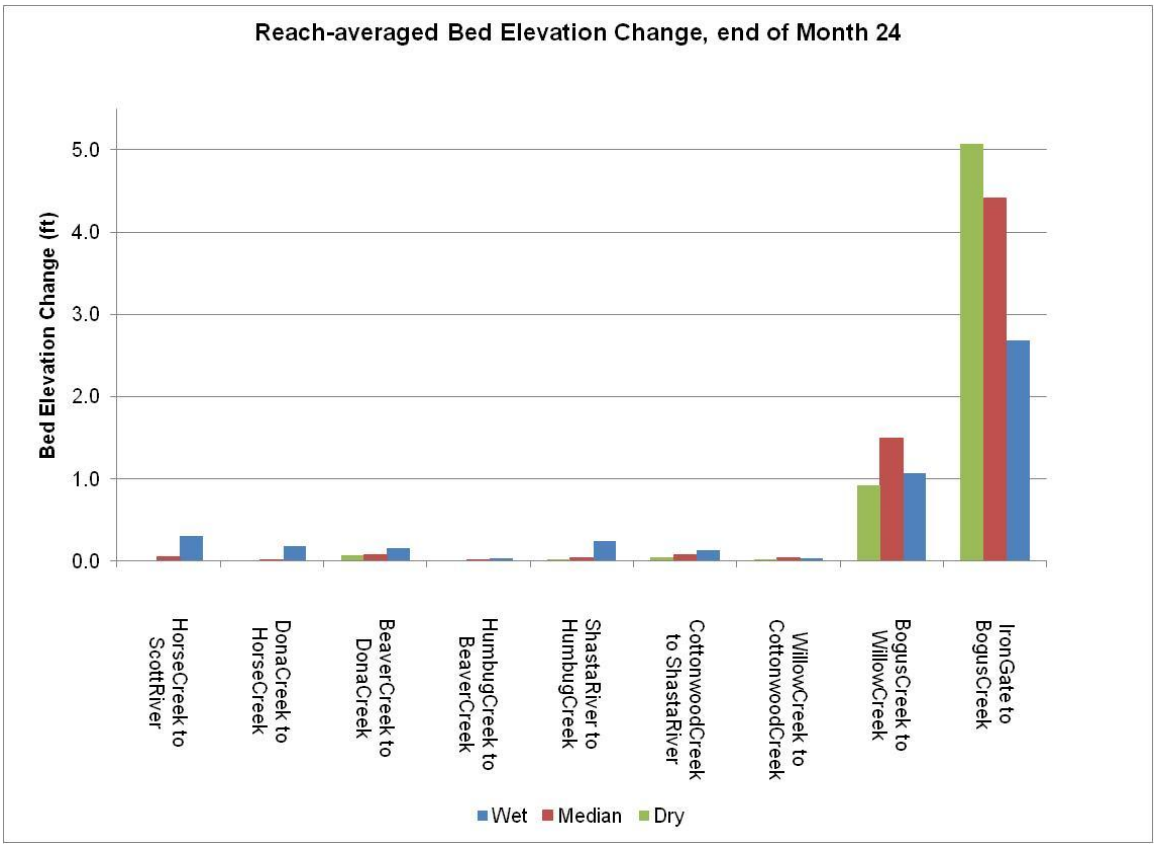
Figure F-10. Reach Averaged Stream Power Downstream of Iron Gate Dam

F.5.2.2 Changes in Bed Elevation

Short-term (2-yr) SRH-1D model simulations estimate up to 5 ft of reach averaged deposition between Iron Gate Dam and Bogus Creek (RM 189.8) (2.5 to 5 ft), decreasing downstream between Bogus Creek and Willow Creek (RM 185.2) (1.0 to 1.5 ft), reaches farther downstream showed no apparent increase (Figure F-11). Reach averaged bed elevation between Iron Gate Dam to Bogus Creek would increase by 5 ft after drawdown (January 2020) until March 2020 under dry and median simulations, and would increase by 3 ft after drawdown until April 2020 under the wet simulation (Figure F-12). Elevations under the dry and median simulation would approach a level similar to the wet simulation (3 feet) over time as flows carry dam released sediment downstream. The

reach from Bogus Creek to Willow Creek would experience lesser increases in average bed elevation, but with similar short-term temporal patterns (Figure F-13).

In the long-term (from 5 to 50 years), after downstream translation of dam released sediment, bed elevation would adjust to a new equilibrium, which includes sediment supplied by upstream tributaries that was formerly trapped by dams within the Hydroelectric Reach. Reclamation (2011) expects 2 to 3 feet of aggradation between Iron Gate Dam and Cottonwood Creek over the next 50 years.



Source: Reclamation 2011.

Figure F-11. Reach Averaged Bed Elevation after Two Successive Wet, Median, or Dry Water Years

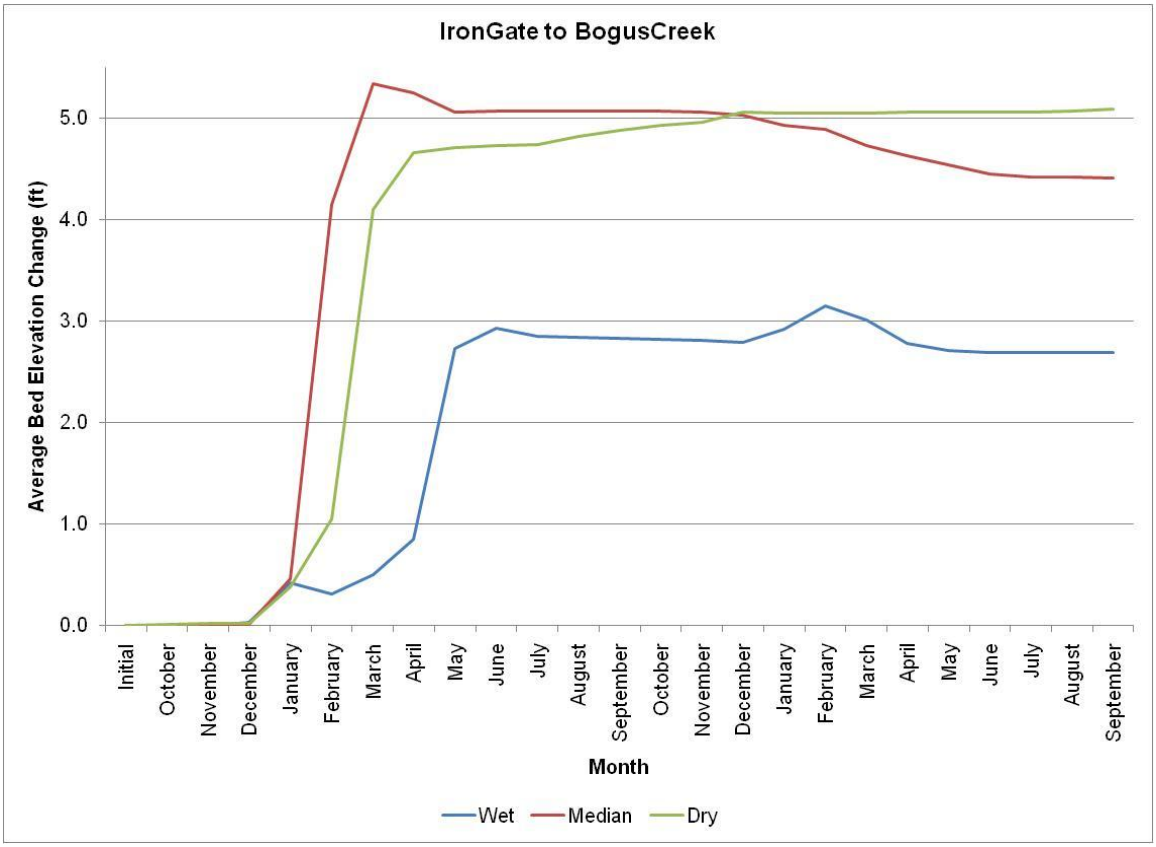


Figure F-12. Reach Averaged Bed Elevation during Two Successive Wet, Median, or Dry Water Years from Iron Gate Dam to Bogus Creek

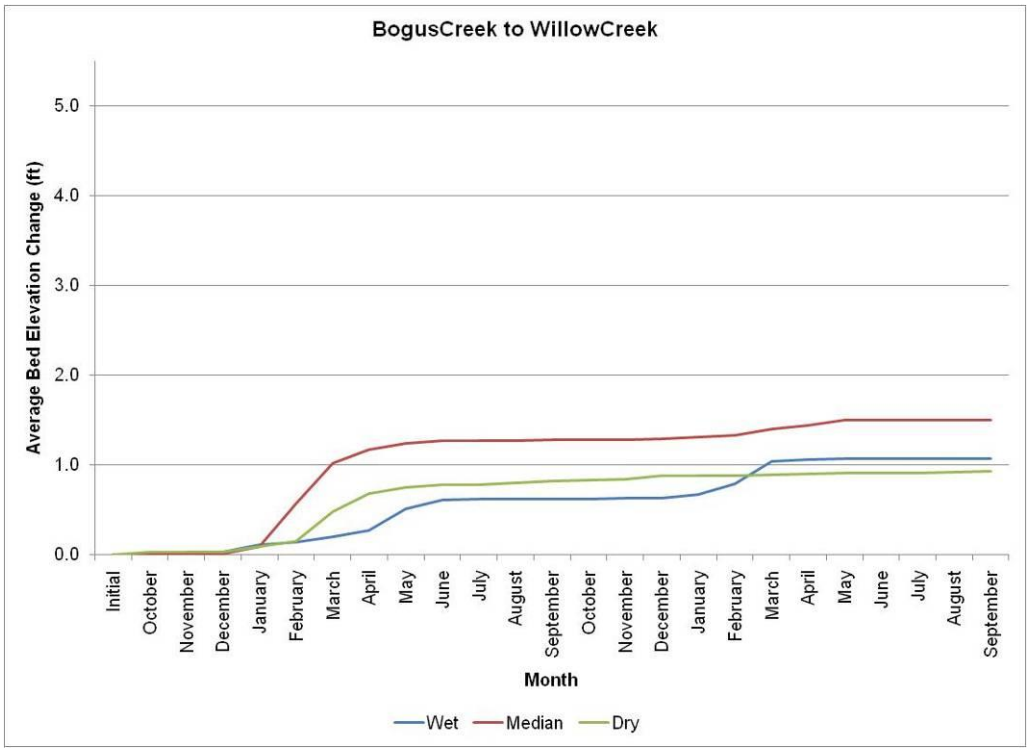
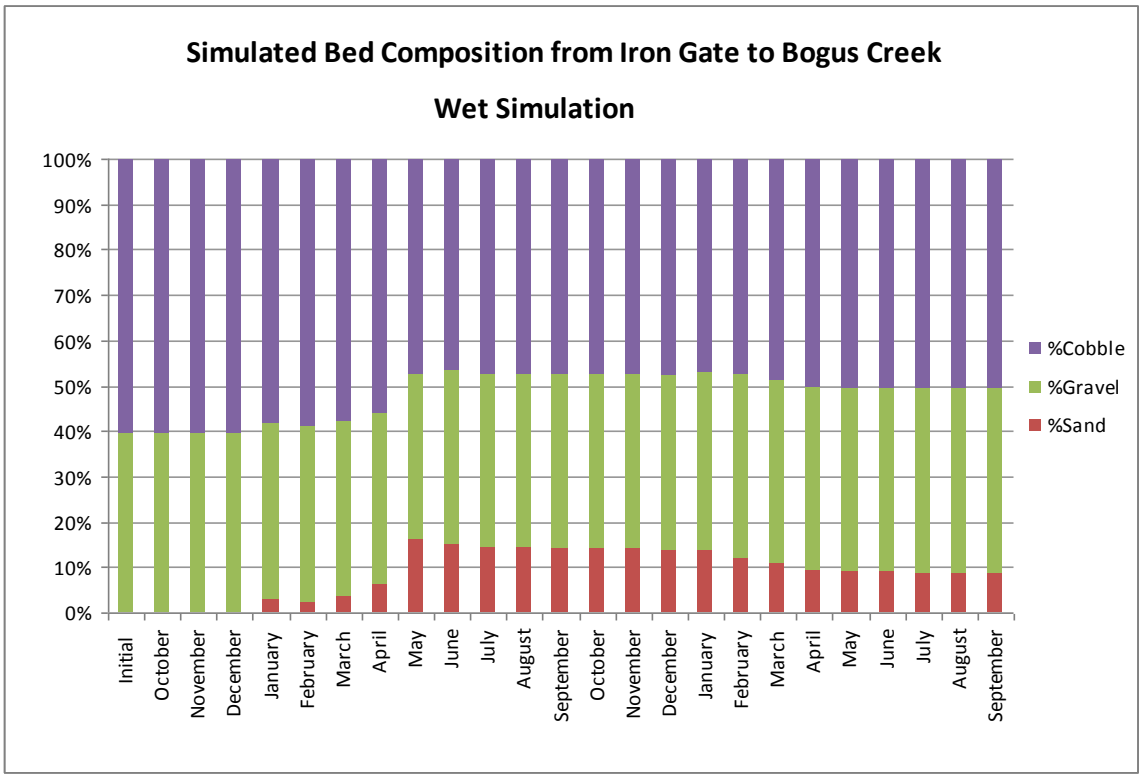


Figure F-13. Changes in Each Averaged Bed Elevation 50 Years after Dam Removal

F.5.2.3 Changes in Bed Substrate

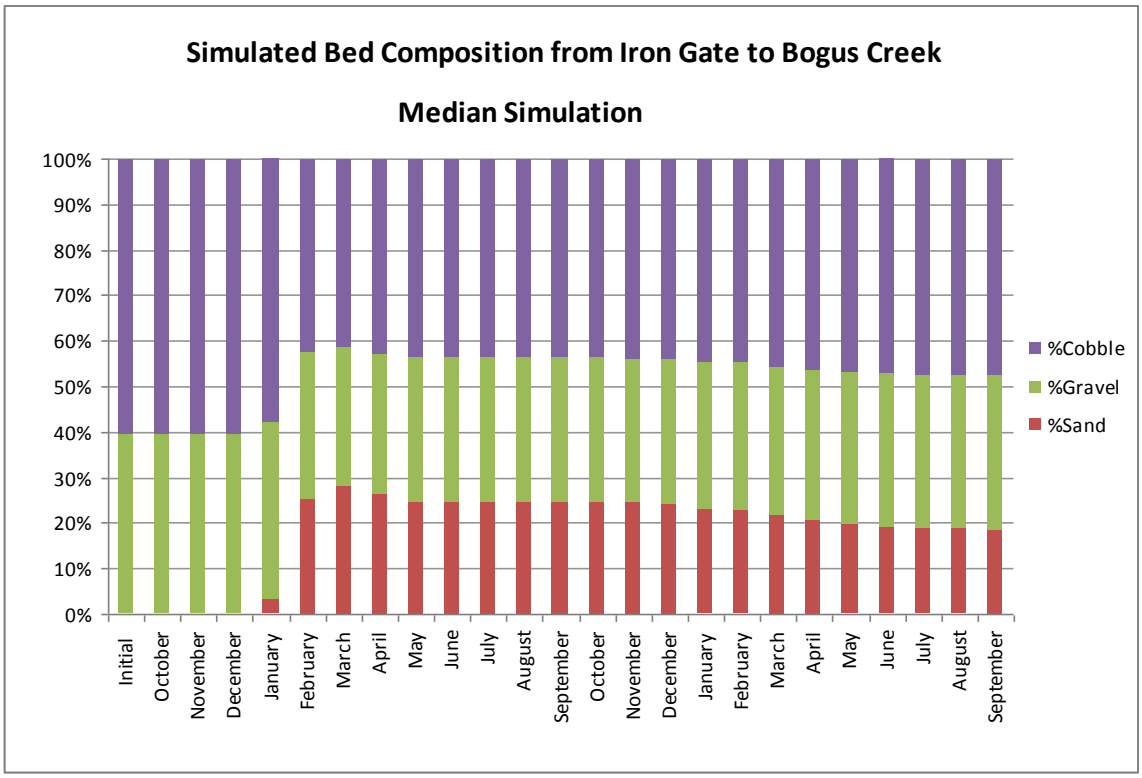
In the short-term (less than 2 years), SRH-1D model output indicates dam released sediment and sediment resupply would increase the proportion of sand in the bed and decrease median bed substrate size (Reclamation 2011). The model assumes that the channel bed is initially sand free with a D50 of 75 mm, representing current conditions where the bed is sediment starved due to upstream trapping of coarse sediment by dams. Under wet and median simulations, sand within the bed would increase to 15 to 30 percent by March 2020 after drawdown, gradually decreasing to 10 to 20 percent by September 2021, while median substrate size would decrease to 50 to 60 mm then gradually increase to 60 to 65 mm (Figure F-14, Figure F-15, and Figure F-16). The model predicts that after two successive dry years, the proportion of sand on the bed would increase to 30 percent and median substrate size would decrease to 45 mm after drawdown in January 2020 to March 2020 and remain at these values though to September 2021 (Figure F-16 and Figure F-17). The reach from Bogus Creek to Willow Creek showed a slight increase in the proportion of sand (less than 10 percent under all simulations) and a minimal decrease in median substrate size (Attachment F-1 Figures F1-16 to F1-19). Willow Creek to Cottonwood Creek showed no short-term changes in sand composition or median substrate sizes (Attachment F-1, Figures F1-20 to F1-23). The probability of flushing dam released fine sediment from the Iron Gate Dam to Bogus Creek reach depends upon flow. Reclamation (2011) estimated a flow of 7,500 cfs would

flush dam released sand and smaller substrate from the reach. The probability of this flow occurring during the drawdown year was 15 percent, increasing to 54 percent by the third year, and 67 percent by the fifth year.



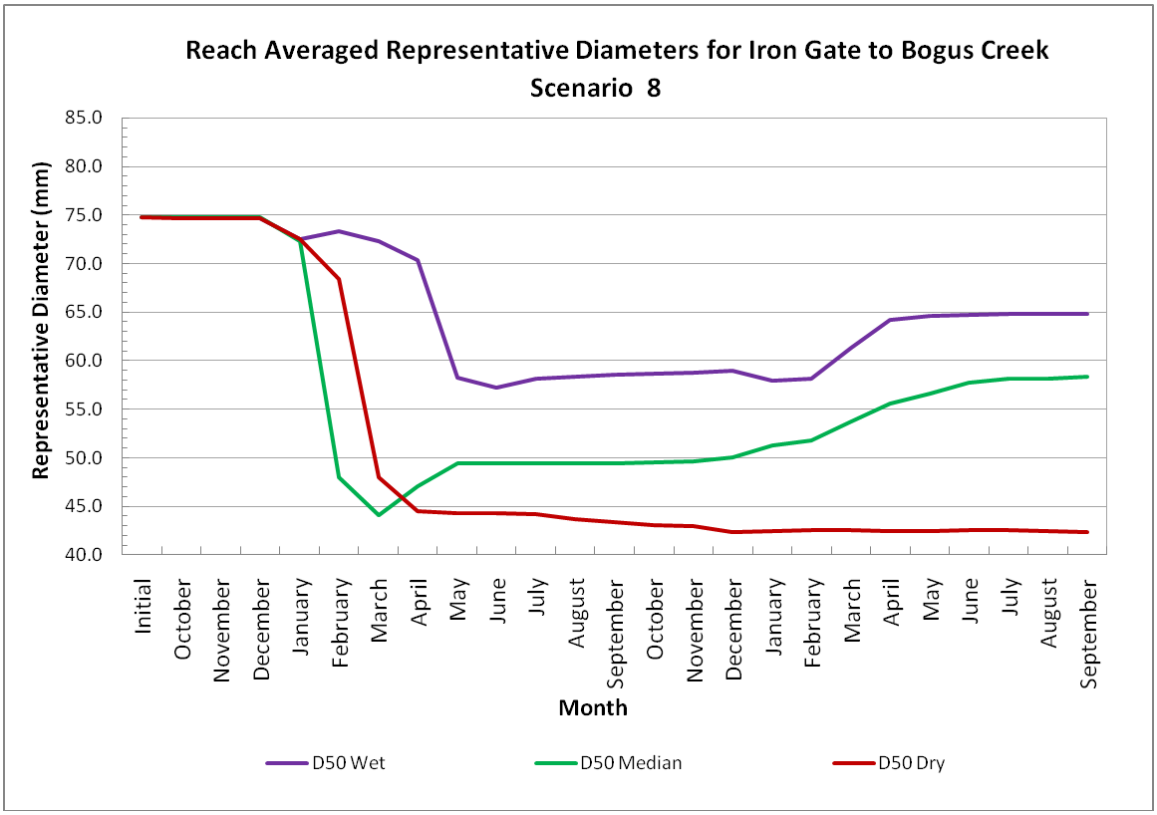
Source: Reclamation 2011.

Figure F-14. Simulated Bed Composition from Iron Gate Dam to Bogus Creek during Two Successive Wet Water Years Dam Removal



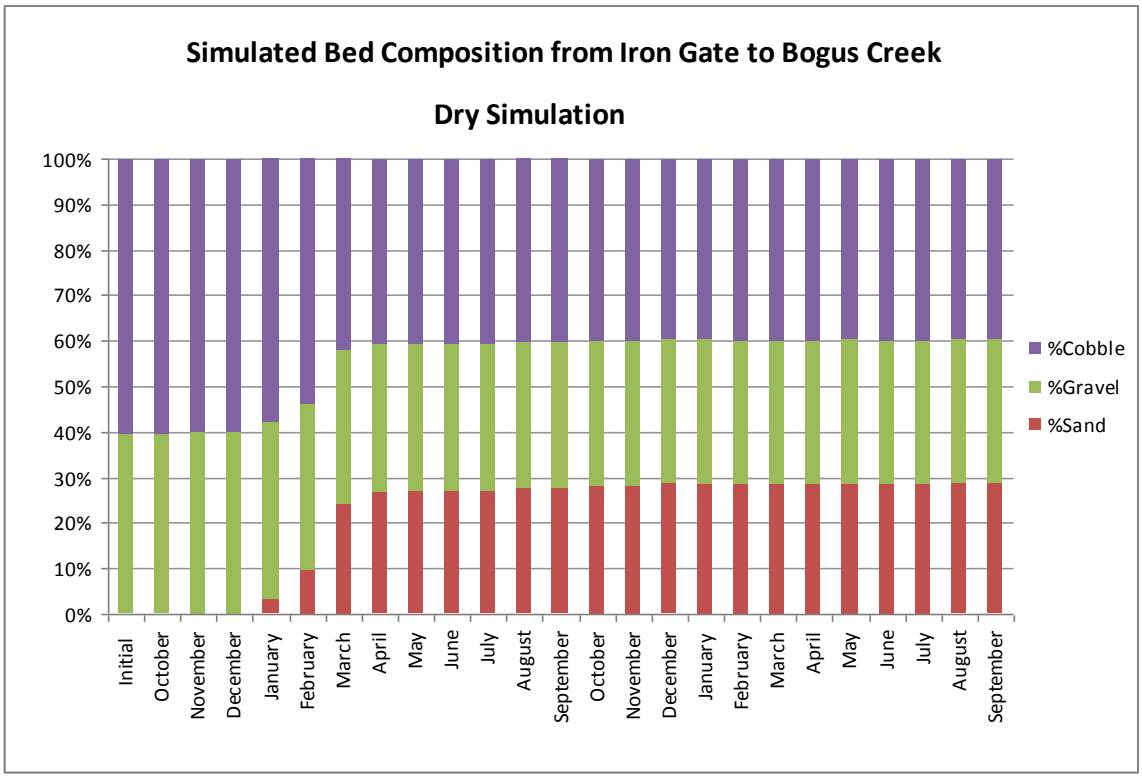
Source: Reclamation 2011.

Figure F-15. Simulated Bed Composition from Iron Gate Dam to Bogus Creek during Two Successive Wet Water Years Dam Removal



Source: Reclamation 2011.

Figure F-16. Simulated D50 (mm) From Iron Gate Dam to Bogus Creek During Successive Wet, Median, and Dry Water Years



Source: Reclamation 2011.

Figure F-17. Simulated Bed Composition from Iron Gate Dam to Bogus Creek during Two Successive Dry Water Years Dam Removal

Longer-term (5, 10, 25, and 50 years) simulations show increases in the proportion of sand to 5 to 22 percent and decreases in D50 to approximately 50 to 55 mm (Attachment F-1, Figures F1-24 to F1-30) after five years that stabilize and continue through to year 50. Reaches downstream of Cottonwood Creek showed no long-term changes to bed composition or substrate size (Reclamation 2011).

Under the Proposed Action, the flows required to mobilize bed sediment would decrease as the bed would become finer due to dam released sediment and sediment resupply from upstream tributaries. Reclamation (2011) estimated the magnitude and return period of flows required to mobilize sediment downstream of Iron Gate Dam 50 years after dam removal using reach averaged predicted grain sizes from long-term SRH-1D simulations. The estimates show that under the Proposed Action, sediment mobilization flows from Bogus Creek to Willow Creek and from Willow Creek to Cottonwood Creek would range from 3,000 to 7,000 cfs (1.5 to 2.5 year return period) and 5,000 to 9,000 cfs (1.5 to 3.2 year return period), respectively, lower than current conditions or the No Action/No Project Alternative. Downstream of the Shasta River, there would be no difference in bed mobilization flows or return period between the Proposed Action and current conditions or the No Action/No Project Alternative.

Impact Statements

Fall-run Chinook Salmon

The Proposed Action Could Have Short-Term Impacts On Spawning Habitat

As discussed above effects on bed substrate are limited to the 8-mile reach from Iron Gate Dam to Cottonwood Creek (4 percent of current total channel length). The most pronounced effects occur in the 0.5-mile reach from Iron Gate Dam to Bogus Creek, where SRH-1D modeling results estimate that from February to April 2020, when fall-run Chinook salmon fry spawned in 2019 would emerge, the proportion of sand in the bed may be as high as 20 to 30 percent under the dry scenario (Figure F-17). This amount of sand could negatively impact embryo survival to emergence (Chapman 1988). During the fall of 2020 under the dry scenario, SRH-1D results also show that when fall-run Chinook salmon first return to spawn after dam removal, median substrate size may be as low as 40 mm (Figure F-16). This falls within the observed range for Chinook salmon spawning (16 to 70 mm [Kondolf and Wolman 1993]), but the high sand composition could impact spawning success.

The high sand content would be limited to a small proportion of the total channel length (less than 1 percent [0.5 mi]), as sediment deposition lessens downstream of Bogus Creek to Cottonwood Creek (Figure F-11). Further, the effects would only occur in successive median or dry years (Figure F-15 and Figure F-17), the proportion of sand in the substrate in successive wet years could be 10 to 15 percent (Figure F-14). If dry or median years occurs in the first two years, there is a 54 percent probability that flows could transport dam released sand and finer substrate from the reach within 3 years, and a 67 percent probability after 5 years (Reclamation 2011). Flume experiments conducted by Stillwater Sciences (2008) also found that the amount of fine sediment infiltrating into the channel bed during sediment pulses decreased with depth below the surface, with significant deposition only observed to a shallow depth. The results suggest that fine sediment infiltration into the gravel bed (and potential spawning gravel) during dam removal would be minimal and short-lived, able to be transported downstream during subsequent high flows.

Short-term (2–yr) aggradation of sediment from the dams could be substantial below Iron Gate Dam downstream to Willow Creek, with up to 5 feet of deposition within 0.5 miles downstream of the dam, to 1.5 feet of deposition near Willow Creek (Figure F-12 and Figure F-13). The amount of deposition within these reaches is expected to bury any salmonid redds and associated eggs to such a depth that alevin emergence would likely be adversely affected. Farther downstream, depositional depths are such that alevins in the gravel would likely not be affected.

Adult fall-run Chinook salmon returning to spawn the Iron Gate Dam to Bogus Creek reach in 2020, and potentially in 2021 would encounter a higher proportion of sand in the substrate than what was present prior to dam removal. The proportion of sand in the bed is projected to be 10 to 30 percent (Figure F-14, Figure F-15, Figure F-17). Salmonids are naturally adapted to select spawning habitat that maximizes egg survival and do so in response to geomorphic processes alter river channels from year to year. Adults returning in 2020 or 2021 would still spawn in the Iron Gate Dam to Bogus Creek reach

if suitable habitat was present. If no suitable habitat exists, adults could choose to spawn in downstream reaches or newly accessible (due to dam removal) upstream reaches with suitable habitat. Because of this behavioral adaptation, eggs of fall-run Chinook salmon returning in 2020 or 2021 would likely be unaffected by the changes described above.

Fall-run Chinook salmon eggs deposited in the fall of 2019 in the reach from Iron Gate Dam to Bogus Creek could be lost; and less substantial losses may continue to occur downstream to the vicinity of Willow Creek. Nonetheless, only a small proportion (4 percent) of basin-wide fall-run Chinook spawning occurs in the mainstem Klamath River (FERC 2007). Additionally, the changes described above affect a small proportion of the total habitat available to the species on the mainstem below Iron Gate Dam (8 miles or 4 percent of current total channel length, Figure F-10) and do not affect tributaries that may provide additional habitat. Finally, these effects are likely to occur in only a single year. **Based on this, potential changes to spawning habitat would likely not have a significant short-term impact to fall-run Chinook salmon.**

The Proposed Action Could Have Long-Term Impacts on Spawning Habitat

Five years after dam removal, SRH-1D estimates that the proportion of sand in the bed would be less than 15 percent and median substrate sizes would be near 55 mm in all reaches from Iron Gate Dam to Cottonwood Creek (Attachment F-1, Figures F1-24 to F1-30) (Reclamation 2011). Less than 15 percent sand in spawning gravel is not expected to substantially reduce survival to emergence and 55 mm falls within the observed range for Chinook salmon spawning (16 to 70 mm [Kondolf and Wolman 1993]). Flows occurring after the pulse of dam released sediment has passed downstream are expected to reduce bed elevations from those that occur immediately following dam removal (Figure F-12), but the bed elevation would be expected to remain higher than pre-dam removal conditions (Reclamation 2011). Additional bed aggradation may occur as sediment supplied from tributaries to the Hydroelectric Reach is transported to and deposited within reaches downstream of the dams. These changes are not expected to negatively affect fall-run Chinook salmon spawning. These changes would stabilize and remain consistent through 50 years and are **not anticipated to impact fall-run Chinook salmon spawning habitat.**

The Proposed Action Could Have Short-Term Impacts on Pool Habitat

The Proposed Action could increase the level of sediment deposition downstream of Iron Gate dam to Cottonwood Creek, a length of 8 miles, or 4 percent of the current total channel length. The deposition may aggrade pools or overwhelm other habitat features used for adult holding or juvenile rearing. The most pronounced effects occur in the 0.5 mile reach from Iron Gate Dam to Bogus Creek where SRH-1D modeling results show that sediment deposition might increase bed elevation by as much as 3 to 5 ft within the first two years (Figure F-11 and Figure F-12), depending on water year type. This may affect the depth and area of available pool habitat. The SRH-1D model estimates reach average changes and is not capable of providing data on a morphologic unit-scale (e.g., pool), or describing how sediment is distributed along the channel (Stillwater Sciences 2008, Reclamation 2011). Flume experiments conducted by Stillwater Sciences (2008) found that a coarse-bedded channel with pool-riffle morphology, similar to that

found in the Klamath River below Iron Gate Dam, would maintain pool topography during temporary channel filling (i.e., during pulses of fine and coarse sediment). Pools are erosional features, evacuating sediment pulses before other morphologic units (e.g., riffles), and would likely return to their pre-sediment release depth after downstream translation of the pulse (Stillwater Sciences 2008). These results suggest that effects on pool habitat would likely be minor. The most severe effects would also be limited to a small proportion of the total channel length (less than1 percent [0.5 mi]), as sediment deposition lessens downstream of Bogus Creek to Cottonwood Creek (Figure F-11). The lifestages of fall-run Chinook salmon that use pools, adults, juveniles, and fry are not tied to specific pools and are capable of seeking desirable areas. **Based on this, potential changes to pool habitat would likely not have a significant short-term impact to fall-run Chinook salmon.**

The Proposed Action Could Have Long-Term Impacts on Pool Habitat

In the long-term (from 5 to 50 years), after downstream translation of dam released sediment, bed elevation would adjust to a new equilibrium that includes sediment supplied by upstream tributaries (sediment that was formerly trapped by dams within the Hydroelectric Reach). Reclamation (2011) expects 2 to 3 feet of aggradation between Iron Gate Dam and Cottonwood Creek over the next 50 years. The river would likely revert to and maintain its natural pool-riffle morphology, similar to current condition, and pool frequency, size, and depth would likely remain similar. **Impacts would be less than significant.**

Spring-Run Chinook Salmon

Spring-run Chinook salmon distribution extends from the mouth of the Klamath River upstream to the Salmon River (Stillwater Sciences 2010b). Most spawning and rearing takes place within the Trinity and Salmon rivers. As discussed in above, bedload sediment effects related to dam released sediment or sediment resupply likely extend as far as the Cottonwood Creek, with the most pronounced effect occurring between Iron Gate Dam and Bogus Creek, and thus would not affect the area currently used by spring-run Chinook salmon. **There would be no impact to spring-run Chinook salmon in the Lower Klamath River Reach under the Proposed Action.**

Coho Salmon

The Proposed Action Could Have Short-Term Impacts on Spawning Habitat

Recent estimates show that 100 adults or fewer spawned within the mainstem Klamath River along the 63 mile reach from Iron Gate Dam to Portuguese Creek from 2001–2004 (Hamilton et al., 2010). Most coho salmon spawn in tributaries to the Klamath River. Most rearing occurs on these tributaries as well, although some coho juveniles may rear in the mainstem when conditions in the tributaries become unsuitable. **The effects of bedload and sediment composition changes would likely eradicate any coho salmon eggs that were spawned on the mainstem above Willow Creek in 2019, although the number is expected to be very low because most spawning occurs in tributaries. In subsequent years, coho salmon would be able to behaviorally adapt to bed**

composition changes (i.e., disperse to suitable spawning habitat), and no effect would be expected.

The Proposed Action Could Have Long-Term Impacts on Spawning Habitat
Five years after dam removal, SRH-1D estimates that the proportion of sand in the bed would be less than15 percent and median substrate sizes would be near 55 mm in all reaches from Iron Gate Dam to Cottonwood Creek (Attachment F-1, Figures F1-24 to F1-30) (Reclamation 2011). The median substrate size may limit coho spawning in the mainstem Klamath River, as the observed range for coho salmon spawning is 5 to 35 mm (Kondolf and Wolman 1993). However, most coho spawn in tributaries with very few observed spawning in the mainstem (Hamilton et al. 2010, Stillwater Sciences 2010c). It is also likely that areas of suitably sized gravel would occur on the mainstem, although their distribution would likely be limited. Less than 15 percent sand in spawning gravel is not expected to substantially reduce survival to emergence (Chapman 1988). **These effects are not anticipated to impact coho salmon spawning habitat.**

The Proposed Action Could Have Short-Term Impacts on Pool Habitat
The impacts to coho salmon resulting from short-term filling of pools in the mainstem would be negligible for the same reasons described for fall-run Chinook salmon. **Impacts would be less than significant.**

The Proposed Action Could Have Long-Term Impacts on Pool Habitat
The impacts to coho salmon resulting from long-term filling of pools in the mainstem would be negligible for the same reasons described for fall-run Chinook salmon. **Impacts would be less than significant.**

Summer Steelhead
Summer steelhead currently occupy the Klamath River downstream of Empire Creek (RM 166.8). This run of steelhead spawns in tributaries, although some fish may rear in the mainstem. **The short-term bedload sediment impacts associated with dam removal are not expected to intersect with their current distribution, and therefore would not impact this species.**

Winter Steelhead
Winter steelhead adults and juvenile use the mainstem Klamath River mainly as a migration corridor (Stillwater Sciences 2010b), but access the river all the way to Iron Gate Dam. A small proportion of the population may rear in some areas where coolwater refugia are present. Like summer steelhead, spawning occurs in tributaries (Stillwater Sciences 2010c). **Changes in bedload and geomorphology would not impact spawning or incubation habitat and would have minimal effect on rearing habitat as described for fall-run Chinook salmon and summer steelhead.**

Green Sturgeon
As discussed above, bedload sediment effects related to dam released sediment or sediment resupply likely extend as far as the Cottonwood Creek. Current green sturgeon distribution extends from the mouth of the Klamath River upstream to the Ishi Pishi Falls

(Moyle 2002, FERC 2007), with some observed migrating into the Salmon River. **As there is no overlap between these two areas, there would be no impact to green sturgeon in the Lower Klamath River Reach under the Proposed Action.**

F.5.3 Klamath River Estuary

As discussed in above, bedload sediment effects related to dam released sediment or sediment resupply likely do not extend as past Cottonwood Creek. **Therefore, there would be no bedload related impacts to aquatic species in the Klamath River Estuary Reach under the Proposed Action.**

F.5.4 Pacific Ocean Near Shore Environment

As discussed above, bedload sediment effects related to dam released sediment or sediment resupply likely do not extend as far downstream as Cottonwood Creek (RM 180). **There would be no bedload related impacts to aquatic species in the Pacific Ocean near shore environment under the Proposed Action.**

F.6 Partial Facilities Removal of Four Dams Alternative

Alternative 3-Partial Facilities Removal would remove enough of each dam to allow free-flowing river conditions and volitional fish passage at all times. Under the partial removal alternative, portions of each dam would remain in place along with ancillary buildings and structures such as powerhouses, foundations, tunnels, and pipes, all of which would be outside of the 100-year flood prone width. Under this alternative, embankment/earth-filled dam and concrete dam structures would be removed (see Chapter 5) similar to the Proposed Action, allowing release of dam-stored sediment. Effects and impacts to bedload sediment under the Partial Facilities Removal Alternative are expected to be the same as those for the Proposed Action: Full Facilities Removal.

F.7 Fish Passage at Four Dams Alternative

Under Alternative 4, Fish Passage at Four Dam, fish passage structures would be installed at each dam to allow for upstream fish passage (see Chapter 5). No portion of the dams would be removed under this alternative and sediment would continue to be stored behind project dams, similar to the No Action/No Project Alternative. Effects and impacts to bedload sediment under the Partial Facilities Removal Alternative are expected to be the same as under the No Action/No Project Alternative.

F.8 Fish Passage at J.C. Boyle and Copco 2, Remove Copco 1 and Iron Gate

Under this alternative, J.C. Boyle Dam would continue to store sediment, but the storage capacity of Copco 2 Dam would likely be filled by the release of sediments during the Copco 1 Dam. This scenario has not been modeled, but the effects of bedload sediment

movement under the Fish Passage at J.C. Boyle and Copco 2, Remove Copco 1 and Iron Gate Alternative are expected to be similar to, but of slightly lesser magnitude, than under Alternative 2 Proposed Action: Full Facilities Removal.

F.9 Mitigation Measure Analysis: Proposed Action with Mechanical Sediment Removal

The Mechanical Sediment Removal (dredging) mitigation measure would remove sediment from J.C. Boyle, Copco 1, and Iron Gate Reservoirs prior to and during dredging. Dredging would occur where the sediment would be most easily eroded during drawdown of the reservoirs according to the following assumptions:

- Historical river channel would be eroded to its pre-dam elevation
- Historical tributaries would be eroded to their pre-dam course and elevation
- Narrow and steep canyons would erode
- The reservoir side slopes erode at a slope of 10 Horizontal: 1 Vertical

The volume of sediment removed under the Mechanical Sediment Removal mitigation measure is shown in Table F-3.

Table F-3. Estimated Volume (yd^3) and Mass (Tons) of Sediment Currently Stored within Hydroelectric Reach Reservoirs

Reservoir	Sediment Volume (yd^3) Dredged Pre-Drawdown	Sediment Volume (yd^3) Dredged During Drawdown	Sediment Volume (yd^3) Dredged Total
J.C. Boyle	335,900	219,500	555,400
Copco 1	176,600	1,277,500	1,454,100
Copco 2	0	0	0
Iron Gate	106,100	733,100	839,200
Total	618,600	2,230,100	2,848,700

Source: Reclamation 2011

The Mechanical Sediment Removal mitigation measure would reduce the amount of sediment released downstream compared to the Proposed Action. Most sediment eroded from the dams would still be silt and clay (less than 0.063 mm) with smaller fractions of sand (0.063 to 2 mm), gravel (2 to 64 mm), and cobble (64 to 256 mm), but 35-40 percent less overall mass would be released downstream than under the Proposed Action (Table F-4). The discussion below focuses on the reach from Iron Gate Dam to Bogus Creek, which had the greatest changes in bed elevation and bed substrate composition (compared to downstream reaches) under the Proposed Action.

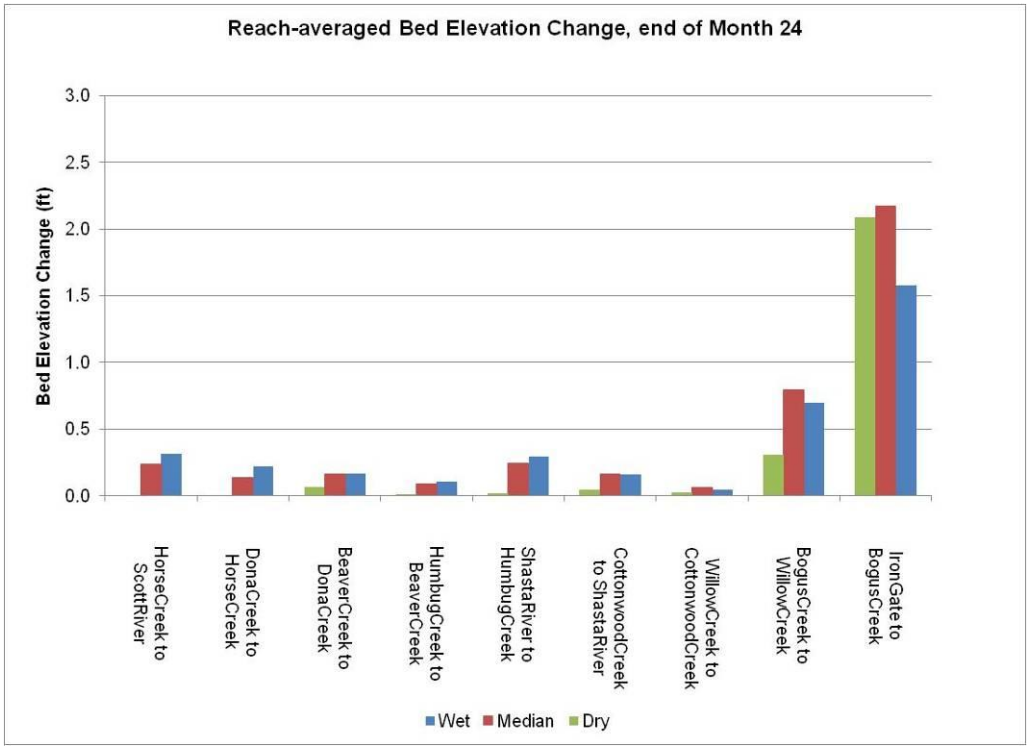
Table F-4. Estimated Mass (Tons) of Reservoir Released Sediment by Size Under Wet, Median and Dry Water Years

Substrate Size	Wet	Median	Dry
Silt (<0.063 mm)	1,617,174	1,213,062	783,952
Sand (0.063 to 2.0 mm)	117,119	134,544	39,718
Gravel (2 to 64 mm)	8,841	7,074	15
Cobble (64 to 256 mm)	1,196	518	3
Total	1,744,331	1,355,199	823,688

Source: Reclamation 2011

F.9.1 Changes in Bed Elevation

Under the Mechanical Sediment Removal mitigation measure, short-term (2-yr) SRH-1D model simulations estimate up to 2 ft of reach averaged deposition between Iron Gate Dam and Bogus Creek (compared to nearly 5 feet under the Proposed Action), decreasing downstream to 0.5 foot between Bogus Creek and Willow Creek (compared to > 1 foot under the Proposed Action) (Figure F-18 and Figure F-11). Reach averaged bed elevation between Iron Gate Dam to Bogus Creek would show the same temporal patterns as under the Proposed Action, with increases after drawdown (January 2020) until March 2020 (Figure F-19 and Figure F-12).



Source: Reclamation 2011.

Figure F-18. Reach Averaged Bed Elevation after Two Successive Wet, Median, or Dry Water Years with Dredging

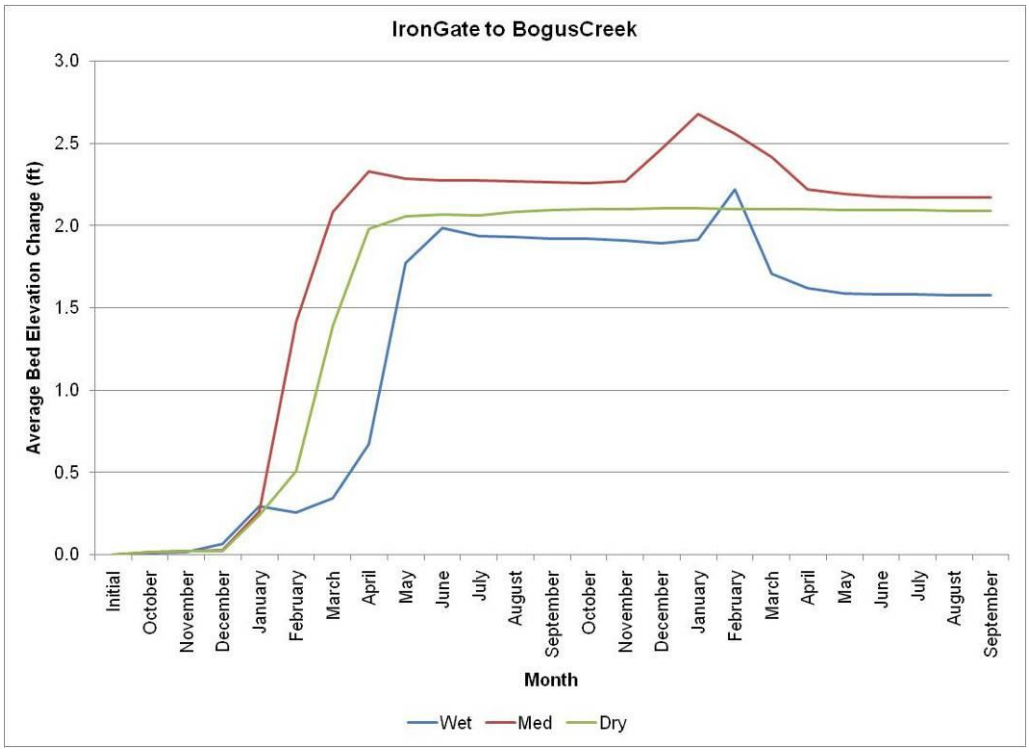
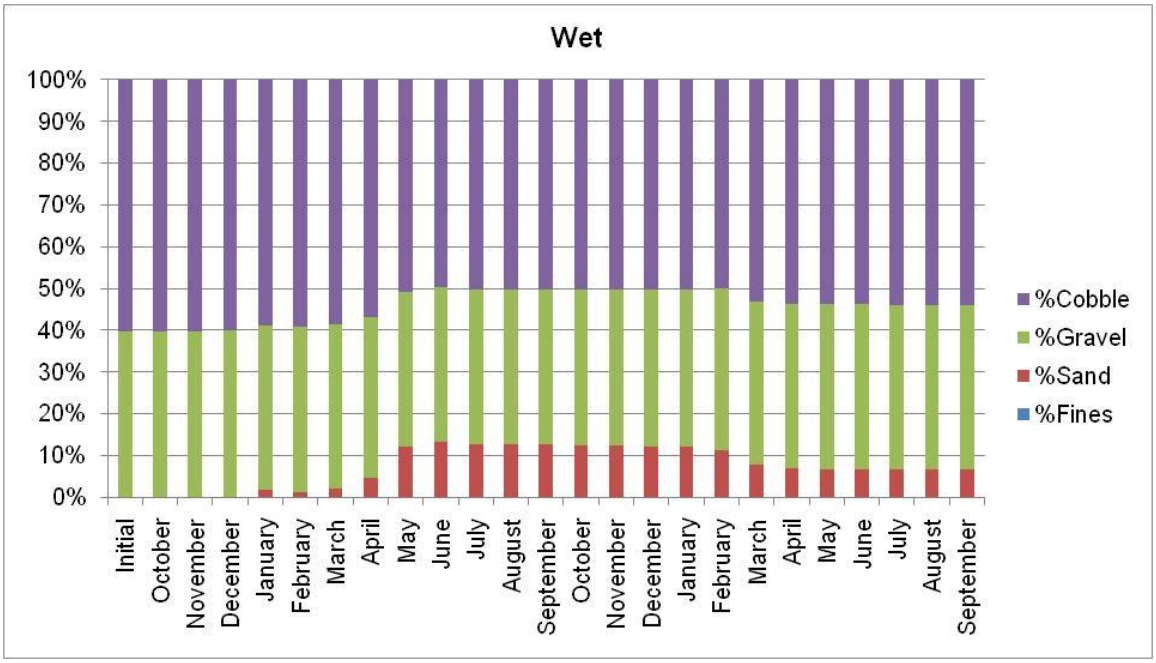


Figure F-19. Reach Averaged Bed Elevation with Dredging during Two Successive Wet, Median, or Dry Water Years from Iron Gate Dam to Bogus Creek

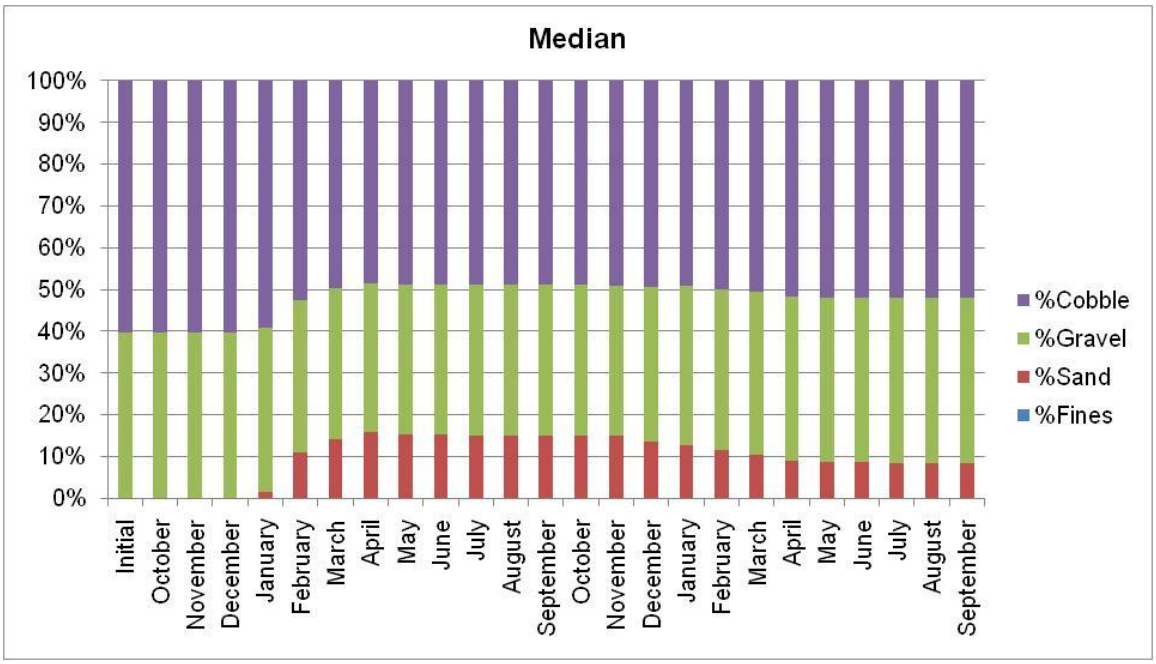
F.9.2 Changes in Bed Substrate

Mechanical Sediment Removal would still result in increases in the proportion of sand in the bed and decreases median bed substrate size, although the changes would be less than under the Proposed Action. SRH-1D estimated that sand within the bed from Iron Gate Dam to Bogus Creek would increase to 10 to 15 percent by March 2020 after drawdown, gradually decreasing to more than 10 percent by March 2021 under wet and median simulations, but remain near 15 percent through 2021 under the dry simulation (Figure F-20, Figure F-21 and Figure F-22). Median substrate size would decrease to 60 mm and gradually increase to 65 mm under wet and median simulations, but remain near 60 mm under the dry simulation (Figure F-23). Reclamation (2011) also predicted that most, if not all, sand and smaller substrate would be flushed from the reach within 3 years.



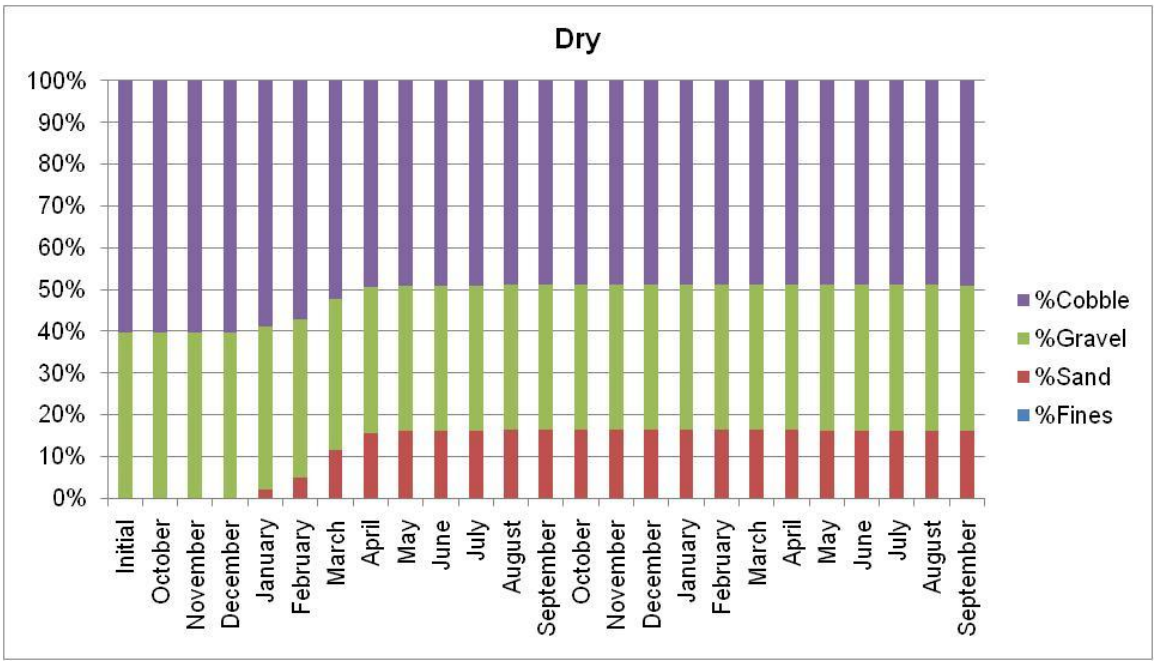
Source: Reclamation 2011.

Figure F-20. Simulated Bed Composition from Iron Gate Dam to Bogus Creek during Two Successive Wet Water Years Dam Removal with Dredging



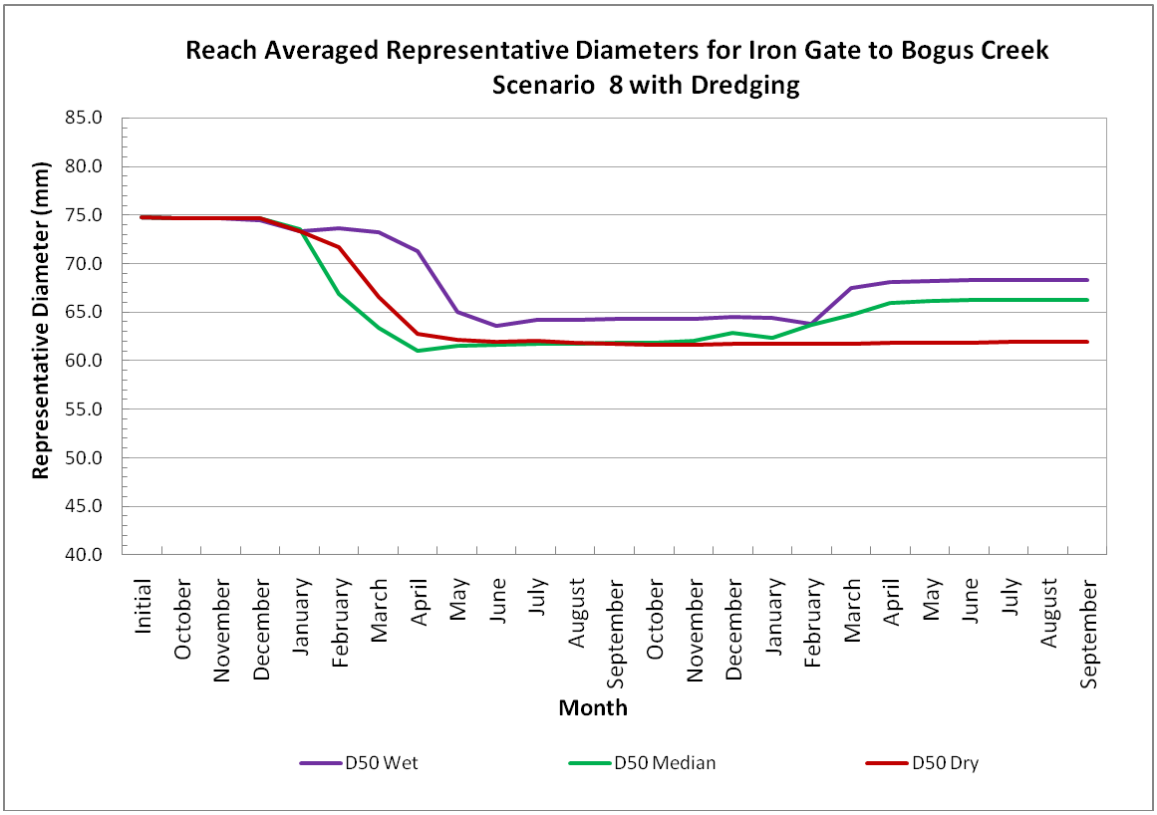
Source: Reclamation 2011.

Figure F-21. Simulated Bed Composition from Iron Gate Dam to Bogus Creek during Two Successive Wet Water Years Dam Removal with Dredging



Source: Reclamation 2011.

Figure F-22. Simulated Bed Composition from Iron Gate Dam to Bogus Creek during Two Successive Dry Water Years Dam Removal with Dredging



Source: Reclamation 2011.

Figure F-23. Simulated D50 (mm) From Iron Gate Dam to Bogus Creek During Successive Wet, Median, and Dry Water Years with Dredging

Overall, the Mechanical Sediment Removal mitigation measure, relative to the Proposed Action, would result in less deposition downstream of Iron Gate Dam, and less sand within the bed and greater median substrate sizes in downstream reaches. These changes would lessen the severity of effects associated with dam released sediment and would also lessen severity of impacts to native fish in the mainstem Klamath River.

F.10 References

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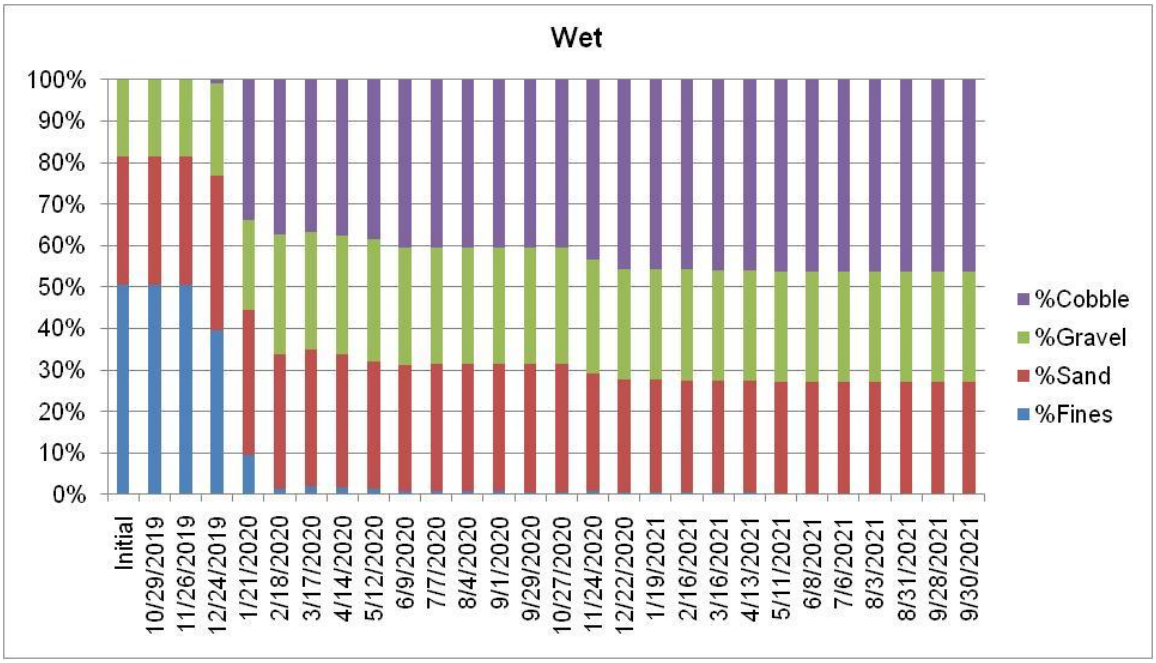
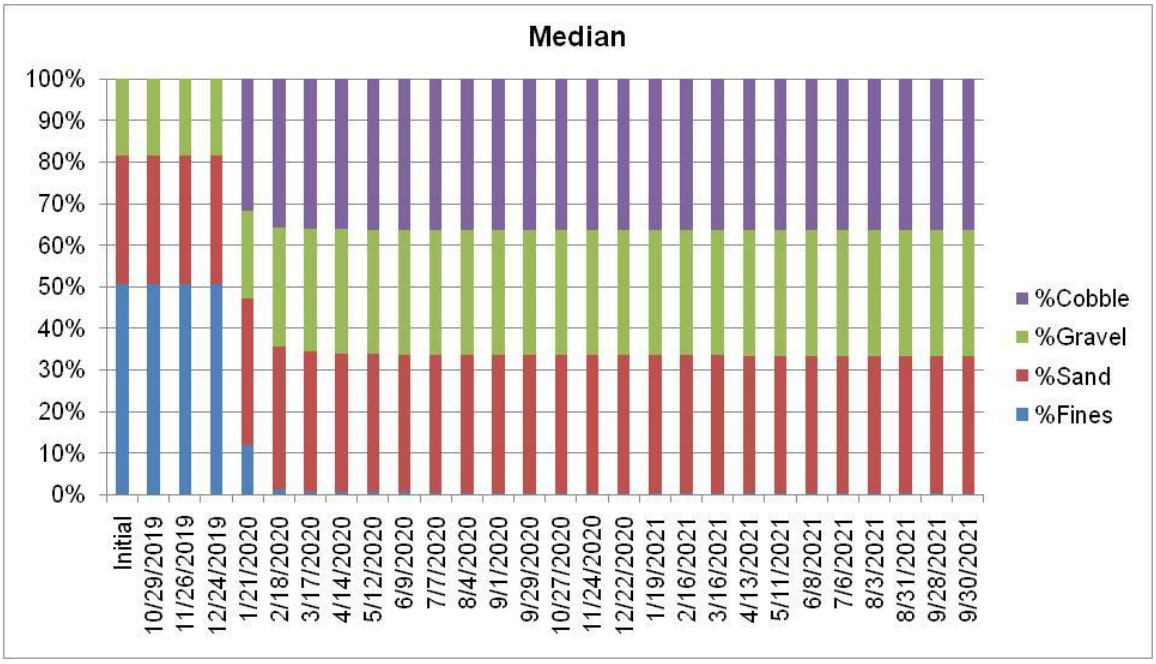
Varyu, D. Pers. comm., January 4, 2011.

Attachment F-1
Bedload Sediment Effects in the Hydroelectric Reach in the Lower Klamath Basin: Downstream of Iron Gate Dam to Cottonwood Creek



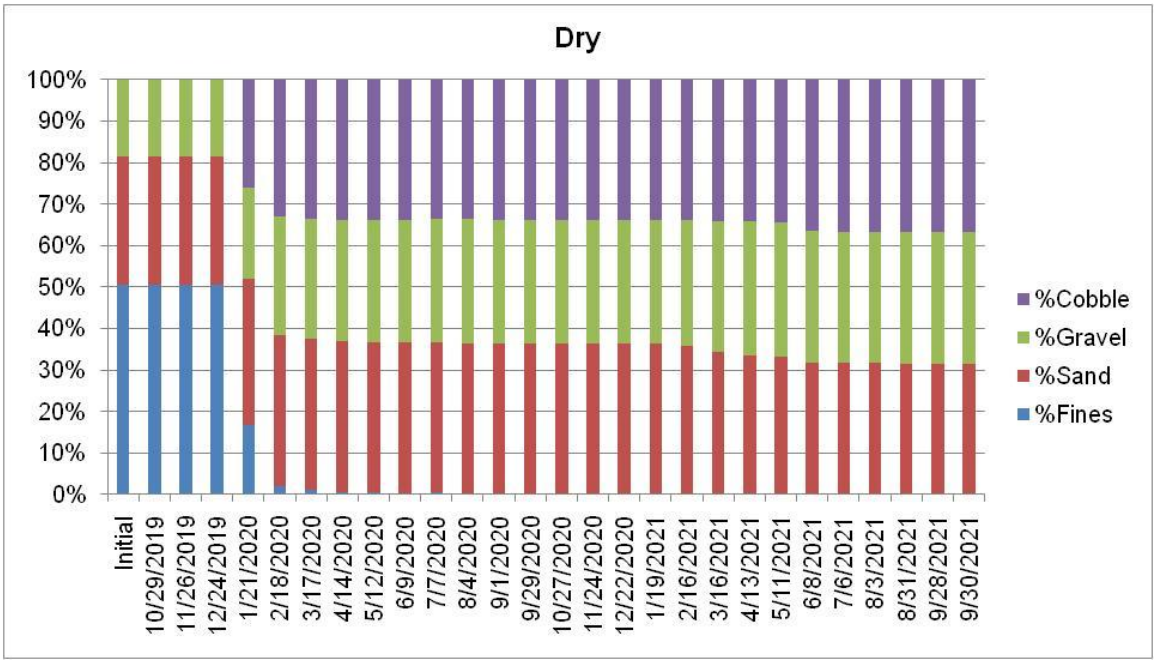
Source: Reclamation 2011.

Figure F1-1. Simulated Bed Composition for J.C. Boyle Reservoir during Two Successive Wet Water Years after Dam Removal



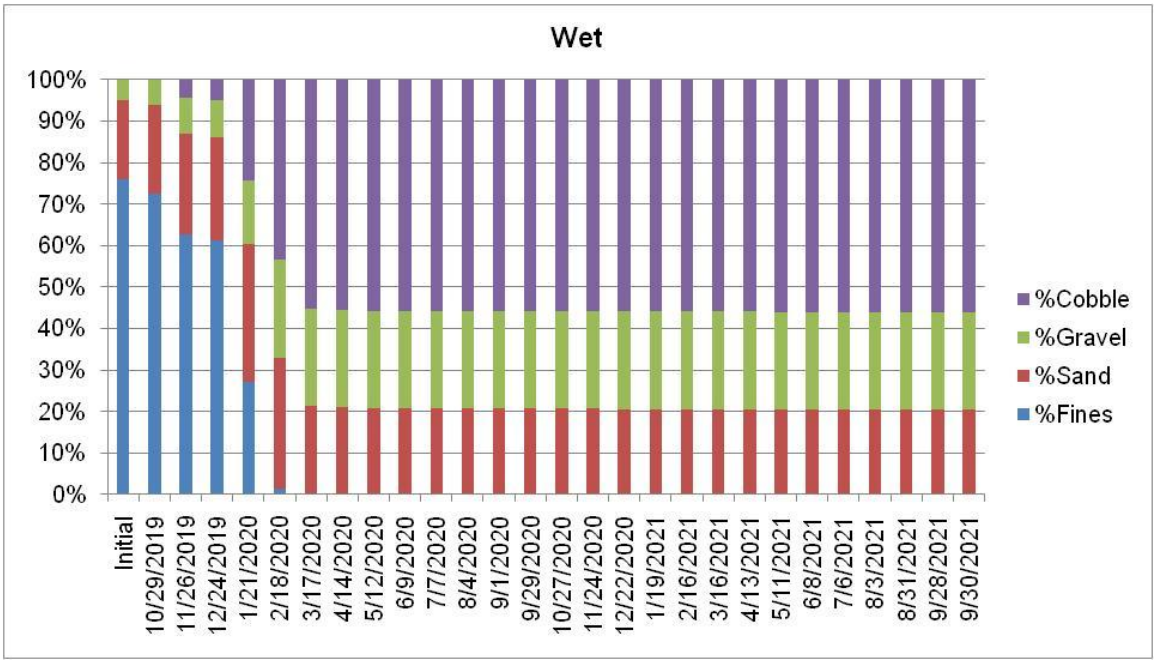
Source: Reclamation 2011.

Figure F1-2. Simulated Bed Composition for J.C. Boyle Reservoir during Two Successive Median Water Years after Dam Removal



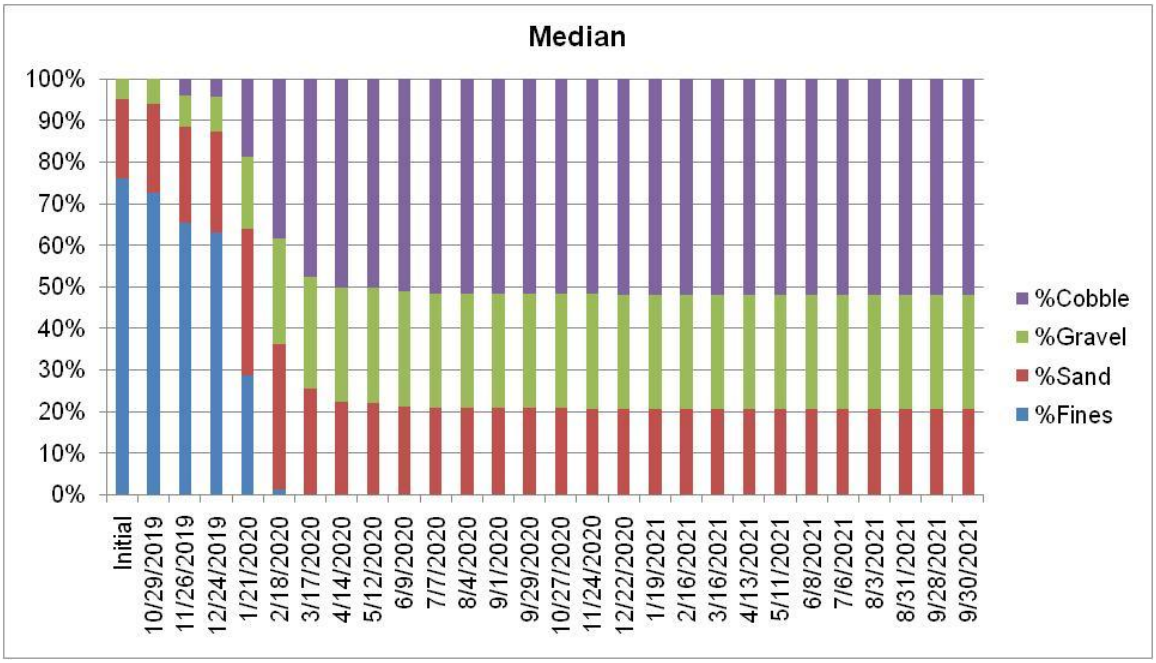
Source: Reclamation 2011.

Figure F1-3. Simulated Bed Composition for J.C. Boyle Reservoir during Two Successive Dry Water Years after Dam Removal



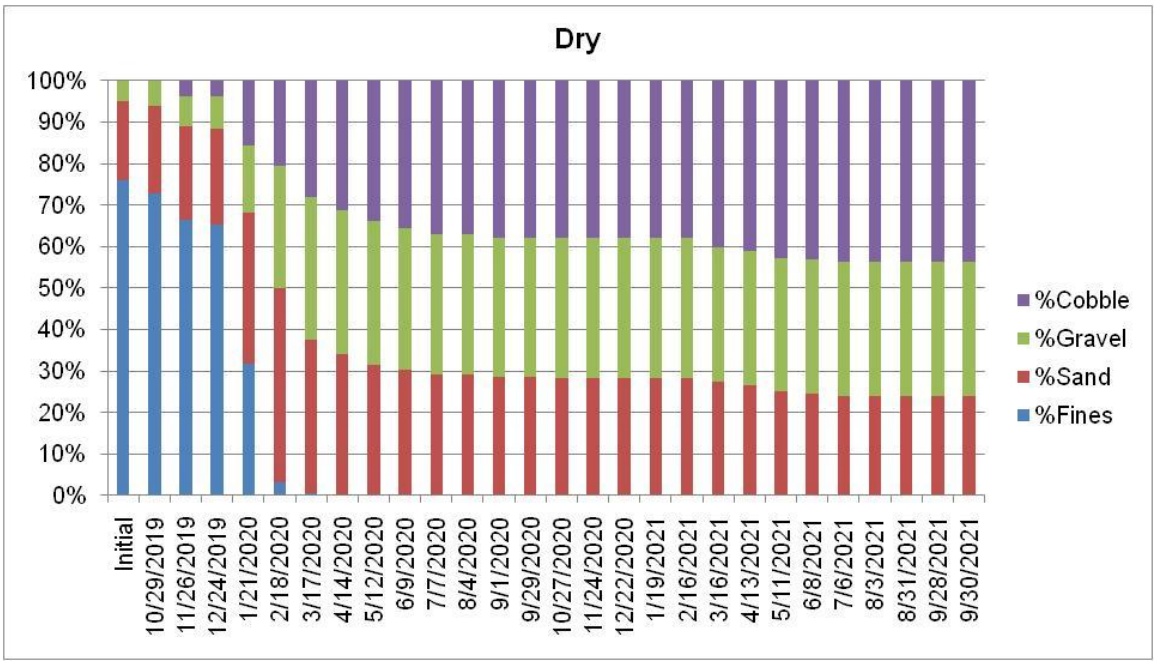
Source: Reclamation 2011.

Figure F1-4. Simulated Bed Composition for Copco 1 Reservoir during Two Successive Wet Water Years after Dam Removal



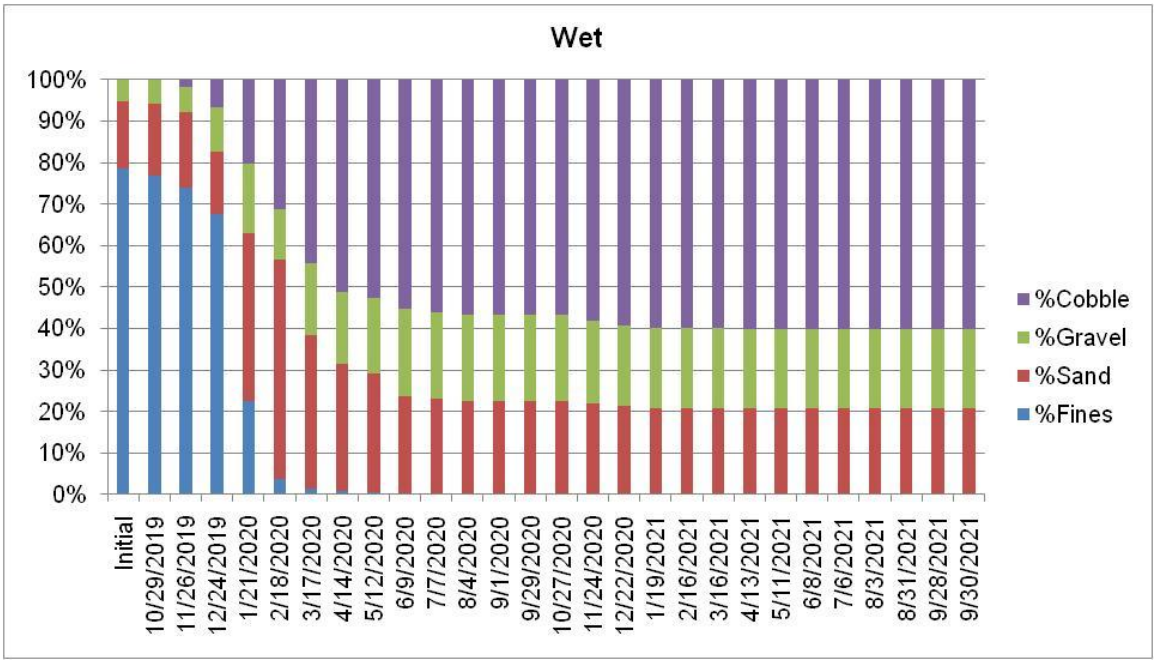
Source: Reclamation 2011.

Figure F1-5. Simulated Bed Composition for Copco 1 Reservoir during Two Successive Median Water Years after Dam Removal



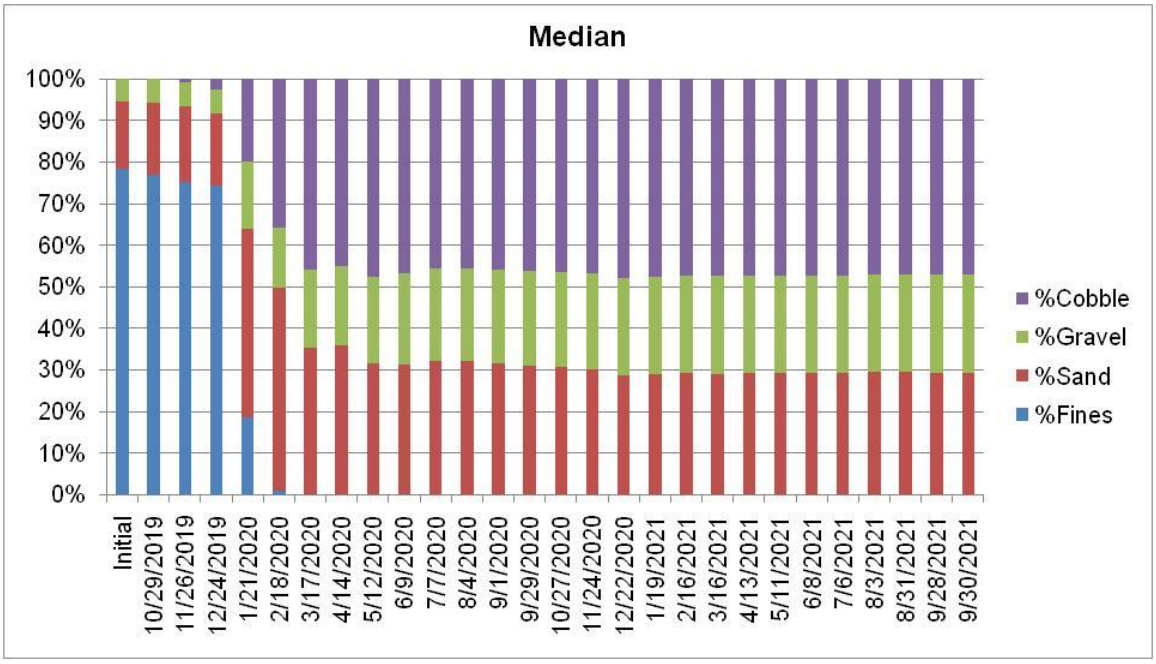
Source: Reclamation 2011.

Figure F1-6. Simulated Bed Composition for Copco 1 Reservoir during Two Successive Dry Water Years after Dam Removal



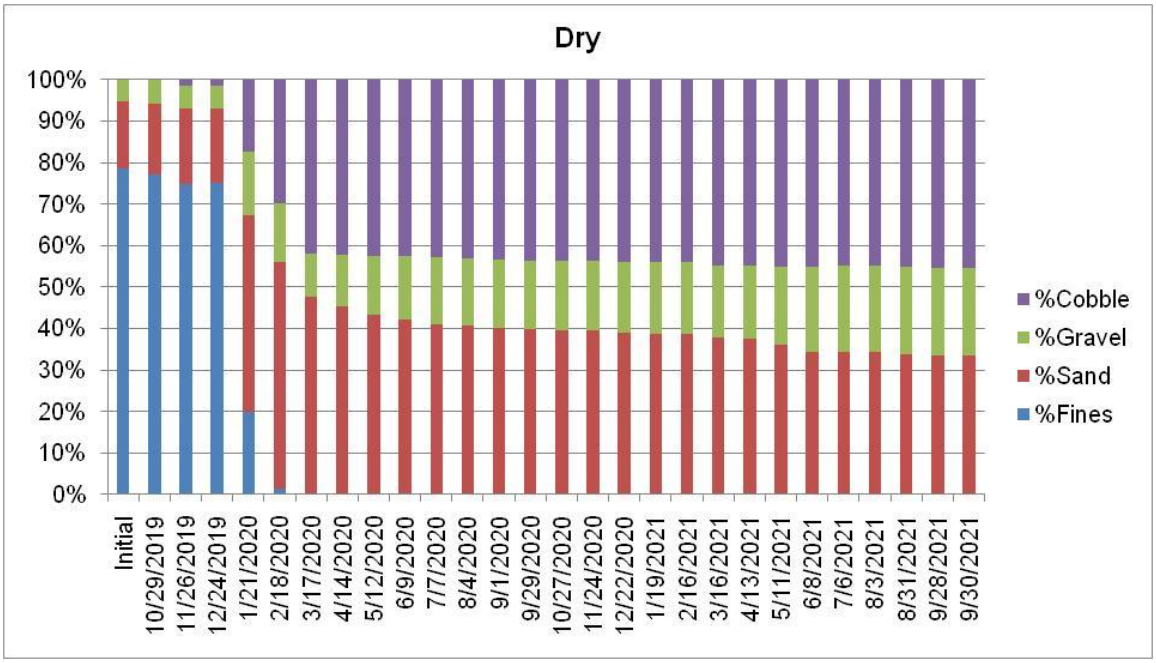
Source: Reclamation 2011.

Figure F1-7. Simulated Bed Composition for Iron Gate Reservoir during Two Successive Wet Water Years after Dam Removal



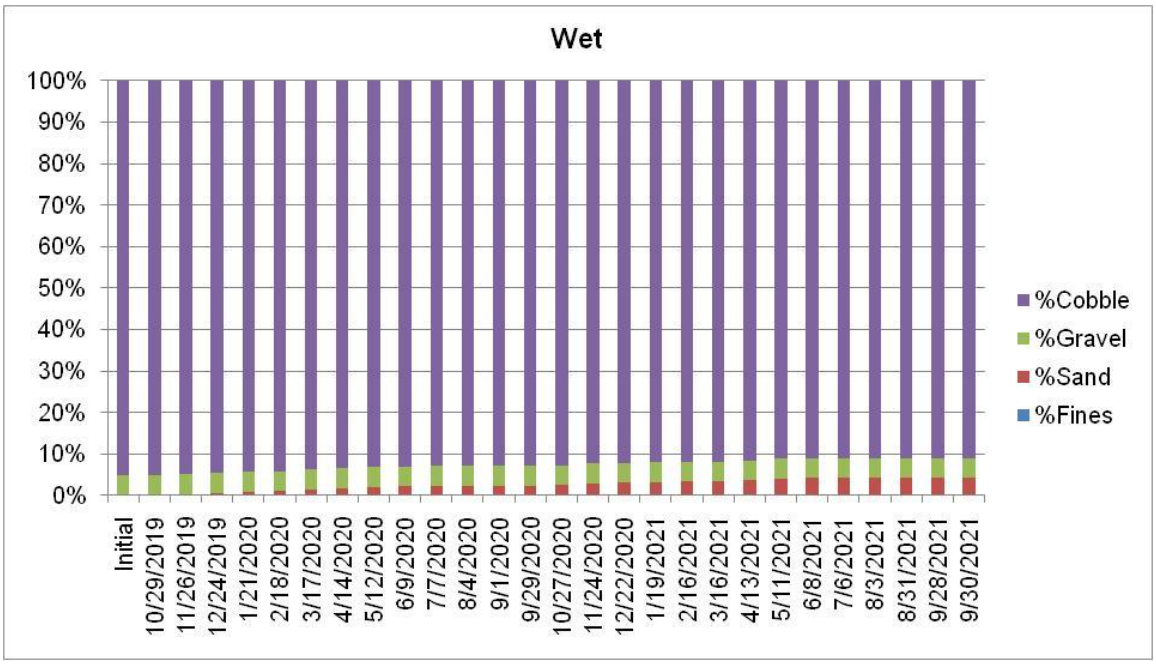
Source: Reclamation 2011.

Figure F1-8. Simulated Bed Composition for Iron Gate Reservoir during Two Successive Median Water Years after Dam Removal



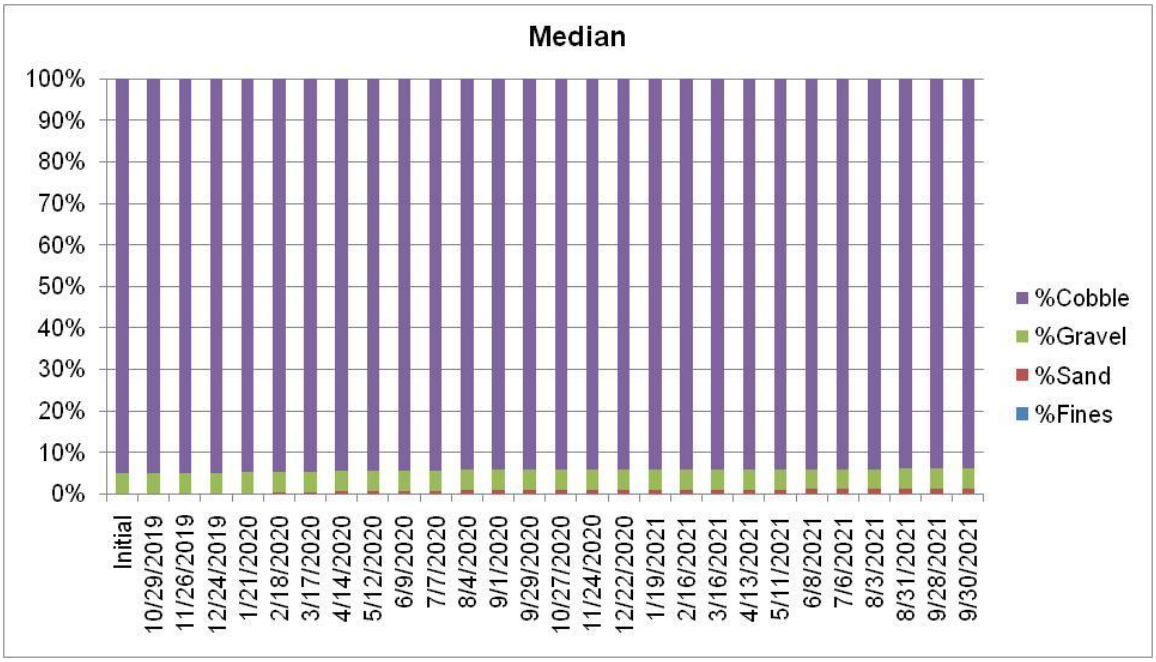
Source: Reclamation 2011.

Figure F1-9. Simulated Bed Composition for Iron Gate Reservoir during Two Successive Dry Water Years after Dam Removal



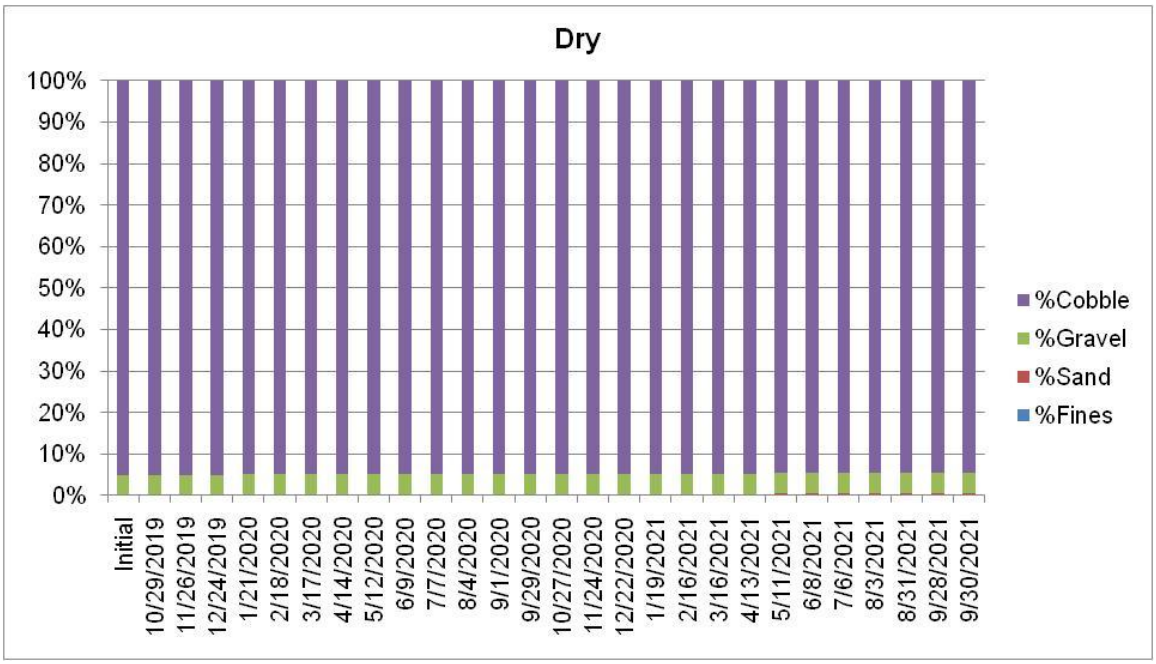
Source: Reclamation 2011.

Figure F1-10. Simulated Bed Composition Upstream of J.C. Boyle Reservoir during Two Successive Wet Water Years after Dam Removal



Source: Reclamation 2011.

Figure F1-11. Simulated Bed Composition Upstream of J.C. Boyle Reservoir during Two Successive Median Water Years after Dam Removal



Source: Reclamation 2011.

Figure F1-12. Simulated Bed Composition Upstream of J.C. Boyle Reservoir during Two Successive Dry Water Years after Dam Removal

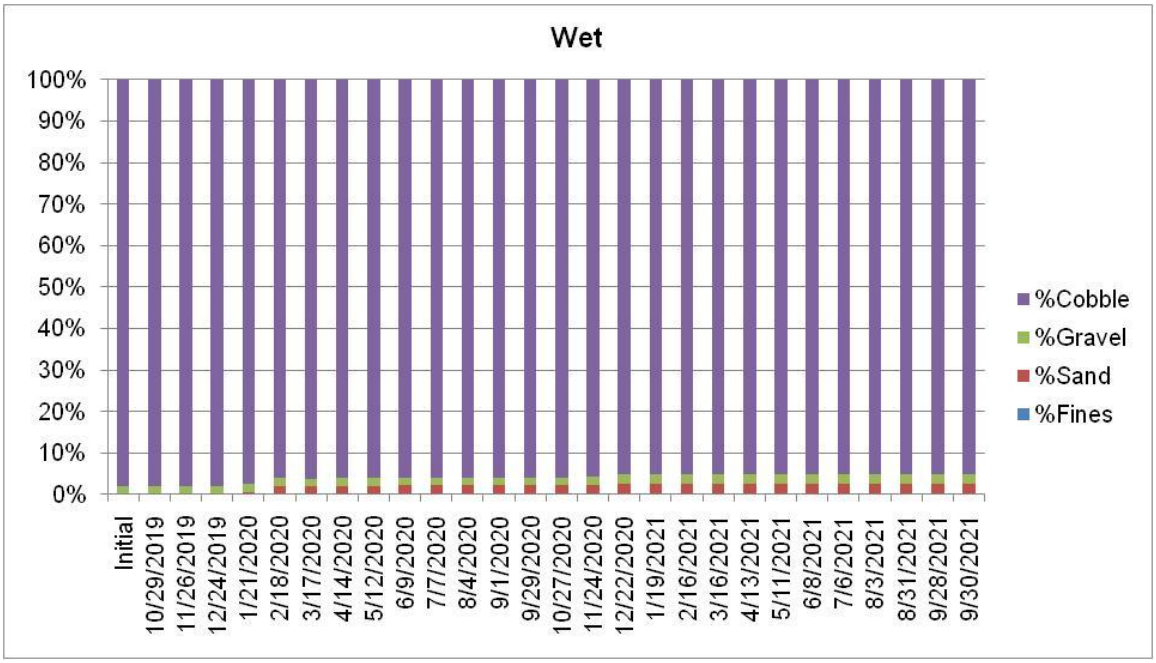
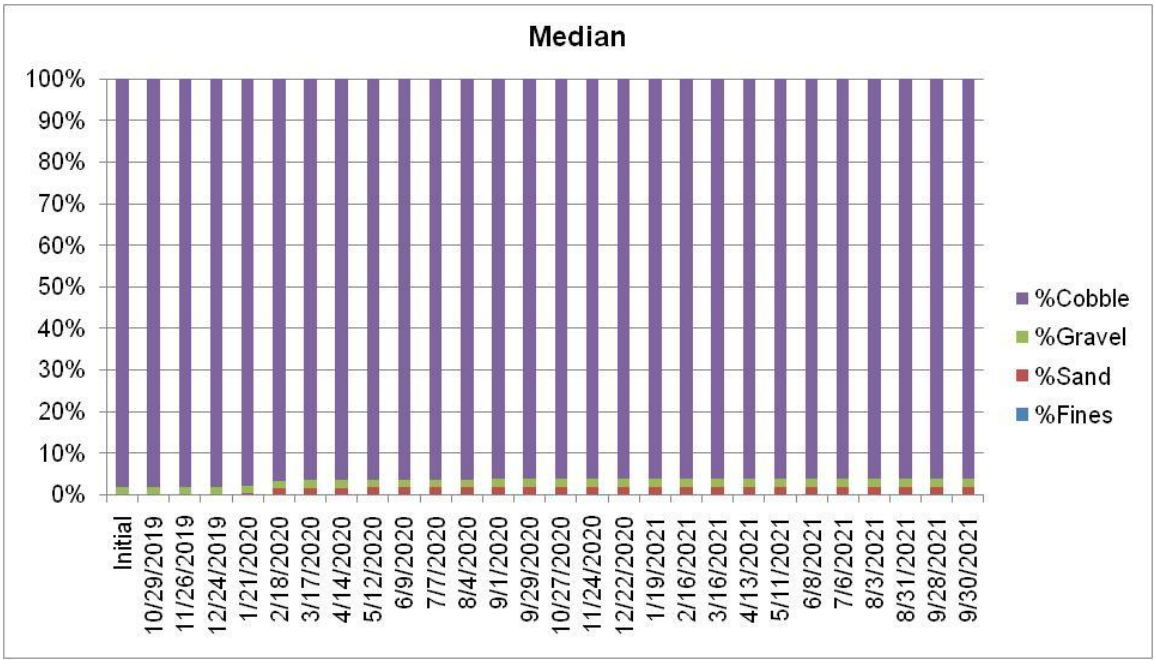
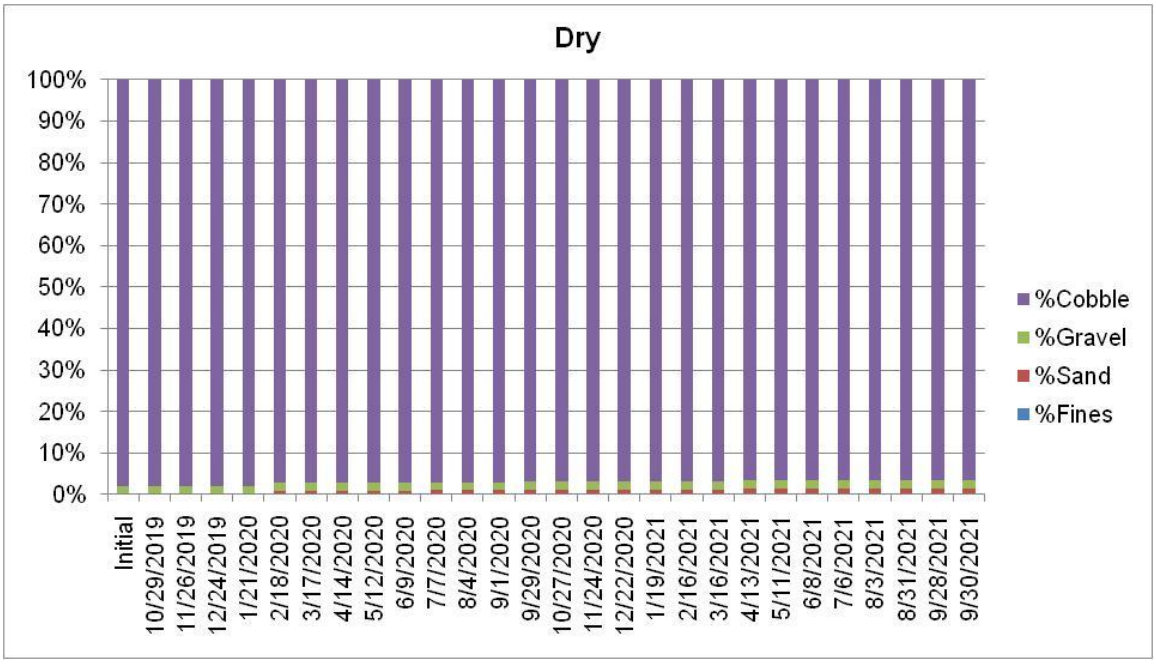


Figure F1-13. Simulated Bed Composition from J.C. Boyle to Copco 1 Reservoirs during Two Successive Wet Water Years after Dam Removal



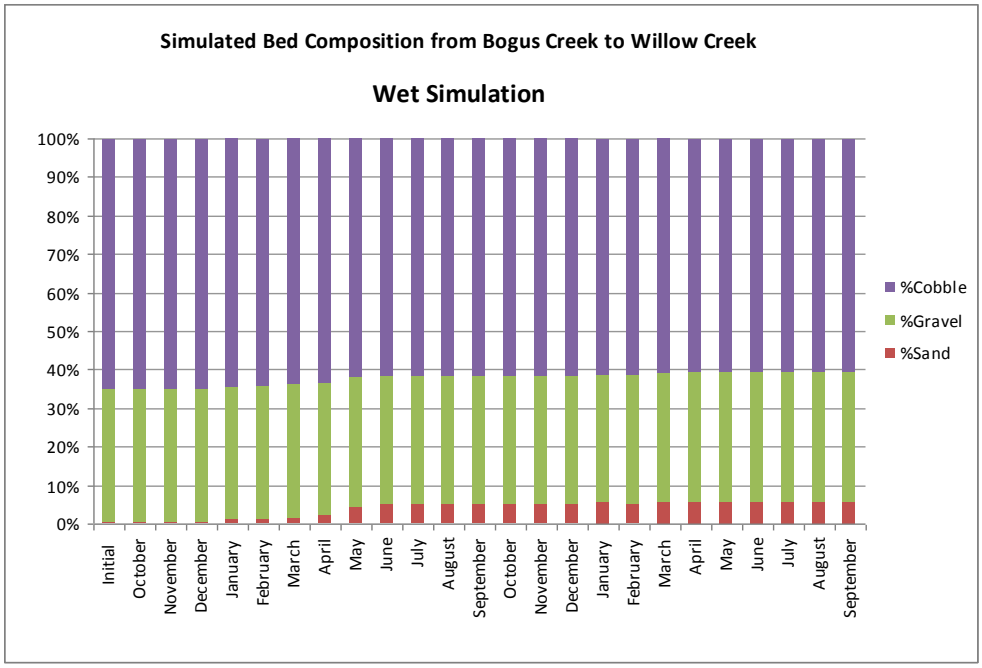
Source: Reclamation 2011.

Figure F1-14. Simulated Bed Composition from J.C. Boyle to Copco 1 Reservoirs during Two Successive Median Water Years after Dam Removal



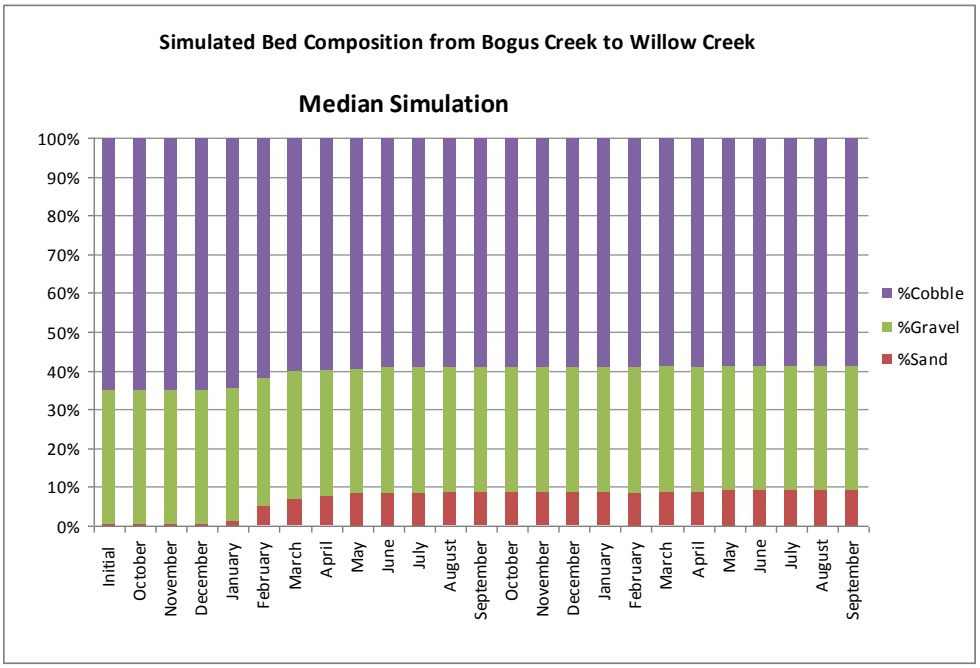
Source: Reclamation 2011.

Figure F1-15. Simulated Bed Composition from J.C. Boyle to Copco 1 Reservoirs during Two Successive Dry Water Years after Dam Removal



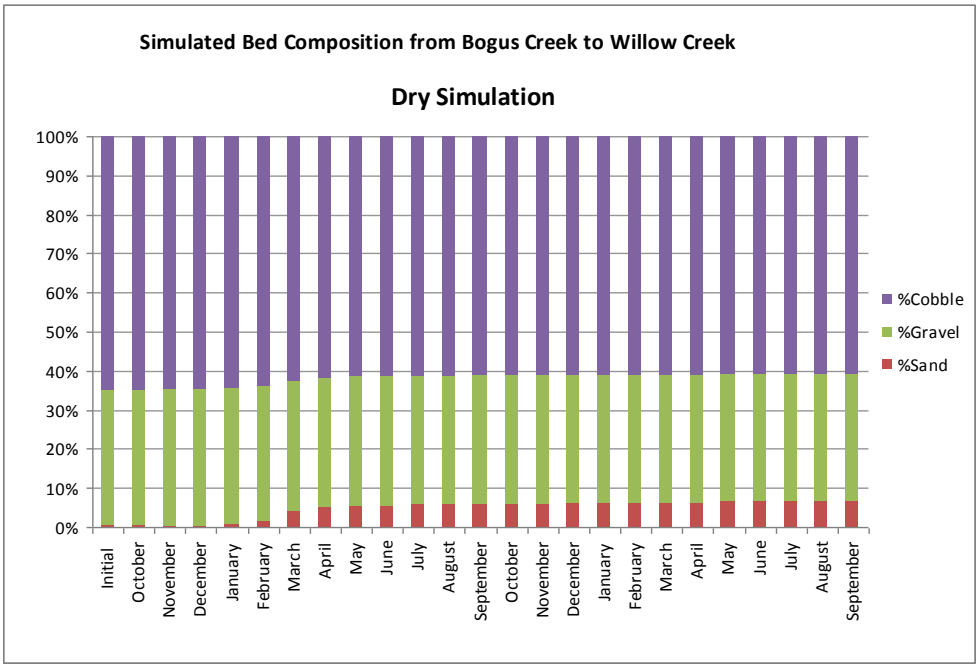
Source: Reclamation 2011.

Figure F1-16. Simulated Bed Composition from Bogus Creek to Willow Creek during Two Successive Wet Water Years after Dam Removal



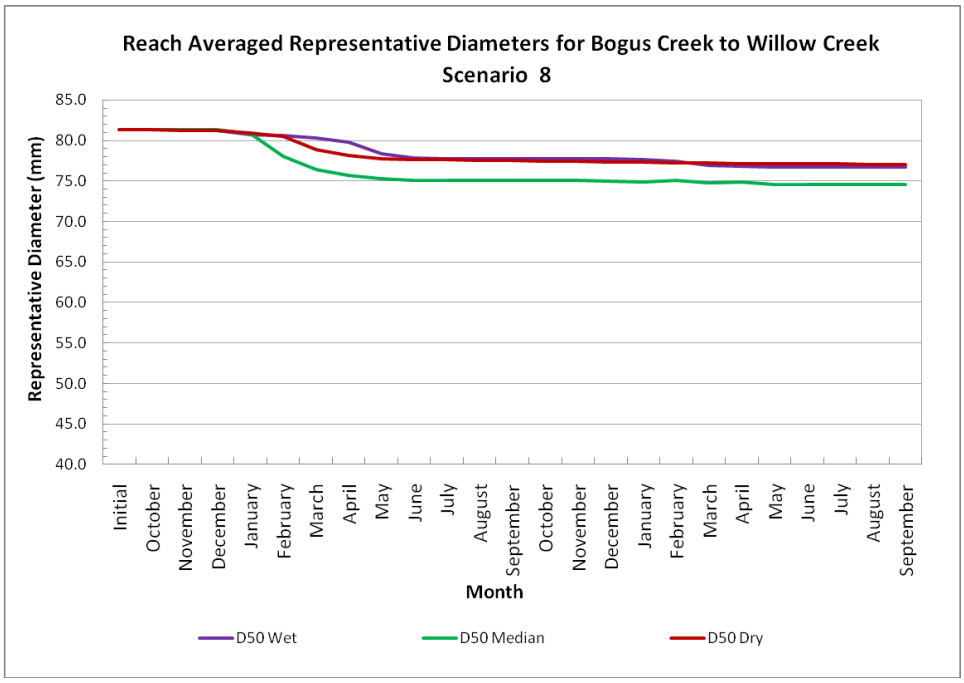
Source: Reclamation 2011.

Figure F1-17. Simulated Bed Composition from Bogus Creek to Willow Creek during Two Successive Median Water Years after Dam Removal



Source: Reclamation 2011.

Figure F1-18. Simulated Bed Composition from Bogus Creek to Willow Creek during Two Successive Dry Water Years after Dam Removal



Source: USBR 2011.

Figure F1-19. Simulated Bed Substrate Size from Bogus Creek to Willow Creek under successive wet, median, and dry years after Dam Removal

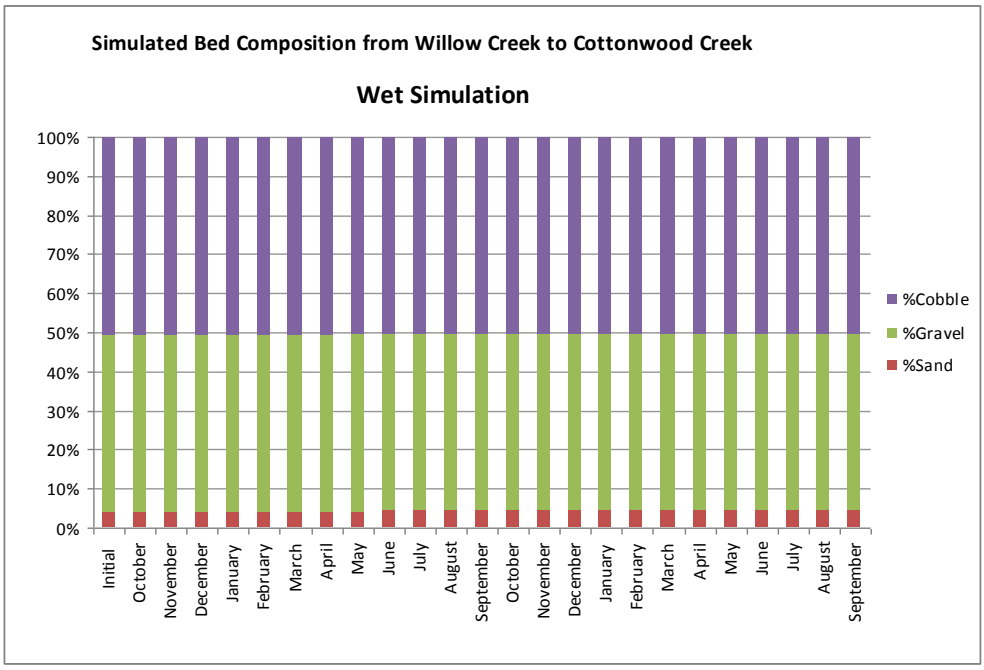
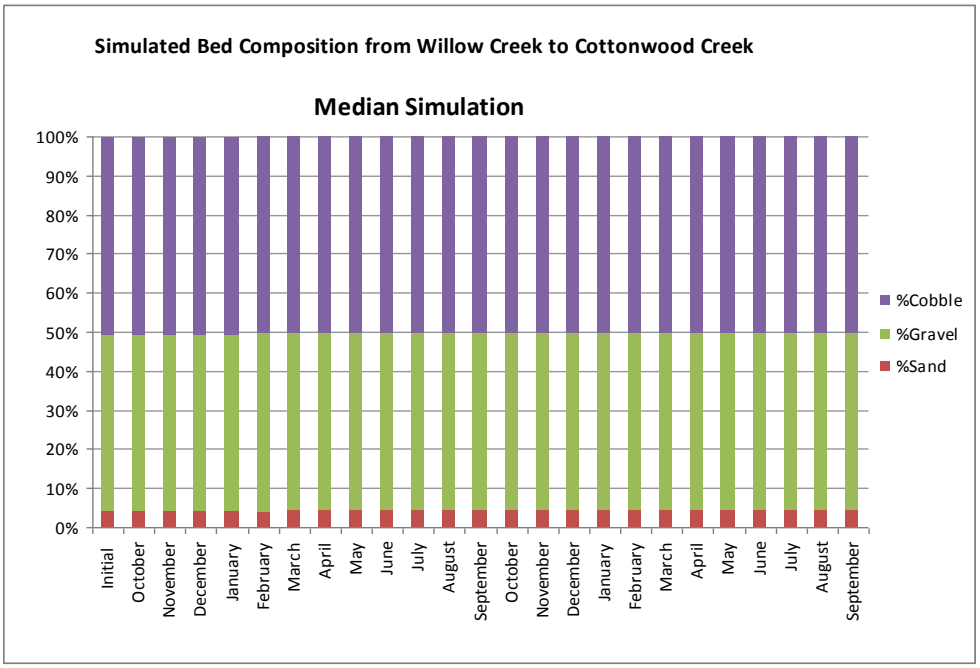
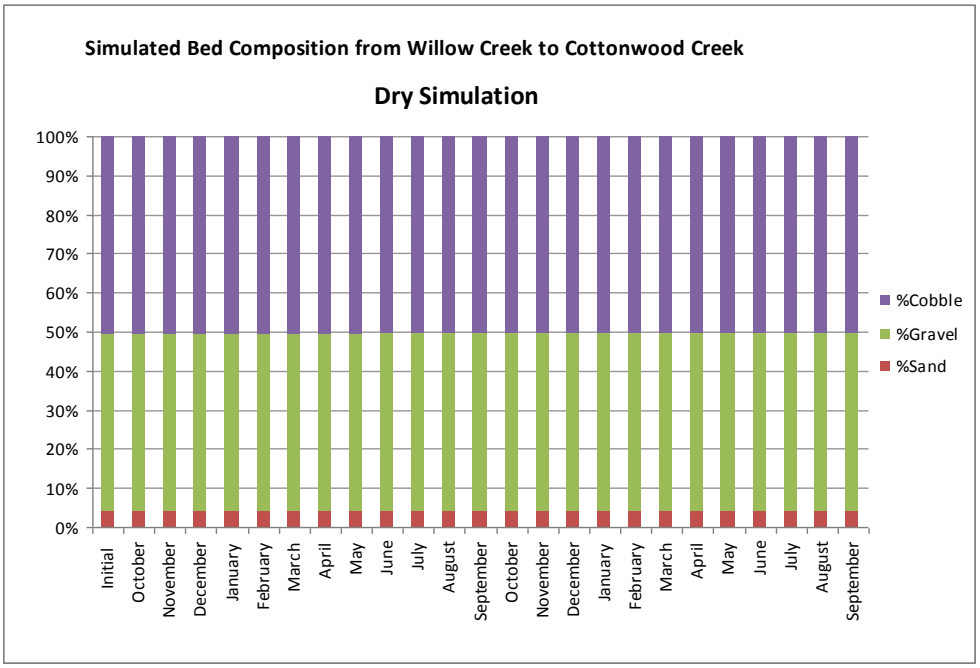


Figure F1-20. Simulated Bed Composition from Willow Creek to Cottonwood Creek during Two Successive Wet Water Years after Dam Removal



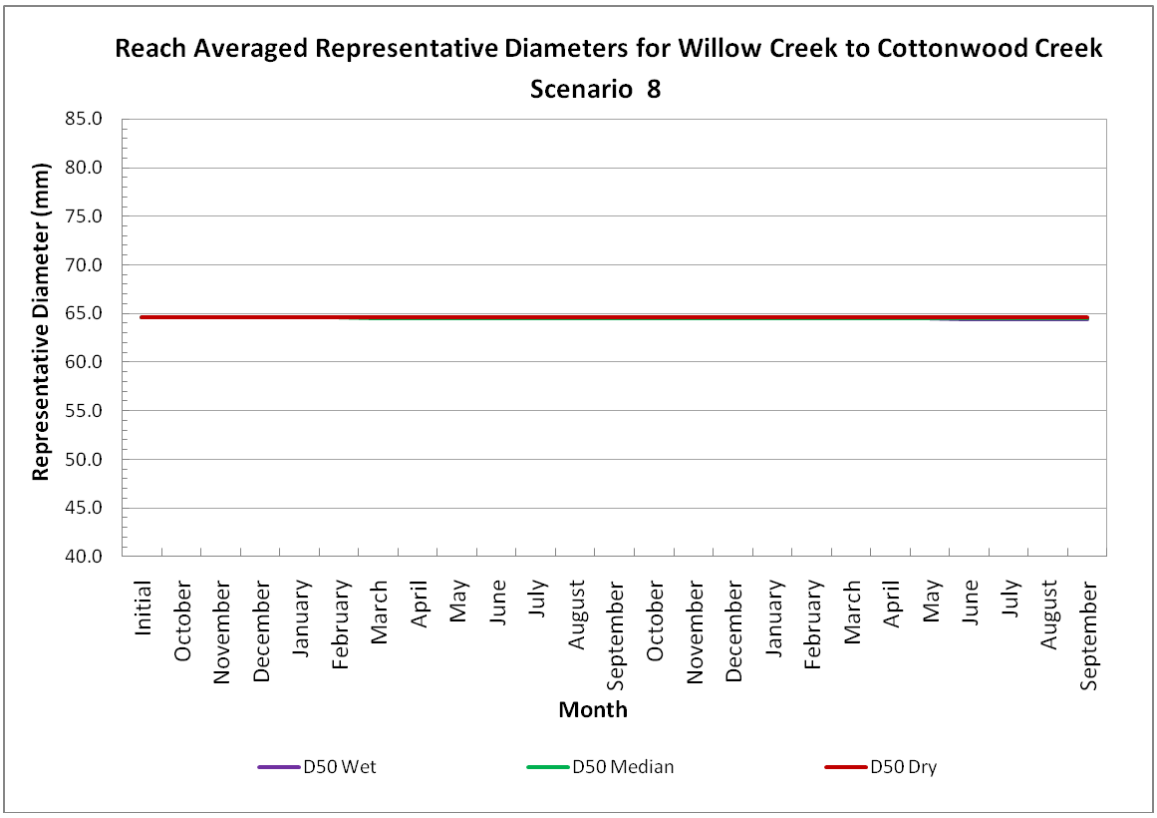
Source: Reclamation 2011.

Figure F1-21. Simulated Bed Composition from Willow Creek to Cottonwood Creek during Two Median Water Years after Dam Removal



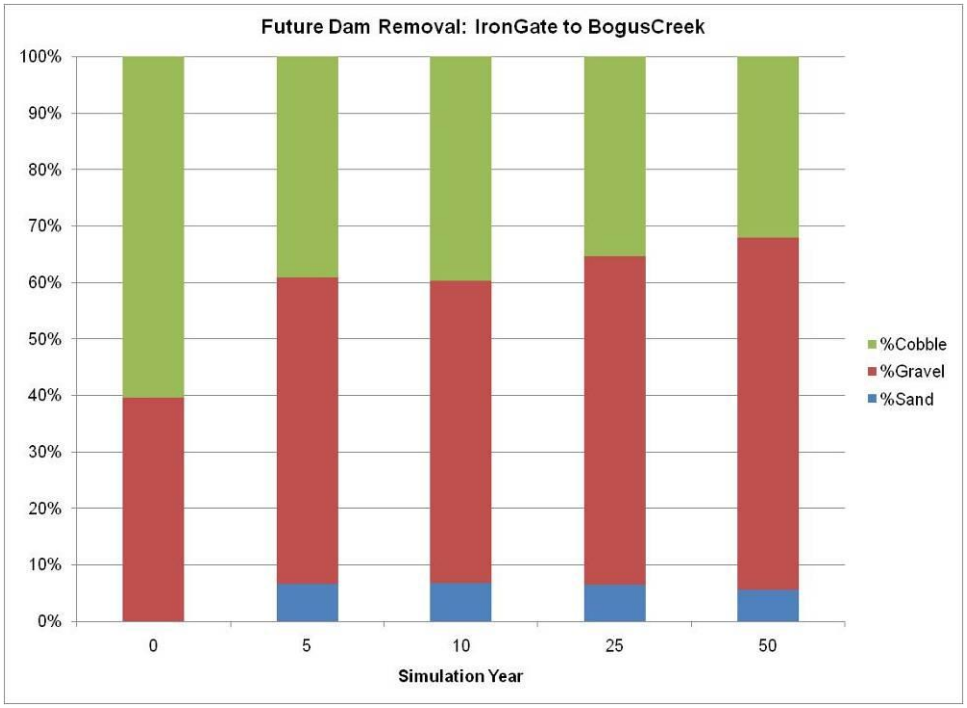
Source: Reclamation 2011.

Figure F1-22. Simulated Bed Composition from Willow Creek to Cottonwood Creek during Two Dry Water Years after Dam Removal



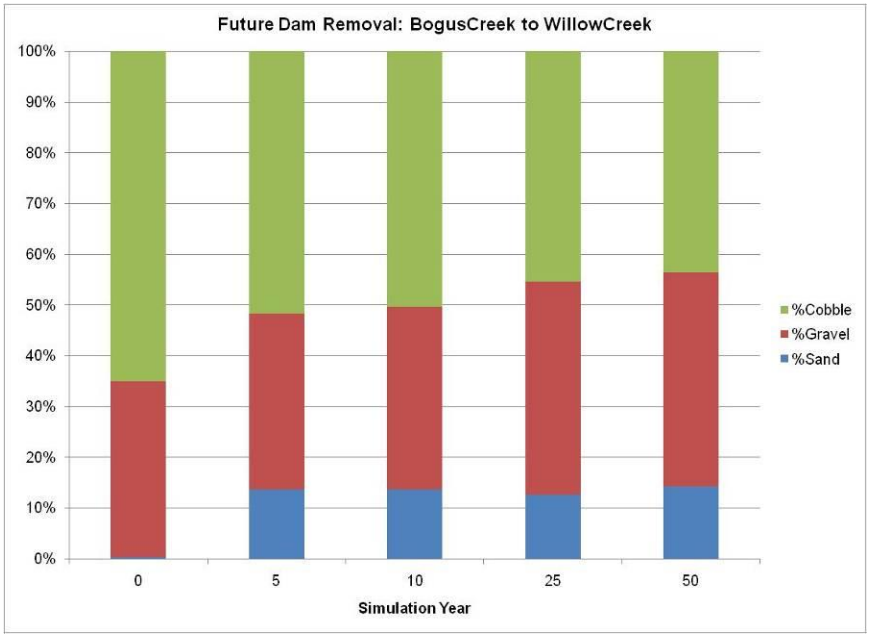
Source: USBR 2011.

Figure F1-23. Simulated Bed Substrate Size from Willow Creek to Cottonwood Creek under successive wet, median, and dry years after Dam Removal



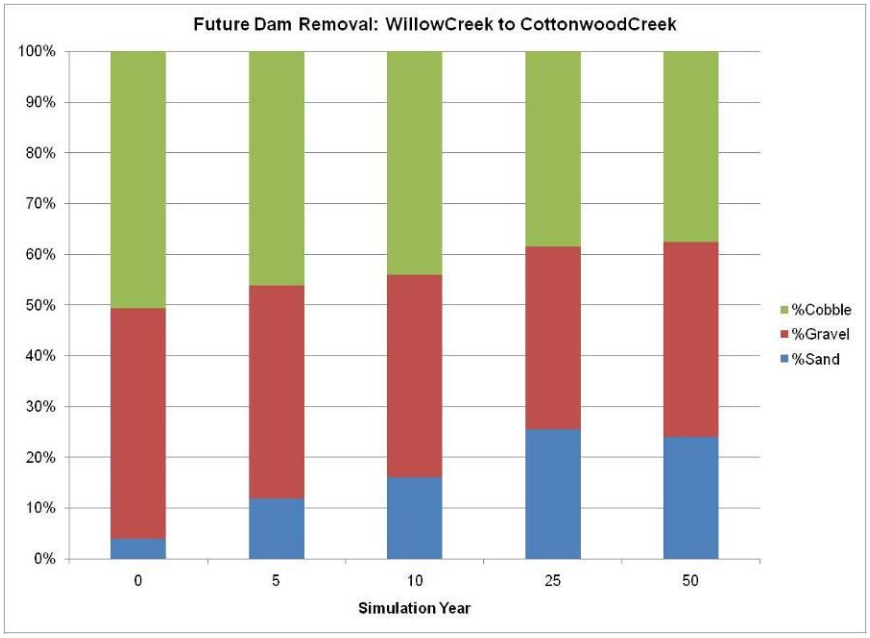
Source: USBR 2011.

Figure F1-24. Simulated Bed Composition of Iron Gate Dam to Bogus Creek Reach 5, 10, 25, and 50 Years after Dam Removal



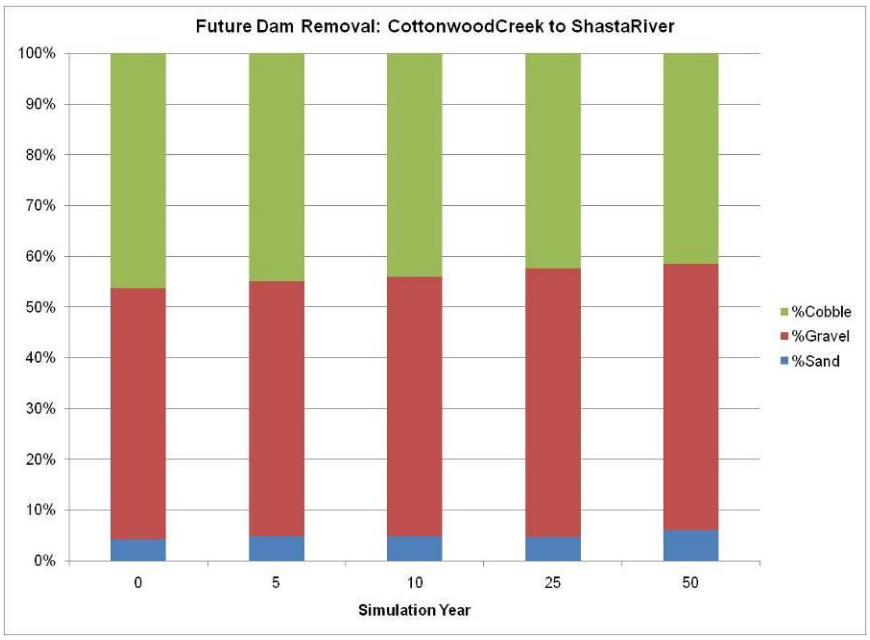
Source: USBR 2011.

Figure F1-25. Simulated Bed Composition of Bogus Creek to Willow Creek Reach 5, 10, 25, and 50 Years after Dam Removal



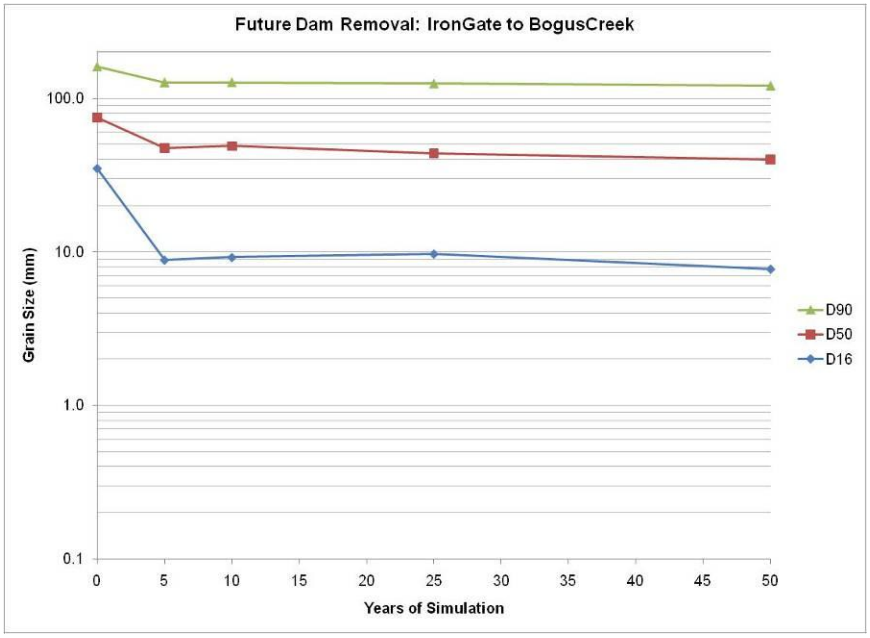
Source: USBR 2011.

Figure F1-26. Simulated Bed Composition of Willow Creek to Cottonwood Creek Reach 5, 10, 25, and 50 Years after Dam Removal



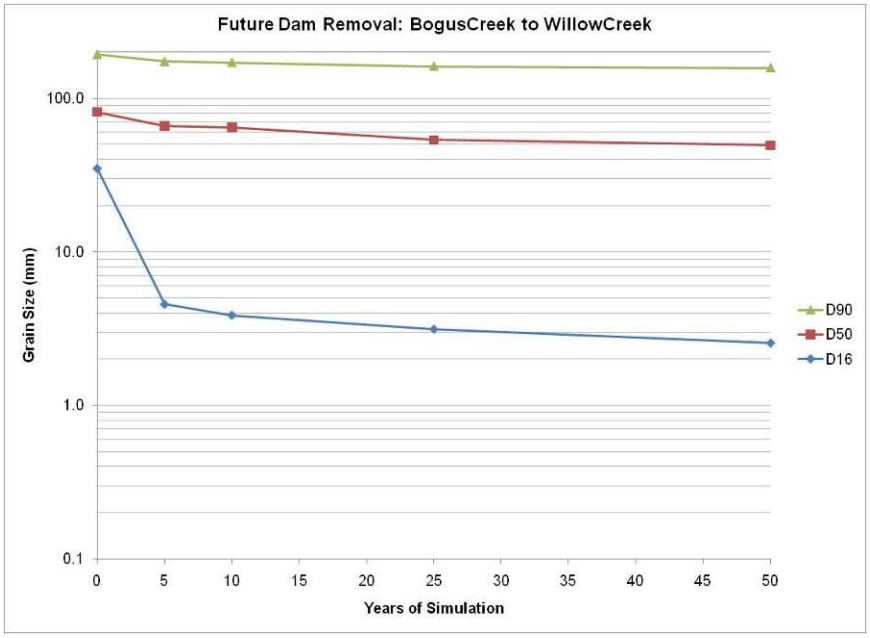
Source: USBR 2011.

Figure F1-27. Simulated Bed Composition of Cottonwood Creek to Shasta River Reach 5, 10, 25, and 50 Years after Dam Removal



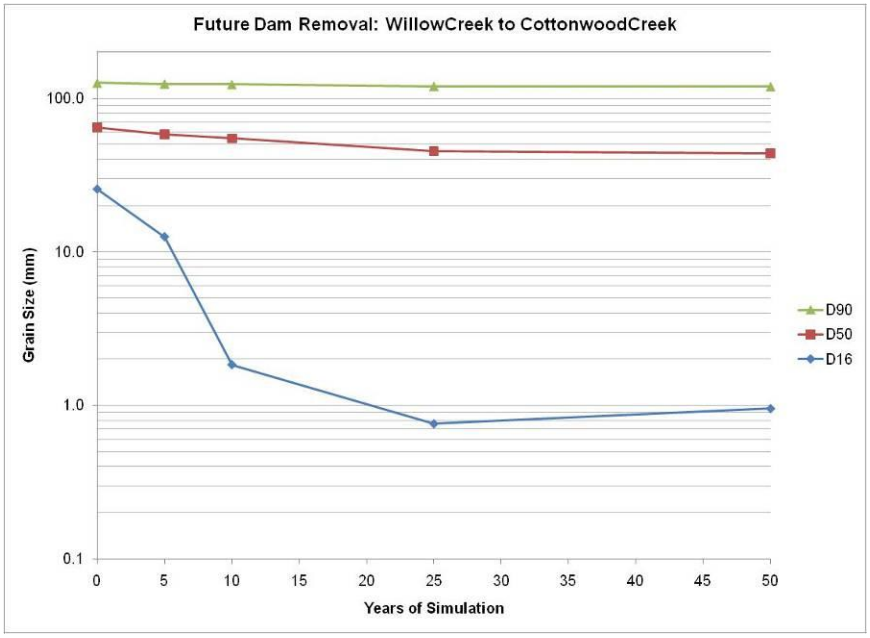
Source: USBR 2011.

Figure F1-28. Simulated Bed Substrate Size from Iron Gate Dam to Bogus Creek 5, 10, 25, and 50 Years after Dam Removal



Source: USBR 2011.

Figure F1-29. Simulated Bed Substrate Size from Bogus Creek to Willow Creek 5, 10, 25, and 50 Years after Dam Removal



Source: USBR 2011.

Figure F1-30. Simulated Bed Substrate Size from Willow Creek to Cottonwood Creek 5, 10, 25, and 50 Years after Dam Removal

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