AN ASSESSMENT OF GRAVEL BAR TEXTURE AND COMPOSITION FOLLOWING IN-CHANNEL MINING IN THE MAD RIVER, CALIFORNIA

by

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ABSTRACT

An Assessment of Gravel Bar Texture and Composition Following
In-Channel Mining in the Mad River, California

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The economy of Humboldt County, California, is dependent on substantial amounts of aggregate skimmed from the local gravel bars, but National Marine Fisheries states that the extraction produces excessive fine sediments, which disrupt salmon behavior, and possibly fill interstitial spaces in the riverbed, and reduce salmon egg viability. The objective of my study is to determine whether sand and gravel extraction from gravel bars is an adverse source of fine materials for spawning salmon before the rivers become opaque with turbid runoff from various other sources. Either a rainstorm or high flows that overtop the extraction surface could wash the fines off the extraction surface and fill interstitial spaces between spawning gravels or produce sediment plumes that disrupt the behavior of adult salmon. I used three tests to determine whether fine sediments are washed off the gravel bar before the extraction surface is inundated by high flows. The tests included direct observation of sediment plumes, particle size analysis, and fluorescent-dyed sand tracers. A comparison of samples from gravel bar surfaces before and after extraction, after the first rains of fall, and after inundation, revealed that there were significantly more coarse sands after extraction and after inundation than on the pre-extraction surface. The percentage of the finest sediments (less than ⅛ mm) was greater on the pre-extraction surface than on the post-extraction surface. The percentage of fines was not significantly different between post-extraction or after rains, or between the post-extraction and after- inundation samples. Fines from these gravel extraction surfaces were not directly a source of fine sediments in the first autumnal rains. In subsurface comparisons, there was a slightly higher percentage of coarse sands in the post-extraction sediments compared with after-rains sample. The use of stained particle tracers did not contribute to the understanding of sediment movement on gravel bars in this study. Stained particles settled when exposed to rain. I observed two sediment plumes from gravel bars in the course of this investigation. In one, the river was already turbid from a variety of sources as the river flowed across the extraction surface. However, the downstream edge of the O'Neill gravel bar contained streamers of clear looking water and sediment plumes. The second sediment plume seemed to be from hyporheic flow at the edge between a haul road and a trench. Neither case fully supported the argument that fine sediments wash off the gravel bars.

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INTRODUCTION

Extractive industries produce a substantial amount of material necessary for forest roads, asphalt, concrete and the construction industry. In Humboldt County, California, the industry extracts 800,000 m^3 (approximately one million cubic yards (cy)) of gravel annually from river gravel bars. Approximately 115,000 m^3 (150,000 cy) comes from the Mad River. The National Marine Fisheries Service (2003, 2004, 2009) stated that extraction on the river bars leaves a higher percentage of fine materials on the surface, which wash into the rivers in the late fall storms. National Marine Fisheries Service (NMFS) also stated that the fine sediments disrupt salmon behavior, and possibly fill the interstitial spaces in the riverbed, and reduce salmon egg viability.

Extraction industries produce raw materials for forest roads, asphalt, concrete aggregate, miscellaneous fill and landscaping. River-run gravel tends to be stronger and superior to quarried gravel for many construction purposes because the sediment transport processes wear and fracture the less resistant materials, leaving stronger materials intact (Oregon Water Resources Research Institute 1995). River-run gravel is also more economical to mine as it is cleaner than upland sources and is already exposed (United States Army Corps of Engineers, 2004).

Approximately 800,000 m^3 of gravel are extracted from the Mad River, Eel River, and its tributary, the Van Duzen River, each year. Five decades ago, more than that was extracted from the Mad River alone (Jager et al. 1993). Knuuti (2003) estimated 344,000 m^3 (450,000 cy) were extracted from the Mad River in 1971 and 1972, annually, before which records are less reliable. Although the market would support additional gravel, regulating agencies have limited the industry to less than 134,000 m^3 (175,000 cy) of aggregate removal from the Mad River annually (United States Army Corps of Engineers, 2004) since 2004. A more recent biological opinion on gravel mining on the Mad River from NMFS, dated July 26, 2010, reduced the average annual extraction to approximately 109,000 m^3 (143,000 cy). Currently companies are restricted to harvesting gravel above the elevation corresponding to a discharge of 25.5 m^3/s (900 cubic feet per second) flow at the Arcata gage on the Mad River, unless the gravel extraction plan also enhances habitat for salmonids (Jager et al. 2003). The newer biological opinion has not changed the extraction floor elevation policy. Gravel companies that remain on the Mad River have a financial interest in defending the remaining extraction volume.

Southern Oregon and Northern California Coast coho salmon (*Oncorhynchus kisutch*), California Coastal Chinook (*O. tshawytscha*), and Northern California steelhead (*O. mykiss*) are all federally listed as threatened species, pursuant to the Endangered Species Act (62 FR 24588, 6 May 1997; 64 FR 50394, 16 September 1999; and 65 FR 36094, 7 June 2000, respectively). Because salmon and steelhead are anadromous species, the NMFS is the federal agency responsible for developing recovery strategies for them. Although there is no recovery plan yet for these specific listed species, NMFS has released a draft recovery plan for Central Coast California coho (another distinct population segment of the *O. kisutch*) (75 FR 13081-13211, 18 March, 2010), which lists, “Logging, agriculture and *mining activities*, urbanization, stream channelization, dams, wetland loss, and water withdrawals and unscreened diversions for irrigation" as the primary causes of habitat destruction and modification. In the absence of an explicit statement, one expects the causes for decline among the Southern Oregon and Northern California coho distinct population segment would be similar.

To address in-stream mining concerns, NMFS developed a National Gravel Extraction Policy documenting extraction activities that result in loss or degradation of spawning beds and juvenile rearing habitat. These activities include migration blockages; channel widening, decreased water depths, and ponding; loss of hydrologic and channel stability; loss of pool/riffle structure and riparian habitat; increased turbidity and sediment transport; increased bank erosion and/or streambed down-cutting (National Marine Fisheries Service, 1996).

Some direct on-site effects of gravel extraction related to salmon habitat include (Oregon Water Resources Research Institute, 1995):

- simplification of the otherwise complex morphology of the channel, reducing the diversity of habitats;
- net lowering of the general bed elevation (channel incisions, bed degradation), perhaps to the extent of disconnecting the channel from its riparian zone and floodplain;
- removal, undercutting or other instability of channel banks;
- potential local destabilization of the river bed by removal of form resistance that is important to energy dissipation;

- increased suspended sediment availability, transport, water turbidity, and gravel siltation;
- decreased light penetration (from greater turbidity) that can have impacts on benthic organisms and energy relations;
- removal of spawning gravel from streams, reducing the amount of usable spawning habitat;
- direct damage to spawning areas;
- changed substrate composition by removal of material from particular locations, with impacts on habitat and bed stability; and
- disturbance of redds and destruction of eggs or developing embryos. The gravel companies necessarily create roads to the gravel bars and even if gravel extraction occurred earlier, the increased foot and vehicle access by others disrupts spawning sites.

"Scalping," or skimming the top of the gravel from gravel bars without excavating below the summer water level, is one of the most common methods of gravel extraction practiced today (Oregon Water Resources Research Institute 1995). Scalping can remove the gravel "pavement," or armor layer, leaving the finer subsurface particles vulnerable to entrainment (erosion) at lower flows than would occur with an intact armor layer (Kondolf 1994, Kondolf et al 2001, Oregon Water Resources Research Institute 1995).

Floods transport large amounts of small-size sediment, as suspended load, over distances of many miles and deposit it over widespread areas such as floodplains (Oregon Water Resources Research Institute 1995). At low flows, there is little or no transport, except in the immediate vicinities of local bed disturbances (Oregon Water Resources Research Institute 1995).

Disturbances that produce suspended sediment result in sediment intrusion into bed gravels reducing interstitial spaces, which directly decreases the habitable area for immature mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) (Bjornn et al. 1974). The insects occupy the interstices in the riverbed and are considered the most productive, preferred, and available foods for stream fishes (Waters 1995 and Spence et al. 1996). Therefore, sediment intrusion reduces the amount of prey available to developing juvenile salmonids, restricting salmonid growth and survival.

Downstream salmonid redds are also affected by deposition of displaced, surplus alluvial material, resulting in egg suffocation or suppressed salmon fry emergence (Pauley et al., 1989). Fine sediments are particularly detrimental to incubating fish eggs because blockage of interstitial spaces by silt prevents oxygenated water from reaching the egg and limits removal of waste metabolites (Chapman 1988, Reiser & White 1988). Factors limiting early life-stages can influence population numbers in later stages. (Anderson 1988). If skim surfaces are a source of fine materials and if the fines are transported to the wetted channel before the river is already opaque, then the sediment loading is an adverse impact to the salmonid species. NMFS has not been concerned with the expected amount of fines that may be washed from the extraction surface when the river is already opaque from suspended sediment, since the salmonids would already be attempting to avoid the suspended sediment.

Many factors have been cited for declines in salmon abundance. Although the limiting factor(s), or the most restrictive factor to reproduction, for these fish in these rivers has not been identified, it is prudent to ensure the salmonids have adequate prey and spawning habitat.

Estimating an animal population with high accuracy is expensive and requires considerable effort (Davis and Winstead 1980) and especially for salmonids. The best available information comes from Green Diamond Resource Company (formerly Simpson Timber Co.), which surveyed the Mad River and found that Chinook salmon redds had decreased from 321 in 1996/1997 to 27 in 2004/2005 in the surveyed section of the North Fork Mad River (Stillwater Sciences 2009). A mark-recapture study during the 2001-2002 season found that approximately 17,164 steelhead migrated upstream of river mile (RM) 13 on the mainstem Mad River (Zuspan and Sparkman 2002). Based on a variety of criteria, including population diversity, population productivity, spatial structure, and population size, NMFS believed that the populations of Northern California steelhead, California Coastal Chinook, and Southern Oregon/Northern California Coasts coho are currently not viable.

In Humboldt County, NMFS has established minimum elevations for gravel bar skimming to reduce adverse effects to listed salmonids, based on the premise that overtopping of skimmed bars causes additional sediment input to the stream. Tauzer (2002) noted that the first rising water readily entrains fine sediment from extraction surfaces because the bar material had been scraped with a tractor leaving loose, fine sediments exposed on the surface. Tauzer compared the various flows of several rivers in Humboldt County and found a dramatic increase in the suspended load at or above those flows that are only exceeded 35% of the time, on average. The Arcata Field Office of NMFS uses the document and the reasoning behind it to justify the 35% minimum skim flow elevation policy. For the river reaches in Humboldt County that have active gravel operations and a stream gage nearby, Tauzer identified the 35% flow rate. Gravel operators are annually required to mark the elevation of the 35% flow on their extraction bars, which then becomes the lowest extraction elevation for most extraction plans and methods.

Kraus (2002, personal communication), an employee of Eureka Ready Mix, a gravel company on the Mad River, has noted that there are typically several rain events, if not storms, along the alluvial reaches of the river before the water level rises more than a couple inches. Instead of washing fines off the gravel bar into the river, he suggested that rain may wash the fines into interstitial spaces within the extraction surface. He also observed that the river was already opaque due to suspended sediments before the water surface elevation reaches the 35% flow. Additionally, since the river widens as it overtops the gravel bars, portions of the flow slow down and may deposit fines.

River mechanics fundamentally is the study of interrelationships concerning flow, sediment transport, and mobile boundaries. The mechanical principles governing the relationships are not yet adequately explained, nor is the causal nature of many correlations resolved. The capacity to scour a channel, transport material, and degrade the landscape depends on the gravitational force and the resistances offered (Leopold et al. 1964). As indicated by the Hjulstrom (1935, 1942) diagram (Figure 1), a stream’s

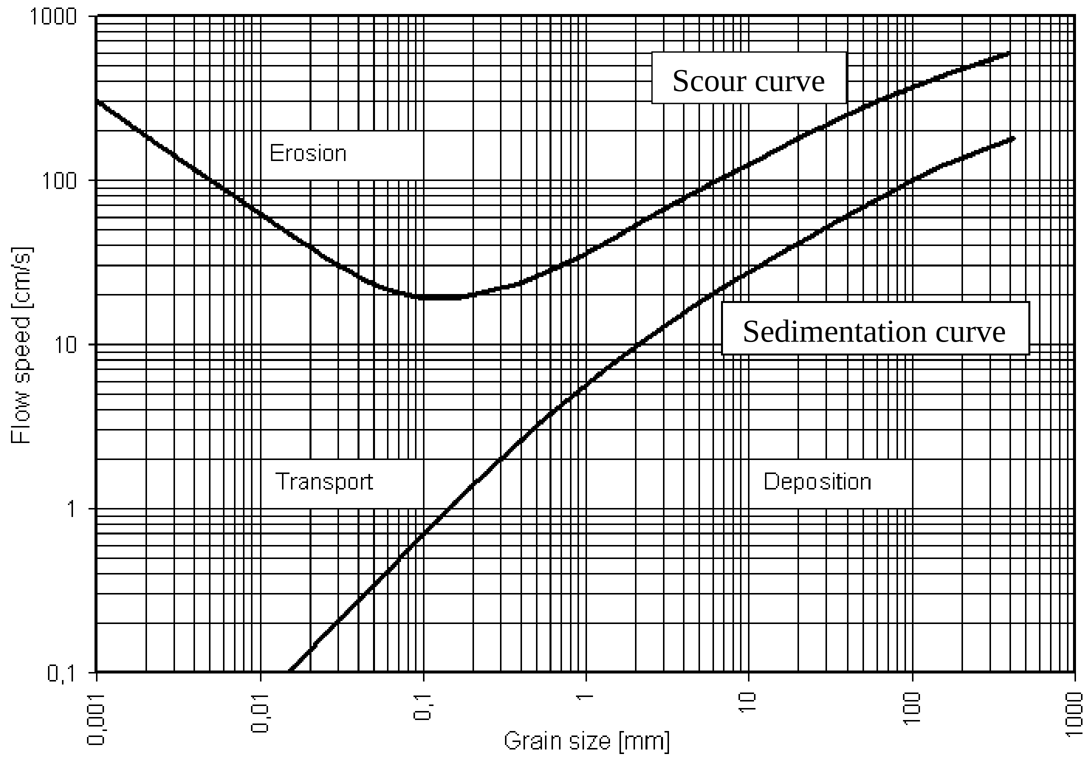

Figure 1. The relationship between stream speed, scour, transport and particle deposition (Hjulstrom, 1935, 1942). This diagram shows the correlation between stream speed, scour and between transport and deposition. Above the scour curve, the speed of the flow is sufficient to entrain particles of the indicated size. Between the scour curve and the sedimentation curve, particles are moved by the flow, but not scoured. Below the sedimentation curve, particles settle and remain stationary. Incipient motion occurs along the scour curve.

ability to move sediment, or competence, is entirely dependent on stream velocity. From Kraus's (2002) perspective, as the rising waters, opaque with suspended sediment and too fast to wade, begin to overtop the extraction surface, the shallower flow on the extraction surface is slower and still wadeable. That portion of the flow has less competence.

Similar to competence, the shear stress, τ, on the stream bed is given by the equation (Leopold 1964):

$$(1) \qquad \tau = \rho g R s \approx \rho g d s = \tau_o,$$

where ρ is mass density of the fluid (water), g is the acceleration due to gravity (9.8 m/s^2), R is the hydraulic radius of the stream, and s is sine of the longitudinal stream slope angle (in radians), which is also quite similar to the stream slope when it is not steep (Leopold 1964). When the stream width is much greater than its depth, the hydraulic radius approximates the depth, *d*. Since the mass density of water and the acceleration due to gravity are constants, and if the slope is relatively constant over long reaches, the equation is simplified to shear stress is proportional to depth:

$$(2) \qquad \tau_o \propto D$$

The equation is relevant to both depth in the thalweg, and on the extraction surface. As flows exceed 25.5 m^3/s, the water surface rises above the extraction floor elevation and slows as it spreads out over the skim floor. Without running the equations with numbers, the equation intuitively seems to support Mr. Kraus' arguments. Whether the sediment transport correlates with stream depth or velocity, the flow is shallower and slower on the extraction surface than in the main channel. From Kraus' standpoint, the flow should already be mobilizing as much sediment as it can before it overtops the bar, where the flow is slower and shallower. A portion of the sediment in the over-bar flow should settle.

A lower flow-rate may be necessary to entrain fines as suspended sediment than is necessary to mobilize the stream bed (bedload), although the process is not entirely understood. The force exerted is commonly considered a drag stress proportional to the exposed area of the particle and the bed stress at the time of incipient motion of the grain is

$$(3) \qquad \tau_c = K(\sigma-\rho)g\underline{\boldsymbol{D}}s,$$

where τ_c is the critical stress (or competence) to move the particle of diameter $\underline{\boldsymbol{D}}$, K is a constant related to particle geometry or packing, σ the mass density of the grain, ρ the mass density of the liquid, g the acceleration due to gravity, and s is the slope of the stream surface (Leopold 1964). As the flow spreads across the extraction surface, the depth, D, decreases and local velocity may slow. As shown in Hjulstrom's diagram (Figure 1) the velocity to sufficiently entrain (scour) a particle is greater than the velocity necessary to transport it. The extraction surface may be a sink for fines during the first moderate and high flows of the rainy season. Certainly the depth, D, on the extraction surface is less than in the main channel.

Fines may be washed into the river from external sources such as landslides and forest roads before the fine sediments within the river bed are entrained. The numerous bare landslides and steep, rutted and heavily used legacy forest roads and driveways are sources of fines which are easily washed into the river by rains (Cederholm et al., 1980) (National Marine Fisheries Service 2010). The hydraulic forces required to maintain these particles in suspension are relatively low, and once entrained the particles are transported downstream at velocities near that of the river's flow rate (Everest et al. 1987). Hence the suspended sediment load could be substantial before the streambed is mobilized.

The objectives of this study are to determine 1) whether the extraction process, rains, or shallow inundation change the percentage of fines on the gravel bars; 2) if the extraction surface is a source of fine sediments that may interfere with either migrating or spawning salmonids, and 3) if the fines are washed off by either the first rains or the early fall stream flows before the river is already turbid with sediments from various upstream or hillslope (upland) sources.

If fine sediments are entrained from the extraction surface before the bedload of the extraction surface is mobilized, then the surface after light inundation would have fewer fines than before inundation. If the after-inundation surface has more fines than the post-extraction surface, it indicates that the extraction is a sink, not a source of fines. I hypothesize that the post-extraction surface has more fines than the pre-extraction surface and the after-inundation surface has more fines than the post- and pre-extraction surfaces. I further hypothesize the after-rains surface has less fines than the post-extraction surface.

This study incorporates two methods to answer the questions associated with the problem of sediment entrainment, suspended sediments, and flows dispersing across the gravel bar. One test places colored sands on the extraction surface and documents whether the first rains wash them into the interstitial spaces below or whether the stained sands are washed off the extraction surface. It also observes the stained sands when the flowing waters overtop the extraction surface. The second test requires the collection and comparison of sediment samples before extraction, after extraction, after rains and after inundation. In addition to the two tests, I observed the river's edge by the gravel bars during the first rains of the season to determine if there is a visible sediment plume from the extraction surfaces.

STUDY AREA

The study area was located on the alluvial reach of the Mad River, Humboldt County, California. Sites were located between the Blue Lake Fish Hatchery at RM 12.3 (40.85909N, 123.98679W) and the O'Neill Gravel Bar at RM 5.0 (40.91329 N, 124.06797W) (Figure 2).

The Mad River drains 1290 km^2 in the Northern Coast Ranges in Humboldt and Trinity Counties, California. The river flows 160 kilometers northwesterly from the headwaters to the Pacific Ocean just north of Arcata, California. The nearest USGS stream gage to the study area is called Mad River near Arcata, California (#11481000). The Mad River Valley is controlled by the Mad River Fault zone (Li 1992). The geologic strata are mostly northwest-striking Franciscan assemblage rocks consisting of sandstones and shales, with some greenstones, chert, conglomerates and serpentine. In some places, the Franciscan rocks are topped by Falor formation, alluvium and river terrace deposits (Tolhurst 1995).

Frequent earthquakes and heavy storms contribute to numerous landslides in the watershed (Tolhurst 1995). The area is one of the most seismically active regions in California (United States Army Corps of Engineers 1972). As a result of the landslides and various sediment producing land management activities (such as road construction, timber harvest, etc.) the Mad River is impaired by excess sediment, and the Environmental Protection Agency, Region IX, has published Total Maximum Daily Loads on December 21, 2007, which determines the allowable amount of sediment and turbidity in the watershed.

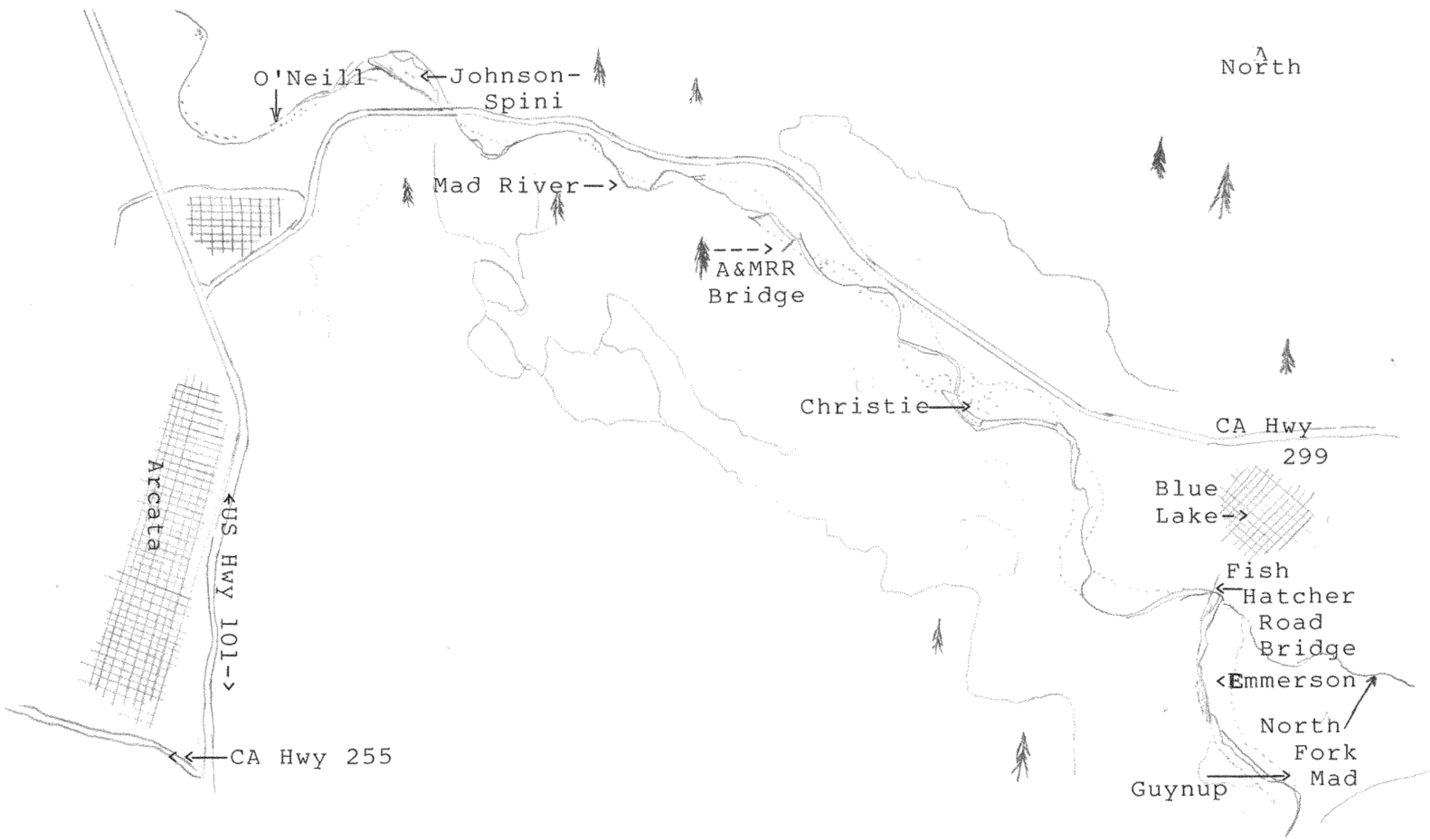

Figure 2. Locations five gravel bars included in this study. The river aggrades downstream (west) of the Annie and Mary Railroad Bridge (AandMRR Bridge) and scours between the Mad River Fish Hatchery and the Bridge (Lehre et al., 2009)

Six gravel companies extract gravel from a sixteen-kilometer reach of the lower Mad River. This reach of the Mad River was selected as the study area because of the proximity to Humboldt State University, the amount of previous research, the needs of the industry, and concern for the federally-listed threatened salmonids.

In the Montgomery-Buffington (1997) classification system, which was developed for use in the Pacific Northwest, the extraction reach would be categorized as pool-riffle since the stream slope fluctuates around 0.3% and the presence of riffles and pools are obvious during the summer and fall (ERM 2011, Streamline Planning 2011). Using the Rosgen classification, the extraction reach of the Mad River would be approximated within the range C3-D4 (Rosgen 1994). Generally, the reach downstream of the Annie and Mary Railroad Bridge is confined and not anastamosing or braided, though it does periodically shift between right or left bank around the Johnson-Spini gravel bar.

For this study, five gravel bars were selected to represent the extraction reach (Figure 2): O'Neill Bar at RM 5.0 (Figure 3); Johnson-Spini at RM 5.7 (Figure 4) downstream of the State Route 299 bridge near the city of Arcata; Christie Bar at RM 9.0 (Figure 5), south of the Glendale overpass at State Route 299 and downstream of the wastewater treatment facility for the city of Blue Lake; Emmerson at RM 11.1 (Figure 6), upstream and adjacent to the Hatchery Road bridge; and Guynup at RM 12.2 (Figure 7). Each gravel bar has a transect across the bar about 2/3 the length of the gravel bar towards the downstream end, with five sample sites spaced 15 meters (50 feet) apart, except O'Neill Bar and Emmerson in 2008, with the first sample location at the edge of

Figure 3. Aerial view of O'Neill Bar with location of sample transect. Sample sites were spaced 12 meters apart because the gravel bar was only 50 meters wide. The first sample was located at the wet edge. The transect is aligned with monitoring cross section 11, which is maintained by Eureka Ready Mix.

Figure 4. Aerial view of Johnson-Spini Bar with sampling transect line. Sample sites were spaced 15 m apart with the first, J1P0, at the wetted channel edge. The transect was aligned with monitoring cross section 3, which is maintained by Eureka Ready mix. The transect is marked in yellow with red endpoints. In this picture the river flows from the southeast corner to west.

Figure 5. Aerial view of Christie Bar with sampling transect. Sampling transect is marked in yellow with red endpoints and coincides with the monitoring cross-section 3, which is maintained by Eureka Ready Mix. In this photo, the river flows from the southeast corner to the northwest.

Figure 6. Aerial view of the Emmerson Bar with sampling transects. In the 2007 season, sampling transects, marked in yellow with red endpoints, aligned with extraction cross section 10, which is specific to the year. In the 2008 season, the transect aligned with the cross section 13+54. In this picture, the river flows northwards to the top of the page, then west.

Figure 7. Aerial view of the Guynup Bar with sampling transect. The transect is marked in yellow with red endpoints. The date of the photo is May 24, 2009. In this picture, the river flows from the southeast towards the northwest.

the gravel extraction closest to the flowing river. Because O'Neill Bar and Emmerson extraction area in 2008 were only about 50 meters wide, the sample sites were spaced 12 m apart.

The aerial photos in Figures 3-7 were produced in May 2009, when the river would be deeper and wider than when the pre-extraction, post-extraction, and after-rains samples were collected. Naturally, the photos do not accurately portray the river condition of the previous year.

Sample sites on the O'Neill Bar (Figure 3) were evenly spaced 12 m (~40 ft) apart with the first, O1P0 at the edge of extraction near the wetted channel along the south, or left bank (LB) as one descends the river, and subsequent sample locations consecutively spaced across the gravel bar to the southeast.

On the Johnson-Spini Bar (Figure 4), samples were evenly spaced 15 m apart, with the first, J1P0 near the wetted channel along the east bank, or right bank (RB) descending, and subsequent sample locations spaced consecutively across the gravel bar towards the east.

Sample sites for Christie Bar were evenly spaced 15 m apart, with the first, C1P0, near the wetted channel along the east bank (RB) and subsequent sample locations spaced consecutively across the gravel bar towards the east.

Samples sites for Emmerson 2007 were aligned along the extraction cross section 10, which did not extend to the site of the 2008 extraction. For the 2008 season, the transect was aligned along the extraction cross-section 13+74. The samples from the 2007 season were evenly spaced 15 m apart, with the first E1P07 near the wetted channel along the east bank (RB). Samples from the 2008 were spaced 12 m apart because the extraction area was only about 50 meters wide, with the first E1P08 at the west edge of the extraction surface and subsequent samples progressively east-wards. There were no after-rains or after-inundation samples collected from Emmerson during the 2008 season, because the site did not drain adequately after the rains. Any sediment would have been "washed" during collection.

Sample sites on the Guynup bar were evenly spaced 15 m (50 feet) apart with the first, G1P0, at the edge of the extraction nearer to the wetted channel right bank (RB) and subsequent sample locations consecutively spaced across the gravel bar.

METHODS

I used two techniques to assess size change and particle mobility. I compared particle sizes from the gravel bar samples before extraction, after extraction, after rains, and after inundation. For the other technique, I placed stained sands to determine if fines are washed off the extraction surface.

Sand Samples

The term “fines” in the literature is ambiguous, and frequently refers to sediment particles that have a *b*-axis smaller than ¼ millimeter and occasionally as large as eight millimeters. The *b*-axis is the intermediate dimension amongst length, width and thickness; neither the longest nor the shortest. Cederholm et al. (1981) found that the size class of less than 0.83 mm was the critical threshold for adverse effects to salmon survival to emergence in the Clearwater River system, Washington. Since the term “fines” is unclear, the sampling method tested various sizes, including fractions less than ⅛ mm, less than ¼ mm, less than ½ mm, less than 1 mm, less than 2 mm, less than 4 mm, and less than 5 mm. Each of the size classes is given as a percentage of the total sample mass.

Transects were placed proportional to the length of the gravel bar because there is a tendency for larger particles to be located at the downstream end and finer particles to be located at the upstream end of gravel bars (Oregon Water Resources Research Institute, 1995). To avoid the variation inherent in the position on the gravel bar, samples were collected from locations proportional to the gravel bar length, specifically at the cross section 2/3 of the distance from the head of bar to the downstream end. To assure reproducibility, each transect was coincident with a monitoring cross-section, which is monumented and surveyed each year for the industry's extraction proposals. When the gravel bar was more than 60 m wide, the five samples were collected from points 15 m apart beginning at the edge of the extraction area nearer the wetted channel, and every 15 m along the monitoring cross-section. For example, the second sample was 15 m from the edge of the extraction surface on the wetted channel side. Because the O'Neill Bar and Emmerson extraction locations in 2008 were only about 50 m wide, the sample sites were located every 12 m along the transect beginning at the edge of extraction.

During the 2007 season, the transect on Emmerson Bar lined up along monitoring cross-section 10. During the 2008 season, the transects on Emmerson Bar lined up along monitoring cross section 11. The transect for Johnson-Spini was aligned with monitoring cross section 3. The transect for Christie Bar was aligned with monitoring cross section 2. The transect for Guynup Bar was aligned with cross section 6.

The study was designed to compare pre-extraction, post-extraction, after-rains and after-inundation sediment samples. Due to a late start on the study, no pre-extraction samples were collected from Emmerson Bar during the 2007 season. The Emmerson Bar experienced a different type of extraction during the 2008 season compared to the other gravel bars and compared to Emmerson Bar in the 2007 season. In 2008, a non-traditional extraction plan, locally called a 'horseshoe skim,' was implemented for Emmerson Bar. This type of extraction is generally replenished by deposition of suspended sediment from the downstream end. Because the skim surface did not drain after the first rains, the gravel bar had puddles that would have washed the sample while it was collected. Because the samples would have been washed and would not replenish in the same manner as the other gravel bars, no samples were collected from Emmerson Bar after fall rains or after inundation during the 2008 season. The 2008 pre-extraction samples should have been comparable to the 2007 samples had they been collected. Post-extraction samples should be comparable for both years on the Emmerson Bar. Table 1 details which samples were collected for each event and describes the naming convention of each sample, where the ‘x’ would be replaced by a numeral between 1 and 5 based on the position on the gravel bar. For example, G1P08 would be from Guynup Bar (G), at the edge of extraction nearest the water’s edge (1), pre-extraction (P), from the top 5 cm (0), in the 2008 season.

At each sample location gravels were photographed and then removed for analysis as described below. Each sample site was also identified by painting the sand and gravel with bright colors around a 60-cm steel ring pushed into the gravel during collection. The ring was removed, and the site photographed from precisely one meter above the surface. Then the ring was carefully replaced, and pushed into the gravel as the particles in the top 5 cm were collected (Figure 8). Colors were selected to distinguish the types of samples: Pink for pre-extraction, yellow for post-extraction samples, green for after-rains, and orange for after-inundation samples. A line was drawn on the inside and outside of the ring to indicate 5- and 10 cm depths.

Most sites were sampled before extraction, after extraction, after first rains, and after the first flow event that overtopped the extraction surface. During the 2007

Table 1. Labeling scheme for gravel samples collected in 2007 and 2008 lower Mad River, Humboldt County, California. In the table below,‘x’s are place markers for the sample number on the gravel bar. A complete sample name would have a number between one and five, which would indicate the samples’ position on the bar; -- indicates that no samples were collected; “P” in the sample name indicates that it’s pre-extraction sample; “S” in the sample name indicates ‘subsequent,’ indicating that it’s a post-extraction sample; “R” in the sample name indicates that the sample is from after the first rains of the fall but before inundation; “I” in the sample name indicates that the sample is from after inundation. G,E,C,J,O are the first initial of the gravel bars that served as sample sites for this study.

Gravel Bar and Year	Pre-Extraction	Post-Extraction	After-rains	After-Inundation
Emmerson 2007	--	ExS07	ExR07	ExI07
Emmerson 2008	ExP08	ExS08	--	--
Guynup 2008	GxP08	GxS08	GxR08	GxI08
Christie 2008	CxP08	CxS08	--	CxI08
Johnson-Spini 2008	JxP08	JxS08	JxR08	JxI08
O’Neill 2008	OxP08	OxS08	OxR08	OxI08

Figure 8. Example of gravel sample site after being marked in 2007 or 2008, lower Mad River, Humboldt County, California.

sampling season, the ring was hammered in to a depth of 5 cm before all the sediment in the ring was collected and identified. Then the ring was hammered into the gravel an additional 5 cm before collecting the sample between 5-10 cm. However, several large rocks (up to 25 cm long) blocked the ring's progress into the sand, and in 2008, I pushed the ring in as deep as feasible to a maximum 10 cm, collected the sediment within, and removed any rocks that were blocking the ring. If the rock was more than half within the sample area, it was retained as part of the sample.

Two samples were collected from each sample location. A sample of the top 5 cm and the second 5 cm of the extraction surface were collected and sieved to separate the sand (up to 5 mm) from larger particles and weighed to quantify sand and rock in each layer. If the aggregate was not sufficiently dry to adequately sieve in the field, the sample was air dried in the lab. The 19 liter (L) collection buckets were marked to indicate the level of 14.7 L volume, being equivalent to the volume of a 60-cm diameter circle 5 cm deep. Aggregate was scooped from the surface within the ring until the 5-cm depth was removed and the bucket was full to the 14.7 L mark. The durable cobbles that were more than half within the ring were included in the rock and gravel sample; stones that were more than half outside the ring were discarded. After the top 5-cm sample was collected, the process continued downwards to collect the sample at the 5- to 10-cm depth. Samples were placed in a 19 L bucket, weighed and sieved in the field with a tripod-mounted Electro Samson scale from Salter Brecknell. The device can be held in the hand, and weighs up to 40 kilograms with 0.05 kg accuracy. Any cobbles that spanned the interface between the surface sample and the subsurface sample were placed with the sample that had contained most of the cobble before excavation. Three stones were large enough that they were partly within the surface sample and the subsurface sample, but were predominantly within the aggregate below; they were discarded. After collecting, the sample was sieved to remove the sand less than 5 mm *b*-diameter from the gravel and cobbles. All sand and fine gravel less than 5mm was simultaneously stirred and rotated in a 19 L bucket to thoroughly mix the sample before a 4.5 kg split was scooped from the bucket. The splits were taken to the lab and sieved into 4-5 mm, 2-4 mm, 1-2 mm, ½ -1mm, ¼ - ½ mm, ⅛ – ¼ mm and less than ⅛ mm size classes. All sample weights were converted to a percentage of the entire sample, including rock and gravel. After weighing, rock and gravel were returned to the excavation pit.

Lab Methods

Samples that were too moist to sieve in the field were weighed in the field, brought to the lab, and spread on a sheet of paper in a drying rack for a couple days to air dry. Then they were re-weighed, and fines less than 5 mm were sieved from the gravels and rocks. Fines were weighed, remixed, and a 4.5 kg split was separated for later analysis. Gravel and rocks were also weighed and discarded. Particles larger than 3 cm often have sands and finer particles imbedded in cracks and other surficial indentations. Gentle brushing with a plastic-bristle scrub brush removed finer particles from the stones.

Samples were sieved for five minutes on the Ro-Tap (W.S. Tyler Industries, Mentor, Ohio) sieve shaker. The Ro-Tap removes the human inconsistencies from the process of sieving the sands.

Frequently, particles slightly larger than the indicated screen size blocked a substantial number of the screen openings, a process that the aggregate industry calls "pegging." For sieves with openings between 1 mm and 5 mm, it was easy to determine if many of the openings were blocked (pegged). However with sieves with openings between ⅛ mm and 1 mm, it is a more subjective observation. If approximately 60% of the openings were pegged and the material seemed reasonably durable, then I cleaned the screen and resieved the sediment trapped in the sieve for another 2-3 minutes. For example, if the ½ mm sieve were more than 60% blocked, then I cleaned the screen and replaced all the sediment in the ½ mm sieve for 2-3 minutes of additional shaking.

A few spherical particles were collected among the ¼, ½, and even 1 mm subsamples that apparently were conglomerations of clay particles that had clumped when wet, and retained enough material strength to withstand five minutes of sieving with sand and gravels. I crushed or abraded many clay spheres to identify their nature, and confirm that there wasn't a sand grain core, but the clay spheres were generally retained in the size class of the sieve.

Stained Particles

I placed three fluorescent-stained sand samples, representing three size classes, on five gravel bars and revisited them during the rain events and after the surface was inundated. I used the techniques described in Yasso (1966) to stain the sands and the technique described in the remainder of this paragraph (Madej, 2006, personal communication) to place the stained particles. Fines used for the stained particles were obtained from samples collected during the 2007 season. Approximately 4.5 kg of sediments in three size classes were collected, sieved into the specific size classes, and stained. Sediments less than ¼ mm were stained green, ¼ - ½ mm were stained fluorescent orange, and ½ - 1 mm were stained bright yellow. Stained sands were placed on smoothed areas 1) near the edge of the extraction surface, 2) near the water's edge, and 3) near sample point 1 of each bar. Three areas on each bar were cleared of pebbles larger than 2.5 cm along the *b*-axis and covered with enough of the three stained sand particles to make three 17 – 18 cm diameter circles that cover the pebbles below. Stained particles were placed on or after September 28, 2008, and revisited while it was raining, after the rain, and after the surface was inundated. I expected that stained particles would leave a 'trail,' similar to a comet's tail, either toward the center of the gravel bar or off the gravel bar. Because no trail was observed, reinspection focused primarily on presence or absence of planted particles and the settling of the wetted particles.

Methods of Analysis

I used NCSS (Hintz, 2004) to perform a paired t-test to compare percentage in each size class in pre-extraction samples against post-extraction, after-rains, and after-inundation, respectively. I also compared post-extraction samples of each size class against after-rain and after-inundation, as well as the after-rain against after-inundation samples. The surficial samples were compared against each other and the subsurface samples were compared with the other subsurface samples. In addition to running the two-tailed, paired t-tests, and providing means, standard deviation, and probability levels, the software also included three tests for assumptions to examine skewness normality, Kurtosis normality, and omnibus normality.

RESULTS

Analysis of 181 samples (surface plus subsurface), in seven size classes, taken from five gravel bars indicated that post-extraction and after-inundation surfaces had a larger proportion of coarser fines (less than 2mm, less than 4mm, and less than 5mm) than did the pre-extraction surfaces. Conversely, post-extraction surfaces had a smaller proportion of the finest sediments (less than ⅛ mm) than the pre-extraction surfaces.

Observations of seventeen planted stained sand samples from five gravel bars in 2008 and two gravel bars in 2007 indicated that fines that remain on the extraction surface after extraction were washed into the interstitial spaces in the gravel below. The examination of planted stained particles suggested that particles did not wash off the gravel bar but rather settled during the rains, and eventually were entrained during inundation.

Sand Samples

Samples were collected at Emmerson, Guynup, Christie, Johnson-Spini and O'Neill Bars during the 2008 season, with the following exceptions. After-rains and after-inundation samples were not taken at Emmerson in 2008, because the site did not drain sufficiently to allow sampling and because the gravel company opted for an alternative configuration which would not be comparable if the data had been collected. After-rain samples were not collected at Christie Bar due to time and weather constraints between first rains and inundation. Samples were also collected from Emmerson Bar for post-extraction, after rains, and after inundation during the 2007 season.

Surface (0-5 cm depth)

An analysis of 91 samples, in seven size classes, indicated that post-extraction and after-inundation surfaces have a larger proportion of coarser fines (less than 2 mm, less than 4 mm, and less than 5 mm) than were found on pre-extraction surfaces. However, there were more of the finest sediments on the pre-extraction surface than on the post-extraction surfaces.

Similarly, there were more of the coarser grains after inundation than pre-extraction, but fewer of the particles within the less than ⅛ mm and less than ¼ mm size classes after inundation than before extraction.

Figure 9 details the average cumulative percentage of fines that each size class represents of the total sample mass. The average percentages given in Figure 10 were calculated from all samples and may vary from the percentages provided in other tables, which only use the samples for which there was a corresponding paired sample in the t-test.

Among all comparisons with surface samples, the most statistically significant differences are between pre-extraction and post-extraction samples. The difference between the amount of fine sediments on pre- and post-extraction gravel bars was significant at 5% or better probability in the less than $^{1}/_{8}$ mm, less than 4 mm, and less than 5 mm size classes (Table 2). The pre-extraction sample included 0.73 % more dust (less than ⅛ mm) than the 2007 post-extraction samples ($p = .046$). However the 2007 post-extraction sample included 6.1% more sand less than 4 mm ($p = .016$) and 6.3% more sand less than 5 mm ($p = .014$) than the pre-extraction samples. Likewise,

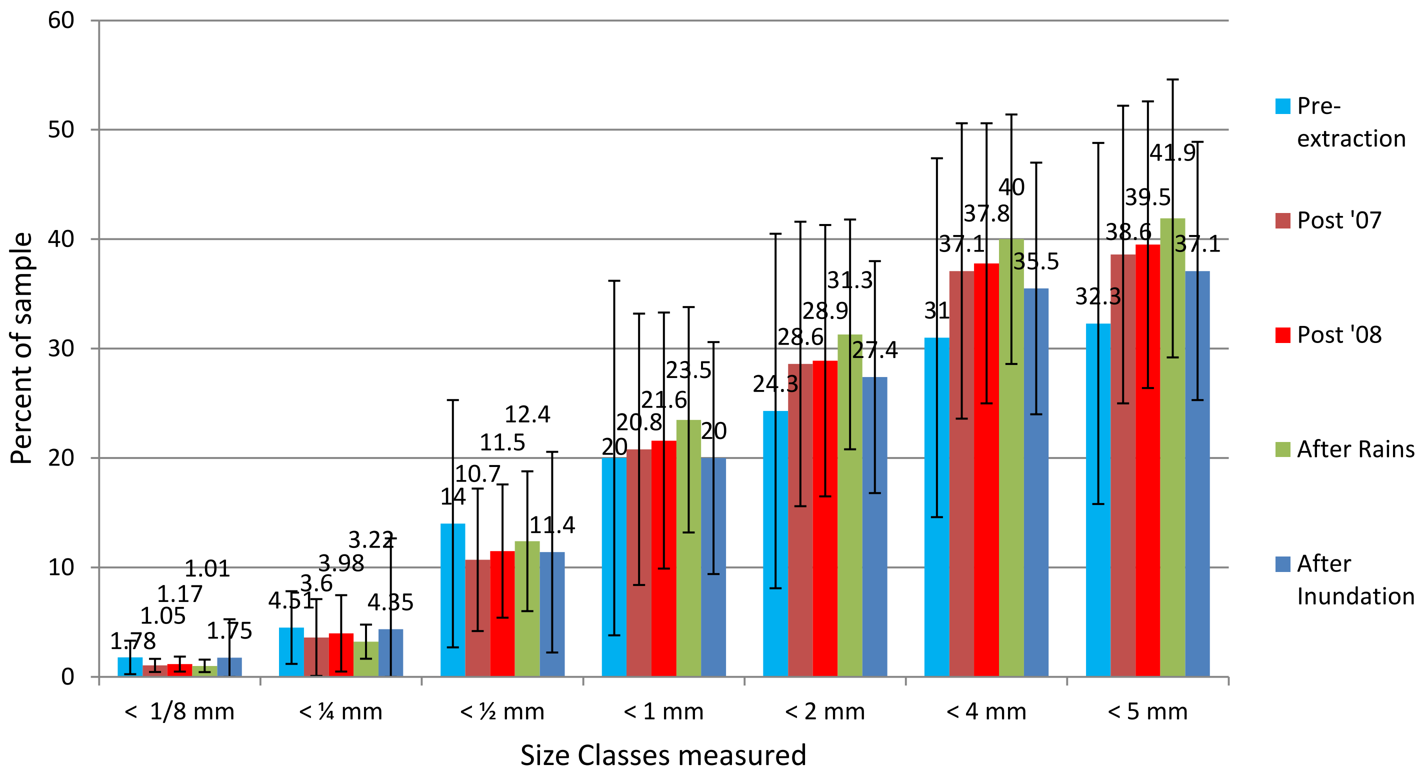

Figure 9. Cumulative percentage of fines in each size class in surface samples in 2007 and 2008 lower Mad River, Humboldt County, California. The percentages reported in this figure indicate the mean percentage when using all the samples collected, however the paired tests only use the values for which there is a corresponding value in the secondary category. Pre-extraction, post-extraction, after-rains and after-inundation data were collected from the Emmerson Bar during the 2007 seasons. Post extraction data were also collected from Emmerson during the 2008 season, also. All other data were collected during the 2008 seasons. The post-extraction '07 data were predominantly collected in the 2008 seasons, except for that which came from the Emmerson Bar. The vertical lines indicate standard deviations.

Table 2. Comparison of the percentages of fine particle size on gravel bar surfaces pre- and post- extraction in 2007, and 2008, lower Mad River, Humboldt County, California. The two-tailed paired t-test indicates that there is no difference between pre- and post-extraction 2008 data, however, a one-sided t-test indicates that there are significantly more fines < 1/8 mm diameter in the pre-extraction surface as compared to the post-extraction (with Emmerson 2008 data) surface, as discussed in Other Observations. The bold numbers are the probabilities that difference exceeds the 5 percentage level of significance. There were 24 sample pairs with both 2007 and 2008 samples (n = 24). Each column of percents also includes the standard deviation. One or more of the tests for normality indicated a failure for the tests with < ⅛ mm and < ¼ mm 2007 data, as well as < ¼ mm, < 4 mm and < 5 mm 2008 data. The percentage given is the percentage of the weight of the grains in the stated size class as a percentage of the total sample, including gravel and rocks, so the < 4 mm size class includes everything smaller and is a subset of the <5 mm size class.

Size Class	Pre-extraction (%)	Post-extraction '07 (%)	Statistical Significance of pre-vs. post-extraction 2007	Post-extraction '08 (%)	Statistical Significance of pre-vs. post-extraction 2008
< ⅛ mm	1.8± 1.5	1.1± 0.6	**.046**	1.2± 0.7	.053*
< ¼ mm	4.5± 3.3	3.6± 3.5	.41	4.0± 3.5	.60
< ½ mm	14.0± 11.3	10.7± 6.5	.15	11.5± 6.1	.23
< 1 mm	20.0± 16.2	20.8± 12.4	.78	21.6± 11.7	.53
< 2 mm	24.3± 16.2	28.6± 13.0	.10	28.9± 12.4	.075
< 4 mm	31.0± 16.4	37.1± 13.5	**.016**	37.8± 12.8	**.0062**
< 5 mm	32.3± 16.5	38.6± 13.6	**.014**	39.5± 13.1	**.0046**

the 2008 post-extraction samples included 6.8 % more sand less than 4 mm ($p = .0062$) and 7.2% more sand than the pre-extraction samples ($p=.0046$). Six or 7% difference over the roughly 31% pre-extraction levels is sufficiently obvious that a soil scientist would typically be able to distinguish the difference by feel if both were available.

The after-inundation samples contained 6.4 % more fine sands less than 2 mm than the pre-extraction samples ($p = 0.020$), 7.7% more sand less than 4 mm ($p = .0065$), and 7.9% more coarse sands less than 5 mm ($p = 0.0037$) than the pre-extraction surface (Table 3). The after-inundation surface appears to have more coarser particles than the pre-extraction surface, and the distinction increases with particle size.

The remaining comparisons were not noteworthy, including

- the post-extraction versus after-rains,
- post-extraction versus after-inundation,
- pre-extraction versus after-rains,
- and after-rains versus after-inundation samples.

Two-tailed paired t-tests for these comparisons demonstrated no significant differences (Table 4, Table 5, Table 6, and Table 7, respectively).

Among all the surface comparisons, there was only a significant difference in two: pre-extraction vs. post-extraction and pre-extraction vs. after-inundation (Table 8). Generally, there was no significant difference between the gravel bar surface before or after the different events.

Table 3. Comparison of the percentages of fine particle size on gravel bar surfaces before extraction and after inundation in 2007 and 2008 lower Mad River, Humboldt County, California. The bold numbers are the probabilities that the difference exceeds the 5 percentage level of significance. There were 24 sample pairs for the paired t-test (n=24). Each column of percentages also includes the standard deviation. The percentage given is the percentage the weight of the grains in the stated size class as a percentage of the total sample, including gravel and rocks, so the < 4 mm size class includes everything smaller and is a subset of the <5 mm size class. Tests for normality found only the < ½ mm comparison did not satisfy the assumptions of normality.

Size Class	Pre-extraction (%)	After Inundation (%)	Statistical Significance
< $^{1}/_{8}$ mm	1.84 ± 1.50	1.75± 3.51	.91
< ¼ mm	4.44 ± 3.34	4.34 ± 8.31	.96
< ½ mm	11.9 ± 7.29	11.4 ± 9.16	.83
< 1 mm	16.7 ± 8.27	20.0 ± 10.6	.23
< 2 mm	21.0 ±8.37	27.4 ± 10.6	**.020**
< 4 mm	27.8 ± 9.96	35.5 ± 11.5	**.0065**
< 5 mm	29.2 ± 10.3	37.1± 11.8	**.0037**

Table 4. Comparison of the percentages of fine particle size on gravel bar surfaces (0-5 cm) post-extraction and after rain in 2007 and 2008, lower Mad River, Humboldt County, California. This table considers the significance of the difference between post-extraction and after-rains samples using the post-extraction ’07 data. There is no statistical difference between the post-extraction and after-rains samples. There were 24 sample pairs for the paired t-test (n=24). Each column of percentages also includes the standard deviation. The percentage given is the percentage the weight of the grains in the stated size class as a percentage of the total sample, including gravel and rocks, so the < 4 mm size class includes everything smaller and is a subset of the <5 mm size class.

Size Class	Post-extraction*	After-rains	Statistical Significance
< $^{1}/_{8}$ mm	0.965 ± 0.563	1.01± 0.65	.78
< ¼ mm	4.03 ± 4.33	3.01 ± 1.61	.37
< ½ mm	12.58 ± 7.48	12.3 ± 6.61	.88
< 1 mm	25.16 ± 13.6	23.5 ± 10.2	.53
< 2 mm	33.7 ±13.6	31.3 ± 10.5	.35
< 4 mm	42.5 ± 14.0	40.0 ± 11.4	.26
< 5 mm	44.0 ± 14.1	41.9 ± 12.7	.29

Table 5. Comparison the percentages of fine particle size on gravel bar surfaces (0-5 cm) post-extraction and after-inundation in 2007 and 2008, lower Mad River, Humboldt County, California. This table considers the significance of the difference between post-extraction and after- inundation samples using the post-extraction ’07 data. There is no statistical difference between the post-extraction and after-rains samples. There were 24 sample pairs for the t-test (n=24). Each column of percentages also includes the standard deviation. The percentage given is the percentage the weight of the grains in the stated size class as a percentage of the total sample, including gravel and rocks, so the < 4 mm size class includes everything smaller and is a subset of the <5 mm size class.

Size Class	Post-extraction	After-inundation	Statistical Significance
< $^1/_8$ mm	1.06 ± 0.60	1.76 ± 3.60	.38
< ¼ mm	3.53 ± 3.57	4.42 ± 8.49	.64
< ½ mm	10.1 ± 5.89	11.5 ± 9.37	.49
< 1 mm	19.4 ± 10.8	19.3 ± 10.1	.95
< 2 mm	27.3 ±11.4	27.0 ± 10.7	.91
< 4 mm	35.8 ± 12.0	35.3 ± 11.6	.76
< 5 mm	35.8 ± 12.0	34.7 ± 11.5	.53

Table 6. Comparison the percentages of fine particle size on gravel bar surfaces (0-5 cm) pre-extraction and after-rain in 2007 and 2008, lower Mad River, Humboldt County, California. This table considers the significance of the difference between pre-extraction and after-rains samples using the post-extraction '07 data. There is no statistical difference between the post-extraction and after-rains samples. There were 15 sample pairs for the t-test (n=15). Each column of percentages also includes the standard deviation. The percentage given is the percentage the weight of the grains in the stated size class as a percentage of the total sample, including gravel and rocks, so the < 4 mm size class includes everything smaller and is a subset of the <5 mm size class.

Size Class	Pre-extraction	After-rains	Statistical Significance
< $^1/_8$ mm	1.60 ± 1.65	1.01 ± 0.65	.23
< ¼ mm	4.74 ± 3.78	3.01 ± 1.61	.14
< ½ mm	16.6 ± 12.8	12.4 ± 6.66	.26
< 1 mm	24.2 ± 19.0	23.5 ± 10.3	.89
< 2 mm	28.9 ±18.7	31.3 ± 10.5	.61
< 4 mm	36.5 ± 18.2	40.0 ± 11.4	.44
< 5 mm	38.2 ± 18.0	41.9 ± 12.7	.35

Table 7. Comparison the percentage of fine particle size on gravel bar surfaces (0-5 cm) after rains and after inundation in 2007 and 2008, lower Mad River, Humboldt County, California. This table considers the significance of the difference between after-rains and after-inundation samples using the post-extraction '07 data. There is no statistical difference between the post-extraction and after-rains samples. There were 14 sample pairs for the t-test (n=14). Each column of percentages also includes the standard deviation. The percentage given is the percentage the weight of the grains in the stated size class as a percentage of the total sample, including gravel and rocks, so the < 4 mm size class includes everything smaller and is a subset of the <5 mm size class.

Size Class	After-rains	After-inundation	Statistical Significance
< $^{1}/_{8}$ mm	1.03 ± .667	2.24 ± 4.58	.34
< ¼ mm	3.00 ± 1.67	5.66 ± 10.8	.37
< ½ mm	12.1 ± 6.78	14.1 ± 11.2	.28
< 1 mm	22.2 ± 9.26	23.5 ± 10.6	.57
< 2 mm	30.1 ± 9.77	32.1 ± 10.2	.34
< 4 mm	39.0 ± 11.1	40.8 ± 11.1	.38
< 5 mm	40.3 ± 11.5	42.5 ± 11.3	.31

Table 8. Relative significance (p-values) in several comparisons in gravel bar surfaces fines in 2007 and 2008, lower Mad River, Humboldt County, California. The first column is the statistical significance of the difference between means, when using the Emmerson'07 post-extraction data and '08 data from the other gravel bars; the second column is the statistical significance of the difference when using the '08 post-extraction data from all gravel bars. The **bold** values indicate the statistical significance is at the 5% or better level.

	Pre-extraction vs post-extraction '07 †	'08	Post-extraction vs after-rains	Post-extraction vs after-inundation	Pre-extraction vs after-rains	Pre-extraction vs after-inundation	After-rains vs after-inundation
< ⅛ mm	**.046**	.053	.78	.38	.23	.91	.34
< ¼ mm	.41	.60	.37	.64	.14	.96	.37
< ½ mm	.15	.23	.88	.49	.26	.83	.28
< 1 mm	.78	.53	.53	.95	.89	.23	.57
< 2 mm	.10	.075	.35	.91	.61	**.020**	.34
< 4mm	**.016**	**.0062**	.26	.76	.44	**.0065**	.38
< 5 mm	**.014**	**.0046**	.29	.53	.35	**.0037**	.31

Subsurface Samples (5-10 cm depth)

The results of comparisons in the subsurface samples were different from surface comparisons. Data indicated the post-extraction subsurface (5-10cm) samples contained slightly, but significantly, more coarse sands than in the after-rain subsurface samples. In addition, post-extraction subsurface samples contained slightly, but significantly, more coarse sands than the after inundation samples. The differences were more pronounced in coarser size classes. Figure 10 documents the average percentage of fines of each size class in the subsurface samples. The average sample weight of the size class in Figure 10 may vary from the average provided in the paired t-test tables, which only use paired samples for calculating averages.

Among subsurface samples the difference between the post-extraction vs. after-rains samples was small but statistically significant. Post-extraction samples contained 3.3 % more grains less than 4 mm ($p = 0.038$) and 3.4% more particles less than 5 mm particles ($p = 0.039$) than the after-rains samples (Table 9). Distinguishing between 40% and 43% would be difficult or unlikely for most people. Normality assumptions were met. The percentage fines for the post-extraction samples in Figure 10 are not the same as shown in Table 9, which only used the data for which there are pairs while Figure 10 used the entire subsurface dataset.

Similarly, there were more particles, in two size classes, in the post extraction subsurface samples than in the after inundation samples. Paired t-test with two-tailed distribution showed post-extraction samples contained 2.2% more grains less than 4mm

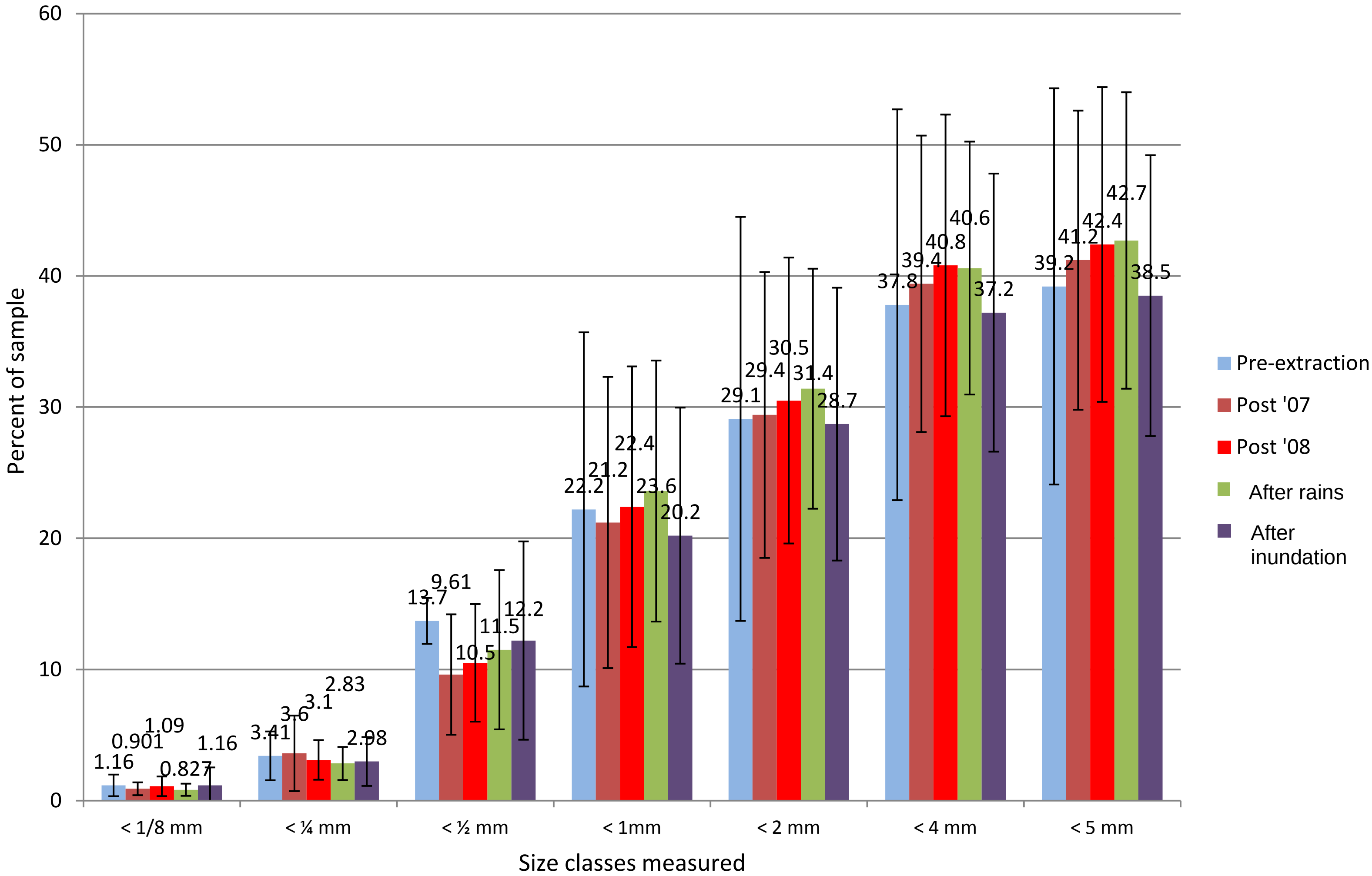

Figure 10. Cumulative percentage of fines in each size class in subsurface samples from 2007 and 2008 gravel bars in the Lower Mad River, Humboldt County, California. The vertical bars depict the standard deviation for each percent. All values have three significant figures, but final zeros have been dropped by the simple graphing software.

Table 9. Comparison of fine particle size in sub-surface samples (5-10 cm) post-extraction and after rain in 2007 and 2008 gravel bars in lower Mad River, Humboldt County, California. This table considers the significance of the difference between after-rains and post-extraction samples. All the paired t-tests between post-extraction and after-rains samples used the Emmerson data collected in 2007, because the Emmerson data does not include after-rains data for ’08 and the ’08 sample locations were a different part of the gravel bar. The bold numerals indicate the test is statistically significant to at least the 5% probability level. There were 15 sample pairs for the t-test (n=15). Each column of percentages also includes the standard deviation. The percentage given is the percentage the weight of the grains in the stated size class as a percentage of the total sample, including gravel and rocks, so the < 4 mm size class includes everything smaller and is a subset of the <5 mm size class. Normality assumptions were met, except for the < ¼ mm samples.

Size Class	Post-extraction (%)	After-rains (%)	Statistical Significance
< ⅛ mm	0.81 ± .52	0.8 ± .5	.89
< ¼ mm	4.3 ± 3.5	2.8 ± 1.3	.14
< ½ mm	10.5 ± 5.5	11.5 ± 6.1	.38
< 1 mm	24. ± 13.	24. ± 10.	.94
< 2 mm	33. ± 12.	31. ± 9.	.29
< 4 mm	44. ± 12.	41. ± 10.	**0.038**
< 5 mm	46. ± 12.	43. ± 11.	**0.039**

contained 2.2 % more grains less than 4 mm (p = .044), and 2.7% more grains less than 5 mm (p = 0.22) than the after-inundation samples (Table 10). This is a 2-3% difference in samples with 40% fines.

The contrast between pre-extraction and post-extraction samples includes a single significant value. There were 4.1 % more fines in the medium and fine sands less than ½ mm in the pre-extraction samples (p = 0.17) than in the post-extraction samples (Table 11). The software's test of assumptions rejected normality.

Significant differences were not observed between pre-extraction subsurface particle sizes (5-10 cm) and sizes measured after extraction, inundation, and rainfall (Table 12, Table 13, Table 14, and Table 15, respectively).

Stained Particles

I placed stained sands on the Johnson-Spini gravel bar on September 22, 2007, and observed the stained sands during the rain between 8:30-9:30 am on September 28, 2007. These were the first rains that occurred after placement. I saw no overland flow or lateral displacement of stained sands. Figure 11 shows that the sand and gravel was wetted and settled enough that larger pebbles under the stained sands were exposed.

On October 7, 2007, three stained sand samples were placed on the Emmerson gravel bar, but were later obliterated by Granite Construction's site grooming associated with removal of temporary summer bridges. It rained 2.7 cm on October 9, and small amounts daily until October 19, when it rained 6.8 cm. The river flow was low 1.8 – 2.8 m^3/s from October 7 until the October 15, then rose to 4.3 – 4.6 m^3/s for three days, and

Table 10. Comparison of the percentage of fine particle sizes in sub-surface samples (5-10 cm) post-extraction and after inundation in 2007 and 2008 gravel bars in lower Mad River, Humboldt County, California. This table considers the significance of the difference between post-extraction and after-inundation samples using the post-extraction ’07 data. The bold numbers indicates that the difference is significant at the 5 % level of significance. There were 25 sample pairs for the paired t-test (n=25). Each column of percentages also includes the standard deviation. The percentage given is the percentage the weight of the grains in the stated size class as a percentage of the total sample, including gravel and rocks, so the < 4 mm size class includes everything smaller and is a subset of the <5 mm size class. Tests for normality found that the all the comparisons between post-extraction and after-rains did not satisfy the assumptions of normality; however, there does not seem to a reason for a correlation.

Size Class	Post-extraction* (%)	After-inundation (%)	Statistical Significance
< $^1/_8$ mm	0.90 ± 0.49	1.16 ± 1.37	.38
< ¼ mm	3.6 ± 2.9	2.9 ± 1.9	.36
< ½ mm	9.6 ± 4.6	12.2 ± 7.6	.085
< 1 mm	21.2 ± 11.3	20.5 ± 9.9	.58
< 2 mm	29.1 ± 15.4	28.7 ± 10.4	.87
< 4 mm	39.4 ± 11.3	37.2 ± 10.6	**.044**
< 5 mm	41.2 ± 11.4	38.5 ± 10.7	**.022**

Table 11. Significance between pre- and post-extraction fines in subsurface (5-10 cm) samples from 2007 and 2008 lower Mad River, Humboldt County, California. All the pre-extraction samples were collected in the 2008 season. This table considers the significance of the difference between pre-extraction and post-extraction samples using the post-extraction ’07 data. The bold numbers are the probabilities that the difference exceeds the 5 % level of significance. There were 25 sample pairs for the paired t-test (n=25). Each column of percentages also includes the standard deviation. The percentage given is the percentage the weight of the grains in the stated size class as a percentage of the total sample, including gravel and rocks, so the < 4 mm size class includes everything smaller and is a subset of the <5 mm size class. The statistical software found that the comparisons for < ¼ mm w/ Emmerson 2008, <1 mm (both), and <5 mm w/ Emmerson 2008 data satisfied the assumptions of normality. The one comparison with an apparent significant difference did not satisfy the tests for normality.

Size Class	Pre-extraction* (%)	Post-extraction ’07 (%)	Statistical Significance of pre-vs. post-extraction 2007	Post-extraction ’08 (%)	Statistical Significance of pre- vs. post-extraction 2008
< $^1/_8$ mm	1.2 ± 0.8	0.9 ± 0.5	.23	1.1 ± .7	.68
< ¼ mm	3.4 ± 1.9	3.6 ± 2.9	.78	3.1 ± 1.5	.43
< ½ mm	13.7 ± 8.8	9.6 ± 4.6	**.017**	10.5 ± 4.5	.055
< 1 mm	22.2 ± 13.5	21.2 ± 11.1	.59	22.4 ± 10.7	.91
< 2 mm	29.1 ± 15.4	29.4 ± 10.9	.88	30.5 ± 10.9	.49
< 4 mm	37.8 ± 14.8	39.4 ± 11.3	.39	40.8 ± 11.5	.16
< 5 mm	39.2 ± 15.1	41.2 ± 11.4	.28	42.4 ± 12.0	.15

Table 12. Comparison of fine particle size in subsurface samples (5-10 cm) pre-extraction and after rain from gravel bars in 2007 and 2008 lower Mad River, Humboldt County, California. This table considers the significance of the difference between pre-extraction and after-rains samples using the post-extraction ’07 data for the Emmerson Gravel Bar. There were no significant differences between pre-extraction and after-rains samples. There were 15 sample pairs for the paired t-test (n=15). Each column of percentages also includes the standard deviation. The percentage given is the percentage the weight of the grains in the stated size class as a percentage of the total sample, including gravel and rocks, so the < 4 mm size class includes everything smaller and is a subset of the <5 mm size class. The statistical software found only the < ¼ mm, < 1 mm, and <5 mm comparisons satisfied the tests for normality.

Size Class	Pre-extraction (%)	After-rains (%)	Statistical Significance
< $^{1}/_{8}$ mm	0.97 ± 0.82	0.83 ± 0.47	.57
< ¼ mm	3.12 ± 1.97	2.83 ± 1.27	.67
< ½ mm	13.0 ± 5.41	11.5 ± 6.07	.39
< 1 mm	24.9 ± 16.2	23.6 ± 9.95	.71
< 2 mm	32.4 ± 18.4	31.4 ± 9.16	.79
< 4 mm	41.5 ± 17.4	40.6 ± 9.64	.80
< 5 mm	43.1 ±17.4	42.7 ±11.3	.89

Table 13. Comparison of fine particle size in sub-surfaces samples (5-10 cm) pre-extraction and after inundation from gravel bars in 2007 and 2008 lower Mad River, Humboldt County, California. This table considers the significance of the difference between pre-extraction and after inundation samples using the post-extraction ’07 data. The bold numbers are the probabilities that the difference exceeds the 5 % level of significance. There were 25 sample pairs for the paired t-test (n=25). Each column of percentages also includes the standard deviation. The percentage given is the percentage the weight of the grains in the stated size class as a percentage of the total sample, including gravel and rocks, so the < 4 mm size class includes everything smaller and is a subset of the <5 mm size class. The statistical software found only the <1/4 mm comparison satisfied the tests for normality.

Size Class	Pre-extraction (%)	After inundation (%)	Statistical Significance
< $^{1}/_{8}$ mm	1.16± .83	1.16±1.37	.99
< ¼ mm	3.41±1.86	2.91±1.86	.33
< ½ mm	13.7±8.77	12.2±7.56	.49
< 1 mm	22.2±13.5	20.2±9.76	.34
< 2 mm	29.1±15.4	28.7±10.4	.87
< 4 mm	37.8±14.9	37.2±10.6	.78
< 5 mm	39.2±15.1	38.5±10.7	.75

Table 14. Comparison of fine particle size in sub-surfaces samples (5-10 cm) after-rains and after inundation in 2007 and 2008, lower Mad River, Humboldt County, California. This table considers the significance of the difference between after-rains and after-inundation samples using the post-extraction ’07 data. The bold numbers are the probabilities that the difference exceeds the 5 % level of significance. There were 15 sample pairs for the paired t-test (n=15). Each column of percentages also includes the standard deviation. The percentage given is the percentage the weight of the grains in the stated size class as a percentage of the total sample, including gravel and rocks, so the < 4 mm size class includes everything smaller and is a subset of the <5 mm size class. The statistical software found all comparisons satisfied the assumptions of normality.

Size Class	After-rains (%)	After-inundation (%)	Statistical Significance
< $^{1}/_{8}$ mm	0.83 ± .47	0.79 ± .73	.88
< ¼ mm	2.83 ± 1.27	2.94 ± 1.52	.79
< ½ mm	11.5 ± 6.07	12.8 ± 6.32	.37
< 1 mm	23.6 ± 9.95	23.5 ± 10.9	.94
< 2 mm	31.4 ± 9.16	32.7 ± 11.1	.53
< 4 mm	40.6 ± 9.64	41.5 ± 11.3	.64
< 5 mm	42.7 ± 11.3	42.9 ± 11.3	.90

Table 15. Significance (p-value) in several comparisons in subsurface samples (5-10 cm) in 2007 and 2008, lower Mad River, Humboldt County, California. The first column is the statistical significance of the difference between means, when using the Emmerson'07 post-extraction data and '08 data from the other gravel bars; the second column is the statistical significance of the difference when using the '08 post-extraction data from all gravel bars. Bold numerals indicate that the comparison is significant at the 5% level or better.

	Pre-extraction vs. post-extraction '07	Pre-extraction vs. post-extraction '08	Post- vs. after-rains	Post- vs. after-inundation	Pre- vs. after-rains	Pre- vs. after-inundation	After-rains vs. after-inundation
< 1/8 mm	.23	.68	.88	.38	.57	.99	.88
< ¼ mm	.78	.43	.14	.36	.67	.34	.78
< ½ mm	**.0017**	.055	.37	.085	.39	.49	.37
< 1 mm	.59	.91	.94	.57	.71	.34	.94
< 2 mm	.88	.49	.29	.29	.80	.87	.53
< 4mm	.39	.16	**.038**	**.044**	.80	.78	.64
< 5 mm	.28	.15	**.039**	**.022**	.89	.75	.90

Figure 11. Stained sands during the rains on Johnson Spini gravel bar, lower Mad River, Humboldt County, California, on September 28, 2007.

increased to 70 m^3/s on October 19th, dropped to 57 m^3/s the next day, and then tapered to 7.8 m^3/s by October 24, 2007. Sample pits for pre-extraction, post-extraction, and after-rains samples had been undisturbed by Granite Construction. On October 24, I returned to collect after inundation samples and noted that the sample pits were filled with sands, though the painted rocks delineating the sample pit (see Figure 9) had not been appreciably relocated.

Stained sands were placed and photographed at the Guynup Bar on September 7, 2008, Emmerson Bar on September 28, 2008, Johnson-Spini bar on October 18, and O'Neill bar on October 13, 2008, (Figure 12). The yellow sands can be seen behind the right elbow of my assistant, Hopi Reid, and under the yellow arrow. The orange sand is to her right, under the orange arrow, and behind the plastic bags. The green sand is about half a meter farther to the right under the green arrow. The colors do not look like fluorescent colors because the inherent colors of granules are not completely masked by the paint and the granules are dusted by unstained particles; they do, however, fluoresce under ultraviolet light.

Throughout the month of September 2008, there were eight days with approximately 0.03 cm of rain, two days with 0.05 cm and one day with 0.15 cm of rain for a total of 0.46 cm. On October 2, there was 0.97 cm rain, followed by 0.43 cm on October 3 and 0.20 cm on October 4. The remainder of the month had no rain or 0.03 cm daily, until October 31, which had 0.13 cm. For October, there was a total of 2.08 cm.

Figure 12. Placement of stained sands at gravel extraction edge with assistant in 2008, lower Mad River, Humboldt County, California.

During the 2008 rainy season, stained particles settled, revealing some unstained gravel beneath the fines. However, no lateral displacement was observed. I examined each of the seeded fines samples on each of the gravel bars during rains and as many seeded sites as possible when the river overtopped the gravel bar. On November 25, 2008, I recovered the sample placed at the edge of the Johnson-Spini Bar on October 18. As seen in Figure 13, the sands that had been rained on, in the top of the picture, settled and revealed some of the larger particles underneath. The green and orange sands that are lower in the picture were placed on November 25, for comparison purposes only. The rained-on stained particles apparently dispersed around the edges and the sample seems to be coarser than the freshly placed samples lower in the picture.

I attempted to observe the stained fines as the river inundated the gravel bar. However, the water was generally too turbid to see the colored sands or the river was unsafe to cross.

Sediment Plumes

While collecting samples and observing the stained sands, I also looked at the river to observe sediment plumes. Between 8:30-9:30 am on September 28, 2007, I observed Johnson-Spini gravel bar in the rain/drizzle. I saw no overland flow or sediment plumes from the extraction surface or from the access road. The sediment plume at Christie Bar was in the trench near Noisy Creek and adjacent to the haul road, which indicates that sediment plumes may be generated from a combination of saturated gravels and localized disturbance such as driving on the gravels near the open water.

Figure 13. Stained sands after-rains with un-wetted and unsettled samples below. The stained sands were placed in 2008 on the gravel bar the lower Mad River, Humboldt County, California.

Sources of Error

Collecting a 5-cm sediment sample from a gravel bar with natural stones is inherently an imprecise process. One pushes a steel ring into the substrate five centimeters deep and collects all the sediment within the ring; however, neither the top nor the bottom of the sample are flat. At the top of the sample are cobbles with spaces in between, so that the determination of the 'top' is rather subjective. The bottom also has stones, that are in both the surface sample and the subsurface sample. The investigator exercises judgment to determine whether each stone is primarily in the surface sample or subsurface sample.

I tried to limit that variability by marking the collection buckets at 14.7 liters so that the bottom in the bucket is flat and the top of the sample is smaller and flatter than the *in situ* condition. It is likely that the collected sample in the bucket is less well packed than the sand and cobbles that were deposited by running water. Although the sediment initially settled on the gravel bar in the presence of water and kinetic disturbance, which are the necessary components of liquefaction, the sediments were generally collected in a dry situation.

The process of sieving fines seems uncertain. Though the mechanical RoTap device does not become tired or express new patterns of effort based on perceived efficiencies, five minutes in the RoTap device may not be sufficient to separate all material that was smaller than ⅛ mm through the entire stack to the bottom pan. However, 5 minutes is likely ample time to break larger soft material into smaller particles. Occasionally, the sieve that separates the material that is smaller than ¼ mm but larger than ⅛ mm would be filled. I doubt that it effectively removed all the material less than ⅛ mm. Retrospectively, it's apparent that the error could have been lessened by separating the 4.5 kg split into 5 Ro-Tap runs that would be sieved instead of the 2 Ro-Tap runs that I usually used for this study.

The process discussed here may be a source of error since it may distort the ratio of fines to larger particles by reducing particle sizes. The particles greater than 5 cm often have sands and finer particles imbedded in cracks and other surficial imperfections. I brushed them off with a stiff plastic-bristled scrub brush. I spent no more than a minute brushing material from a fist-sized cobble. Some stones would fracture along multiple planes into plate-like pieces in the process of drying in the sun; such a stone may be intact before or after extraction, but much smaller before the next sampling. Some have deep clefts that are packed with smaller grains. And some have recognizable crystalline strata. All of these cobbles will function as a single homogenous, if brittle, particle when dry. One expects that much of the sand and mud would continue to adhere to the cobble when it gets wet and tumbled in bedload. Other cobbles are composed of softer, brittle, but essentially homogenous material, such as siltstone and shale. At what point is brush, shaking and even tapping the cobbles justified, and at what point is the 'cleaning' process actually breaking down the particles into finer grains? Further, the sieving process repeats separation, and dislodges smaller grains from larger particles. It may also degrade softer material. It seems an arbitrary decision, but I hope that I at least made it a consistent practice. I may have made more effort to brush dried mud from stones, but at no time did I use metal, wood or other hard picks to pry individual particles off or out of the cobbles and stones.

Clay spheres observed when sieving the fines were generally kept within the size class of the sieve. I reasoned that if they retained enough structural strength to withstand the five minutes of sieving and colliding with gravel, then they would likely retain that strength through the first rains and brief inundation. That may have been an error.

DISCUSSION

This study intended to determine the meaning behind the numerical values of the various sand size classes in results. The following paragraphs further consider the implication of the sand samples, gravel density, and sediment plumes. Within the topic of sand samples, I consider the difference between surficial and subsurface samples, regulatory implications, the effect of rainfall on surface particle sizes, and pre-extraction versus after-inundation surfaces.

There is a curious lack of correlation between surficial effects and subsurface effects. The post-extraction surficial samples contained significantly more fines than pre-extraction samples. However, subsurface post-extraction samples were not statistically distinct from the pre-extraction samples. The after-inundation gravel bar surface contained significantly more fines than the pre-extraction gravel bar surface, but there was no observed effect of inundation on the subsurface samples. Although there was a difference between subsurface post-extraction samples versus after-inundation samples, it’s reasonable to imagine that the shift had actually occurred between the extraction and the rain event, and some of that difference remained after inundation. Indeed, post-extraction samples contained 3.4 % more sediments that were less than 5 mm than the after-rains samples, while the post-extraction samples contained only 2.7 % more than the after-inundation samples. Generally there was no correlation between differences in surface samples and differences in subsurface samples. I expected that the differences between surface comparisons and subsurface comparisons would indicate the direction of sand movement. However, surface comparisons that had significant differences did not correspond to subsurface comparison with significant differences. For example post-extraction samples versus after rains samples was not significantly different for surface samples, but was for subsurface samples. Almost all the differences are in the surface layer. It seems that the differences indicated are the result of surficial effects: the greater proportion of fines on the post-extraction surface are the result of the extraction process and the greater proportion of after-inundation fines indicates the overflowing water delivered sands onto the extraction surface.

A sensitivity test would improve the reliability of these findings. For instance, if the transitional cobbles that were classified as surface rocks were instead considered part of the subsurface sample, the proportion of fines in the subsurface would decrease. If the differences between the pre- vs. post-extraction samples remained significant, we would find the results more robust. Likewise sensitivity tests for post-extraction vs. after-rains and post-extraction vs. after-inundation samples could better improve the robustness of the findings.

Within surficial comparisons, the process of extracting gravel increased the amount of fines on the surface of the bars in the less than 4mm and less than 5mm size categories by a 7.7 % and 7.9%., respectively. Rempel and Church (2003) also found that skimming gravel immediately raised the percentage of sand from 11% pre-extraction to 32% after extraction on the Harrison Bar on the Fraser River, British Columbia.

Because NMFS has asserted, and many researchers have documented that gravel extraction generates more fines, it's surprising to find that the pre-extraction bar has more of the finest size class (less than ⅛ mm), which I call dust, than the post-extraction bar. The excess fines in the pre-extraction site should not be an artifact of the silt band which forms on the edge of the gravel bar when flows are receding. This is because the silt band typically forms at the elevation of the 25-26 m^3 flow, approximately the elevation of the skim surface. Obviously, the pre-extraction surface is higher than the skim surface. Further study is needed to determine the source of the excess fines less than ⅛ mm.

The after-inundation samples contained significantly greater proportions of coarse sands within the less than 2 mm, less than 4 mm, and less than 5 mm size classes in the after-inundation samples than in the pre-extraction samples at the surface (Table 4). The level of significance increased with progressively larger size classes. After-inundation samples were not statistically different from other samples, except for pre-extraction samples. However, Rempel and Church (2003) found flows overtopping the bar considerably reduced the amount of sands. Perhaps Rempel and Church's post-inundation samples were collected after flushing flows rather than freshets.

The composition of sediments in gravel bars is unique to the location and river, even within the alluvial reach of the rivers. The pre-extraction surface samples in my study varied from 31 to 32.3% for less than 4 and less than 5 mm size classes. However, Pitlick et al. (2008) studied many rivers in Idaho and Colorado and found that fines on those rivers varied considerably, but were consistently less than 5% of these size classes in the surface samples of their rivers.

Within the subsurface, post-extraction samples contained significantly more fines than the after-rains or after-inundation subsurface samples in both the less than 4 mm and less than 5 mm size classes. The process by which the extraction process could generate more fine gravel in the substrate 5-10 cm below the extraction floor is not readily apparent. The differences may be flukes erroneously identified as real differences (type 1 errors). One possible explanation is that the subsurface proportion of fines is independent of extraction and that another phenomenon such as rain, inundation, or liquefaction may have removed coarse sands from the subsurface and left the coarse sands on the surface unaffected. Contrariwise, I would expect that a mechanism that mobilized the fine gravels would also mobilize the coarse and fine sands. Another possible explanation may be that a post-extraction gravel bar is drier and more disturbed, resulting in less clumping of fines to larger sized particles. That is, dry mud that is knocked from a larger particle remains separate, whereas a moist clay or silt clump may remain attached or may re-attach to another particle after being disturbed. The pre-extraction surface was also dried and disturbed but the pre-extraction subsurface area was obviously deeper and may have been moister. However, several of the gravel bars exhibited compacted layers in the post-extraction samples. Perhaps the compacted layers contribute to the identified anomaly. The compacted layer is probably caused by the consistent extraction to a specific elevation, which necessarily includes the operation of heavy equipment over precisely the same substrate. The process may also grind softer particles into smaller particles, resulting in the production of excess fines at that specific elevation.

The lack of a correlation between surficial comparisons and subsurface comparisons is provocative. One would expect that the rains would wash some of the fines from the surface to the subsurface or to wash fines from both to deeper levels. The only comparison which indicates a significant difference in surficial and subsurface tests is pre-extraction vs. post-extraction comparison. However, the differences are apparent in different size classes. Although the differences between pre-extraction vs. post-extraction samples were significant in the surface samples for less than ⅛ mm, less than 2mm, less than 4 mm, and less than 5mm size classes, the only clear difference in the subsurface samples was between the less than ½ mm size classes, which, like the less than ⅛ mm, was more prevalent in the pre-extraction samples than post-extraction. The difference in results for surface and subsurface tests suggests that the differences observed for the surface tests are due to the surficial treatments.

It is reasonable that results of the pre-extraction versus post-extraction for the subsurface samples is a Type 1 error, or a false positive. Since the level of significance is 0.05, there is a 1 in 20 chance that there could be a false positive for any one test. And since there are 98 tests, a few false positives would be likely. It seems unlikely that the false positives would be in both pre- versus post-extraction and pre-extraction versus after inundation because both have a couple significant results in adjacent size classes.

And because both comparisons have progressively greater levels of significance, I am confident about them.

As mentioned previously, the alluvial reaches of rivers are quite variable. In the granitic gravel bars in their study, Pitlick et al. (2008) found that sediment in the subsurface samples contained about 18-30% fines less than 4 or 5 mm. As shown in Table 10, the sand fraction less than 5 mm varies from 39 to nearly 43% in my subsurface samples. Pitlick et al. (2008) also found a fundamental difference between the amount of fines in surface and subsurface samples. They observed consistently less than 5% coarse sands in the surface samples and 18-30% in the subsurface samples.

The amount of fines in the sediment has important regulatory implications. This study has confirmed that gravel extraction increases the amount of fines on extraction surfaces in the Mad River. However the increase was only 6-8%, and mostly in coarse fines. Cederholm et al. (1980) indicated that coarse fines were less problematic for invertebrates and spawning gravels. As currently performed, skimming does not appreciably contribute to suspended sediment in the Mad River during the first rains and first pulses of stream flow (freshets) in the late autumn and early winter. Instead, the first freshets deposit sands on the extraction surface, temporarily and locally reducing the suspended sediment. Occasionally, regulatory staff suggests leaving a berm around the upstream portion of an extraction to postpone the time when rising water flows over the extraction surface. Implementation of this suggestion may miss an opportunity to improve water quality. Further studies should be performed to clarify at what flows a skim floor is a beneficial feature that sequesters sand. If the skim floor elevation could be lowered to further improve water quality, it would benefit the industry and habitat as less acreage of gravel bar would be disturbed to extract the specified limit.

Rempel and Church (2003) found that the pre-extraction roughness and armor are re-established within two years of extraction, even with lower than normal flows. Since gravel companies on the Mad River prefer to extract every year, the two-year lag becomes a recurring effect.

The sediment analyses conducted here indicate that Mad River gravel bars do not meet targets set by the EPA's target substrate composition of percentage fines, which are based on North Coast Regional Water Quality Control Board (2006). For particles less than 0.85 mm, the target is less than 14%, which is intended to be an appropriate proportion of fines in the river bed (United States Environmental Protection Agency 2007). The report also states that particles less than 0.85 mm should be less than 14% of the substrate to facilitate incubation and fry emergence from the redds. Particles less than 6.5 mm should be less than 30% (United States Environmental Protection Agency 2007) of the substrate so that salmonids can construct the redds. While my data did not include those precise size classes, the data (Figure 10) indicated that approximately 40% of the subsurface substrate was less than 5mm, which is well above the (6.5 mm) target though it is a smaller size class. The surface samples varied from 32 to 42% (Figure 10), which is better but still unacceptable. The closest to EPA's less than 0.85 mm size class would be our less than 1 mm, which varies around 20-25%. Extrapolating between our less than

1 mm and our less than ½ mm, a value for 0.85 mm would be between 15-20% of the substrate, which is close to the 14% target. If skims are effective at removing coarse sands from flowing water, as seems to be the case, the activity would improve water quality over the short duration, while storing the fines where the agencies will be testing for them.

The qualitative observations of rainfall on stained particles on the extraction surfaces indicated that rains caused finer particles to settle into the extraction surface. The results indicate that the percentage of fines on the surface samples (0-5 mm) did not change as a result of rainfall events of this size and intensity. This suggests that the fines might not be washed or settled beyond the (arbitrary) 5-cm boundary of the surface layer used in this study. This would also suggest the post-extraction surface was not a source of fines to the river from rain events observed in this study. It is possible a more intense rainfall could have resulted in fines washed into the river from rainfall.

Future research should use more controlled conditions to determine the type of rainfall that effectively causes fines to settle. Tubes of uniformly mixed stained fines and gravels could be exposed to a variety of simulated precipitation events. The sample could be dried, and several thin sections through the horizontal planes of the column could be compared. Such a study could be conveniently conducted on a regular schedule instead of being subjected to the variances of the river and weather.

My results indicate that the percentage of fines in the gravel bar surfaces after inundation has significantly *more* fines than the pre-extraction surface in the less than

2mm, less than 4 mm, and less than 5mm size classes, which would not support the assertion that the gravel extraction produces a surface that releases more fines into the freshets of autumn. The premise that extraction surfaces could be sinks for suspended sediment is reinforced, at least in the less than 2 mm, less than 4 mm, and less than 5 mm size classes. This makes intuitive sense since the finest particles are more likely to be transported downstream and the coarser grains are more likely to settle (Table 1).

The amount and composition of fines deposited on the gravel bar could more readily have been studied by placing several sheets of fabric on the gravel bar in different locations and elevations prior to the freshets. The sheet could be placed on the gravel bar and sprayed with water so that it clings to the underlying cobbles, and closely simulates the natural bar roughness, and the edges of the sheets could be buried or anchored by local rocks to prevent them from washing away in a freshet. Many samples could be collected in a short amount of time, and no pre-extraction, post-extraction or after-rains samples would have to be collected for comparison.

Although it was not a stated objective of the study to identify the gravel density at these study sites, the data were collected and were readily calculated. I calculated the density by dividing the weights of the samples by the volumes (14.9 L) and converting to metric tons and cubic meters. Based on 181 samples of gravel collected from the gravel bars, the density of gravel on the Mad River gravel bars was 1.87 metric tons per m^3 with a standard deviation of 0.227. The density of surficial samples was 1.90 metric tons per m^3 and the subsurface samples was 1.84 metric tons per m^3. My estimate is somewhat smaller than the 1.92 tons per m^3 reported by SI metric in the United Kingdom (Walker 2009). This may be entirely explained by differences in source materials. Dunne et al. (1980) found the density of the bedload was 2.06 metric tons/ m^3 in the lower Snohomish River basin near the village of Snohomish, Washington. Brown (1975) assumed a density of slightly less than 1.7 metric tons per m^3 (1.4 tons per cubic yard) when he estimated the density of bedload transport in the Mad River at Highway 299.

While sediment plumes are frequently seen at gravel bars (Tauzer and Free 2010) they are not reliably present during rain events. My half-dozen observations seem to indicate that the sediment plumes are more likely observed if the gravel bar has vehicular traffic on the extraction bar near the water's edge within the few days before the storm or during the event. The general lack of a visible sediment plumes and the lack of a statistical difference between post-extraction versus after-inundation samples or between after-rain and after-inundation samples is consistent with the recent conservation recommendations from NMFS Northwest Region which states that plumes from bar surfaces are likely to last the duration of the first storm or two, but do not measurably exceed upstream control samples on the Chetco River (National Marine Fisheries Service 2011).

There are a few observations that are also noteworthy although they were not part of the study design. First, while excavating post-extraction samples, I frequently found a hard pan, or a layer of compacted aggregate, especially when sampling after-rains or post-extraction samples. On October 18, 2008, I found a hard pan at Johnson-Spini Bar essentially at the extraction surface. There was a light covering of sand over the bar, but otherwise the bar was thoroughly compacted and had to be chiseled with a railroad spike to loosen it up. J3S08, J4S08, and J5S08 were all quite compacted.

Another curious observation is a nuance of statistics. Frequently the two-tailed, paired t-test, which is used to determine whether the mean of A is the same as the mean of category B, found that samples were not statistically different, but the single-tailed, paired, t-test found that the mean of A was larger than B. The single-tailed test is used to determine if A is greater than B. So, the tests and results depend on the hypothesis. The single-tailed test for less than 2 mm fines also found significantly more fines in post-extraction compared to the pre-extraction sample. Subsequent research in this inquiry should consider that that more fines in the post-extraction than in the pre-extraction sample is likely. Also, it seems odd that the difference between pre-extraction and after inundation is significant, but the difference between post-extraction or after-rains is not significant, though the difference is greater. Likewise, the difference between pre-extraction and post-extraction is significant but the difference between pre-extraction and after-rains samples is not significant. It seems that my sample size is right at the cusp where missing a few samples greatly changes the confidence limits.

The pre-extraction samples contained more dust (less than ⅛ mm) than post-extraction samples. This may be a result of the extraction process, which involves heavy equipment driving around the extraction surface. Perhaps during the extraction process the dust is mobilized by vehicular and heavy equipment traffic, then carried away in the wind. Additionally, receding spring flows would be depositing dust and other fine sediments on the gravel bar, though admittedly the dust is most likely to be held in suspension. Perhaps the dust is blown onto the extraction surface in the months between the receding flows (commonly March) and the time of the extraction (typically August or September); supporting this hypothesis would be the detail that nearby farmers are tilling their fields around March.

When I compared the post-extraction versus after-rains samples from the surface layer, the means of the post-extraction samples were not statistically different from the after-rains samples; however, the post-extraction means were uniformly greater than the after-rains' means.

The sequence of the gravel sampling progressed from pre-extraction, post-extraction, after rains, to after inundation. The comparison of pre-extraction versus post-extraction samples confirmed that gravel extraction results in a higher percentage of sand and fine gravel on the extraction surface, as expected. However, the comparison, alone doesn't answer the question about whether the extra fines migrate into the river before the river is opaque with suspended sediment. The comparison of pre-extraction grains to after-inundation grains indicates that more fines settle on the gravel bars during the freshets than during the spring receding flows. This also indicates that the gravel bars are a sink rather than a source for fine gravel and coarse-medium sand during the freshets.

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APPENDIX A: Precipitation history near the Lower Mad River, September –November, 2001-2011.

Date	Sept. Avg.(cm)	Oct. Avg.(cm)	Nov. Avg.(cm)	Sept. 2001(cm)	Oct 2001(cm)	Nov. 2001(cm)	Sept. 2002(cm)
1	0.01	0.09	0.40	0.00	0.00	0.00	0.00
2	0.02	0.16	0.36	0.05	0.00	0.03	0.00
3	0.01	0.13	0.89	0.00	0.03	0.00	0.00
4	0.01	0.11	0.29	0.03	0.03	0.03	0.00
5	0.03	0.02	0.21	0.00	0.00	0.00	0.00
6	0.01	0.01	0.71	0.00	0.00	0.00	0.00
7	0.02	0.01	0.84	0.00	0.00	0.00	0.00
8	0.01	0.24	0.51	0.00	0.00	0.00	0.00
9	0.12	0.30	0.46	0.03	0.00	0.00	0.00
10	0.01	0.06	0.34	0.00	0.05	0.03	0.03
1	0.02	0.08	0.24	0.03	0.23	0.08	0.03
12	0.01	0.02	0.89	0.00	0.00	3.76	0.00
13	0.14	0.29	0.66	0.03	0.00	0.53	0.00
14	0.01	0.46	0.15	0.05	0.00	0.03	0.00
15	0.01	0.27	0.67	0.00	0.00	2.29	0.00
16	0.03	0.12	0.51	0.03	0.00	2.06	0.00
17	0.07	0.30	0.38	0.00	0.00	0.00	0.30
18	0.04	0.17	0.15	0.00	0.00	0.00	0.03
19	0.10	0.99	0.38	0.00	0.00	1.12	0.00
20	0.00	0.06	0.51	0.03	0.00	0.71	0.00
21	0.03	0.01	0.38	0.00	0.03	1.83	0.00
22	0.01	0.41	0.46	0.00	1.35	0.76	0.00
23	0.02	0.20	0.03	0.03	0.00	0.08	0.03
24	0.01	0.02	0.47	0.00	0.00	3.15	0.00
25	0.05	0.59	0.72	0.41	0.00	2.34	0.03
26	0.04	0.08	0.65	0.30	0.03	0.13	0.03
27	0.01	0.06	0.16	0.00	0.05	0.13	0.00
28	0.06	0.15	0.63	0.05	0.05	3.12	0.00
29	0.02	0.11	0.41	0.00	0.56	1.00	0.03
30	0.14	0.48	0.52	0.00	1.96	0.89	0.00
31		0.03			0.08		

Appendix A. Precipitation history near the Lower Mad River, September –November, 2001-2011 (continued).

Date	Oct. 2002(cm)	Nov. 2002(cm)	Sept. 2003(cm)	Oct. 2003(cm)	Nov 2003(cm)	Sept. 2004(cm)	Oct. 2004(cm)
1	0.00	0.00	0.03	0.03	0.00	0.00	0.03
2	0.00	0.00	0.00	0.03	1.30	0.03	0.00
3	0.00	0.00	0.05	0.03	0.00	0.00	0.03
4	0.00	0.00	0.00	0.00	0.66	0.00	0.03
5	0.03	0.00	0.05	0.00	0.00	0.00	0.03
6	0.00	0.00	0.00	0.00	0.86	0.03	0.00
7	0.00	2.79	0.08	0.03	0.86	0.00	0.00
8	0.00	0.20	0.03	0.46	2.00	0.03	1.65
9	0.00	1.07	0.97	0.00	1.32	0.00	0.03
10	0.00	0.51	0.03	0.00	0.00	0.03	0.03
11	0.00	0.00	0.00	0.30	0.00	0.03	0.00
12	0.00	0.64	0.03	0.03	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.03	0.00
14	0.00	0.03	0.00	0.00	0.91	0.00	0.00
15	0.03	0.00	0.00	0.00	1.32	0.00	0.00
16	0.00	0.58	0.03	0.00	0.79	0.00	0.00
17	0.03	0.00	0.00	0.00	0.00	0.20	1.65
18	0.00	0.00	0.00	0.00	0.00	0.33	0.03
19	0.00	0.03	0.00	0.08	0.79	0.69	1.73
20	0.00	0.00	0.00	0.03	0.05	0.00	0.00
21	0.00	0.03	0.00	0.03	0.28	0.03	0.00
22	0.03	0.03	0.00	0.36	0.00	0.00	1.83
23	0.03	0.00	0.00	0.03	0.03	0.03	1.70
24	0.03	0.00	0.03	0.03	0.00	0.03	0.00
25	0.00	0.00	0.00	0.00	0.74	0.00	3.07
26	0.00	0.00	0.03	0.00	0.28	0.00	0.33
27	0.00	0.00	0.03	0.00	0.00	0.03	0.00
28	0.00	0.00	0.03	0.00	0.30	0.08	0.03
29	0.00	0.00	0.00	0.00	2.06	0.05	0.03
30	0.00	0.00	0.03	0.00	0.89	0.00	2.29
31	0			0			0

Appendix A. Precipitation history near the Lower Mad River, September –November, 2001-2011 (continued).

Date	Nov. 2004 (cm)	Sept. 2005(cm)	Oct. 2005cm)	Nov. 2005(cm)	Sept. 2006(cm)	Oct. 2006(cm)	Nov. 2006(cm)
1	0.00	0.03	0.64	0.69	0.00	0.00	0.00
2	1.30	0.00	0.36	0.03	0.03	0.00	0.00
3	0.03	0.00	0.58	3.73	0.03	0.00	2.90
4	0.00	0.00	0.00	1.27	0.03	0.30	0.00
5	0.00	0.03	0.03	0.91	0.00	0.00	0.51
6	0.03	0.00	0.03	3.96	0.00	0.03	0.05
7	0.00	0.00	0.00	1.27	0.03	0.00	2.44
8	0.00	0.00	0.03	0.00	0.00	0.03	0.33
9	0.30	0.03	0.00	0.03	0.00	0.00	0.03
10	0.18	0.00	0.03	0.00	0.00	0.00	1.50
11	0.03	0.03	0.00	0.43	0.00	0.03	0.36
12	0.20	0.00	0.03	0.00	0.03	0.03	1.47
13	0.00	0.03	0.03	2.29	0.00	0.00	1.35
14	0.03	0.00	2.03	0.23	0.03	0.03	0.10
15	0.08	0.03	0.91	0.05	0.03	1.00	1.88
16	0.03	0.10	0.03	0.03	0.03	0.20	0.30
17	0.03	0.03	0.00	0.03	0.00	0.03	0.03
18	0.00	0.00	0.03	0.03	0.00	0.03	0.03
19	0.00	0.03	0.00	0.03	0.03	0.03	0.70
20	0.00	0.00	0.03	0.03	0.00	0.05	0.48
21	0.00	0.05	0.03	0.03	0.23	0.00	1.14
22	0.00	0.03	0.03	0.03	0.00	0.00	2.41
23	0.00	0.00	0.00	0.03	0.00	0.00	0.08
24	0.00	0.00	0.03	1.00	0.00	0.00	0.08
25	1.07	0.00	2.16	2.01	0.00	0.00	0.25
26	0.74	0.00	0.05	0.05	0.00	0.00	3.10
27	0.15	0.00	0.43	0.00	0.03	0.00	0.69
28	0.00	0.03	1.22	1.93	0.03	0.00	0.25
29	0.00	0.00	0.00	0.51	0.03	0.00	0.03
30	0.08	0.00	0.03	2.72	0.08	0.00	0.03
31			0			0	

Appendix A. Precipitation history near the Lower Mad River, September –November, 2001-2011 (continued).

Date	Sept. 2007 (cm)	Oct. 2007(cm)	Nov. 2007 (cm)	Sept. 2008(cm)	Oct. 2008(cm)	Nov. 2008(cm)	Sept. 2009(cm)
1	0.00	0.05	0.03	0.00	0.03	2.82	0.00
2	0.00	0.03	0.03	0.00	0.97	0.53	0.03
3	0.01	0.03	0.03	0.03	0.43	1.27	0.00
4	0.00	0.43	0.00	0.00	0.20	0.64	0.03
5	0.15	0.03	0.03	0.00	0.03	0.36	0.08
6	0.00	0.00	0.03	0.00	0.03	0.13	0.03
7	0.00	0.03	0.03	0.00	0.00	0.00	0.03
8	0.00	0.00	0.03	0.03	0.03	2.06	0.00
9	0.01	2.69	0.00	0.00	0.00	0.38	0.00
10	0.00	0.41	0.74	0.00	0.00	0.03	0.03
11	0.00	0.13	0.03	0.00	0.00	1.22	0.03
12	0.00	0.13	1.30	0.03	0.00	0.61	0.03
13	0.00	0.03	0.48	0.03	0.00	1.12	1.17
14	0.00	0.03	0.03	0.03	0.00	0.03	0.00
15	0.00	0.43	0.36	0.00	0.00	0.00	0.03
16	0.00	0.81	0.74	0.05	0.03	0.03	0.00
17	0.00	0.43	1.00	0.05	0.03	0.03	0.03
18	0.00	1.42	1.14	0.00	0.03	0.00	0.00
19	0.00	6.83	0.76	0.15	0.03	0.00	0.00
20	0.00	0.38	0.00	0.00	0.00	0.84	0.00
21	0.00	0.00	0.03	0.00	0.03	0.03	0.00
22	0.00	0.03	0.05	0.00	0.00	0.36	0.03
23	0.00	0.00	0.00	0.03	0.00	0.05	0.03
24	0.00	0.03	0.00	0.03	0.03	0.00	0.00
25	0.00	0.00	0.03	0.00	0.03	0.03	0.03
26	0.00	0.00	0.64	0.00	0.00	0.03	0.00
27	0.00	0.03	0.20	0.00	0.03	0.00	0.03
28	0.25	0.00	0.00	0.03	0.03	0.03	0.00
29	0.00	0.38	0.00	0.00	0.03	0.03	0.03
30	1.12	0.00	0.03	0.00	0.00	0.00	0.00
31		0.03			0.13		

Appendix A. Precipitation history near the Lower Mad River, September –November, 2001-2011 (continued).

Date	Oct. 2009 (cm)	Nov. 2009 (cm)
1	0.00	0.05
2	0.03	0.03
3	0.00	0.03
4	0.03	0.00
5	0.00	0.10
6	0.00	1.37
7	0.00	0.20
8	0.00	0.00
9	0.00	1.00
10	0.05	0.05
11	0.00	0.03
12	0.00	0.05
13	2.59	0.20
14	2.03	0.00
15	0.03	0.03
16	0.05	0.00
17	0.53	2.31
18	0.03	0.13
19	0.20	0.00
20	0.03	2.46
21	0.00	0.08
22	0.03	0.53
23	0.05	0.03
24	0.03	0.03
25	0.03	0.05
26	0.30	0.91
27	0.00	0.30
28	0.00	0.00
29	0.00	0.03
30	0.03	0.03
31	0.00	

APPENDIX B: Weights(kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California. The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	G1P0	G1P2	G2P0	G2P2	G3P0	G3P2	G4P0	G4P2	G5P0	G5P2
Total	28.90	30.56	31.20	26.50	30.55	30.13	33.26	33.22	31.82	31.62
Rock	24.51	22.07	23.81	12.27	25.14	18.47	25.75	24.59	26.32	21.66
Sand	4.40	8.46	7.44	14.15	5.40	11.63	4.65	8.63	5.47	9.95
Split	4.37	4.46	4.53	5.00	5.40	4.97	4.65	4.72	4.87	5.44
>4mm	0.10	0.15	0.10	0.23	0.37	0.05	0.18	0.09	0.28	0.15
2-4mm	1.08	1.27	0.91	1.03	1.51	0.44	1.22	1.24	1.63	1.79
1-2mm	0.85	1.00	0.80	1.16	1.09	0.57	1.26	1.41	1.01	1.47
1/2-1mm	1.37	0.94	1.34	1.38	1.00	2.47	1.03	1.08	0.83	1.05
1/4-1/2	0.68	0.82	0.91	0.82	0.64	1.15	0.38	0.36	0.62	0.58
1/8-1/4	0.11	0.16	0.27	0.19	0.30	0.22	0.22	0.21	0.27	0.25
<1/8	0.17	0.11	0.21	0.17	0.52	0.07	0.37	0.31	0.25	0.14

APPENDIX B: Weights (kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	G1S0	G1S2	G2S0	G2S2	G3S0	G3S2	G4S0	G4S2	G5S0	G5S2
Total	32.90	32.60	27.30	26.22	28.71	24.90	27.91	24.96	25.40	25.23
Rock	26.21	21.90	18.22	15.56	14.38	14.34	17.71	16.72	17.91	17.31
Sand	6.70	10.55	9.08	10.60	14.20	10.45	10.20	8.05	7.40	7.71
Split	4.41	4.42	4.70	4.70	5.20	4.69	4.99	4.69	4.46	4.75
>4mm	0.23	0.25	0.37	0.29	0.17	0.07	0.18	0.08	0.23	0.23
2-4mm	1.33	1.42	1.37	1.52	0.95	0.64	1.00	0.86	1.07	1.42
1-2mm	1.04	1.20	0.93	1.04	1.10	0.83	0.87	0.80	0.92	1.16
1/2-1mm	0.78	0.59	0.96	0.94	1.89	2.04	1.22	1.12	0.91	1.03
1/4-1/2	0.69	0.69	0.69	0.66	0.78	0.86	1.01	1.14	0.73	0.55
1/8-1/4	0.21	0.20	0.20	0.16	0.18	0.18	0.39	0.40	0.31	0.18
<1/8	0.13	0.08	0.18	0.10	0.13	0.08	0.34	0.28	0.29	0.16

APPENDIX B: Weights (kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California. The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2). (Continued)

	G1I0	G1I2	G2I0	G2I2	G3I0	G3I2	G4I0	G4I2	G5I0	G5I2
Total	30.55	26.70	28.82	28.35	27.25	26.51	29.17	29.00	29.63	27.20
Rock	21.80	18.85	18.57	18.83	14.22	14.93	17.12	18.51	19.98	16.87
Sand	8.30	7.85	9.10	8.79	11.73	10.80	10.45	9.14	8.44	8.75
Split	4.67	4.61	4.79	4.80	4.71	4.72	4.30	4.70	4.62	4.32
>4mm	0.34	0.11	0.31	0.08	0.13	0.07	0.24	0.22	0.34	0.13
2-4mm	1.39	1.53	1.49	1.12	0.79	0.74	0.82	0.72	1.23	1.09
1-2mm	1.08	1.30	0.96	1.04	1.02	1.06	0.82	0.80	1.00	0.95
1/2-1mm	0.66	0.59	1.33	1.02	1.64	1.86	0.93	1.08	0.82	1.40
1/4-1/2	0.80	0.76	0.73	0.68	0.83	0.78	0.84	1.00	0.78	0.61
1/8-1/4	0.22	0.19	0.34	0.15	0.14	0.12	0.34	0.53	0.14	0.11
<1/8	0.18	0.13	0.22	0.11	0.14	0.09	0.31	0.35	0.31	0.03

APPENDIX B: Weights(kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

2007	ES1 02	ES1 2-4	ES2 02	ES2 2-4	ES3 02	ES3 2-4	ES4 02	ES4 2-4	ES5 02	ES5 2-4
Total	22.18	21.70	22.17	24.28	21.25	23.22	20.10	23.05	21.30	20.50
Rock	15.38	12.92	17.88	14.65	11.59	14.93	15.37	16.05	13.90	15.80
Sand	6.18	6.19	4.18	9.02	10.59	9.18	5.70	7.28	7.43	5.70
Split	4.50	4.55	4.17	4.46	4.55	4.44	5.64	4.55	4.53	4.53
>4mm	0.08	0.11	0.22	0.15	0.12	0.23	0.19	0.11	0.00	0.01
2-4mm	0.56	0.92	1.46	1.53	0.73	0.99	1.37	1.01	1.33	1.35
1-2mm	1.07	1.23	1.31	1.62	0.71	0.80	1.33	1.00	2.81	1.08
1/2-1mm	2.00	1.39	0.73	0.71	1.41	1.58	1.41	0.97	1.05	1.09
1/4-1/2	0.60	0.54	0.29	0.22	0.90	0.70	0.80	0.99	0.73	0.57
1/8-1/4	0.13	0.10	0.10	0.10	0.20	0.15	0.33	0.21	0.23	0.16
<1/8	0.06	0.08	0.11	0.05	0.14	0.01	0.21	0.10	0.18	0.07

APPENDIX B: Weights(kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

2007	E1ar02	E1ar24	E2ar02	E2ar24	E3ar02	E3ar24	E4ar02	E4ar24	E5ar02	E5ar24
Total	22.52	25.47	23.23	23.50	21.50	24.34	22.68	20.59	20.95	22.37
Rock	16.49	16.74	18.15	15.49	11.83	13.50	17.00	13.55	15.11	15.60
Sand	5.86	7.72	7.85	8.01	10.22	10.78	5.70	6.67	5.60	6.30
Split	4.30	4.41	4.31	4.20	4.42	4.47	4.40	4.40	4.20	4.38
>4mm	0.07	0.00	0.21	0.32	0.06	0.22	0.21	0.22	0.21	0.18
2-4mm	1.03	1.03	1.34	1.43	0.83	1.08	1.01	1.31	1.12	1.20
1-2mm	1.41	1.23	1.49	1.55	0.75	0.97	0.89	1.04	0.89	0.93
1/2-1mm	1.24	1.20	0.92	0.71	1.35	1.37	1.01	0.88	1.10	0.99
1/4-1/2	0.47	0.66	0.40	0.40	1.03	0.68	0.76	0.62	0.75	0.60
1/8-1/4	0.07	0.11	0.11	0.40	0.19	0.10	0.29	0.20	0.21	0.20
<1/8	0.03	0.05	0.01	0.14	0.07	0.01	0.22	0.15	0.11	0.10

APPENDIX B: Weights(kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

2007	E1I0	E1I2	E2I0	E2I2	2[1]E2I0	2[2]E2I2	E3I0	E3I2	2[3]E3I0	2[2]EI32
Total	24.62	24.52	29.31	24.94	27.12	22.25	--	25.45	23.21	23.47
Rock	18.58	18.28	19.35	17.48	20.15	13.02	--	13.20	13.19	13.97
Sand	7.00	6.70	9.16	7.47	6.97	6.58	12.83	12.80	10.02	9.17
Split	4.35	4.62	4.30	4.45	4.40	4.28	4.46	4.37	4.57	4.41
>4mm	0.14	0.22	0.10	0.13	0.13	0.18	0.27	0.10	0.33	0.05
2-4mm	1.02	1.10	1.20	1.35	1.44	1.19	0.93	0.64	0.57	1.16
1-2mm	1.28	1.25	1.34	1.57	1.34	1.46	2.72	0.75	0.68	2.86
1/2-1mm	1.30	1.17	0.85	0.82	0.30	0.84	1.22	2.13	4.16	1.39
1/4-1/2	0.46	0.41	0.37	0.31	0.32	0.29	0.54	0.51	1.13	0.64
1/8-1/4	0.09	0.11	0.17	0.10	0.16	0.13	0.19	0.06	0.23	0.09
<1/8	0.03	0.05	0.14	0.04	0.11	0.10	0.20	0.00	0.12	0.02

[1]This column of data was a replacement for the column titled E2I0, which was vandalized

[2] This column of data was a replacement to the subsurface sample, which was paired with a vandalized surface sample.

[3] This column of data was a replacement for the column titled E3I0, which was vandalized.

APPENDIX B: Weights(kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	E4I0	E4I2	E5I0	E5I2	E5I2
Total	22.55	21.67	23.23	25.48	25.48
Rock	13.75	9.61	16.06	19.17	19.17
Sand	8.80	10.94	6.82	5.50	5.50
Split	4.47	4.44	4.48	5.50	5.50
>4mm	0.05	0.22	0.15	0.41	0.41
2-4mm	0.83	0.82	1.13	1.74	1.74
1-2mm	1.20	1.07	0.82	0.98	0.98
1/2-1mm	1.18	1.09	0.61	0.82	0.82
1/4-1/2	0.80	0.68	1.31	0.87	0.87
1/8-1/4	0.22	0.29	0.28	0.46	0.46
<1/8	0.19	0.25	0.18	0.23	0.23

APPENDIX B: Weights(kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

2008	E1PO	E1P2	E2P0	E2P2	E3P0	E3P2	E4P0	E4P2	E5P0	E5P2
Total	31.60	28.10	25.27	29.93	30.59	29.20	26.71	28.05	27.32	31.73
Rock	21.10	18.42	20.07	20.01	23.85	21.00	26.70	17.97	14.71	22.23
Sand	10.45	9.65	5.23	9.90	6.72	8.12	6.00	10.13	12.57	9.50
Split	5.20	4.90	4.85	4.59	4.70	4.75	5.94	4.67	4.44	4.40
>4mm	0.23	0.25	0.12	0.09	0.13	0.20	0.18	0.16	0.14	0.09
2-4mm	1.19	1.37	0.82	0.92	1.21	1.26	1.10	0.89	0.53	0.89
1-2mm	0.75	0.80	0.57	0.76	0.86	1.12	0.82	0.79	0.34	0.81
1/2-1mm	0.84	0.90	0.67	1.39	0.81	1.10	1.26	1.81	0.38	0.98
1/4-1/2	1.29	1.07	1.29	1.01	0.72	0.59	0.98	0.63	1.47	0.96
1/8-1/4	0.34	0.55	0.55	0.28	0.50	0.24	0.71	0.21	0.96	1.00
<1/8	0.32	0.16	0.32	0.14	0.48	0.22	0.88	0.18	0.63	0.67

APPENDIX B: Weights(kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

2008	E1S0	E1S2	E2S0	E2S2	E3S0	E3S2	E4S0	ERS2	E5S0	E5S2
Total	26.20	24.05	26.50	25.05	26.32	24.03	28.19	25.90	30.50	27.30
Rock	15.37	10.19	20.50	19.51	14.95	13.30	18.98	15.10	19.99	16.36
Sand	11.41	13.64	5.95	5.26	11.21	10.35	9.31	10.58	10.52	10.96
Split	4.65	4.44	4.94	4.38	5.43	4.40	5.04	4.56	5.51	5.21
>4mm	0.16	0.30	0.17	0.10	0.17	0.08	0.16	0.14	0.17	0.16
2-4mm	1.15	1.36	1.21	1.50	1.01	0.96	1.00	1.05	1.12	1.05
1-2mm	0.99	0.92	0.88	1.14	1.06	1.01	0.95	1.02	0.66	0.75
1/2-1mm	1.50	0.99	0.87	0.80	1.86	1.46	1.24	1.45	0.87	0.99
1/4-1/2	0.55	0.70	1.24	1.04	0.95	0.64	0.81	0.62	1.64	1.16
1/8-1/4	0.22	0.12	0.35	0.39	0.25	0.14	0.57	0.21	0.60	0.61
<1/8	0.08	0.05	0.22	0.25	0.12	0.07	0.31	0.05	0.44	0.51

APPENDIX B: Weights(kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California(continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	C1P0	C1P2	C2P0	C2P2	C3P0	C3P2	C4P0	C4P2	C5P0	C5P2
Total	28.00	28.30	30.97	25.82	29.95	26.43	30.50	30.22	29.78	27.00
Rock	21.67	19.52	22.96	18.45	21.75	17.97	19.82	18.16	22.85	19.89
Sand	6.34	8.66	8.06	7.35	7.86	8.46	10.74	12.12	6.96	7.02
Split	4.57	5.00	4.49	4.35	4.57	4.92	4.68	5.67	5.47	4.83
>4mm	0.14	0.11	0.13	0.18	0.19	0.17	0.18	0.30	0.12	0.22
2-4mm	1.27	1.46	0.70	1.11	1.24	1.35	0.84	1.58	1.35	1.21
1-2mm	1.15	1.35	0.27	0.77	0.65	0.97	0.47	0.97	1.00	0.79
1/2-1mm	0.67	0.82	0.24	0.34	0.28	0.45	0.28	0.42	0.76	0.74
1/4-1/2	0.60	0.77	2.11	1.13	1.11	1.16	1.83	1.43	0.90	0.95
1/8-1/4	0.40	0.30	0.47	0.48	0.61	0.53	0.48	0.55	0.70	0.51
<1/8	0.33	0.19	0.56	0.34	0.49	0.28	0.61	0.41	0.64	0.41

APPENDIX B: Weights (kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	C1S0	C1S2	C2S0	C2S2	C3S0	C3S2	C4S0	C4S2	C5S0	C5S2
Total	27.40	27.30	24.00	24.10	25.16	23.76	25.45	25.51	27.30	27.35
Rock	21.82	19.95	18.00	17.38	17.70	15.63	17.19	14.85	18.55	15.49
Sand	6.16	6.99	5.93	6.72	7.34	7.70	10.01	10.34	8.72	9.77
Split	4.47	5.02	4.68	4.66	4.15	4.17	4.54	4.34	4.67	4.65
>4mm	0.26	0.27	0.38	0.36	0.23	0.14	0.15	0.09	0.16	0.26
2-4mm	1.35	1.24	1.67	1.63	1.23	1.22	1.03	0.83	1.36	1.35
1-2mm	1.00	0.97	1.11	1.02	1.03	1.17	1.18	1.07	1.19	1.21
1/2-1mm	0.74	0.95	0.64	0.72	0.74	0.82	0.97	1.09	0.72	0.85
1/4-1/2	0.72	1.09	0.58	0.65	0.59	0.51	0.89	0.88	0.70	0.64
1/8-1/4	0.26	0.30	0.18	0.20	0.21	0.20	0.22	0.16	0.34	0.26
<1/8	0.15	0.22	0.11	0.09	0.12	0.12	0.10	0.06	0.20	0.12

APPENDIX B: Weights (kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	C1I0	C1I2	C2I0	C2I2	C3I0	C3I2	C4I0	C4I2	C5I0	C5I2
Total	25.69	24.16	24.91	25.16	24.19	24.14	26.04	26.61	24.36	24.61
Rock	19.56	17.81	20.04	18.04	19.52	16.55	15.94	15.96	16.51	15.84
Sand	5.80	5.96	4.66	6.71	4.68	7.04	9.84	10.29	7.61	8.36
Split	4.42	4.81	4.66	4.64	4.60	7.05	4.75	4.89	4.51	4.78
>4mm	0.18	0.19	0.21	0.08	0.15	0.77	0.28	0.11	0.10	0.08
2-4mm	1.02	1.22	1.30	1.35	1.53	2.24	1.01	1.28	1.50	1.32
1-2mm	1.02	1.04	1.05	1.26	1.18	1.51	1.17	1.38	1.25	1.45
1/2-1mm	0.81	1.02	0.87	1.13	0.80	1.07	0.94	0.91	0.67	0.89
1/4-1/2	0.67	0.85	0.76	0.59	0.62	0.90	0.94	0.80	0.68	0.78
1/8-1/4	0.23	0.31	0.30	0.15	0.24	0.30	0.23	0.23	0.21	0.19
<1/8	0.13	0.19	0.17	0.07	0.08	0.26	0.18	1.03	0.08	0.05

APPENDIX B: Weights (kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	J1P0	J1P2	J2P0	J2P2	J3P0	J3P2	J4P0	J4P2	J5P0	J5P2
Total	23.53	21.93	27.45	25.30	24.20	25.14	26.15	28.42	18.53	15.80
Rock	18.00	16.38	15.08	16.88	16.20	11.34	18.39	15.72	1.21	0.65
Sand	5.53	5.55	12.20	8.20	8.10	13.65	7.77	12.68	17.33	15.10
Split	5.53	5.54	4.28	4.38	4.31	4.43	5.05	4.68	4.70	4.43
>4mm	0.31	0.33	0.07	0.19	0.15	0.19	0.32	0.26	0.02	0.02
2-4mm	1.26	1.38	0.29	0.87	0.97	0.99	1.44	1.18	0.15	0.16
1-2mm	0.85	0.92	0.28	1.03	0.69	0.99	1.11	1.06	0.22	0.66
1/2-1mm	1.21	0.55	1.19	1.10	0.87	1.19	1.31	1.46	1.55	2.30
1/4-1/2	1.49	1.73	2.09	0.88	1.57	0.93	0.70	0.66	2.54	1.19
1/8-1/4	0.29	0.43	0.27	0.12	0.20	0.12	0.12	0.05	0.20	0.10
<1/8	0.11	0.18	0.10	0.10	0.05	0.03	0.04	0.02	0.01	0.01

APPENDIX B: Weights (kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	J1S0	J1S2	J2S0	J2S2	J3S0	J3S2	J4S0	J4S2	J5S0	J5S2
Total	27.19	27.95	26.47	24.80	25.31	22.10	25.50	24.37	21.40	20.00
Rock	18.30	17.60	15.87	13.33	12.10	8.49	11.90	11.45	6.54	5.95
Sand	8.86	10.24	10.56	11.37	13.13	13.48	13.61	12.67	14.78	13.81
Split	4.86	4.98	4.81	4.59	4.97	4.16	4.65	4.78	4.89	4.51
>4mm	0.24	0.15	0.20	0.09	0.12	0.16	0.12	0.12	0.11	0.06
2-4mm	0.99	1.32	0.87	1.00	0.89	0.62	0.81	0.85	0.56	0.45
1-2mm	1.04	1.46	0.95	1.00	0.79	0.66	0.72	0.76	0.56	0.53
1/2-1mm	1.43	0.81	1.72	1.29	1.78	1.65	1.33	1.03	1.89	2.10
1/4-1/2	0.90	0.57	0.83	0.87	1.04	0.91	1.25	0.19	1.39	1.12
1/8-1/4	0.18	0.52	0.17	0.21	2.49	0.13	0.24	0.19	0.26	0.20
<1/8	0.08	0.12	0.06	0.13	0.10	0.02	0.13	0.05	0.11	0.05

APPENDIX B: Weights (kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	J1R0	J1R2	J2R0	J2R2	J3R0	J3R2	J4R0	J4R2	J5R0	J5R2
Total	27.95	26.30	27.80	26.54	26.63	24.70	27.42	25.47	22.60	22.00
Rock	17.96	17.60	16.00	13.41	14.32	11.61	13.45	13.30	7.75	7.10
Sand	9.82	8.46	11.79	13.13	12.31	12.83	13.90	11.96	14.75	14.90
Split	4.80	4.78	5.11	4.94	5.04	5.18	4.70	4.33	4.50	4.42
>4mm	0.16	0.17	0.22	0.18	0.14	0.22	0.17	0.20	0.94	0.99
2-4mm	1.24	1.27	0.95	1.02	0.94	0.97	0.75	0.79	0.48	0.50
1-2mm	1.20	1.35	1.07	1.09	0.86	0.88	0.65	0.62	0.51	0.57
1/2-1mm	1.23	0.84	1.62	1.67	1.80	1.85	1.22	1.17	2.07	2.03
1/4-1/2	0.76	0.77	0.93	0.74	0.99	1.03	1.23	1.17	1.08	1.03
1/8-1/4	0.17	0.25	0.20	0.16	0.23	0.18	0.47	0.25	0.21	0.17
<1/8	0.05	0.13	0.13	0.06	0.09	0.04	0.20	0.13	0.06	0.28

APPENDIX B: Weights (kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	J1I0	J1I2	J2I0	J2I2	J3I0	J3I2	J4I0	J4I2	J5I0	J5I2
Total	26.19	25.85	26.12	23.65	23.29	24.47	23.69	25.00	22.97	24.35
Rock	18.10	16.34	14.58	12.04	9.79	9.68	12.13	12.39	7.38	8.22
Sand	7.80	9.52	11.15	10.90	13.19	13.85	10.90	11.87	15.23	15.57
Split	4.70	4.63	4.10	4.38	4.30	4.29	4.58	4.77	--	4.59
>4mm	0.18	0.10	0.07	0.08	0.11	0.08	0.13	0.23	--	0.10
2-4mm	1.16	1.28	0.83	0.42	0.75	0.46	0.77	0.70	--	0.60
1-2mm	1.23	1.37	0.86	0.68	0.81	0.74	0.72	0.70	--	0.68
1/2-1mm	1.07	1.03	1.15	1.57	1.24	1.44	1.57	1.53	--	1.68
1/4-1/2	0.77	0.55	0.94	1.25	1.06	1.17	1.09	1.29	--	1.23
1/8-1/4	0.18	0.17	0.17	0.26	0.24	0.26	0.20	0.22	--	0.24
<1/8	0.11	0.11	0.08	0.11	0.10	0.13	0.10	0.13	--	0.07

APPENDIX B: Weights (kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	O1P0	O1P2	O2P0	O2P2	O3P0	O3P2	O4P0	O4P2	O5P0	O5P2
1										
Total	27.88	25.21	28.27	23.34	26.82	25.45	27.10	24.70	23.32	23.07
Rock	17.78	15.17	18.30	10.57	13.11	12.16	15.75	13.81	13.92	13.22
Sand	9.99	9.83	9.96	12.76	13.70	13.20	11.37	10.88	9.47	9.85
Split	4.55	4.39	4.39	4.50	4.70	4.59	4.87	4.88	4.75	5.18
>4mm	0.21	0.24	0.06	0.03	0.11	0.13	0.28	0.26	1.79	0.45
2-4mm	1.00	0.83	0.69	0.42	1.55	1.38	1.97	1.97	1.79	1.81
1-2mm	0.68	0.51	0.63	0.63	0.76	1.01	0.75	0.85	0.87	0.81
1/2-1mm	1.09	1.07	1.34	2.02	0.31	0.61	0.23	0.21	0.25	0.20
1/4-1/2	1.26	1.24	1.33	1.16	1.11	1.16	0.92	1.25	1.07	1.42
1/8-1/4	0.21	0.17	0.27	0.18	0.64	0.24	0.52	0.26	0.33	0.37
<1/8	0.08	0.04	0.08	0.03	0.23	0.04	0.21	0.07	0.07	0.11

APPENDIX B: Weights (kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	O1S0	O1S2	O2S0	O2S2	O3S0	O3S2	O4S0	O4S2	O5S0	O5S2
Total	26.50	27.50	29.51	27.79	25.73	26.69	27.29	24.43	25.91	24.72
Rock	15.41	16.84	17.30	13.05	8.79	14.09	12.55	11.19	12.84	9.86
Sand	11.10	10.73	12.21	14.74	16.95	12.61	14.67	13.24	13.03	14.80
Split	4.82	5.01	4.50	4.82	4.39	4.89	5.40	4.90	5.04	5.29
>4mm	0.22	0.32	0.09	0.14	0.06	0.08	0.27	0.24	0.51	0.43
2-4mm	1.18	1.64	0.70	0.65	0.44	0.61	1.86	1.41	2.39	2.58
1-2mm	1.25	1.45	0.59	0.69	0.71	0.61	0.81	0.77	1.10	1.07
1/2-1mm	1.20	1.00	1.77	2.07	2.20	2.34	0.32	0.69	0.47	0.20
1/4-1/2	0.66	0.41	1.38	1.01	0.72	0.95	1.65	1.34	0.50	0.66
1/8-1/4	0.18	0.12	0.21	0.17	0.20	0.24	0.29	0.27	0.29	0.31
<1/8	0.13	0.06	0.13	0.08	0.06	0.06	0.20	0.19	0.04	0.06

APPENDIX B: Weights (kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	O1R0	O1R2	O2R0	O2R2	O3R0	O3R2	O4R0	O4R2	O5R0	O5R2
Total	29.20	25.74	28.50	25.75	25.51	25.21	24.47	25.83	28.35	24.45
Rock	21.55	17.31	16.60	15.45	12.00	11.86	10.00	11.93	14.20	13.13
Sand	7.66	8.46	11.90	10.35	13.41	13.10	14.45	13.77	14.15	11.13
Split	4.67	4.47	4.73	4.70	4.50	4.96	4.64	5.25	4.71	4.88
>4mm	0.13	0.21	0.19	0.14	0.15	0.16	0.18	0.24	0.11	0.19
2-4mm	1.29	1.01	1.25	0.87	1.12	0.93	0.88	0.86	0.94	1.17
1-2mm	0.97	1.14	0.86	0.86	0.81	0.73	0.66	0.52	0.68	0.65
1/2-1mm	0.78	1.12	0.87	1.86	0.89	1.92	1.68	1.15	0.47	0.64
1/4-1/2	1.01	0.72	1.20	0.75	1.09	0.92	0.93	2.03	2.21	1.86
1/8-1/4	0.31	0.22	0.22	0.17	0.22	0.22	0.21	0.29	0.19	0.28
<1/8	0.19	0.06	0.15	0.04	0.21	0.09	0.09	0.17	0.11	0.10

APPENDIX B: Weights (kilograms) of samples collected from gravel bars in 2007 and 2008 on the lower Mad River, Humboldt County, California (continued). The first letter of the site name refers to the gravel bar, Guynup, Emmerson, Christie, Johnson-Spini, and O'Neill. The first numeral refers to the sample's position on the gravel bar. The second letter of the site name refers to the type of sample: (P)re-extraction, (S)ubsequent or post extraction, after (R)ains, after (I)nundation. The second numeral refers to whether the sample was a surface sample (0) or a subsurface sample (2).

	O1I0	O1I2	O2I0	O2I2	O3I0	O3I2	O4I0	O4I2	O5I0	O5I2
Total	25.49	27.00	26.43	28.26	29.01	35.15	28.48	30.38	22.04	22.19
Rock	16.38	14.08	9.87	11.54	12.83	16.99	11.84	14.21	4.11	9.82
Sand	7.51	10.25	13.13	14.07	13.43	14.14	13.85	13.80	14.10	11.44
Split	4.51	4.18	4.61	4.28	4.32	4.57	4.51	4.57	4.48	4.61
>4mm	0.31	0.16	0.27	0.10	0.23	0.19	0.15	0.11	0.15	0.18
2-4mm	0.73	0.85	0.87	0.87	0.65	0.89	1.63	1.28	0.56	1.83
1-2mm	0.41	0.62	0.49	0.68	0.52	0.48	0.86	0.76	0.25	1.13
1/2-1mm	1.99	1.38	1.08	1.22	1.08	1.14	0.32	0.48	0.06	0.26
1/4-1/2	0.90	1.00	0.87	1.25	1.33	1.49	1.33	1.66	0.45	0.94
1/8-1/4	0.11	0.15	0.17	0.14	0.27	0.26	0.19	0.24	1.72	0.24
<1/8	0.05	0.03	0.04	0.03	0.24	0.13	0.04	0.06	1.27	0.03