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1.0 INTRODUCTION

Southern California Edison Company (SCE) occasionally augments streamflows in the North Fork Stevenson Creek by releasing flow from Tunnel 7. Historically, SCE used Tunnel 7 for regular delivery of water to Shaver Lake, until the construction of Eastwood Powerhouse in 1987. Since operation of Eastwood Powerhouse, flow augmentation occurs only when it is necessary for SCE to shut-down the Eastwood Powerhouse for maintenance purposes. Augmented flows can exceed 1,000 cfs. Three such events of this magnitude have occurred during the past 10 years. Otherwise, there are no planned or controlled releases from Tunnel 7, except for minimum instream flows, which range from 3.5 cfs to 5.0 cfs depending upon the season and water year type.

Augmented streamflows have the potential to scour spawning gravels used by brown and rainbow trout, which can adversely affect the survival of incubating eggs and alevins (newly hatched fish). This gravel mobility study was designed to determine the flow threshold below which scour of spawning gravels will not occur. A related goal was to determine the flows needed to maintain spawning gravels in good condition. Flows are periodically needed to initiate motion for gravel sizes so that sand is winnowed from spawning habitat and transported through the reaches of concern. Such gravel transporting flows should, however, not occur during periods when eggs are incubating, or when alevins are in the gravel matrices.

A gravel mobility Study Plan was prepared, reviewed, and approved by the U.S. Forest Service (USDA-FS), and California Department of Fish and Game (CDFG) in April 2005. Field work under this study plan was conducted during April 24-29, 2005 and builds upon similar work conducted in 2003.

2.0 OBJECTIVES

The primary study objective was to determine the flow that initiates gravel transport but does not scour subsurface gravels. At the request of the USDA-FS, the study also addressed two related objectives, as follows.

- Identify the water surface elevation associated with each test flow release;
- Evaluate whether gravels placed in areas upstream of boulders would be transported and deposited as pocket gravels in the low-velocity areas downstream of boulders (lee).

The methods used to accomplish these study objectives are described below.

3.0 OVERVIEW OF STUDY APPROACH

The basic study approach is the same as the approach used for the 2003 study. During the 2003 study, tracer gravels were installed and monitored along two reaches of the North Fork Stevenson Creek where spawning gravels and spawning habitat is present. A flow release of 200 cfs was provided to test for the mobility of gravels. The results of the 2003 study found that flows up to 200 cfs did not mobilize spawning gravels. Flows greater than 200 cfs were not evaluated at that time. The study performed in 2005 builds on the results of the 2003 study and evaluates higher flows.

The 2005 study was performed in the same two reaches evaluated during the 2003 study. The study method uses both surface and subsurface tracer gravels (distinguished by color). This provided an "early warning system" to indicate when test flow releases may be approaching a discharge that has the potential to disturb gravels down to a depth equivalent to the egg-pocket in a redd (approximately 2 to 3 inches). The study was terminated at the first indications that sub-surface tracer gravels were being disturbed, so as to protect the fishery. As a safeguard, a survey was conducted to locate any redds that may have been present prior to releasing the test flows. No redds were observed in either study reach during the study period.

4.0 METHODS

4.1 SITE SELECTION

The two reaches had been previously defined in 2003. Both study reaches are located on Stevenson Creek and contain areas that have deposits of spawning gravels. The Upper Study Reach is located just above Forest Service Road 9S58 (RM 1.8-2.4). The Lower Study Reach is located near Shaver Lake (RM 1.2-1.3). These study reaches are shown on Figure 1. Both study reaches are similar in geomorphic character, with cobble and gravel substrate, except that the Lower Study reach is quite short and represented by only one mid-channel bar. The Upper Study reach is comprised of a sequence of bars (no mid-channel bars).

Five site-specific tracer gravel installations were selected in the Lower Reach and six installations were selected in the Upper Reach. One additional tracer installation was placed at the Upper site for the purposes of tracking transport and potential deposition in low-velocity areas such as the lee of boulders. There were no suitable sites in the Lower Reach for conducting this part of the study due to the lack of boulders. Each of the study sites is briefly described in the following. Photographs of each site are included in Appendix A.

4.1.1 UPPER STUDY REACH SITE DESCRIPTIONS

The sites within the Upper Study Reach are described in the following from downstream to upstream.

Site 1

Site 1 is a pool tailout adjacent to a large cobble and gravel bar, located just upstream from the USGS gaging site. The particle size of the pool tailout was mostly sand and very small gravels. Tracers were placed at the crest of the pool tailout, in a tightly clustered oval grouping. Both surface and subsurface tracers were installed. The tracer installation following the first test flow release on April 27 is shown in Photograph 1. Forty-three surface tracers and 29 subsurface tracers were installed.

Site 2

Site 2 is just below a riffle crest, near the left bank where velocity slows, and a small group of gravels had deposited at the channel margin. Surface and subsurface tracers were placed in a tight cluster emulating a redd. The tracer installation following the first test flow release on April 27 is shown in Photograph 2. Forty-four surface tracers and 32 subsurface tracers were installed.

Site 3

Site 3 is a pool-tailout, just upstream from a riffle crest. The tracer installation is centered about mid-channel, and is a tight cluster of surface and subsurface tracer gravels. Photograph 3 shows the installation site prior to the first test release. Fifty-two surface and 33 subsurface tracer particles were installed.

Site 4

Site 4 is on the riffle crest (between Sites 2 and 3). The tracers were installed as a straight line across a section of the channel. Only surface tracers (32 particles) were placed at this site as it was difficult to install subsurface tracers due to cobble size material in the bed. Photograph 4 shows the installation site.

Site 5

Site 5 is at the base of a long riffle, near the left bank. The gravel deposit is in slower velocity water near the bank, and partly due to a low-velocity shadow created a boulder about 10 ft upstream, as shown in Photograph 5. Surface and subsurface tracers were installed. Forty-nine surface tracers and 30 subsurface tracers were installed.

Site 6

Site 6 is a pocket gravel installation in the lee of a 1.5 ft tall boulder, in a high-gradient riffle, as shown in Photograph 6. Both surface and subsurface tracers were installed at this site. Forty-nine surface and 30 subsurface tracers were installed.

Site 7

Site 7 tracers were installed specifically to monitor transport and the potential for deposition behind boulders, as might occur as part of a gravel augmentation program. This site was not used to represent conditions at a spawning site. Site 7 is in a high-gradient riffle, near mid-channel in fast water. A small boulder near the left bank is about 20 ft downstream (this is the boulder providing a velocity shadow for Site 5), and another boulder is about 50 ft downstream on the left bank. Photograph 7 shows the site location in the high-gradient riffle, relative the downstream boulders. This site was intentionally selected with the expectation that gravels would be readily moved and distributed downstream during the test flow releases. Gravel movement was tracked in order to see if they would be deposited as pockets near either of these downstream boulders. One hundred and six tracer particles were placed here as surface gravels, in two distinct piles, side-by-side about mid-channel.

4.1.2 Lower Study Reach Site Descriptions

The Lower Study Reach sites are described in the following from downstream to upstream.

Site 1

This site is located in the side channel formed by a large, well-vegetated mid-channel bar. The study site is a long, low-gradient gravel riffle. Gravels were installed in a straight line across the width of the side channel, as shown in Photograph 8. Forty-six surface tracers and 33 sub-surface tracers were installed at Site 1.

Site 2

Site 2 is located in the side channel, in the tailout of a small pool. Twenty-six surface tracers and 25 subsurface tracers were placed into a tight cluster, as shown in Photograph 9.

Site 3

Site 3 is located a few feet away from Site 2, in the same pool tailout as shown in Photograph 9. Twenty-five surface tracers and 13 subsurface tracers were installed.

Site 4

Site 4 is a riffle crest in the main channel, as shown in Photograph 10. Fifty-one surface tracers and 22 subsurface tracers were installed as a straight line across the channel width.

Site 5

Site 5 is at the base of a high gradient riffle in the main channel, next to the left bank. The site is somewhat protected by large woody debris. A cluster of surface and subsurface gravels was installed, as shown in Photograph 11. Thirty-two surface tracers and 18 subsurface tracers were installed.

4.2 Tracer Gravel Installation

Gravels were collected from within the channel and/or from bars, and laid-out on tarps to dry prior to painting. Particle sizes ranging from 16mm to 64mm were selected for painting. Tracers smaller than 16mm are not feasible to use, because they are difficult to track owing to their small size. Most of the tracers used at each site-specific emplacement ranged from 22.5mm to 45mm, with a few tracer particle sizes in the 16mm and 64mm categories. The 16mm to 64mm range encompasses the suitable gravel sizes for spawning. The D_{50} particle size was measured during the 2003 gravel mobility study. At the lower study site, the D_{50} particle size was 21 mm in the side channel and 51 mm in the main channel. The D_{50} particle size at the Upper Study site was 74 mm. After drying, the gravels were spray-painted various colors, to distinguish them from the native bed material and to aide in the recovery of tracer gravels transported from their original emplacement.

Selected sites were representative of observed spawning habitat conditions, predominantly pool tail-outs, riffles, and in a side channel. Several different types of gravel placement configurations were used to both emulate site-specific spawning gravel deposits, and to be most representative of gravel movement from deposits in that locale. Most tracer installations were clustered together at the tailout of a pool/riffle crest to represent the configuration of a redd. A few installations were placed as a straight line across the channel, normal (perpendicular) to the flow path, near the crest of a riffle. This is a common location selected by the female spawning trout for constructing a redd because upwelling water and intra-gravel flow is usually maximized by the contours of the bed topography. One site (Upper Reach) was selected as an example of a pocket gravel, with tracers placed in a tight cluster in the lee of the boulder. Field inspection found only one existing pocket gravel site in the two study reaches.

The number of gravels in each particle size category (1/2-phi unit intervals) installed at each site were recorded. The particle sizes were measured using a metal-frame template (gravelometer), with pre-sized holes in 1/2-phi unit intervals. Surface and subsurface tracers are distinguished by paint color and separately tracked. The subsurface tracers were placed 2-3 inches below the ground surface, with the surface tracers placed on top. The entire tracer installation was gently pressed by foot and/or hand into the bed to best represent undisturbed gravel deposits. Generally, about 70 or more tracer particles were placed at each of the study sites. Over 400 tracer particles were installed at six separate sites in the Upper Study Reach, and over 290 tracers were installed at five separate sites in the Lower Study Reach.

4.3 Controlled Test Flow Releases and Post-Flow Data Collection

Following emplacement of the tracer gravels at all sites, a flow release was initiated. Flow releases were ramped up to the test discharge, and then held steady for at least six hours, before down-ramping. After the test flows were ramped back down to the natural base flow, each site was inspected for gravel movement. The channel downstream from the tracer emplacement was inspected to recover any mobilized tracers.

If no tracers were observed downstream, and it was apparent that there had been little or no movement from the tracer study site, then a visual count of the surface tracers at the installation site was made (without removing any gravels from the installation). The count was compared to the number of surface gravels originally installed. If the count was the same number as originally installed, then it was recorded as "no movement" at that study site. If the visual count indicated that no more than two tracer pieces from the total installation were missing, then this was noted, but the installation was purposely not excavated in order to minimize any unnecessary disturbance to the study site.

If there was apparent movement at the site, and gravels were recovered downstream, then each recovered tracer particle was sized, tallied, and recorded. The distance traveled from the installation site was measured and recorded into one of three categories: < 1 ft, 1-5 ft, and > 5 ft. The remaining gravels at the study site were also visually counted. If the tracer particles remaining in place plus the recovered particles, matched (to within two tracer pieces) the original total emplaced, then the installation was not further disturbed. The recovered tracers were placed back at the original study site. If the total recovered plus those remaining at that study site did not match the total originally emplaced (within 2 tracer pieces), then the installation was excavated, and all surface and if necessary, subsurface particles, were tallied, sized, and recorded, before replacing them into the study site. Any particles not accounted for after removing and sizing all remaining particles at the installation, plus those recovered downstream, were presumed transported and recorded as such.

Once all sites had been inspected and the results recorded, and the tracer installation was "re-set", then the next test flow was released. Three controlled test releases were made during the course of the study. After the final test release, tracers were removed from each site, sized, counted, and recorded.

The stage-discharge associated with each flow was tracked by placing wood stakes at the water surface elevation where it intersected the streambank. Water surface elevation stakes were placed at several locations in both the Upper and Lower Study Reaches, where it was accessible to do so. The date and time were placed on the wood stakes, and photographs were taken to document conditions at the time. No other water surface elevation data was collected.

4.4 CONTROLLED TEST FLOW RELEASES

Three controlled test flows were released on April 27, 28, and 29. The peak instantaneous and average discharge during the controlled release on each of these days is shown in Table 1. A hydrograph of flows recorded at the USGS gaging station during the study period is shown in Figure 2.

Table 1. Controlled Test Flow Release

Date	Average Flow (cfs)	Instantaneous Peak (cfs)
April 27	287	314
April 28	428	481
April 29	713	794

5.0 GRAVEL MOBILITY RESULTS

The study results are presented below. Gravel mobility is discussed first followed by the water surface elevation results.

5.1 GRAVEL MOBILITY RESULTS

The following results of the gravel mobility study are organized according to the three controlled flow releases. The major findings at each test flow release are summarized as bullet points at the beginning of each subsection. Subsurface tracer results are summarized first, followed by the surface tracer results.

The number and percentage of tracers moved at each study site are shown in Table 2 for the Upper Study Reach, and Table 3 for the Lower Study Reach. Appendix B provides greater detail on tracer gravel movement, indicating the number of particles that moved in each size class after each of the test flow releases, and the distances moved. Appendix B counts tracers in one of three categories; "Not Moved", "Moved", and "Not Recovered". The "Not Recovered" column includes those tracers unaccounted for because they were not recovered downstream and were not recovered in-place as part of the original installation. For purposes of calculating the percentage of tracers that had moved, these "Not Recovered" tracers are always assumed to have moved. However, it is possible that in many instances these tracers had simply been buried in-place, and therefore could not be found, but were not mobilized. Tracers that moved less than 1 ft were also included in the calculation of gravel movement. This could be considered an over-representation of the amount of true gravel movement. Many researchers allow for a small amount of movement in this type of study before it is characterized as gravel mobility. This is because tracers which are not naturally deposited by flow, and are placed by hand which automatically disturbs existing particles on the bed at that site, are more likely to be mobilized than an undisturbed site. Particles that moved less than 1 ft were tracked to make note of such instances where it may be relevant to interpretation of the overall results.

5.1.1 FLOW RELEASE 314 CFS (APRIL 27, 2005)

Upper Study Reach

- With the peak flow release of 314 cfs there was virtually no subsurface movement at any of the study sites.
- No surface tracers moved at Site 1 or Site 2.
- Site 3 and Site 5 had minimal movement (7 particles out of 52 and 1 particle out of 49, respectively). At Site 3, 13% of the surface tracers were mobilized.

Table 2. Tracer Gravel Mobility Results for Upper Study Reach[1]

	Total Installed Count[2]	314 cfs		481 cfs		794 cfs	
		Total Moved	% Moved	Total Moved	% Moved	Total Moved	% Moved
Site 1							
Surface	43	0	0%	15	35%	32	74%
Subsurface	29	0	0%	3	10%	19	66%
Site 2							
Surface	44	0	0%	0	0%	1	2%
Subsurface	32	0	0%	0	0%	0	0%
Site 3							
Surface	52	7	13%	7	13%	8	15%
Subsurface	33	0	0%	0	0%	0	0%
Site 4							
Surface	32	15	47%	5	16%	3	9%
No Subsurface	-	-	-	-	-	-	-
Site 5							
Surface	49	1	2%	0	0%	2	4%
Subsurface	30	0	0%	0	0%	0	0%
Site 6							
Surface	49	26	53%	20	43%	38	90%
Subsurface	30	1	3%	4	13%	8	27%

[1]Site 7 is not included in this table since this study site was used only to monitor the potential for gravels to be deposited behind boulders if they were introduced as part of a gravel augmentation program. The number of tracer particles moved at Site7 is shown in Appendix B.

[2] This is the originally installed total count prior to the first test flow release. The total tracer count following the first flow release may be reduced by any gravel particles that were transported but were not recovered (i.e., they were not replaced in order to restore the original total tracer count). The calculation of % Moved is based on the total tracer count at the beginning of each test flow release.

Table 3. Tracer Gravel Mobility Results for Lower Study Reach

	Total Installed Count[1]	314 cfs		481 cfs		794 cfs	
		Total Moved	% Moved	Total Moved	% Moved	Total Moved	% Moved
Site 1							
Surface	46	0	0%	0	0%	0	0%
Subsurface	33	0	0%	0	0%	0	0%
Site 2							
Surface	26	0	0%	0	0%	0	0%
Subsurface	25	0	0%	0	0%	0	0%
Site 3							
Surface	25	0	0%	0	0%	0	0%
Subsurface	13	0	0%	0	0%	0	0%
Site 4							
Surface	53	18	34%	21	40%	31	58%
Subsurface	22	3	14%	2	10%	6	27%
Site 5							
Surface	32	4	13%	1	3%	31	97%
Subsurface	18	0	0%	0	0%	16	89%

[1]This is the originally installed total count prior to the first test flow release. The total tracer count following the first flow release may be reduced by any gravel particles that were transported but were not recovered (i.e., they were not replaced in order to restore the original total tracer count). The calculation of % Moved is based on the total tracer count at the beginning of each test flow release.

- Substantial surface tracer movement was observed at Site 4 and Site 6. At Site 4, 47% of the tracers were mobilized. Site 6 (pocket gravel in lee of small boulder) had the most movement, 53% of the surface tracers (26 particles) were mobilized. It should be noted, however, that 6 of the 15 particles recovered downstream moved less than 1 ft.

- Site 7 was established to determine if gravels will migrate to lee of nearby boulders. At Site 7, 93% of the tracers (99 of 106) were mobilized. This was anticipated since the gravels were placed in the middle of a high gradient riffle with the intention of tracking downstream transport and deposition. None were observed to have moved into a position downstream of the nearby boulders. Most had moved less than 1 ft (34 particles), 12 had moved between 1-5 ft, 26 moved greater than 5 ft, and 27 particles were not recovered. The closest boulder is about 20 ft from the placement site. Most of the particles were found individually scattered, mixed into the interstitial spaces between large cobbles.

Lower Study Reach

- No subsurface tracer movement was observed at study sites 1, 2, 3, or 5.

- A modest amount of subsurface movement was observed at Site 4, with 14% of the gravels (3 particles) recovered less than 1 ft downstream.

- No surface tracer movement was observed at Sites 1, 2, or 3.

- Site 4 had the most movement, 34% of the surface tracers (18 particles out of 53).

- Site 5 had a modest amount of movement, 13% of the tracers (4 out of 32 particles).

5.1.2 Flow Release 481 cfs (April 28, 2005)

Upper Study Reach

- No subsurface tracer movement was observed at sites 2, 3, 5 (Site 4 has no subsurface tracers).

- A modest amount of movement was observed at Site 1 with 10% (3 particles) of the subsurface tracers moved and at Site 6, where 13% (4 particles) moved. This is an increase in movement compared with the 314 cfs test flow.

- No surface tracer movement was observed at Site 2 and Site 5.

- A modest amount of surface tracer movement was observed at Site 4 with 16% (5 particles out of 32) moving, which represents a decline in mobility compared with the test flow at 314cfs. A modest amount of movement was also observed at Site 3 with 13% (7 particles) moving; this is the same as under the 314 cfs test flow.

- Site 1 and 6 experienced a substantial amount of surface gravel mobilization. At Site 1, 35% (15 particles out of 43) of the tracers moved, which is a significant increase compared with the 314 cfs test flow. Of the 15 particles that moved at Site 1, six were in the less than 1 ft category (see Appendix B). At Site 6, 43% (20 out of 46 particles) moved. This is a small decline compared with the 314 cfs release.

- At Site 7, the tracers that had moved with the prior 314 cfs release were left where they were found in the channel. Upon field inspection, 63% of the 79 tracers (50 particles) that had been recovered after the 314 cfs release were recovered (out of the original placement of 106 particles). None of the tracers were identified in the lee of downstream boulders. As with the 314 cfs release, most particles were found mixed into the interstitial spaces with cobbles and small boulders.

<u>Lower Study Reach</u>

- No subsurface tracer movement was observed at sites 1, 2, 3, or 5. These were the same results as found during the 314 cfs test flow.

- A limited subsurface movement was observed at Site 4, with 10% (2 particles) moved. This is similar to the 314 cfs test flow.

- No surface tracer movement was observed at Sites 1, 2, or 3. This is the same result as during the 314 cfs release.

- A very limited amount of movement was observed at Site 5, with just 1 particle moved. This is a small decrease in mobility compared with the 314 cfs test release.

- At Site 4 substantial movement was observed with 40% (21 particles out of 53) of the surface tracers moved.

5.1.3 Flow Release 794 cfs (April 29, 2005)

<u>Upper Study Reach</u>

- No subsurface tracer movement was observed at Site 2, Site 3, or Site 5 (Site 4 had no subsurface tracers).

- Substantial subsurface tracer movement occurred at Site 1 and Site 6. At Site 1, 66% (19 particles out of 29) moved. Particles in all of the size classes installed moved, up to 45mm. At Site 6, 27% (8 out of 30 particles) moved. The largest particle size moved was 32mm (up to 45mm sizes were installed).

- All sites showed at least a minimal amount of surface tracer movement.

- Very limited surface tracer gravel movement occurred at Sites 2, 4, and 5. At Site 2, 2% percent (1 particle) of the tracers moved. At Site 4, 9% (3 particles) moved, with two of those tracers moving less than 1 ft. At Site 5, 4% (2 particles) moved, with one of those particles moving less than 1 ft.

- A modest amount of surface tracer movement occurred at Site 3, with 15% (8 particles out of 52) moving. This is a slight increase from results at 481 cfs release.
- Substantial movement occurred at Site 1 and Site 6. At Site 1, 74% (32 out of 43 particles) of the tracers moved. All gravel sizes emplaced were mobilized, up to 45mm. At Site 6, 90% (38 out of 42) of the tracers moved. Of the 38 particles moving, 19 traveled greater than 5 ft, and 16 were not recovered (see Appendix B). Particle sizes up to 45mm, the largest size installed, were mobilized.
- At Site 7, the tracers that had moved with the prior 481 cfs release were left where they were found in the channel. Upon field inspection after the 794 cfs release, 70% were recovered (35 particles) of the 50 tracers that had been recovered after the 481 cfs release. None of the tracers were identified in the lee of downstream boulders. As with the 481 cfs release, most particles were found mixed into the interstitial spaces with cobbles and small boulders.

Lower Study Reach

- No subsurface gravel movement occurred at Sites 1, 2, or 3. This continues the same trend of no subsurface scour at these sites with the lower test flows.
- Substantial subsurface gravel movement occurred at Site 4 and Site 5, with 27% and 89% of subsurface tracers moving, respectively (see Table 3).
- No surface gravel movement was observed at Sites 1, 2, or 3. This continues the same trend of no surface scour at these sites with the lower test flows.
- Substantial surface gravel movement occurred at Site 4 and Site 5, with 58% and 97% of the tracers moving, respectively. This is an increase in mobility compared with the 481 cfs test flow.

5.2 WATER SURFACE ELEVATION RESULTS

Photographs of water surface elevation conditions in the two study reaches during each of the test flow releases are shown in Appendix C. There were no study plans to survey water surface elevations relative to fixed landmarks, therefore, there are no other water surface elevation data to show river stage other than the photographs.

Based on field observations and the photographic record, the 314 cfs release was at an elevation approximately within the range of rooted riparian willows growing along the perimeter of the bars, but the bars were not fully inundated. Flow was just beginning to enter into the cut-off chute channels on the inside of some bars. The 481 cfs flow was well above the willow vegetation on the bar perimeter, and flow was cutting across the inside chute channel of most of the bars. The 794 cfs flow nearly inundated all bars at both monitoring sites.

6.0 CONCLUSIONS

The study conclusions are presented below. Gravel mobility is discussed first followed by a discussion of water surface elevations and conclusions regarding gravel transport and deposition.

6.1 GRAVEL MOBILITY

6.1.1 LOWER STUDY REACH

In the Lower Study Reach, tracer Sites 1, 2, and 3 were stable during all three test flow releases, with virtually no surface or subsurface gravel transport. All three sites are in a side channel along the right bank that is divided from the main flow by a well-vegetated mid-channel bar. The channel geometry provides shelter from high-velocity flows, and is an excellent depositional area for gravel size material, which are plentiful in this side channel.

Site 5, located in the main channel, was mostly stable for surface gravels at the 314 cfs and 481 cfs test flows, with a limited amount of mobility. Subsurface gravels remained quite stable with these test flows. A substantial amount of surface and subsurface gravel movement was observed (>25% of the installed tracers) with the 794 cfs test flow.

A substantial amount of surface gravel movement occurred at Site 4 (main channel) with all three test flows. Subsurface gravel movement was limited with the 314 cfs and 481 cfs test flows, but substantially increased at 794 cfs.

The data show that there was at least some surface gravel movement in the main channel during the 314 cfs and 481 cfs test flows, but subsurface gravels were quite stable. Both surface and subsurface gravel transport increased dramatically at the 794 cfs test flow, with most of the full range of tracer particle sizes becoming mobile, indicating that the main channel bed was subject to some scour.

6.1.2 UPPER STUDY REACH

In the Upper Study Reach, the 314 cfs test release caused virtually no surface gravel movement at Sites 1, 2 and 5; a modest amount of movement at Site 3; and substantial movement at Sites 4 and 6. Almost no subsurface tracer gravel movement was observed at any of the six tracer sites.

Comparing the results from the 314 cfs and 481 cfs test flows, several of the individual study sites did not perform consistently (i.e., gravel mobility decreased at some sites, increased at other sites, and remained the same at a couple of sites), but overall there was about the same amount of gravel mobility. No change in surface gravel mobility at Site 2 or Site 3 was observed, and a small decrease in mobility at Site 5 and Site 6. Surface tracer gravels at Sites 2 and 5 remained very stable. There was a dramatic increase in mobility at Site 1, but also a large decrease in mobility at Site 4. The reduced mobility of surface tracers recorded at Site 4, 5, and 6 with the 481 cfs release is not unusual. This is because bedload movement can be largely random when the transport threshold for most bed particle sizes has not been exceeded and only very limited or partial transport is occurring. In addition, tracer gravels tend to "settle" into their hand-placed positions on the bed after the first high flow release, so that they may be more stable during subsequent high flows.

Subsurface gravel movement increased slightly with the 481 cfs release (Sites 1 and 6), but none of the sites indicated substantial scour, with no subsurface scour at sites 2, 3, and 5.

Surface and subsurface transport increased dramatically with the 794 cfs test release, with substantial surface movement and subsurface scour at Sites 1 and 6. Sites 2, 3, and 5 did not show evidence of subsurface scour (no subsurface tracers were installed at Site 4), and small to moderate transport of surface tracer gravels.

Considering all of the study sites in the two monitoring reaches, the 794 cfs test flow release clearly caused a dramatic increase in both surface and subsurface tracer gravel transport. Had the test flows been of a much longer duration (e.g., several days), nearly complete mobility of all particle sizes at 4 of the 11 study sites could be expected, and likely greater surface gravel transport for at least one other tracer study site could be expected.

Substantial subsurface tracer gravel movement did not occur with either the 314 cfs or 481 cfs test flows at any of the study sites. There were three sites with substantial surface gravel movement at the 341 cfs test flow, and also 3 sites with substantial surface movement at the 481 cfs test flow, out of the total 11 study sites.

Flows of approximately 500 cfs would cause limited movement of surface bed material, indicative of partial bed transport, but would not scour the streambed. Therefore, 500 cfs can be safely routed through North Fork Stevenson Creek without disturbing the structure of trout redds in the two study reaches. This is probably a conservative flow magnitude from the point of view of protecting spawning gravels. It is not known at what discharge greater than 500 cfs subsurface scour begins to occur, but on the basis of this study approximately 800 cfs will cause scour to a depth which would disrupt redds, at least at some sites.

6.2 WATER SURFACE ELEVATION

At approximately 300 cfs the water surface elevation is at or above most of the rooted willows along the bar perimeter. At 480 cfs, flow is well above the elevation of rooted willows, is inundating a portion of most bars, and is cutting across the inside chute channels of most bars. At 794 cfs, flow nearly completely inundates the entire bar surface.

6.3 GRAVEL TRANSPORT AND DEPOSITION

Site 7 tracers in the Upper study site were installed specifically to monitor transport and the potential for deposition behind boulders, as might occur as part of a gravel augmentation program. Gravel movement was tracked in order to see if they would be deposited as pockets near downstream boulders. This site was not used to determine the mobility of gravels typical of a spawning site. Many of the tracer gravels were mobilized during the first 314 cfs test release and almost all had been mobilized during the subsequent flow releases.

Although many tracers had been transported as far downstream as the first boulder site (approximately 20 ft), no tracer particles were found to be deposited in the lee of this boulder. No particles were found to be deposited in the lee of the second boulder, about 50 ft downstream. It was unclear whether or not some tracers had migrated this far downstream after the last test flow release. Only about 1/3 of the tracers were recovered following the 794 cfs release; the remainder was not recovered. Of the recovered gravels, it was found that almost all had been scattered into the interstitial spaces of cobbles in the bed, and some were found with a layer of sand covering the top of the tracer particle. Based on this study, it cannot be conclusively determined whether or not a gravel augmentation program would result in gravel deposition at locations such as in the lee of boulders. A much larger amount of gravel would be used for augmentation purposes than the 106 tracer particles used in this study. Accordingly, the results could be very different when a large volume of gravel is installed. However, there appears to be a tendency for gravels to be quickly dispersed and deposited in locations such as cobble interstitial spaces where they will not provide suitable spawning habitat.

FIGURES

Placeholder for Figure 1

Non-Internet Public Information

This Figure has been removed in accordance with the Commission regulations at 18 CFR Section 388.112.

This Figure is considered Non-Internet Public information and should not be posted on the Internet. This information is provided in Volume 4 of the Application for New License and is identified as "Non-Internet Public" information. This information may be accessed from the FERC's Public Reference Room, but is not expected to be posted on the Commission's electronic library, except as an indexed item.

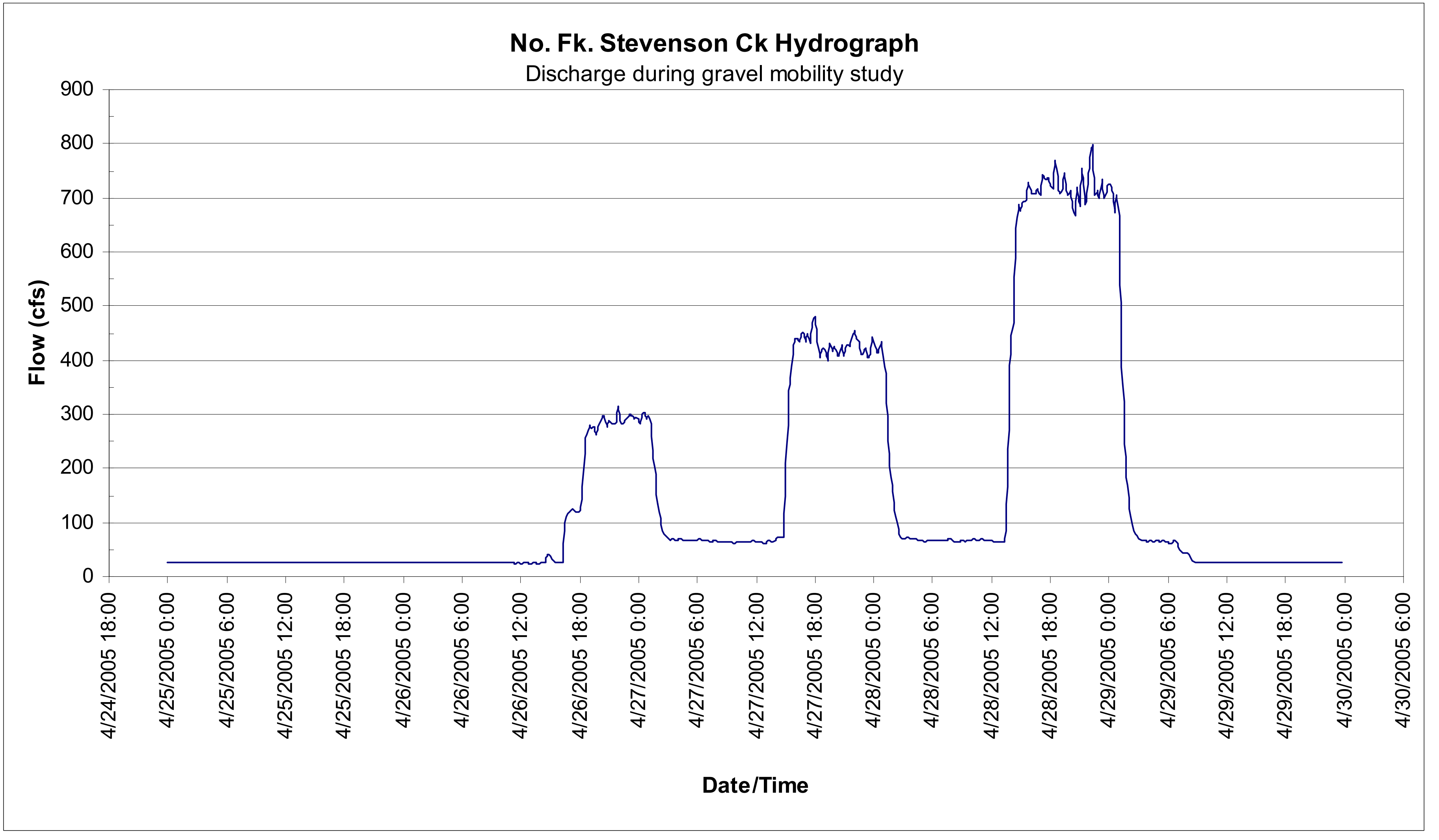

Figure 2. Hydrograph for North Fork Stevenson Creek During Gravel Mobility Study.

APPENDIX A

TRACER GRAVEL PHOTOGRAPHS

Photo 1. Upper Study Reach Site 1 following 314 cfs release.

Photo 2. Upper Study Reach Site 2 following 314 cfs release.

Photo 3. Upper Study Reach Site 3 at pool tailout following installation.

Photo 4. Upper Study Reach Site 4 (white line of tracers) near top of riffle. Site 3 (red tracers) is just to the left of Site 4 in the pool tail-out. Flow is from photograph left to right.

Photo 5. Upper Study Site 5 following installation. Surface and subsurface gravels are about 10 ft downstream from a boulder (not visible) that create a velocity shadow. Flow is from the bottom right corner of photograph to the upper left corner.

Photo 6. Upper Study Site 6, white tracer gravels in lee of small boulder (center of photograph) following installation. Flow is from left to right (camera view is perpendicular to flow direction).

Photo 7. Upper Study Site 7 on high gradient riffle. Two white "patches" visible on the left of the photograph indicate the tracer gravels placed on the bed to track movement downstream toward the small boulder about 20 ft downstream, and the boulders visible in the center of the channel, about 50 ft downstream.

Photo 8. Lower Study Site 1. Side channel separated from the main channel by a well-vegetated bar (right). Tracers are arrayed in a cross-section line (view upstream - flow toward bottom of photograph).

Photo 9. Lower Study Site 2 (red tracers) and Site 3 (yellow tracers). Downstream portion of the side channel (view upstream).

Photo 10. Lower Study Site 4. The tracers are arrayed in a cross-section line at the riffle crest (view upstream).

Photo 11. Lower Study Site 5. Main channel (view upstream).

APPENDIX B

TRACER GRAVEL RESULTS

LOWER REACH 314 cfs

SURFACE

SITE: 1

Size (mm):	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft	
128						
90						
64	4	4				
45	16	16				
32	17	17				
22.5	8	8				
16	1	1				
11.2						
TOTAL	**46**	**46**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SITE: 2

Size (mm):	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft	
128						
90						
64						
45	4	4				
32	7	7				
22.5	10	10				
16	5	5				
11.2						
TOTAL	**26**	**26**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SITE: 3

Size (mm):	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft	
128						
90						
64						
45	3	3				
32	11	11				
22.5	6	6				
16	5	5				
11.2						
TOTAL	**25**	**25**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SUBSURFACE

SITE: 1

Size (mm):	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft	
128						
90						
64						
45	5	5				
32	10	10				
22.5	10	10				
16	8	8				
11.2						
TOTAL	**33**	**33**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SITE: 2

Size (mm):	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft	
128						
90						
64						
45	4	4				
32	8	8				
22.5	6	6				
16	7	7				
11.2						
TOTAL	**25**	**25**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SITE: 3

Size (mm):	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft	
128						
90						
64						
45	1	1				
32	3	3				
22.5	9	9				
16						
11.2						
TOTAL	**13**	**13**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

Tracer Gravel Mobility Results for Lower Reach at 314 cfs (Sites 1, 2 and 3).

LOWER REACH 314 cfs

SURFACE

	SITE: 4						SITE: 5					
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128												
90												
64	3	1	2									
45	4	4					3			3		
32	12	8		3	1		11	10		1		
22.5	23	16	1	4	2		11	11				
16	11	6		2	3		7	7				
11.2												
TOTAL	**53**	**35**	**3**	**9**	**6**	**0**	**32**	**28**	**0**	**4**	**0**	**0**
Total Moved and %:					**18**	**34%**					**4**	**13%**

SUBSURFACE

	SITE: 4						SITE: 5					
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128												
90												
64	1	1										
45	5	3	2				1	1				
32	4	4					5	5				
22.5	7	7					7	7				
16	5	4	1				5	5				
11.2												
TOTAL	**22**	**19**	**3**	**0**	**0**	**0**	**18**	**18**	**0**	**0**	**0**	**0**
Total Moved and %:					**3**	**14%**					**0**	**0%**

Tracer Gravel Mobility Results for Lower Reach at 314 cfs (Sites 4 and 5).

LOWER REACH 481 cfs

SURFACE

	SITE: 1						SITE: 2						SITE: 3					
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128																		
90																		
64	4	4																
45	16	16					4	4					3	3				
32	17	17					7	7					11	11				
22.5	8	8					10	10					6	6				
16	1	1					5	5					5	5				
11.2																		
TOTAL	**46**	**46**	**0**	**0**	**0**	**0**	**26**	**26**	**0**	**0**	**0**	**0**	**25**	**25**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**					**0**	**0%**					**0**	**0%**

SUBSURFACE

	SITE: 1						SITE: 2						SITE: 3					
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128																		
90																		
64																		
45	5	5					4	4					1	1				
32	10	10					8	8					3	3				
22.5	10	10					6	6					9	9				
16	8	8					7	7										
11.2																		
TOTAL	**33**	**33**	**0**	**0**	**0**	**0**	**25**	**25**	**0**	**0**	**0**	**0**	**13**	**13**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**					**0**	**0%**					**0**	**0%**

Tracer Gravel Mobility Results for Lower Reach at 481 cfs (Sites 1, 2 and 3).

LOWER REACH 481 cfs

SURFACE

	SITE: 4						SITE: 5					
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128												
90												
64	3	2			1							
45	4	2	2				3	3				
32	12	6	2	3	1		11	11				
22.5	23	16	1	2	4		11	11				
16	11	6		4	1		7	6				1
11.2												
TOTAL	**53**	**32**	**5**	**9**	**7**	**0**	**32**	**31**	**0**	**0**	**0**	**1**
Total Moved and %:					**21**	**40%**					**1**	**3%**

SUBSURFACE

	SITE: 4						SITE: 5					
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128												
90												
64	1	1										
45	5	5					1	1				
32	4	4					5	5				
22.5	7	5		1	1		7	7				
16	5	5					5	5				
11.2												
TOTAL	**22**	**20**	**0**	**1**	**1**	**0**	**18**	**18**	**0**	**0**	**0**	**0**
Total Moved and %:					**2**	**9%**					**0**	**0%**

Tracer Gravel Mobility Results for Lower Reach at 481 cfs (Sites 4 and 5).

LOWER REACH 794 cfs

SURFACE

	SITE: 1						SITE: 2						SITE: 3					
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128																		
90																		
64	4	4																
45	16	16					4	4					3	3				
32	17	17					7	7					11	11				
22.5	8	8					10	10					6	6				
16	1	1					5	5					5	5				
11.2																		
TOTAL	**46**	**46**	**0**	**0**	**0**	**0**	**26**	**26**	**0**	**0**	**0**	**0**	**25**	**25**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**					**0**	**0%**					**0**	**0%**

SUBSURFACE

	SITE: 1						SITE: 2						SITE: 3					
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128																		
90																		
64																		
45	5	5					4	4					1	1				
32	10	10					8	8					3	3				
22.5	10	10					6	6					9	9				
16	8	8					7	7										
11.2																		
TOTAL	**33**	**33**	**0**	**0**	**0**	**0**	**25**	**25**	**0**	**0**	**0**	**0**	**13**	**13**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**					**0**	**0%**					**0**	**0%**

Tracer Gravel Mobility Results for Lower Reach at 794 cfs (Sites 1, 2 and 3).

LOWER REACH 794 cfs

SURFACE

	SITE: 4						SITE: 5					
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128												
90												
64	3	2		1								
45	4	2		1	1		3			2		1
32	12	5		3	4		11	1		3	7	
22.5	23	7		5	11		11			5	5	1
16	11	6		2	3		7		1	1	2	3
11.2												
TOTAL	**53**	**22**	**0**	**12**	**19**	**0**	**32**	**1**	**1**	**11**	**14**	**5**
Total Moved and %:					**31**	**58%**					**31**	**97%**

SUBSURFACE

	SITE: 4						SITE: 5					
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128												
90												
64	1	1										
45	5	4			1		1			1		
32	4	3		1			5	1		3	1	
22.5	7	4		2	1		7	1		3	2	1
16	5	4	1				5		2	1	2	
11.2												
TOTAL	**22**	**16**	**1**	**3**	**2**	**0**	**18**	**2**	**2**	**8**	**5**	**1**
Total Moved and %:					**6**	**27%**					**16**	**89%**

Tracer Gravel Mobility Results for Lower Reach at 794 cfs (Sites 4 and 5).

UPPER REACH 314 cfs

SURFACE

SITE: 1

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90						
64						
45	7	7				
32	9	9				
22.5	15	15				
16	12	12				
11.2						
TOTAL	**43**	**43**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SITE: 2

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90						
64	2	2				
45	5	5				
32	12	12				
22.5	15	15				
16	10	10				
11.2						
TOTAL	**44**	**44**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SITE: 3

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90	1	1				
64	2	2				
45	7	7				
32	14	14				
22.5	17	13		4		
16	11	8	1	1	1	
11.2						
TOTAL	**52**	**45**	**1**	**5**	**1**	**0**
Total Moved and %:					**7**	**13%**

SITE: 4

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90	2	2				
64	6	5	1			
45	5	2	1	2		
32	10	4	2	3	1	
22.5	9	4	2	2	1	
16						
11.2						
TOTAL	**32**	**17**	**6**	**7**	**2**	**0**
Total Moved and %:					**15**	**47%**

SUBSURFACE

SITE: 1

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90						
64						
45	3	3				
32	10	10				
22.5	11	11				
16	5	5				
11.2						
TOTAL	**29**	**29**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SITE: 2

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90						
64						
45	3	3				
32	10	10				
22.5	11	11				
16	8	8				
11.2						
TOTAL	**32**	**32**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SITE: 3

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90						
64						
45	3	3				
32	10	10				
22.5	10	10				
16	10	10				
11.2						
TOTAL	**33**	**33**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

Tracer Gravel Mobility Results for Upper Reach at 314 cfs (Sites 1, 2, 3 and 4).

UPPER REACH 314 cfs

SURFACE

	SITE: 5						SITE: 6						SITE: 7					
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128																		
90																		
64	2	2											3		2		1	
45	8	8					5	4				1	29	5	5	2	9	8
32	15	14				1	22	12		9	1		33	1	17	4	11	
22.5	20	20					18	6		11		1	31	1	9	5	3	13
16	4	4					4	1		1	1	1	10		1	1	2	6
11.2																		
TOTAL	**49**	**48**	**0**	**0**	**0**	**1**	**49**	**23**	**0**	**21**	**2**	**3**	**106**	**7**	**34**	**12**	**26**	**27**
Total Moved and %:					**1**	**2%**					**26**	**53%**					**99**	**93%**

SUBSURFACE

	SITE: 5						SITE: 6						SITE: 7 No Subsurface					
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128																		
90																		
64																		
45	6	6					3	3										
32	10	10					10	10										
22.5	10	10					11	10		1								
16	4	4					6	6										
11.2																		
TOTAL	**30**	**30**	**0**	**0**	**0**	**0**	**30**	**29**	**0**	**1**	**0**	**0**						
Total Moved and %:					**0**	**0%**					**1**	**3%**						

Tracer Gravel Mobility Results for Upper Reach at 314 cfs (Sites 5, 6 and 7).

UPPER REACH 481 cfs

SURFACE

SITE: 1

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90						
64						
45	7	7				
32	9	5	4			
22.5	15	9	2	3	1	
16	12	7		3	2	
11.2						
TOTAL	**43**	**28**	**6**	**6**	**3**	**0**
Total Moved and %:					**15**	**35%**

SITE: 2

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90						
64	2	2				
45	5	5				
32	12	12				
22.5	15	15				
16	10	10				
11.2						
TOTAL	**44**	**44**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SITE: 3

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90	1	1				
64	2	2				
45	7	5	2			
32	14	13	1			
22.5	17	14		3		
16	11	10		1		
11.2						
TOTAL	**52**	**45**	**3**	**4**	**0**	**0**
Total Moved and %:					**7**	**13%**

SITE: 4

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90	2	2				
64	6	5		1		
45	5	1	1	3		
32	10	10				
22.5	9	9				
16						
11.2						
TOTAL	**32**	**27**	**1**	**4**	**0**	**0**
Total Moved and %:					**5**	**16%**

SUBSURFACE

SITE: 1

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90						
64						
45	3	3				
32	10	10				
22.5	11	9		2		
16	5	4		1		
11.2						
TOTAL	**29**	**26**	**0**	**3**	**0**	**0**
Total Moved and %:					**3**	**10%**

SITE: 2

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90						
64						
45	3	3				
32	10	10				
22.5	11	11				
16	8	8				
11.2						
TOTAL	**32**	**32**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SITE: 3

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90						
64						
45	3	3				
32	10	10				
22.5	10	10				
16	10	10				
11.2						
TOTAL	**33**	**33**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SITE: 4 No Subsurface

Size (mm):	Initial Count	Not Moved	Moved ≤ 1 ft	Moved 1-5 ft	Moved > 5 ft	Not Recovered
128						
90						
64						
45						
32						
22.5						
16						
11.2						
TOTAL						

Tracer Gravel Mobility Results for Upper Reach at 481 cfs (Sites 1, 2, 3 and 4).

UPPER REACH 481 cfs

SURFACE

SITE: 5

Size (mm):	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft	
128						
90						
64	2	2				
45	8	8				
32	14	14				
22.5	20	20				
16	4	4				
11.2						
TOTAL	**48**	**48**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SITE: 6

Size (mm):	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft	
128						
90						
64						
45	4	3		1		
32	22	13			8	
22.5	17	9	1	2	2	
16	3	1		1	1	
11.2						
TOTAL	**46**	**26**	**1**	**4**	**11**	**4**
Total Moved and %:					**20**	**43%**

SITE: 7 **Not Applicable**

Size (mm):	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft	
128						
90						
64	3					
45	29					
32	33					
22.5	31					
16	10					
11.2						
TOTAL	**106**					
Total Moved and %:						

SUBSURFACE

SITE: 5

Size (mm):	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft	
128						
90						
64						
45	6	6				
32	10	10				
22.5	10	10				
16	4	4				
11.2						
TOTAL	**30**	**30**	**0**	**0**	**0**	**0**
Total Moved and %:					**0**	**0%**

SITE: 6

Size (mm):	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft	
128						
90						
64						
45	3	2			1	
32	10	9			1	
22.5	11	11				
16	6	4	1	1		
11.2						
TOTAL	**30**	**26**	**1**	**1**	**2**	**0**
Total Moved and %:					**4**	**13%**

SITE: 7 **Not Applicable**

Size (mm):	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft	
128						
90						
64						
45						
32						
22.5						
16						
11.2						
TOTAL						

Tracer Gravel Mobility Results for Upper Reach at 481 cfs (Sites 5, 6 and 7).

UPPER REACH 794 cfs

SURFACE

	SITE: 1						SITE: 2						SITE: 3						SITE: 4					
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128																								
90													1	1					2	2				
64							2	2					2	2					6	4				
45	7	3	2	2			5	5					7	5	1	1			5	7				
32	9	3	3	3			12	11				1	14	13		1			10	8	1	1		
22.5	15	4	2	8	1		15	15					17	13		4			9	8	1			
16	12	1	3	7	1		10	10					11	10			1							
11.2																								
TOTAL	**43**	**11**	**10**	**20**	**2**	**0**	**44**	**43**	**0**	**0**	**0**	**1**	**52**	**44**	**1**	**6**	**1**	**0**	**32**	**29**	**2**	**1**	**0**	**0**
Total Moved and %:					**32**	**74%**					**1**	**2%**					**8**	**15%**					**3**	**9%**

SUBSURFACE

	SITE: 1						SITE: 2						SITE: 3						SITE: 4		No Subsurface			
Size (mm):	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered	Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128																								
90																								
64																								
45	3	2		1			3	3					3	3										
32	10	4	1	4			10	10					10	10										
22.5	11	4	2	5	1		11	11					10	10										
16	5		1	3		1	8	8					10	10										
11.2																								
TOTAL	**29**	**10**	**4**	**13**	**1**	**1**	**32**	**32**	**0**	**0**	**0**	**0**	**33**	**33**	**0**	**0**	**0**	**0**						
Total Moved and %:					**19**	**66%**					**0**	**0%**					**0**	**0%**						

Tracer Gravel Mobility Results for Upper Reach at 794 cfs (Sites 1, 2, 3 and 4).

UPPER REACH 794 cfs

SURFACE

Size (mm):	SITE: 5 Initial Count	Not Moved	Moved			Not Recovered	SITE: 6 Initial Count	Not Moved	Moved			Not Recovered	SITE: 7 Not Applicable Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128																		
90																		
64	2	2											3					
45	8	8					4	1			3		29					
32	15	13	1			1	21	2		2	14		33					
22.5	20	20					14	1		1	2		31					
16	4	4					3	0					10					
11.2																		
TOTAL	**49**	**47**	**1**	**0**	**0**	**1**	**42**	**4**	**0**	**3**	**19**	**16**	**106**					
Total Moved and %:					**2**	**4%**					**38**	**90%**						

SUBSURFACE

Size (mm):	SITE: 5 Initial Count	Not Moved	Moved			Not Recovered	SITE: 6 Initial Count	Not Moved	Moved			Not Recovered	SITE: 7 Not Applicable Initial Count	Not Moved	Moved			Not Recovered
			≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft				≤ 1 ft	1-5 ft	> 5 ft	
128																		
90																		
64																		
45	6	6					3	3										
32	10	10					10	8		1	1							
22.5	10	10					11	9				2						
16	4	4					6	2				4						
11.2																		
TOTAL	**30**	**30**	**0**	**0**	**0**	**0**	**30**	**22**	**0**	**1**	**1**	**6**						
Total Moved and %:					**0**	**0%**					**8**	**27%**						

Tracer Gravel Mobility Results for Upper Reach at 794 cfs (Sites 5, 6 and 7).

APPENDIX C

WATER SURFACE ELEVATION PHOTOGRAPHS

Photo C-1. Water surface elevation at Site 1, Lower Study Site, during 314 cfs flow release. Wood stake near bottom center of photograph marks the river stage, which is slightly below the rooted elevation of nearby willows.

Photo C-2. Water surface elevation at Site 1, Lower Study Site, during 481 cfs flow release. Wood stake with pink flagging marks the water surface elevation.

Photo C-3. Water surface elevation at Site 1, Lower Study Site, during 794 cfs flow release. Wood stake at bottom of photograph marks the river stage.

Photo C-4. Water surface elevation at Site 2, Lower Study Site, during 314 cfs flow release. Wood stake with red flagging in lower center of photograph marks the river stage. Note that willow roots are inundated.

Photo C-5. Water surface elevation at Site 2, Lower Study Site, during 481 cfs flow release. Wood stake in lower center of photograph marks the river stage, which is well above many of the willows.

Photo C-6. Water surface elevation at Site 2, Lower Study Site, during 794 cfs flow release. Wood stake marks the water surface elevation.

Photo C-7. Water surface elevation at Site 1, Upper Study Site, during 300 cfs flow release.

Photo C-8. Water surface elevation at Site 1, Upper Study Site, during 481 cfs flow release. Wood stake in snow marks the water surface elevation (flow has undercut snow bank on bar, not visible in photograph). Note the water surface elevation is well above the existing line of willows at edge of bar.

Photo C-9. Water surface elevation at Site 2, Upper Study Site, during 314 cfs flow release. Note that flow is just above the existing willow rooting elevation.

Photo C-10. Water surface elevation at Site 2, Upper Study Site, during 481 cfs flow release. The band of willows near the top of the photograph is at the edge of the bar next to the thalweg. The small island with a willow in the center of the photograph is well up onto the bar. Flow is breaking out onto and over the bar at various locations.

Photo C-11. Water surface elevation at Site 2, Upper Study Site, during 794 cfs flow release. Nearly the entire bar (not all of the bar is visible in photograph) is inundated. The thalweg is behind the band of willows near the top of the photograph.