U.S. Army Corps of Engineers
Seattle District

Water Year 2004 Monitoring Report
Howard Hanson Dam Additional Water Storage Project
Zone 1 Fish Habitat Restoration Project
Green River, Washington

June 2005

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Additional Water Storage Project
Zone 1 Fish Habitat Restoration Project

King County, WA

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1. INTRODUCTION

The U.S. Army Corps of Engineers, Seattle District (Corps) and the City of Tacoma (Tacoma) are currently implementing Phase I of the Howard Hanson Dam (HHD) Additional Water Storage Project (AWSP). The AWSP is a dual purpose water supply and ecosystem restoration project authorized in the Water Resources Development Act of 1999. Funds were first appropriated for construction in 2002. Phase 1 of the AWSP includes additional water storage behind HHD to 1167 ft for municipal and industrial purposes and construction of a suite of habitat restoration and mitigation projects (USACE 1998). The mitigation projects are required to offset impacts to habitat caused by the additional water storage and larger reservoir.

Three of the AWSP habitat projects are located in the middle Green River immediately downstream of HHD. They include:

- Annual gravel nourishment of the Green River below HHD.
- Placement in the lower river of approximately 50% of large wood debris (LWD) and 50-70 tons of small wood debris (SWD) that collects behind HHD each year. This is referred to as ‘loose’ wood.
- Construction of two engineered log jams (ELJs) in the Green River below HHD.

Gravel nourishment and ‘loose’ wood are considered AWSP restoration projects. Log jams are considered AWSP mitigation projects.

The general objective of these projects is to restore in part the natural processes that have been disrupted by HHD. The dam and reservoir currently trap 100% of gravel and wood that reaches the dam. Consequently, downstream reaches have become gravel and wood ‘starved’, resulting in an armoring of the streambed and decrease in habitat complexity that adversely affects fish spawning and rearing (Perkins 1999, Kerwin and Nelson 2000). This condition has progressively worsened since dam completion in 1962.

In 1999, Puget Sound Chinook salmon and bull trout were each listed as threatened under the Endangered Species Act (ESA) (64 FR 14308, 64 FR 58910). As a result the Corps was required to consult with NOAA Fisheries and U.S. Fish and Wildlife Service to ensure that HHD operations including the AWSP did not jeopardize Chinook salmon or bull trout. The resulting biological opinions (Bi-op) identified several reasonable and prudent measures including gravel nourishment, wood transport around the dam, and log jam construction that are necessary and appropriate to minimize take under the ESA (NOAA 2000, USFWS 2000).

1.1. Project Description and Location

In order to meet objectives of the AWSP habitat projects described above and ESA requirements, the Corps constructed the zone 1 fish habitat restoration project in 2003. The zone 1 project is located at RM 60 of the Green River, three miles upstream from Kanaskat-Palmer State Park, and 4.5 miles downstream from HHD. The project included construction of two ELJs and two gravel nourishment berms. The log jams contained 81 and 88 logs each and are designed to be stable to the 100-year flood. The gravel berms were constructed with spawning size gravel 0.5 – 4 inches in diameter below ordinary high water.

The gravel berms were designed to erode over the winter during high flows. They will be re-constructed each August. The initial AWSP project goal was 3,900 cubic yards of spawning size gravel to be placed annually. As a result of the ESA consultation, the gravel restoration project was expanded to include up to an additional 8,000 cubic yards for a potential maximum of 12,000 cubic yards placed annually in the Green River. Monitoring data will determine the actual amount of gravel placed to ensure that project objectives are met and potential adverse effects minimized. Additional project details can be found in the project construction report (USACE 2003a). Figure 1 illustrates the constructed project in 2003.

Transport of wood debris around the dam and placement on the gravel berms was implemented in 2004. A total of 3 pieces of LWD approximately 24 inches in diameter and 25-30 ft long were placed on the upstream gravel berm. Annual decisions regarding transport of wood around the dam will be dependent on the amount of wood received at the reservoir over the previous year, mobilization and effectiveness of wood placed at RM 60, and the need for wood at other habitat projects. This decision process will be adaptive and based on discussions with stakeholders.

All three of these projects were designed and constructed in concert to achieve certain synergies between the individual habitat projects. For example, it was recognized that the log jams would effectively sort and store gravel from the nourishment berms creating salmonid spawning habitat.

General Project Objectives

Gravel nourishment:

- Increase available spawning opportunities in the middle Green River for Chinook salmon, coho salmon, and steelhead trout.
- Reconnect side channel and floodplain habitat.
- Reverse streambed armoring in the middle Green River.
- Restore the natural gravel transport process interrupted by HHD.

'Loose' wood:

- Increase habitat complexity and LWD in the middle Green River.
- Increase the amount of riverine pool area in the middle Green River.
- Increase cover habitat for salmonids.
- Create conditions for local gravel storage.
- Restore the natural wood transport process interrupted by HHD.

Log jams:

- Provide cover for both adult and juvenile salmonids.
- Provide rearing habitat for juvenile salmonids.
- Create riverine pool habitat.
- Sort and store gravel to create salmonid spawning habitat.
- Increase flow to the left bank side channel immediately downstream of the log jams.

Specific design criteria can be found in sections 3.2 for the gravel project and section 4.1 for the log jams.

Figure 1. Post construction aerial photo of constructed gravel berms and log jams at RM 60 of the Green River, 21 September 2003.

1.2. Monitoring Plan Overview

The project is designed to be adaptively managed so that monitoring data will determine whether project modifications or maintenance is required. The first five years of gravel nourishment will be intensively monitored to determine gravel transport rates, effective loading quantities, optimal size specifications, and general project effectiveness. The Corps plans to experiment with gravel quantities and sizes in order to better understand gravel transport in the middle Green River and to determine the most effective loading strategy. The data collected during this five year pilot period will provide the background for management of the 50 year project. Periodic monitoring will still be required after this five year period to adaptively manage the project and ensure that objectives are met. A GIS database has been developed that will become the repository for collected data and a tool for project analysis.

The log jams and 'loose' wood project will also be monitored during this period to ensure that objectives are being achieved. A detailed monitoring schedule is outlined in Table 1. Additional detail including methodology can be found in the project monitoring plan (USACE 2003b).

Specific monitoring questions include:

Gravel

- Are gravel berms effectively providing spawning gravels to the river each year?
- What is the rate of gravel transport through the reach? How does gravel size affect transport?
- How is substrate composition changing downstream?
- What is the effect of gravel nourishment on Chinook salmon and steelhead trout spawning?

Log jams

- Are log jams stable?
- Is flow being directed into the side channel?
- Do log jams create pool and cover habitat for fish? Are fish using the habitat?

Geomorphology

- Is there any change in channel morphology?
- Is there a change in water surface elevation?
- Is there any channel migration?
- Is there localized storage of spawning gravel?

Downstream habitat and loose LWD

- How has ‘loose’ LWD and gravel affected habitat in the middle Green River?
- Is there an increase in number of pools?
- Is there an increase in LWD?
- Is there increased side channel habitat available to fish?

This monitoring report covers the 2004 water year which is from fall 2003 to fall 2004. It includes data collected from post-high flow site visits in 2003 and 2004, annual gravel monitoring in summer 2004, and Chinook spawner surveys in fall 2004. Due to the timing of Chinook spawning in the early fall, this species will typically use gravels that were eroded the previous winter. For example, gravel placed in any given year will typically erode in the November-December period, and subsequently be available for Chinook spawning the following September – October. Monitoring data for Chinook salmon spawning therefore indicates use of gravels eroded during the previous year.

This report contains limited data regarding ‘loose wood’ placement. This project was implemented in 2004 with transport and placement of 3 LWD at RM 60. Figure 19 indicates the location of these LWD at the time of the Chinook spawner survey. Separate annual monitoring reports will be produced in future years that describe the downstream movement of ‘loose wood’ placed in the river for this project.

Table 1. Monitoring Schedule.

	Methods	Year 0 WY 2003	Year 1 WY 2004	Year 2 WY 2005	Year 3 WY 2006	Year 4 WY 2007	Year 5 WY 2008
1. Gravel Nourishment							
1.1 Gravel Transport							
1.1.1 Gravel Berm Erosion and Transport Rate	Low flow/Spring survey of gravel berms.		X	X	X	X	X
	Post high-flow survey/visual inspection of gravel berms		X	X			
1.1.2 Gravel Transport, Deposition, and Composition	Survey established cross sections	X	X	X	X	X	X
	Wolman pebble counts	X	X	X	X	X	X
	Gravel patch mapping/aerial photo analysis		X	X	X	X	X
	Post high flow visual inspection		X	X	X	X	X
1.2 Chinook Spawning Activity							
1.2.1 Chinook Spawning	Spawner Survey (fall)	X	X	X	X	X	X
2. Engineered Log Jams							
2.1 Performance and Stability							
1.1.1 Settlement and Deformation	Low flow visual inspection and photo comparison		X	X	X	X	X
	Topographic survey of control points (if settling observed or suspected)	X	X				
	Post high-flow visual inspection and photo analysis		X	X			
1.1.2 Wood Accumulation/Loss	Visual inspection and photo anaylsis		X	X	X	X	X
1.1.3 Ballast Material	Visual inspection and photo anaylsis		X	X	X	X	X
2.2 Effect on hydraulics							
2.2.1 Pool Development	Survey pool dimensions		X	X	X	X	X
2.2.2 Side Channel Flow	Flow survey at 1000 cfs	X	X				X
2.3 Fisheries Use							
2.3.1 Juveniles	Snorkel surveys (spring, summer, fall)	X	X				X
2.3.2 Adult Chinook	Snorkel survey (fall)	X	X				X
3. Channel Geomorphology							
3.1 Planform Analysis	Survey established cross sections	X	X	X			X
	Thalweg profile mapping	X					X
	Aerial photo analysis	X	X	X	X	X	X
3.2 Side Channel and Floodplain Connectivity	Aerial photo analysis	X	X	X	X	X	X
	Side channel water level (low flow)	X	X	X	X	X	X
3.3 Channel Stability	Field survey	X	X	X	X	X	X
4. Habitat Monitoring							
4.1 Habitat mapping	Field survey	2001			X		

<u>**Annual Schedule**</u>

Low flow gravel berm survey: no later than June 15 assuming flows allow access.

Post high-flow monitoring: at least 10 days following first 5500 cfs event of the year or any 7000+ cfs events.

Low-flow monitoring: Completed before July 31.

Reporting: draft by October 30, final by December 30

2. HYDROLOGIC SUMMARY

2.1. Water Year 2004 Overview

Figure 2 shows the annual hydrograph for the 2004 water year (October 1, 2003 - September 30, 2004), as measured at the USGS gage at Palmer (#12106700), located at RM 60.3 in Zone 1, just above the upper gravel loading site. The gage is downstream from HHD and reflects routine management of outflows for flood control, provision of in-stream minimum flows for fisheries, and water supply needs. Compared to the average annual hydrograph, 2004 was characterized by its near normal runoff, but dearth of large floods (one 80% chance exceedence event in January 2004). Also, the first high flow events occurred in the middle of October 2003, earlier than usual, and in August 2004 HHD experienced near record precipitation and outflows (Figure 3).

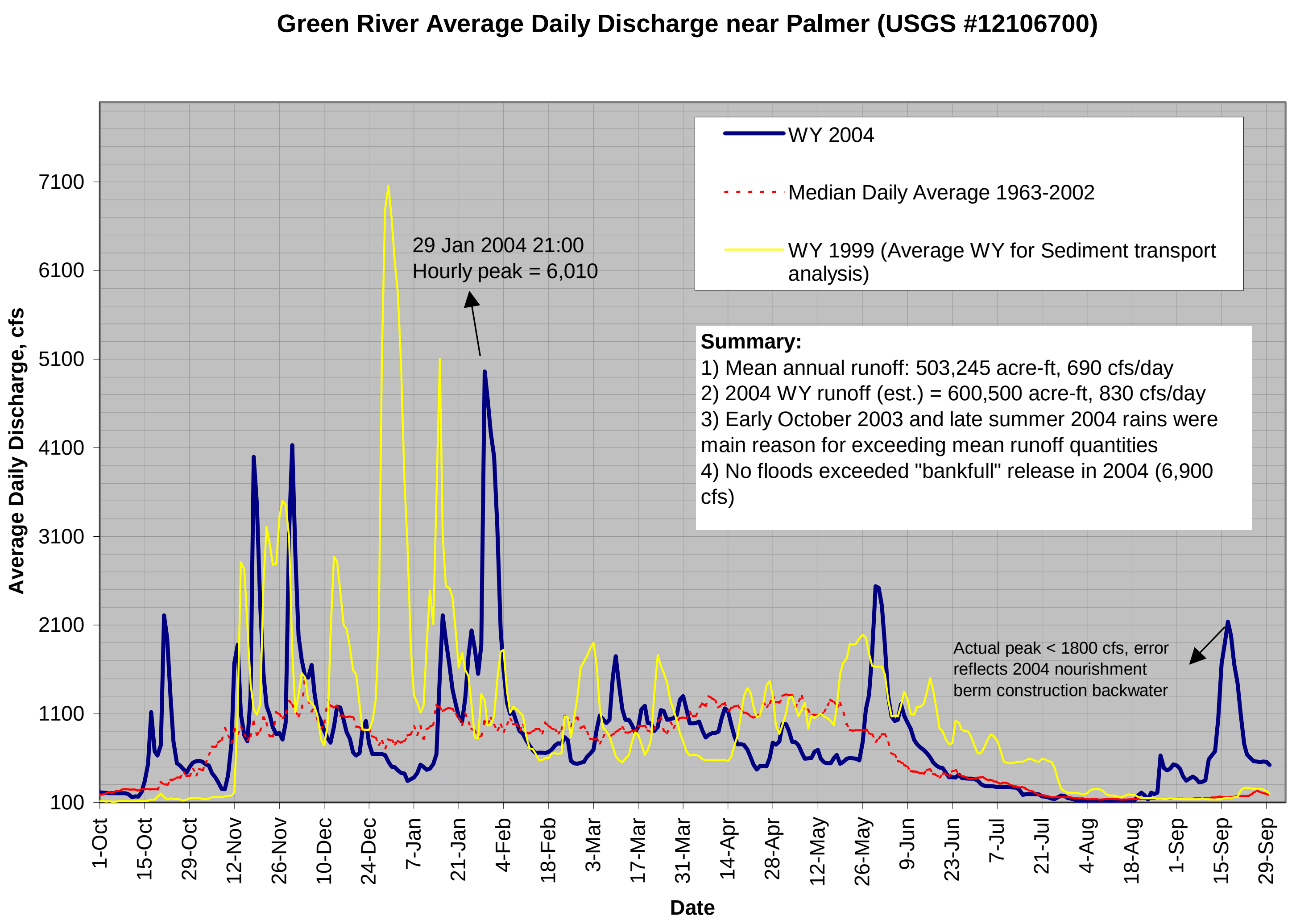


Figure 2. Green River at Palmer 2004 Water Year Hydrograph.

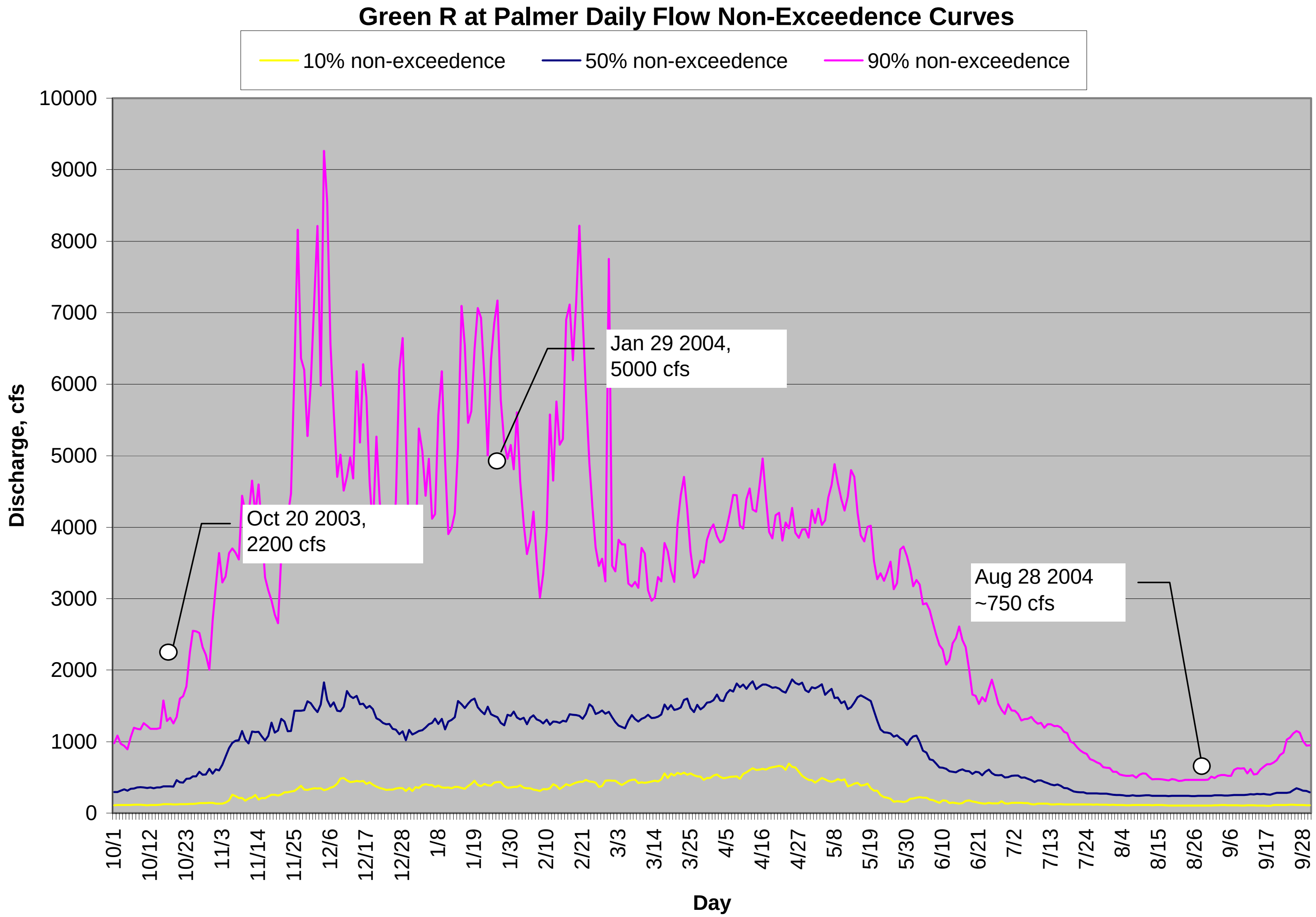


Figure 3. Green River at Palmer Non-Exceedence Discharge Curves Comparing Select WY 04 Events

3. GRAVEL NOURISHMENT

3.1. 2003 Gravel Nourishment

In summer 2003, a total of 7,555 tons of gravel was placed in two locations and in two different configurations at approximately RM 60 of the Green River (Figure 4). The upper loading zone is located on the left bank just downstream from the USGS gage in a riffle-cascade reach. The lower loading zone is located just upstream of the log jams on the left bank in a run-riffle-cascade reach and is not as steep or confined as the upper zone. The pre-project streambed material in the upper loading zone consisted primarily of boulders, with some cobble and gravel. The lower loading zone streambed consisted of sands, gravels, cobbles, and boulders. The gravel nourishment berms were constructed by end-dumping from dump trucks onto the landward edge of the berm. This gravel was then pushed out and graded up to the ordinary high-water mark by a small bulldozer. A total of 3,604 tons and 3,951 tons of nourishment gravel were placed at the lower and upper loading zones, respectively. The upper berm was constructed in a “sawtooth” pattern. The lower berm was composed of two “teardrops”. The purpose of the two configurations was to determine if certain gravel berm configurations or more easily eroded by the river. The specifications for gravel placed in 2003 are described in Table 2. Additional details about the 2003 construction can be found in the project construction report (USACE 2003a).

Table 2. Summary of gravel placed at RM 60 in 2003.

	1998 FR/EIS proposed	2003 placed
sieve	% finer	% finer
6 inch (152 mm)		
5 inch (127 mm)		
4 inch (102 mm)	100	100
3 inch (76 mm)		
2 inch (51mm)	70-85	65
1 inch (25 mm)	25-50	27
0.5 inch (13 mm)	0	6
Quantity placed:		
total tons:		7555
tons (not including fines < 0.5 inches):		7102
cubic yards (0.6 cubic yards/ton):		4261

3.2. Performance Criteria

Gravel performance criteria include:

- Mobilize a majority (90%) of the gravel at the bankfull event (1.5 year recurrence interval = 6870 cfs)

- Load gravel in a manner to achieve a relatively heterogeneous gravel composition in downstream locations
- Store gravel in zone 1 reach to provide salmonid spawning opportunities
- Increase spawning opportunities downstream of gravel nourishment locations

3.3. Monitoring Activities

In WY 2004, gravel monitoring consisted of high flow inspections, aerial photo analysis, low flow cross section surveys, pebble counts, gravel patch mapping, and spawner surveys. Raw data can be found in the attached appendices. Four sets of aerial photos were collected:

- 21 October 2003: As-built condition
- 1 November 2003: After first flood
- 13 March 2004: Post high flows, leaf off period
- 23 July 2004: Summer low flow

Photograph negative scale was 1" = 600' with 0.5-foot pixel resolution. The vertical accuracy met standards for Class 2 orthophotographs: as accurate as the USGS Digital Elevation Model (DEM) data used to create orthophotographs. Thereby, 90 percent of all points have at least a 7-meter RMSE accuracy and 10 percent are in the 8-15 meter range. The flight line was from approximately RM 56 to RM 61.

3.3.1. Gravel Berm Erosion Rates

After the first high flow event of WY 2004 (October 17-21, 2003, peak flow of 2,450 cfs) an aerial photograph was obtained for the site. The flight occurred November 1, 2003, during a discharge of 250 cfs. The aerial photography was compared with the as-built baseline flight photo (September 21, 2003, 150 cfs). The photo indicated significant berm erosion had occurred. Gravel waves could be seen several hundred feet downstream from the upper berm. Based on GIS spatial analysis, it was estimated that over 60% of the berm gravel was eroded and transported from the berms during this moderate event (Figure 4). Gravel patch mapping indicated that the river had eroded more than 95% of the upper and lower berm gravel by July 2004 (Figure 5). Remnant berm gravel was observed downstream of obstructions to scouring flows, such as large boulders that shield the gravel, backwater effects of ELJs, and vegetation that creates roughness along the bank, slowing flow.

Gravel berm configuration did not appear to be an important factor in berm erosion. The upstream berm appeared to erode more efficiently; however, this section of the river is also steeper. Each berm configuration was efficiently eroded at relatively moderate flows indicating that future gravel loading does not require special configuration to facilitate gravel erosion.

Figure 4. Zone 1 before and after gravel berm erosion from October flood event (2,450 cfs).

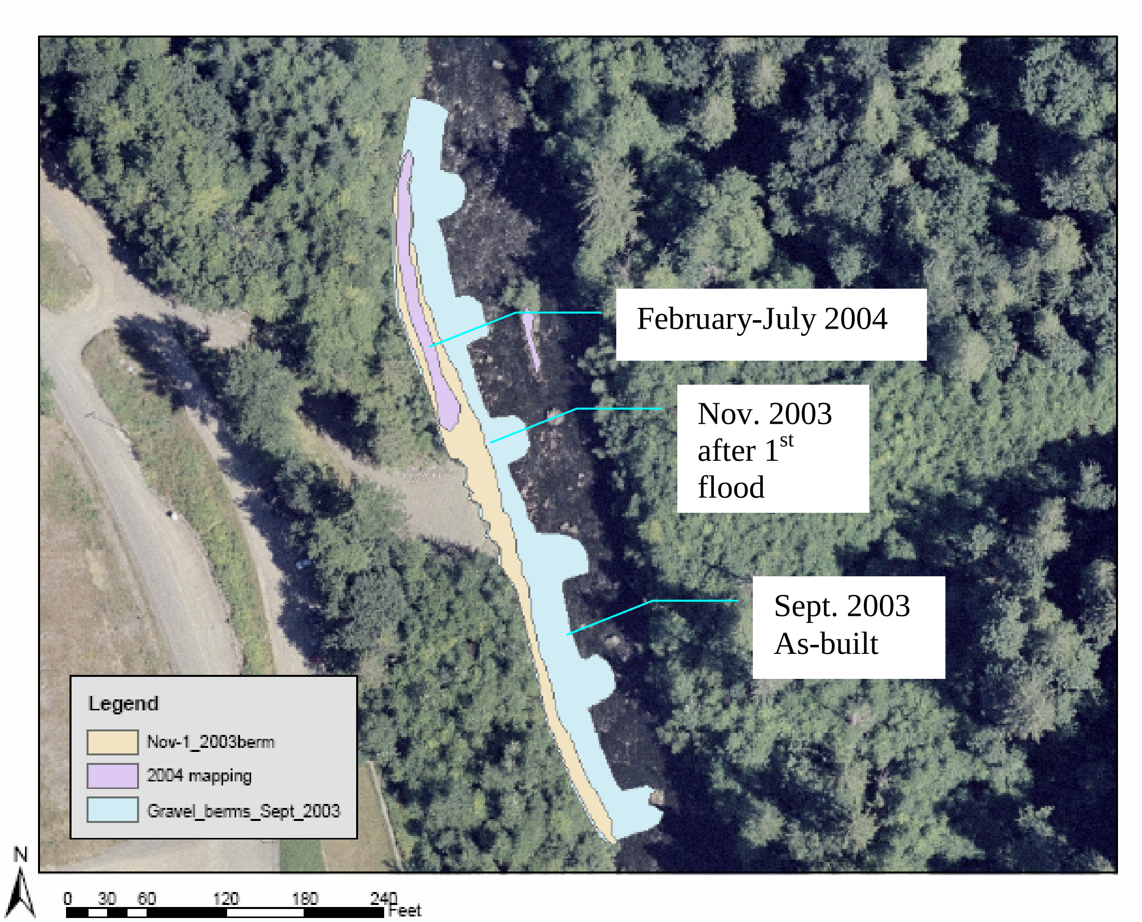


Figure 5. Upper nourishment berm erosion, 2003-2004

Based on aerial photo analysis and field surveys it is estimated that over 95% of the nourishment gravel was eroded from the gravel nourishment berms between summer 2003 and summer 2004. In summer 2004 the un-eroded gravel volume estimates were 120 CY and 150 CY.

3.3.2. Gravel Transport, Deposition, and Composition

3.3.2.1. Cross Section Surveys

Twenty-eight baseline cross-sections were established in 2002 (USACE 2003c). Permanent cross sections were established with cap and rebar and adjacent tagline post; intermediate cross sections were also established with rebar endpoints and have decimal numbering system. Cross section locations are identified in Figures 6-8.

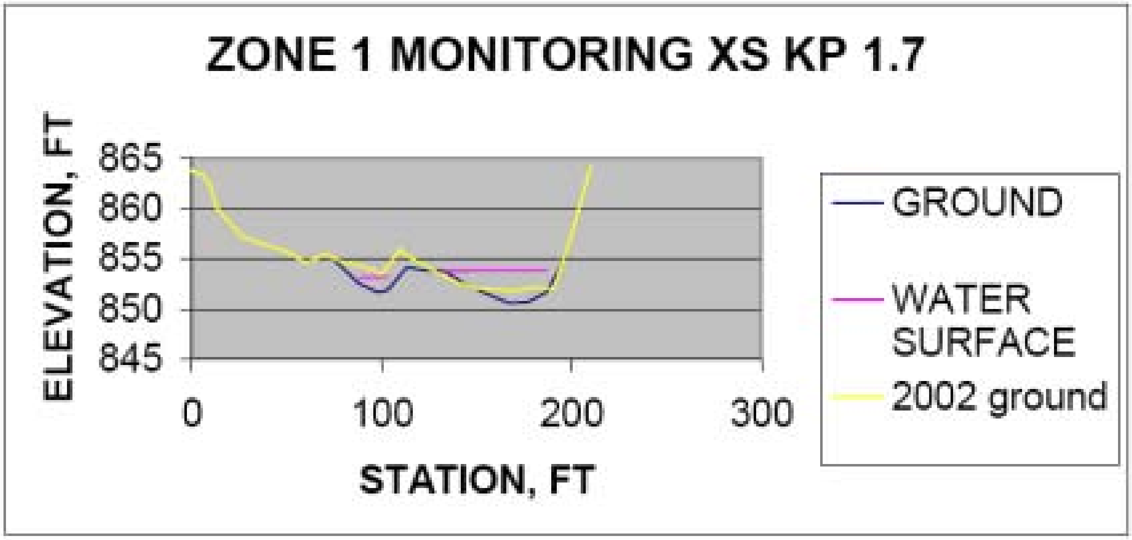
In summer 2004, 8 cross sections were surveyed including KP 1.7, 2.0, 3.0, 3.2, 4.2, 4.6, and 5.0. A new cross section was established above ELJ 2 and designated KP 1.9. This latter cross section was established to capture gravel deposits that may build up over time in the ELJ2 backwater zone. Cross sections were qualitatively compared with baseline surveys. At KP 2.0 and 3.0 (Figure 7 and 10) the baseline cross sections were directly altered by log jam

Figure 6. Cross section locations RM 60 – 60.5.

Figure 7. Cross section locations RM 59.5 - 60.

Figure 8. Cross section locations RM 59 – 59.5.

construction activities. The 2004 survey is therefore the result of construction of the log jams and gravel nourishment. These two cross sections indicate gravel is being stored in the reach, although it is not possible to discern the magnitude of the trend because of alterations to the stream bed caused by log jam construction. Still, it is apparent that significant amounts of gravel are being stored in this reach. KP 2.0 illustrates the gravel bar deposit that accumulated upstream of ELJ2. Cross section KP 4.0 was not surveyed because depths prohibited wading; however, nourishment gravel was observed at this location. Other surveyed cross sections only indicated minor changes. Gravel patch mapping and Wolman pebble counts provide better resolution of geomorphic and habitat change than cross sections at this stage of the project.



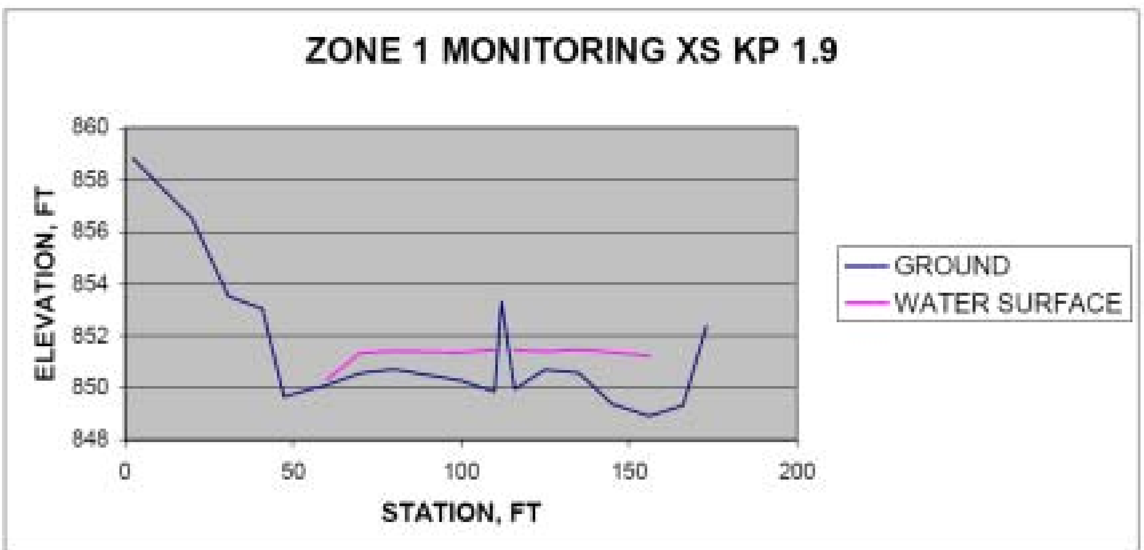
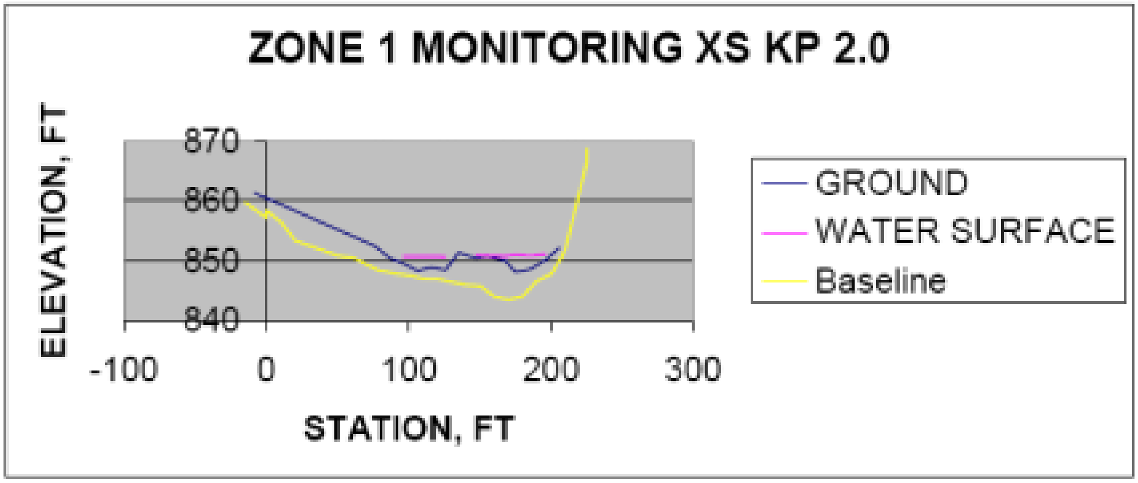
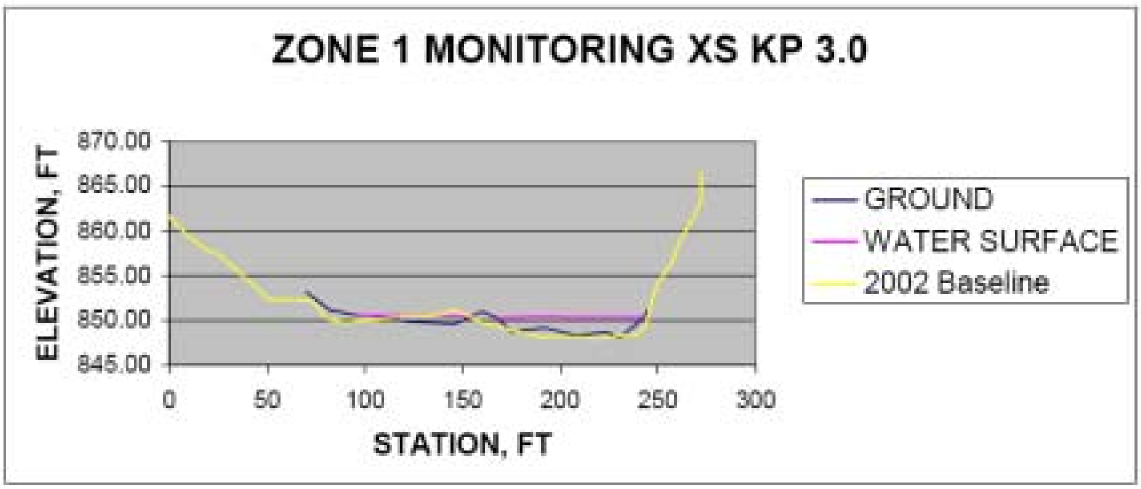


Figure 9. Cross section survey data KP 1.7 and 1.9.





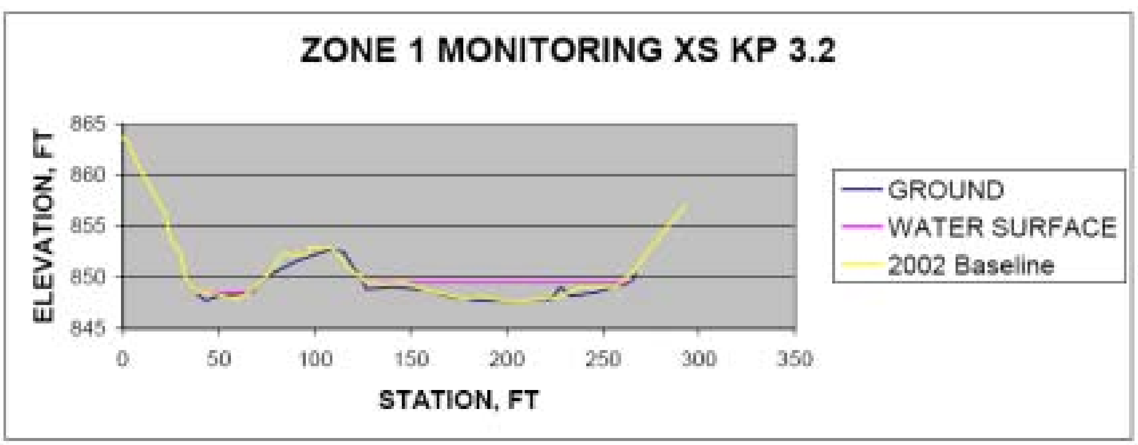


Figure 10. Cross section survey data KP 2.0, 3.0, and 3.2.

3.3.2.2. Gravel Transport Rates

Aerial photo surveys taken between September 2003 and November 2003 allow for ready tracking of gravel transport attributable to a flood event that occurred between October 15 and October 26, 2003 (peak discharge 2,450 cfs on October 21). By November 1, 2003 the leading edge of a pronounced gravel plume was 900 ft from the midpoint of the upper gravel berm (Figure 11). The midpoint of the plume was 600 ft from the midpoint of the berm. The estimated average daily gravel wave transport velocity for this event is 54 ft / day (midpoint to midpoint). Based on erosion volume estimates this equates to a daily gravel transport rate of 180 tons/day for this event (based on 2,000 ton transport estimate past KP 1.5, USACE 2004a).

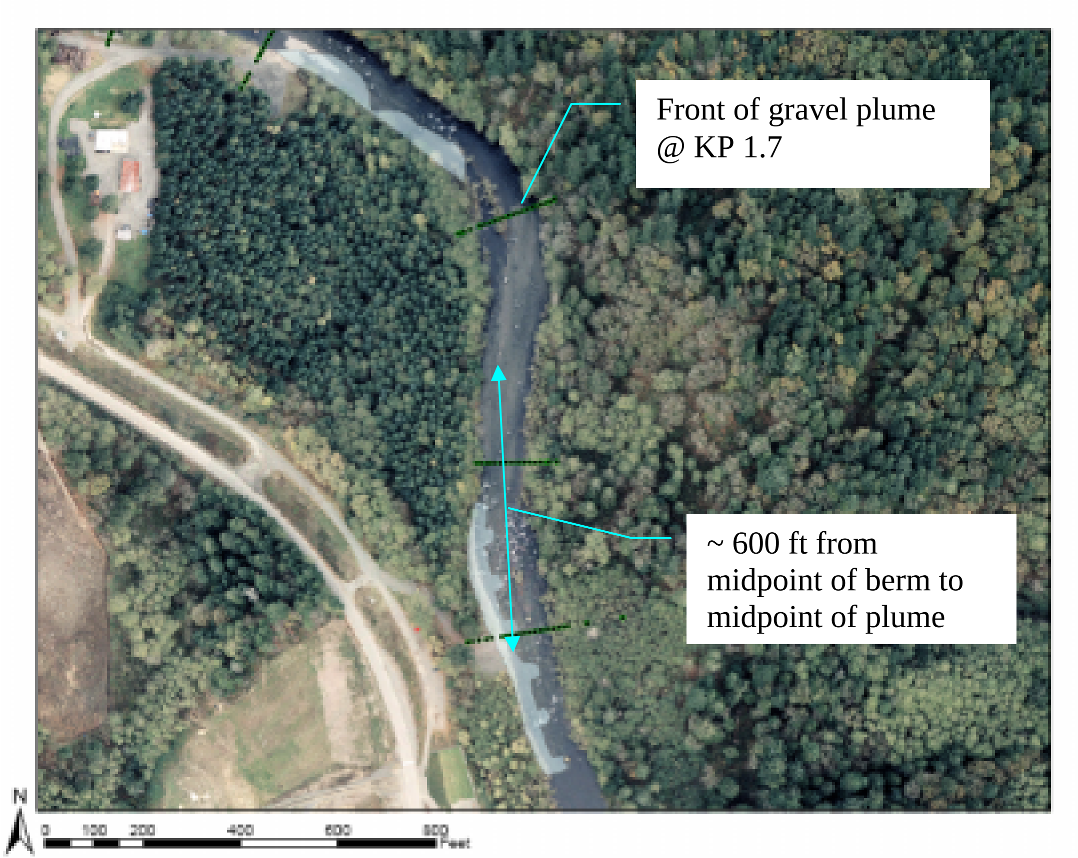


Figure 11. Observed gravel transport, November 1, 2003

As early as December 2003, nourishment gravel was observed in the side channel downstream of the ELJs near KP 3.7 (USACE 2004b). This deposit is located about 1,400 ft from the midpoint of the lower berm, and 2,600 ft from the upper berm. In August 2004 the possible leading edge of the nourishment gravel was observed at KP 4.6, 3,600 ft from the lower berm, and 4,800 ft from the upper berm. Thus this reach was able to transport gravel at least 3,600 feet in one year, despite only one near "bankfull" flood event. Fine streambed material was turned up during log jam construction upstream of the side channel. As this material eroded in response to high flows, it was incorporated with incoming nourishment gravel. Thus some portion of the transported gravel is native to the treatment area and not imported.

3.3.2.3. Gravel Patch Mapping

Gravel patch deposition areas were mapped during low-flow field surveys and to the extent feasible using aerial photographs. Areas of deposition were measured and hand drawn on maps in the field. The field data were used to create a GIS layer of the depositional areas that were added to the GIS database. Gravel patch mapping was conducted between KP 1.3 and KP 5.0. The mapping exercise estimated the depth of gravel deposit, percent native/nourishment gravel, as well as the aerial extent of the deposit. Between KP 1.3 and KP 5.0 over 3.6 acres of channel area that consisted of 25% to 100% nourishment gravels was mapped. The clean, round, ½ to 4-inch nourishment gravel deposits were easily discerned from the larger, angular, dark native gravels and cobbles. Nourishment gravel deposit depths were estimated visually by the amount that embedded native boulders protruded from the deposit. In two instances pits were excavated in gravel bars to measure depth directly. Rebar was also driven into the streambed to check depths. Rebar was unable to penetrate through the deposits at the pit excavation sites.

The purpose of estimating gravel depths was to provide a rough check of potential deposit volumes. This allows a “ball-park” check on the gravel patch mapping ability to identify a majority of the deposited nourishment gravel. Ideally the “mass in” from the loading zone should be equal to the mass of material deposited in the study area, minus losses to floodplain storage and pass-through (both not measured). Table 3 describes the area, depth, and volume of each individually numbered gravel deposit. Figures 12 and 13 identify locations of the individual gravel deposits. A total of thirty-two deposits were identified. The average estimated deposit depth was 1.0 ft. The total estimated volume of gravel mapped was 4,835 CY. Of this total, 3,831 CY or 79% was estimated to be nourishment gravel with the remainder being native existing gravel.

Figures 14 and 15 indicate the area and volume of gravel respectively in the river relative to each identified cross section. Figure 16 provides an estimate of this total that is placed nourishment gravel. This data indicates gravel storage is occurring both upstream and downstream of the ELJs, and at the bend in the river upstream from ELJ 2. This will be a key location in future years as it has been identified in the hydraulic model as the point where gravel transport is most limited in the reach. As additional nourishment gravel is placed in future years, it will be more difficult to distinguish this from the previous years gravel. Total gravel volumes, as indicated in Figure 16, will therefore be a primary method for tracking gravel movement through the reach.

Table 3. Gravel Patch Mapping Area and Volume Estimates

Gravel Deposit ID# [1]	Gravel Deposit Area [2]		Average Deposit Depth[3]	Gravel Deposit Volume - Total		Percent Nourishment Gravel [5]	Estimated Volume of Nourishment Gravel	
	ft2	acres	ft	ft3	CY[4]	%	ft3	CY[6]
0	1,657	0.038	2.5	4,141	153	100	4,141	153
1	5,926	0.136	2.7	15,999	593	90	14,400	533
2	9,630	0.221	0.5	4,815	178	80	3,852	143
3	7,081	0.163	0.5	3,541	131	80	2,833	105
4	5,534	0.127	0.5	2,767	102	80	2,214	82
5	2,739	0.063	0.5	1,370	51	80	1,096	41
6	443	0.010	0.5	221	8	90	199	7
7	5,395	0.124	0.5	2,697	100	95	2,563	95
8	3,828	0.088	4.0	15,314	567	100	15,314	567
9	5,606	0.129	1.3	7,007	260	80	5,606	208
10	7,396	0.170	1.3	9,245	342	90	8,320	308
11	403	0.009	1.0	403	15	60	242	9
12	115	0.003	1.0	115	4	80	92	3
13	199	0.005	1.3	249	9	80	199	7
14	870	0.020	0.5	435	16	80	348	13
15	12,772	0.293	0.5	6,386	237	35	2,235	83
16	3,761	0.086	1.5	5,642	209	95	5,360	199
17	11,970	0.275	0.5	5,985	222	60	3,591	133
18	2,982	0.068	0.5	1,491	55	90	1,342	50
19	7,927	0.182	0.5	3,964	147	25	991	37
20	9,147	0.210	0.5	4,573	169	50	2,287	85
21	5,910	0.136	0.5	2,955	109	25	739	27
22	2,093	0.048	0.8	1,570	58	70	1,099	41
23	3,303	0.076	1.0	3,303	122	80	2,643	98
24	686	0.016	1.0	686	25	75	514	19
25	6,349	0.146	0.5	3,175	118	25	794	29
26	6,172	0.142	0.5	3,086	114	60	1,852	69
27	22,120	0.508	0.5	11,060	410	95	10,507	389
28	3,247	0.075	1.0	3,247	120	95	3,084	114
29	1,715	0.039	1.0	1,715	64	95	1,629	60
30	2,178	0.050	1.5	3,268	121	100	3,268	121
31	254	0.006	0.5	127	5	75	95	4
Total:	159,409	3.660	1.0	130,552	4,835		103,447	3,831

Notes:
1. Gravel deposit ID #, see figures 12 and 13.
2. Area based on gravel patch mapping.
3. Depth based on visual estimates. Average depth is indicated in the 'totals' row.
4. Cubic Yards = (gravel deposit area ft2) X (gravel deposit depth ft) / (27 ft3/yd3)
5. Estimated percentage of nourishment gravel based on visual characteristics of gravel relative to native existing gravel (color, etc).
6. Cubic Yards = (gravel deposit area ft2) X (gravel deposit depth ft) x (% nourishment gravel) / (100 x 27 ft3/yd3)

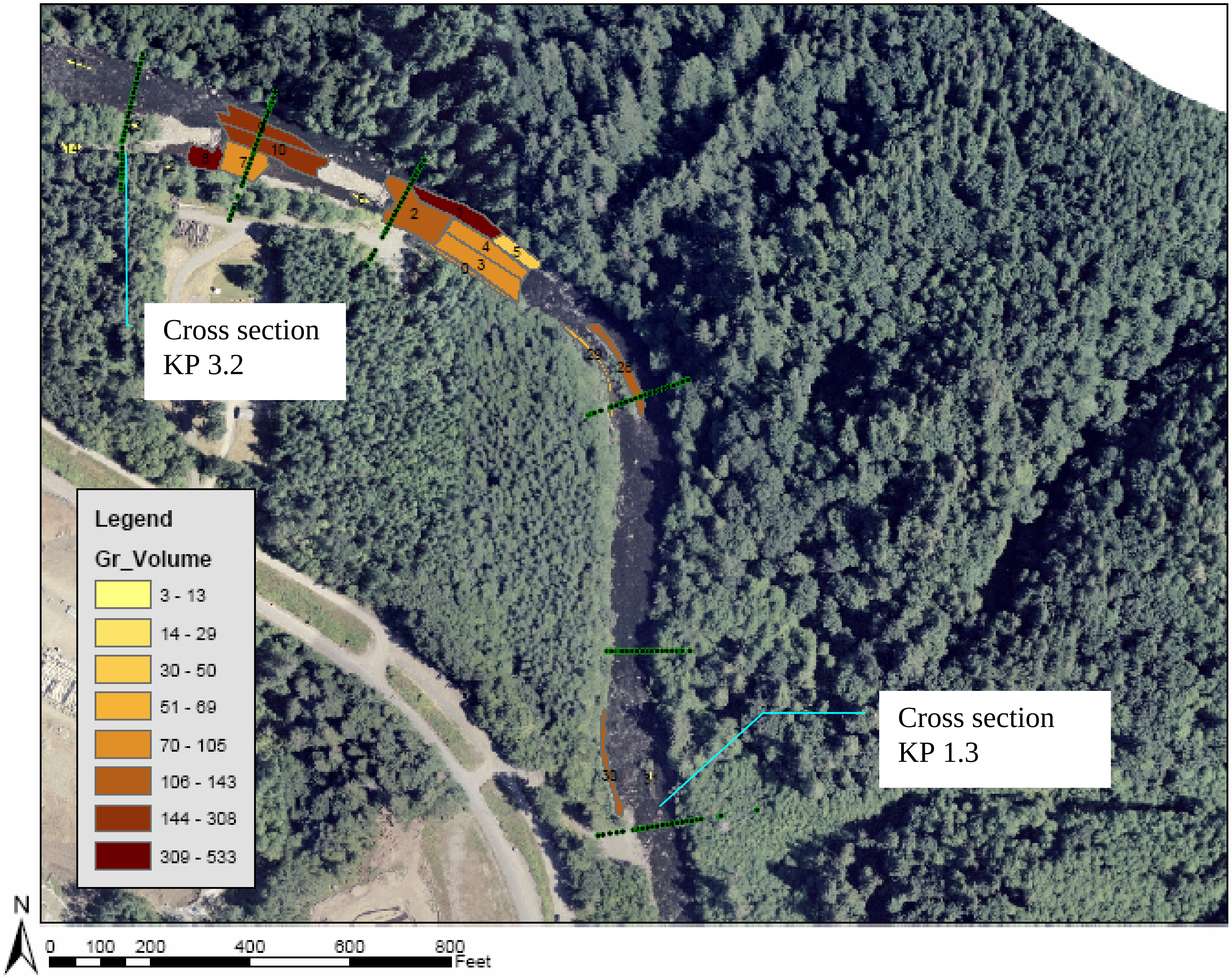


Figure 12. Zone 1 Gravel Patch mapping, KP 1.3 to KP 3.2 (gravel volumes in cubic yards)

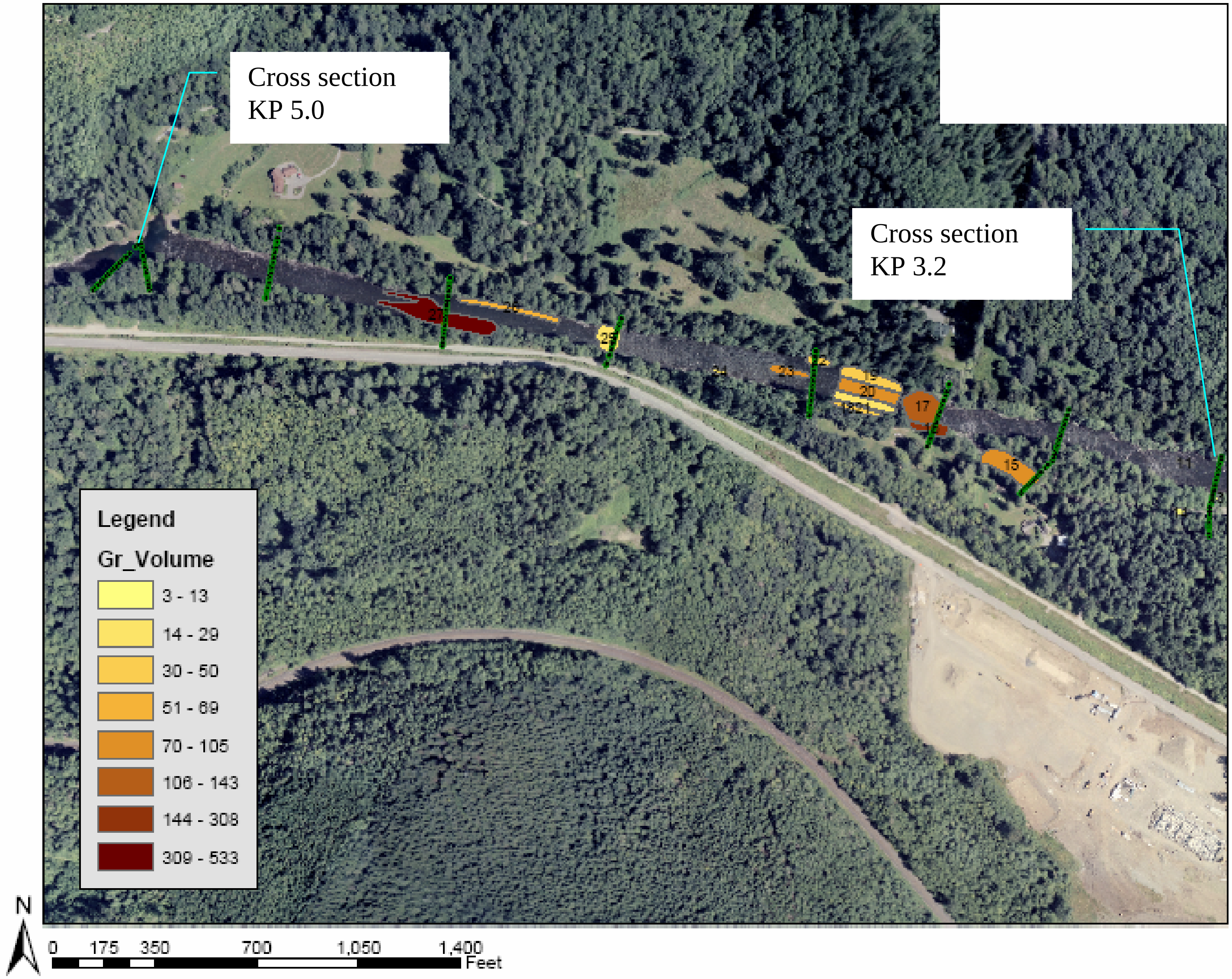


Figure 13. Zone 1 Gravel Patch mapping, KP 3.2 to KP 5.0 (gravel volumes in cubic yards)

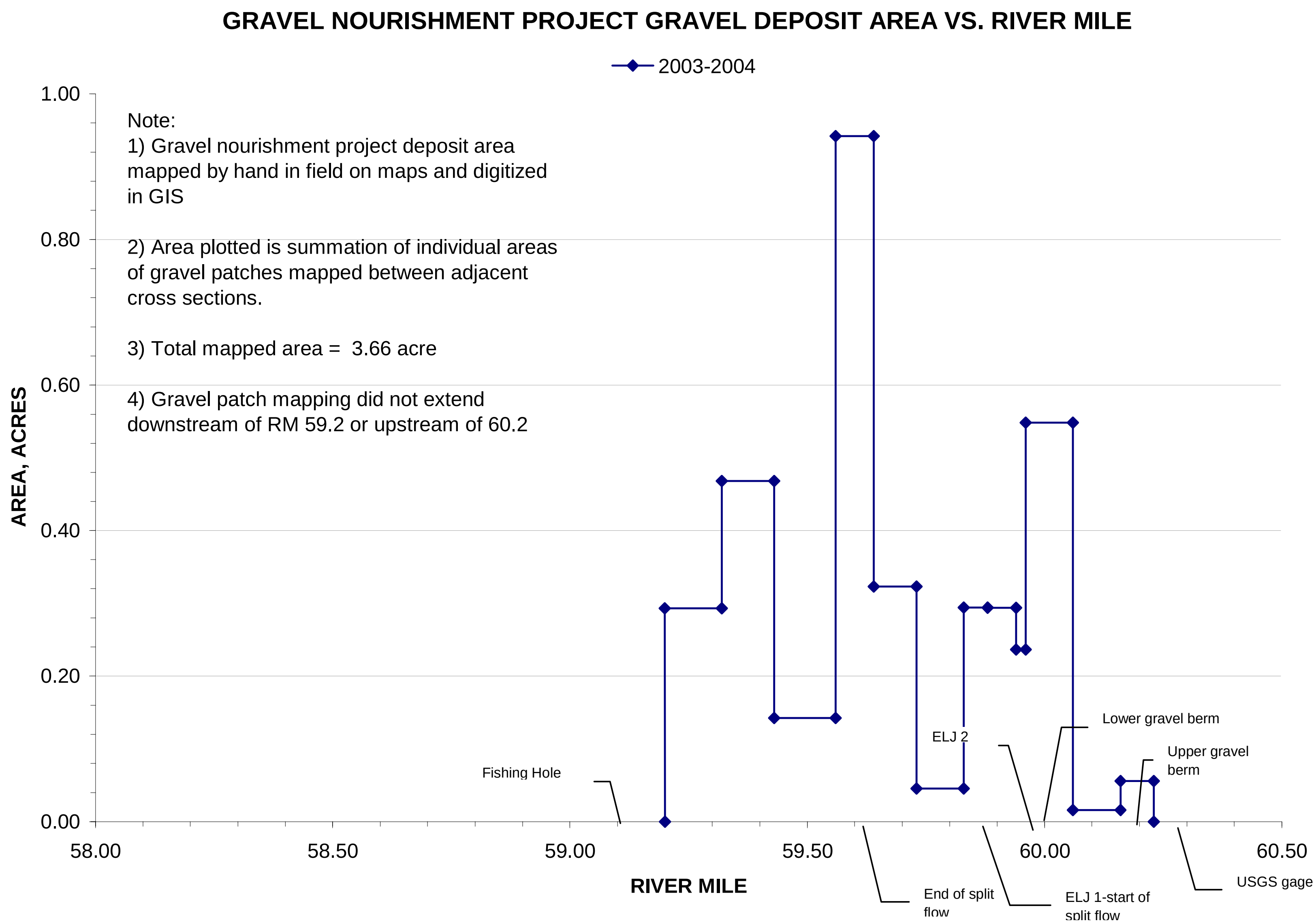


Figure 14. Summary of gravel area mapped between each established cross section.

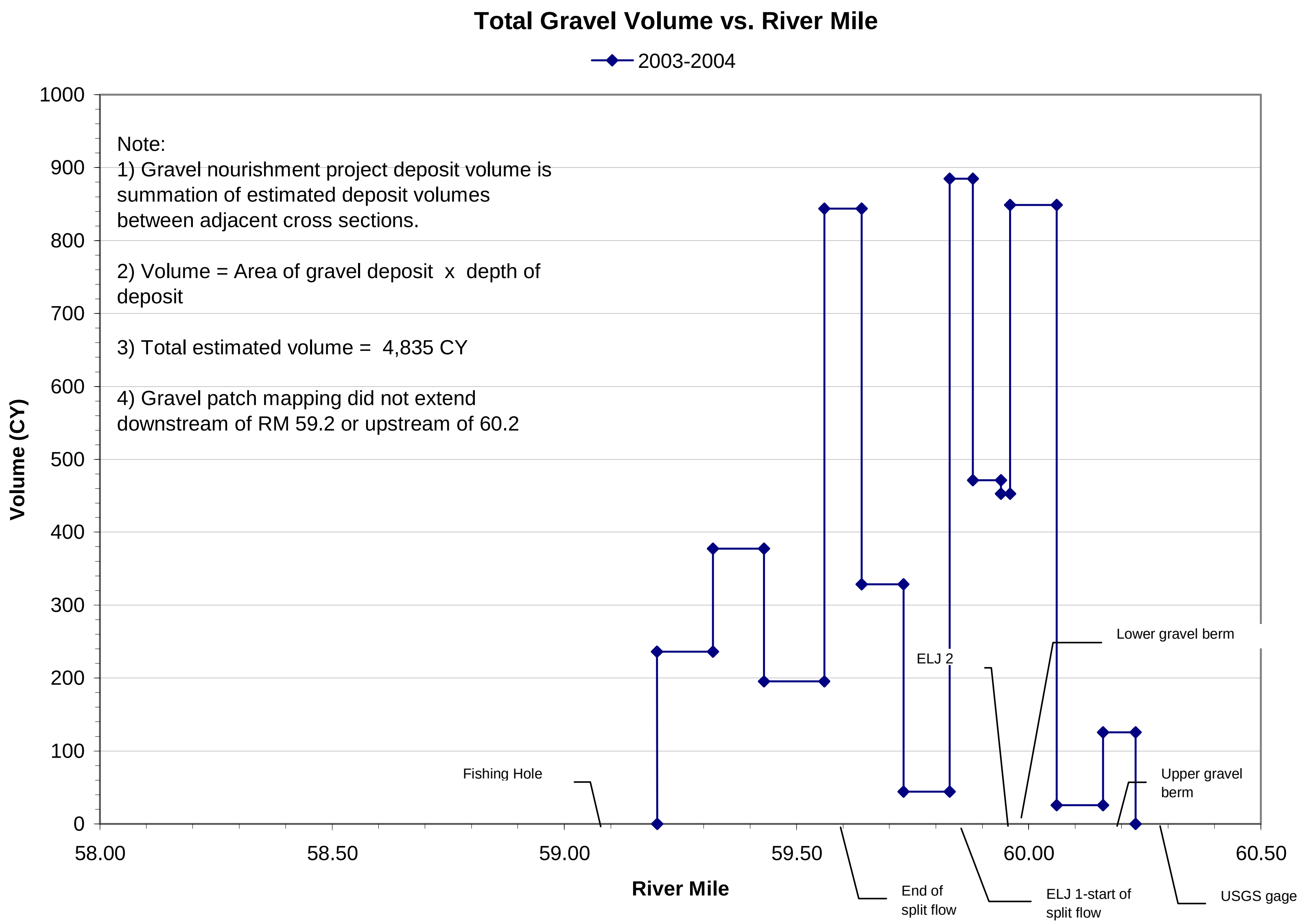


Figure 15. Summary of total gravel volume between each established cross section.

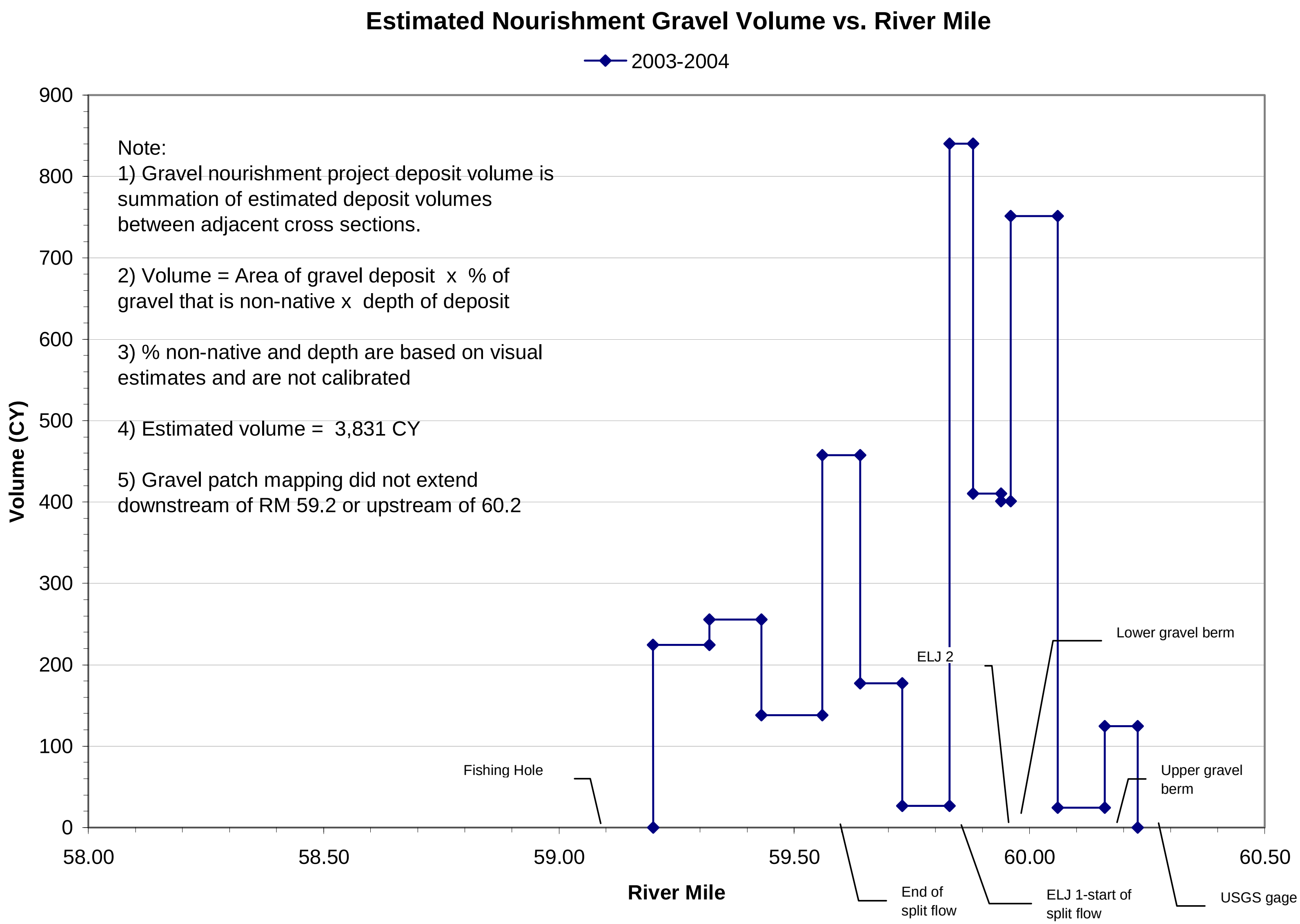


Figure 16. Summary of estimated nourishment gravel volume between each established cross section.

3.3.2.4. Downstream Sediment Composition

Sediment size distribution and composition data was collected using the Wolman pebble count method. This consisted of collecting samples along a channel grid at predefined monitoring sections (Figure 17). The grid was a 100-ft long strip where pebbles were measured at 2 ft intervals along the grid. The median axis diameter of each pebble was measured using an engineer scale. The original plan required Wolman counts at all cross sections. USACE decided to restrict the pebble counts to sections that had readily observable changes in the dominant streambed material. These changes are most pronounced at KP 2.0 and KP 3.0, and to a lesser extent at KP 1.7, KP 3.2, and KP 4.0.

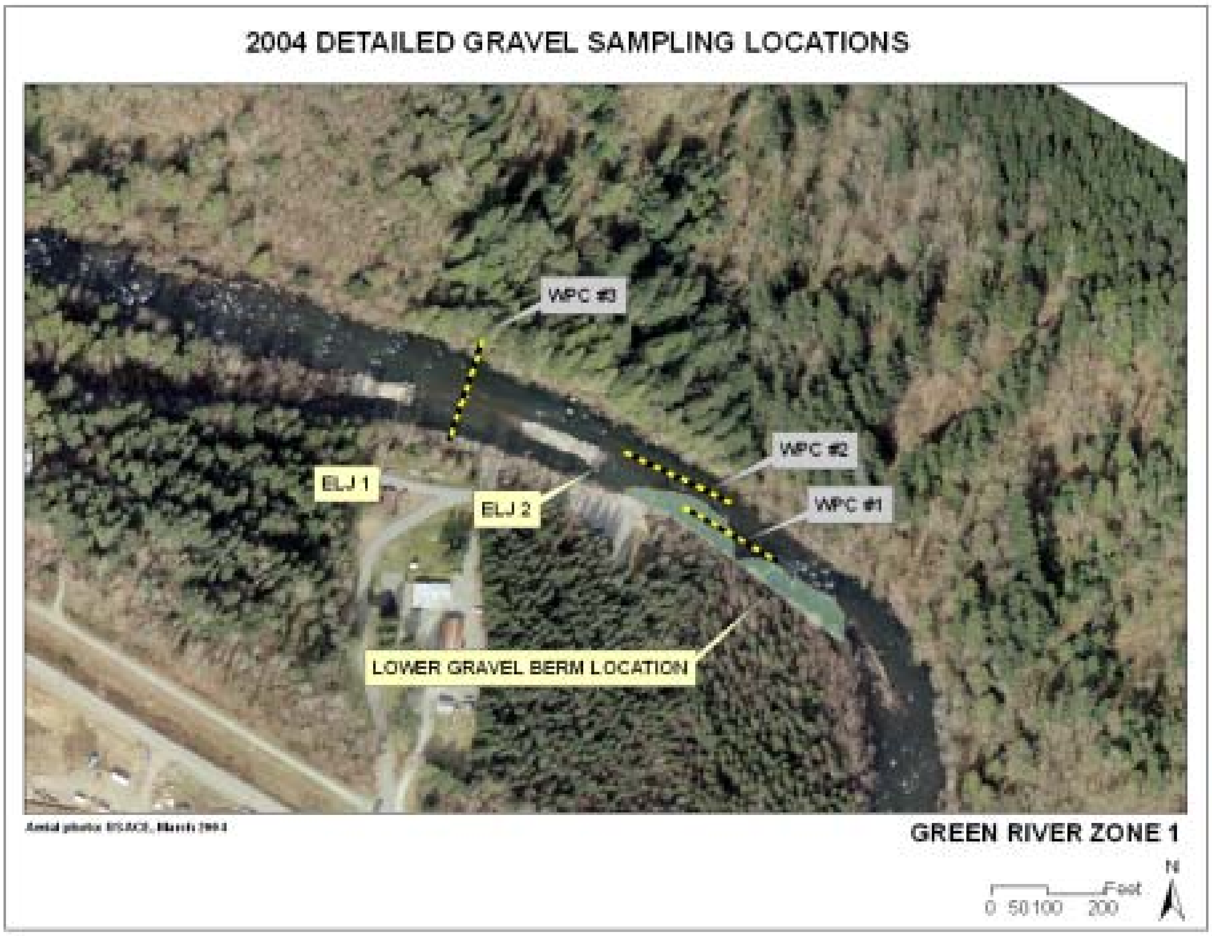


Figure 17. 2004 pebble count locations.

Figure 18 shows the change in streambed composition at KP 2.0 and 3.0 from the baseline condition. The d-50 bed material size decreased 65% at PC#3 and 76% at PC#2. PC#3 is taken across KP 3.0. PC#2 is taken along the river, perpendicular to KP 2.0 atop a mid channel gravel bar. PC#1 is taken mid-channel between KP 1.7 and KP 2.0

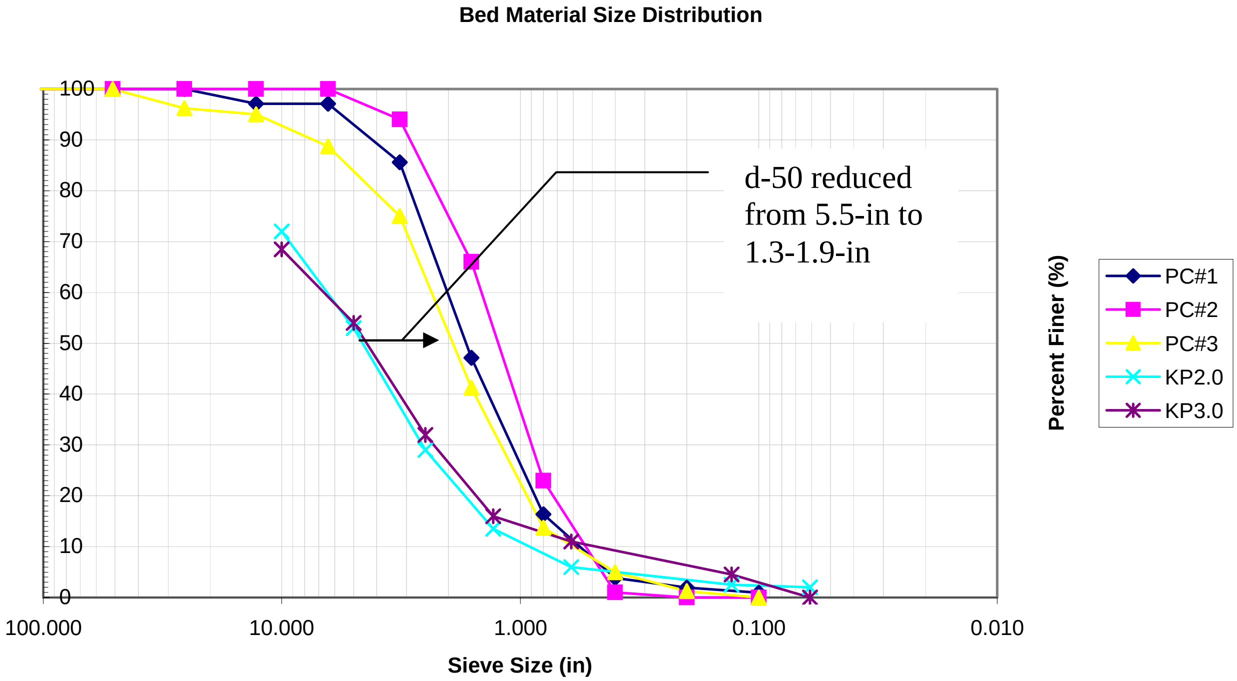


Figure 18. Change in dominant grain size (d-50) near ELJs. KP2.0 and 3.0 indicate pebble count data from 2002 collected at the cross section locations.

3.3.3. Chinook Salmon Spawning Activity

Chinook salmon spawning is a primary endpoint used to evaluate effectiveness of the gravel nourishment. Two separate and independent data sets will be used to evaluate Chinook spawning: 1) spawner surveys conducted by the Corps in the Palmer reach that identify and map locations of individual redds, and 2) spawner surveys conducted by Washington Department of Fish Wildlife (WDFW) that sum the number of redds for defined reaches.

3.3.3.1. Palmer Reach Spawner Survey

Methods

The objective of the fall spawner survey was to identify the specific location of individual Chinook salmon redds so that data can be analyzed in the context of Restoration Zone 1 logjam placement and gravel nourishment locations. Chinook salmon spawning surveys were conducted near the expected peak of the 2004 fall spawning season on 15 October 2004 and two weeks after the expected peak on 29 October 2004 (peak based on WDFW unpublished data 1999-2004). The spawning surveys encompassed 23,175 lineal ft of the upper Green River between RM 56.0 and RM 60.4.

The spawner survey was conducted by a team of three biologists floating in a 12 ft rubber raft, beginning at the upper site boundary (Tacoma Foot Bridge) and proceeding downstream to the end of the survey reach (Kanaskat-Palmer State Park). Salmon redds were marked with survey flagging tied to rocks and placed adjacent to observed redds during the initial survey to avoid duplicate counts. A single observer surveyed each shoreline while the third observer surveyed the deepwater portion of the channel while floating in the raft. Total spawner counts represented all live and dead fish observed within the survey reach. Longitudinal distribution of redds and spawner count data were delineated using a Garmin 76™ handheld GPS unit, USGS 7.5 minute topographical maps, and aerial photographs. While Chinook salmon were the primary species of interest, other spawning salmonids (e.g., sockeye and coho salmon) were identified and enumerated. Water temperature (to the nearest 0.5°C) and stage (to the nearest (0.01 ft) were recorded using a handheld thermometer and staff gage measurements, respectively. Underwater visibility, measured using a Secchi disk attached to a tag line, was used to denote the survey coverage. Representative photographs were taken of individual redds and geographical reach demarcations. All data were entered electronically using MS Excel™ and cross-referenced with original field data forms for QA/QC purposes. Data were also entered into the GIS database. Unless otherwise noted, all statistical analyses were performed using SigmaStat™.

Results

A total of 266 adult salmon (11.5 salmon•1,000 ft^{-1}) were observed during initial spawner surveys conducted on 15 October 2004 in the upper Green River (Table 4). The spawner survey encompassed the upper Green River beginning at the City of Tacoma Foot Bridge, downstream to Kanaskat-Palmer State Park. Chinook salmon were the most abundant species, accounting for more than 95% of the live fish, 99% of the carcasses, and 99% or the redds that were observed. The number of spawning salmon (29.3 salmon•1,000 ft^{-1}), carcasses (52.3 carcasses salmon•1,000 ft^{-1}), and redds (53.9 redds salmon•1,000 ft^{-1}) was greatest within Restoration Zone 1 compared to upstream or downstream reaches of the Green River (Table 4; Figure 19).

Table 4. Reach delineation, species, and total number of live, dead, and redds observed during spawner survey conducted in upper Green River, King County, Washington, 15 October 2004.

Zone	Reach Length (ft)	Species	Live Fish	Carcasses	Redds
RESTORATION ZONE 1					
ELJ Site 1	**325**	**Chinook**	6	16	15
		Coho	0	0	0
		Pink	0	0	4
		Sub-total	6	16	15
		No.•1,000 ft^{-1}	***18.5***	***49.2***	***46.2***
RESTORATION ZONE 1					
ELJ Site 2	**325**	**Chinook**	11	18	19
		Coho	0	0	0
		Sockeye	2	0	1
		Sub-total	13	18	20
		No.•1,000 ft^{-1}	***40.0***	***55.4***	***61.5***
NON RESTORATION ZONES					
	21,775	**Chinook**	237	358	280
		Coho	10	1	2
		Sockeye	0	0	0
		Sub-total	285	359	282
		No.•1,000 ft^{-1}	***13.1***	***16.5***	***13.0***
GRAND TOTAL					
	23,175	**Chinook**	254	392	314
		Coho	10	1	2
		Sockeye	2	0	1
		Total	266	393	317
		No.•1,000 ft^{-1}	***11.5***	***17.0***	***13.7***

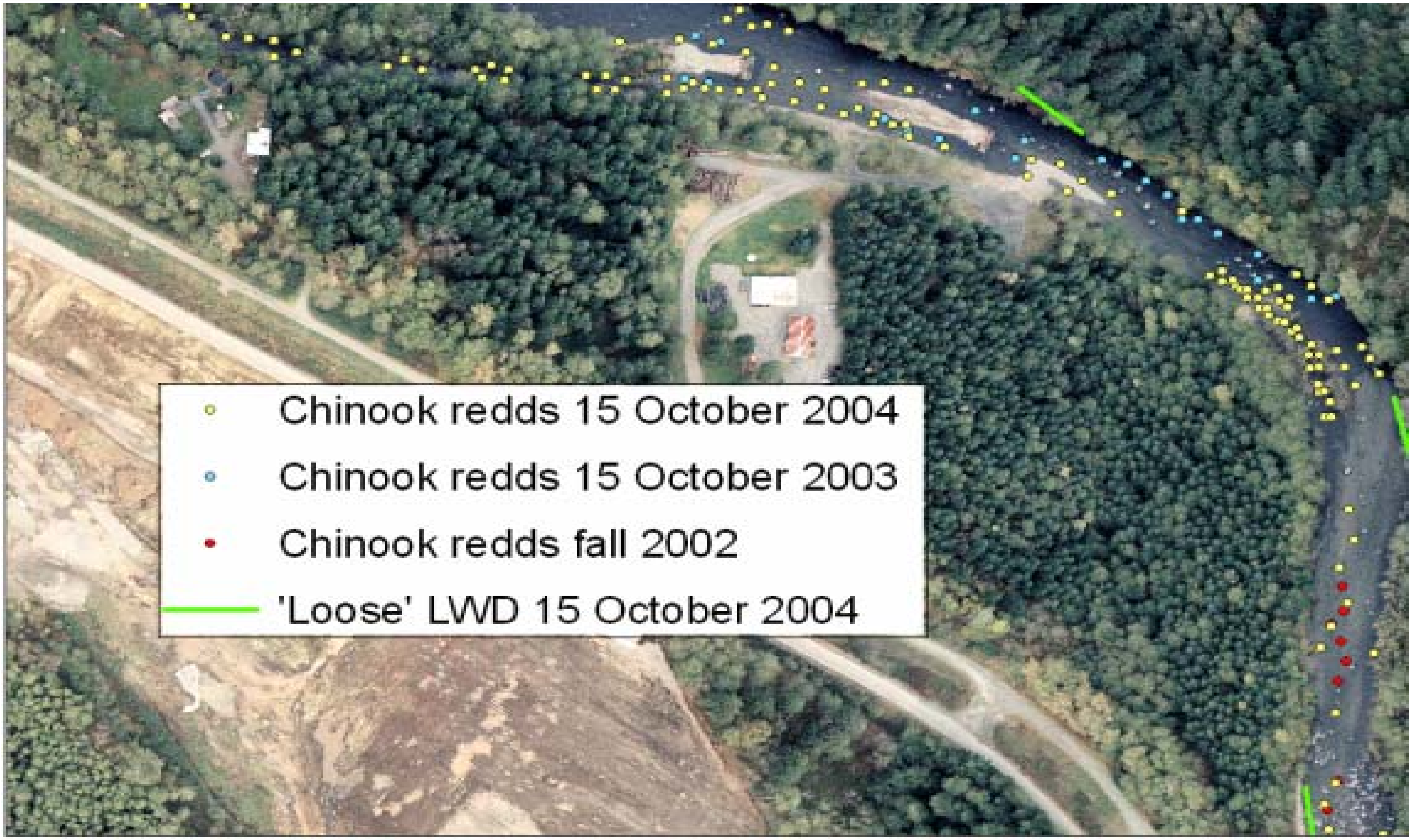


Figure 19. Location of Chinook salmon redds in Restoration Zone 1, 2002, 2003, and 2004.

A second spawning survey was conducted on 29 October 2004. A total of 68 adult salmon (3.0 salmon•1,000 ft^{-1}) were observed (Table 5; Figure 20). Coho salmon were the most abundant live species at the time of the second spawner survey, accounting for more than 51% of the live fish; however, Chinook salmon accounted for more than 84% of the redds, and 96% of the carcasses that were observed.

Table 5. Reach delineation, species, and total number of live, dead, and redds observed during spawner survey conducted in Green River, King County, Washington, 29 October 2004.

Zone	Reach Length (ft)	Species	Live Fish	Carcasses	Redds
RESTORATION ZONE 1					
ELJ Site 1	**325**	**Chinook**	1	8	3
		Coho	0	0	0
		Pink	0	0	0
		Sub-total	1	8	3
		No.•1,000 ft^{-1}	***3.1***	***24.6***	***9.2***
RESTORATION ZONE 2					
ELJ Site 2	**325**	**Chinook**	1	32	10
		Coho	3	0	1
		Sockeye	0	0	0
		Sub-total	4	32	11
		No.•1,000 ft^{-1}	***12.3***	***98.5***	***33.8***
NON RESTORATION ZONES					
	21,775	**Chinook**	30	317	96
		Coho	32	15	19
		Sockeye	1	0	0
		Sub-total	63	332	115
		No.•1,000 ft^{-1}	***2.9***	***15.2***	***5.3***
GRAND TOTAL					
	23,175	**Chinook**	32	357	109
		Coho	35	15	20
		Sockeye	1	0	0
		Total	68	372	129
		No.•1,000 ft^{-1}	***3.0***	***16.6***	***7.0***

Figure 20. Location of Chinook salmon redds in Restoration Zone 1, Green River, 29 October 2004.

Chinook redd density (52.3 redds•1,000 ft^{-1}) observed in this study during the initial survey was higher than the average Chinook redd density observed in the upper Green River from 1999-2004 by WDFW (20.3 redds•1,000 ft^{-1}; std. dev. = 12.9). In addition, total Chinook redd density combining both surveys (72.3 redds•1,000 ft^{-1}) is more than three times the mean density obtained by WDFW from 1999-2004 (Figure 21). While higher than 2003, the Chinook redd densities observed in Restoration Zone 1 compare favorably to densities obtained from the highest concentration of Chinook spawners on the Green River (Malcom 2002). Overall redd densities in the reach were buoyed by large concentrations of spawning Chinook observed downstream from the Kanaskat-Palmer Highway Bridge in 2004 (see Appendix D).

A high flow event occurred in late August 2004 that eroded much of the 3,900 yd^3 gravel loaded on the upstream gravel berm. Chinook spawning was not observed on the gravel berm itself, however numerous redds were located immediately downstream from the gravel berm (Appendix D). Chinook spawning on these gravels may have utilized unconsolidated materials resulting in scoured redd locations during subsequent higher flow events that occurred in late November and mid-December.

The effect of gravel nourishment is beginning to be demonstrated downstream of the project reach. For example, in 2004, we observed numerous Chinook spawning in reaches downstream from the gravel supplementation zone that were devoid of spawning-sized gravels the previous year. The transport of spawning-sized gravels to further downstream reaches should be expected in the coming years, increasing the importance for annual spawning surveys in the upper Green River. As the gravels are dispersed, we should expect to see spawning Chinook more evenly distributed throughout this reach, instead of the heavy concentrations in areas of suitable substrate.

3.3.3.2. WDFW Redd Counts

Chinook salmon redds/mile around the project reach are presented in Figure 21. These data are an estimate of total redds in the reach based on a series of aerial and boat surveys. Data indicate that number of redds in the 59.2 – 60.4 zone 1 project reach has increased slightly since project construction. Table 6 indicates number of redds/mile in this reach divided by average redds/mile in the Green River for the given year. This provides some indication of the amount of spawning in this reach relative to the rest of the Green River.

Table 6. Chinook redds per mile at zone 1 project reach divided by Green River average (from Cropp 2004)

Chinook redds/mile	
Year	RM 59.2 - 60.4 / Green River average
1999	0.35
2000	0.14
2001	0.96
2002	0.55
2003	1.21
2004	0.83

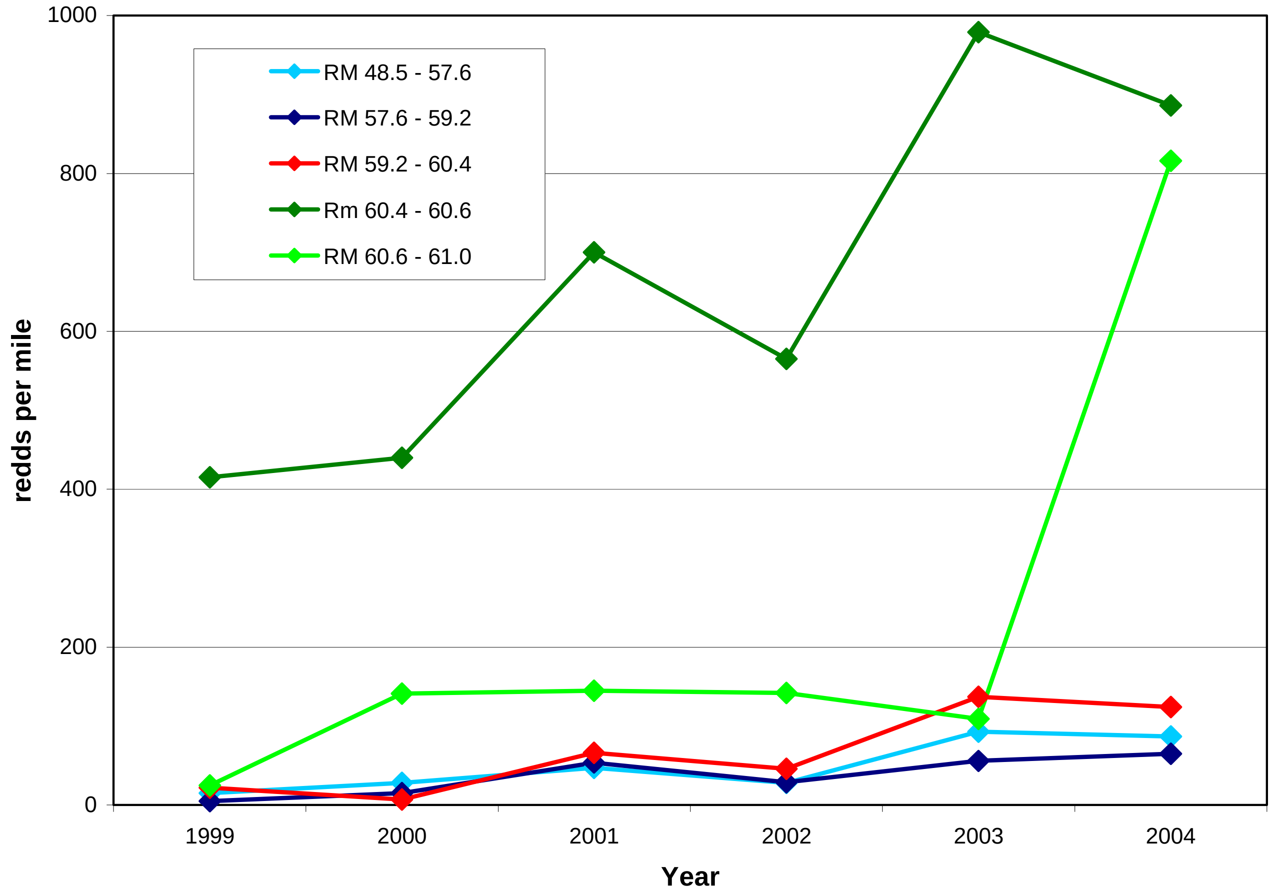


Figure 21. Chinook salmon redd density (redds per mile) observed in Green River above and below gravel nourishment site at RM 60, King County, Washington, 1999-2004 (from Cropp 2004).

The RM 60.4 – 60.6 and 60.6 – 61.0 reaches contain the last available spawning gravels before the Tacoma Headworks Dam. This area typically sees high spawning activity due at least in part to juvenile releases above the dam and an inability to pass beyond the dam. In 2004, a spike was observed in the 60.6 – 61.0 reach that is probably the result of construction activities at the Tacoma Headworks. Isolation berms composed of spawning gravels were built in the river to facilitate this construction. The gravels were subsequently released to the river at the conclusion of construction and were thus available to spawning fish in fall 2004 (Hickey 2005).

3.3.3.3. Gravel Composition of Chinook Redds

In order to further evaluate the effectiveness of gravel nourishment, an analysis of Chinook redd gravel size was undertaken to compare gravel sizes at the project reach with a downstream non-gravel starved reach of the Green River.

Methods

Two river segments separated by 30 km were chosen for the study: one downstream at approximately RM 40 (Metzler reach) and one upstream segment RM 57-61 (Figure 22). These two segments represent major spawning areas upstream and downstream of the Green River gorge (Kerwin and Nelson 2000; Malcom 2003). The upstream segment is subject to Howard Hanson Dam-induced gravel starvation, while the downstream segment is not. Each segment was subdivided into smaller reaches based upon channel configuration and the location of restoration activities to permit comparisons of substrate size and redd dimensions within segments. Surveys were conducted weekly from mid-September until the end of November.

The river was walked by an observer wearing polarized glasses. The observer moved downstream in a zig-zag pattern, water depths permitting, to identify Chinook redds. Only redds judged to be completed by a well defined tailspill and pit (Schmetterling 2000) were measured. Redd location was recorded by GPS.

Substrate composition was determined using a modified Wolman pebble-count method (Wolman 1954) around the redd perimeter were conducted to determine surface substrate size. However, since this study sought to determine the influence of gravel and larger substrate size upon redd area, no effort was made to sample fines that could be readily excavated and transported downstream in the current. Following Rennie and Miller (2000), the pebble count was performed at 0.5 m intervals in the undisturbed substrate immediately adjacent to the disturbed substrate. With the eyes averted, a hand was lowered into the water column and the first pebble encountered retrieved (Pasternack et al. 2004). If surface fines were present, the finger was pushed through till it encountered granular material. The pebble counts extended from the upstream edge of the redd downstream to where the tailspill mound rose above the original streambed. In most cases, samples taken at or adjacent to redds are considered to represent substrate used by spawning salmon (Kondolf 2000). Particles were measured along their median axes (that smallest axis that fits through a sieve) to the nearest mm using calipers.

Additional data collected included water depths over redds, redd length and width, determination of whether redds were confined, and an estimate of Chinook size.

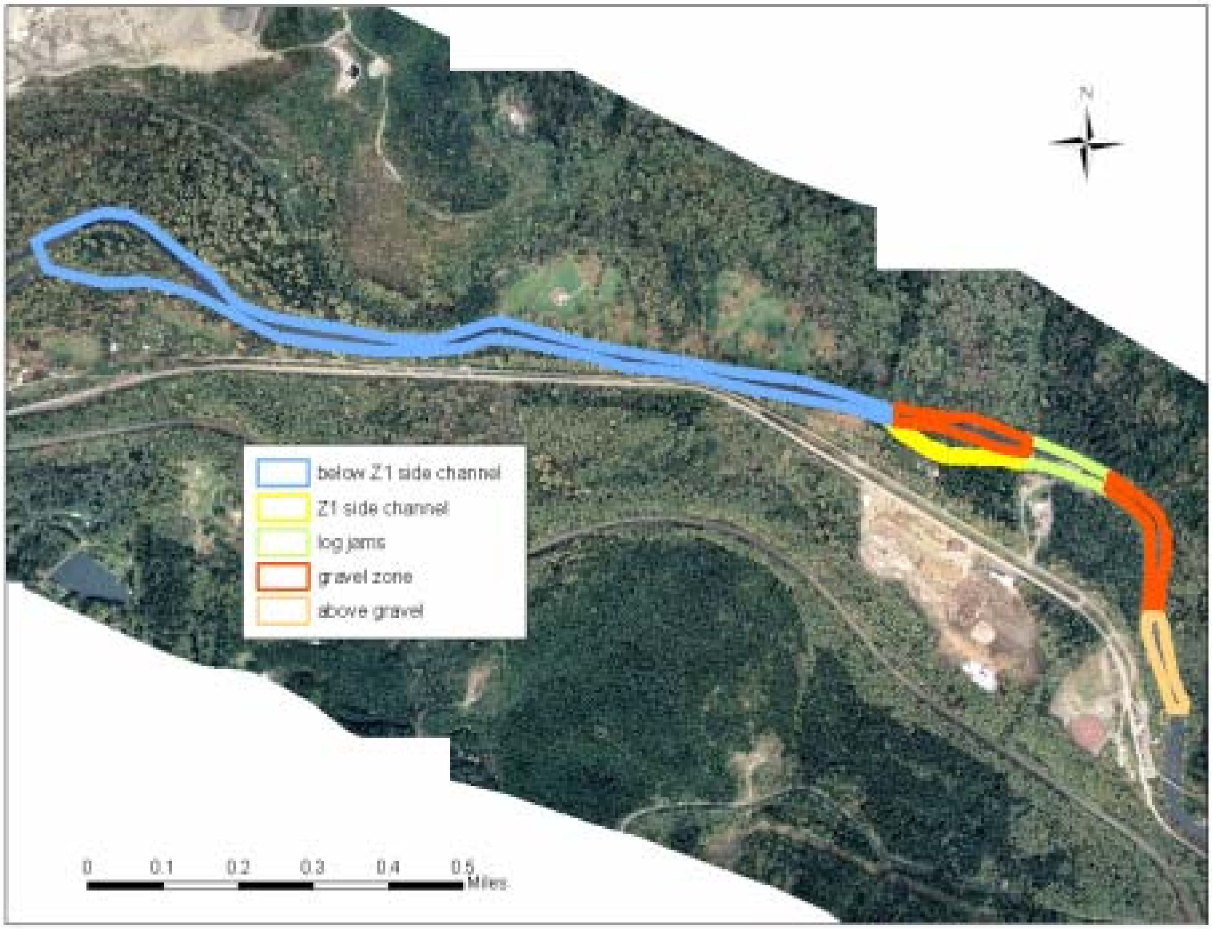


Figure 22. Stream sections upstream of Green River Gorge used to compare Chinook redd gravel size.

Results

Individual median gravel sizes from all redds within the identified segment are presented in Figure 23. The data indicate that redds were constructed in similar sized gravels in all segments except for the zone 1 side channel and the gravel zone where redds were generally constructed in coarser gravels. Both of these locations have received gravel nourishment since 2003. However, they are relatively steep sections of the river where limited gravel has accumulated (Figures 12 and 13). The log jam segment indicates redds in this segment consisted of gravel size similar to the 'unstarved' reaches downstream. Further details can be found in appendix E.

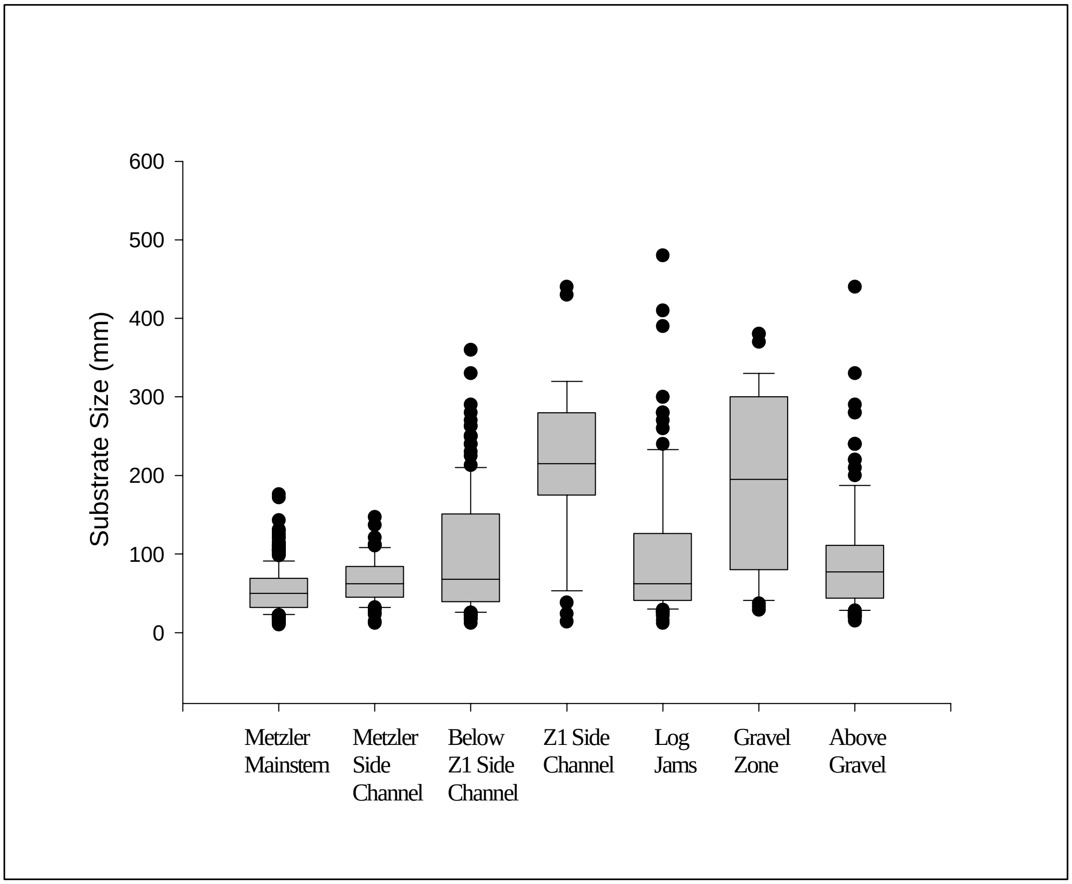


Figure 23. Box-plot of median gravel size along perimeter of Chinook redds by stream section.

3.3.4. Steelhead Trout Spawning Activity

3.3.4.1. Restoration Zone Spawner Survey

Steelhead redd data (number and locations) were collected within ELJ test and control sites on 26 April and 21 May 2004. Overall steelhead redd density was greatest within the ELJ 2 test site (Figure 24; Table 7). Steelhead redd densities ranged from 33.9 redds•1,000 ft^{-1} (ELJ 2 Test Site) to zero at the ELJ 2 Control Site. All live steelhead were observed holding under the upstream footprint of the ELJ structure. The redd densities observed within Restoration Zone 1 are higher than the average redd density (7.4 redds•1,000 ft^{-1}; std. dev. = 6.2) observed by WDFW in the upper Green River from 1998-2004 (Cropp 2004).

Table 7. Steelhead redd density (no·1,000 ft^{-1}) and total number of live steelhead observed during juvenile snorkel surveys conducted in Restoration Zone 1, Green River, King County, Washington, 2004.

Site	Reach Length (ft)	26 April 04		21 May 04		Total Redd Density
		Redd Density	*Live Fish*	Redd Density	Live Fish	
ELJ 1 Test	325	6.2	9	12.3	14	18.5
ELJ 1 Control	325	3.1	0	3.1	0	6.2
ELJ 2 Test	325	12.3	5	21.5	8	33.8
ELJ 2 Control	325	0.0	0	0.0	0	0.0
Total			14		22	

Figure 24. Location of steelhead redds in Restoration Zone 1, upper Green River, King County, Washington, 26 April and 21 May 2004.

3.3.4.2. WDFW Redd Counts

Steelhead redd data collected by Washington Department of Fish and Wildlife are presented in Table 8. These data are an estimate of total redds in the reach based on a series of aerial and boat surveys. Steelhead trout spawning activity was increased in the zone 1 reach in 2004 relative to previous years (Figure 25). Gravels were placed in August 2003, so Winter/Spring 2004 was the first year that nourishment gravels were available to Steelhead.

Table 8. Steelhead redds per mile divided by the Green River average (from Cropp 2004)

Steelhead redds/mile	
Year	RM 57.5 – 61.0 reach / Green River average
1998	0.52
1999	1.06
2000	1.95
2001	0.53
2002	1.37
2003	0.59
2004	2.15

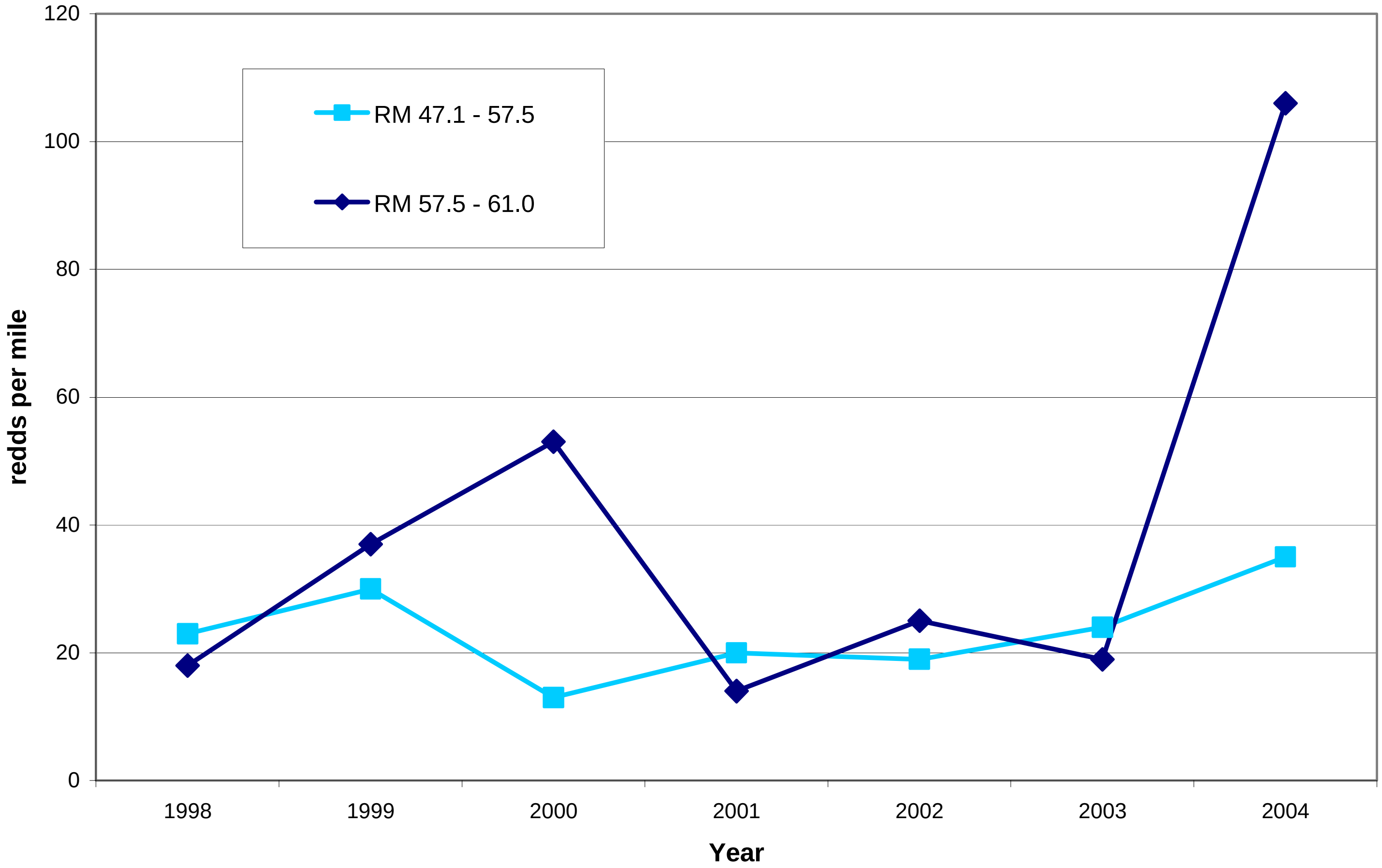


Figure 25. Steelhead trout redd density (redds per mile) observed in middle Green River above and below gravel nourishment site at RM 60, King County, Washington, 1999-2004 (from Cropp 2004).

3.4. Performance Summary

- The project experienced erosion of 95% of the berm gravel under moderate flow conditions. This met the performance criterion of 90% mobilization.
- Gravel berm configuration is of limited importance in facilitating gravel berm erosion.
- USACE mapped 1.36 acres of streambed around the ELJs and 0.32 acres in the downstream side channel composed of spawning sized gravels. Pebble counts in this area indicate that the baseline d-50 grain size was reduced from 5.5-inches to less than 2-inches.
- USACE mapped 3.66 acres of gravel deposits in the Zone 1 reach, indicating that the impacts of the nourishment project on bed material composition are on a “reach scale”.
- Redd data indicates use of the nourishment gravels by both steelhead and Chinook salmon (Figures 26 and 27). Coho salmon were also observed at the site; however, spawning activity of coho was not specifically monitored.
- Spawning Chinook were also attracted to the side channel as evidenced by the difference in redd density in 2004 compared to 2003.
- The USGS Palmer stream gage experienced increased stages due to a flow constriction created by the upper gravel berm. In order to provide accurate discharge information at this site, USGS frequently made physical measurements of discharge to adjust the rating curve. This gage is used by TPU and the Corps to regulate flows in the Green River. The upper nourishment berm will be reconfigured to eliminate the backwater effect on the gage (see Section 3.5.1).

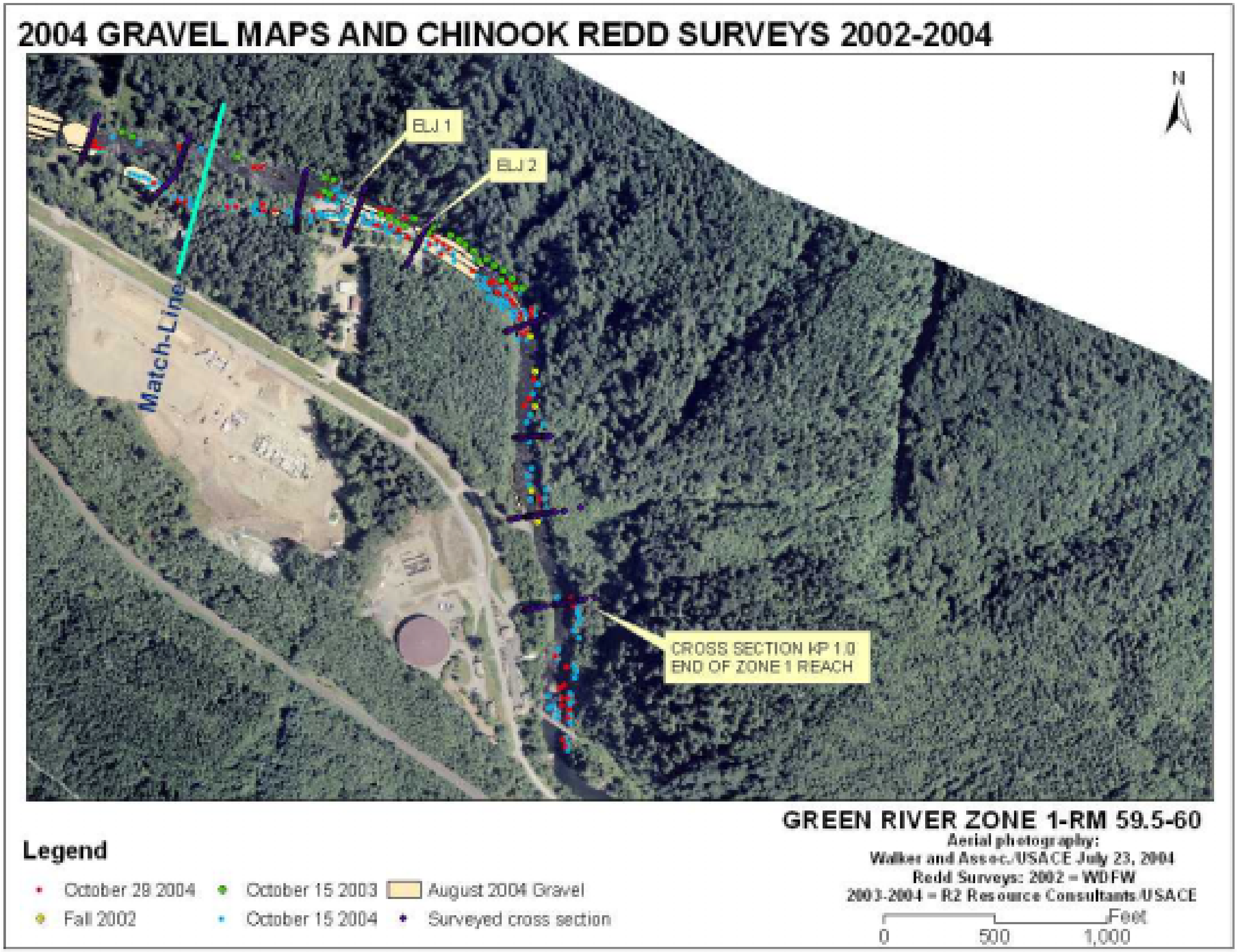


Figure 26. Zone 1 Gravel Patch mapping and 2003-2004 Chinook redd locations, RM 59.5-60

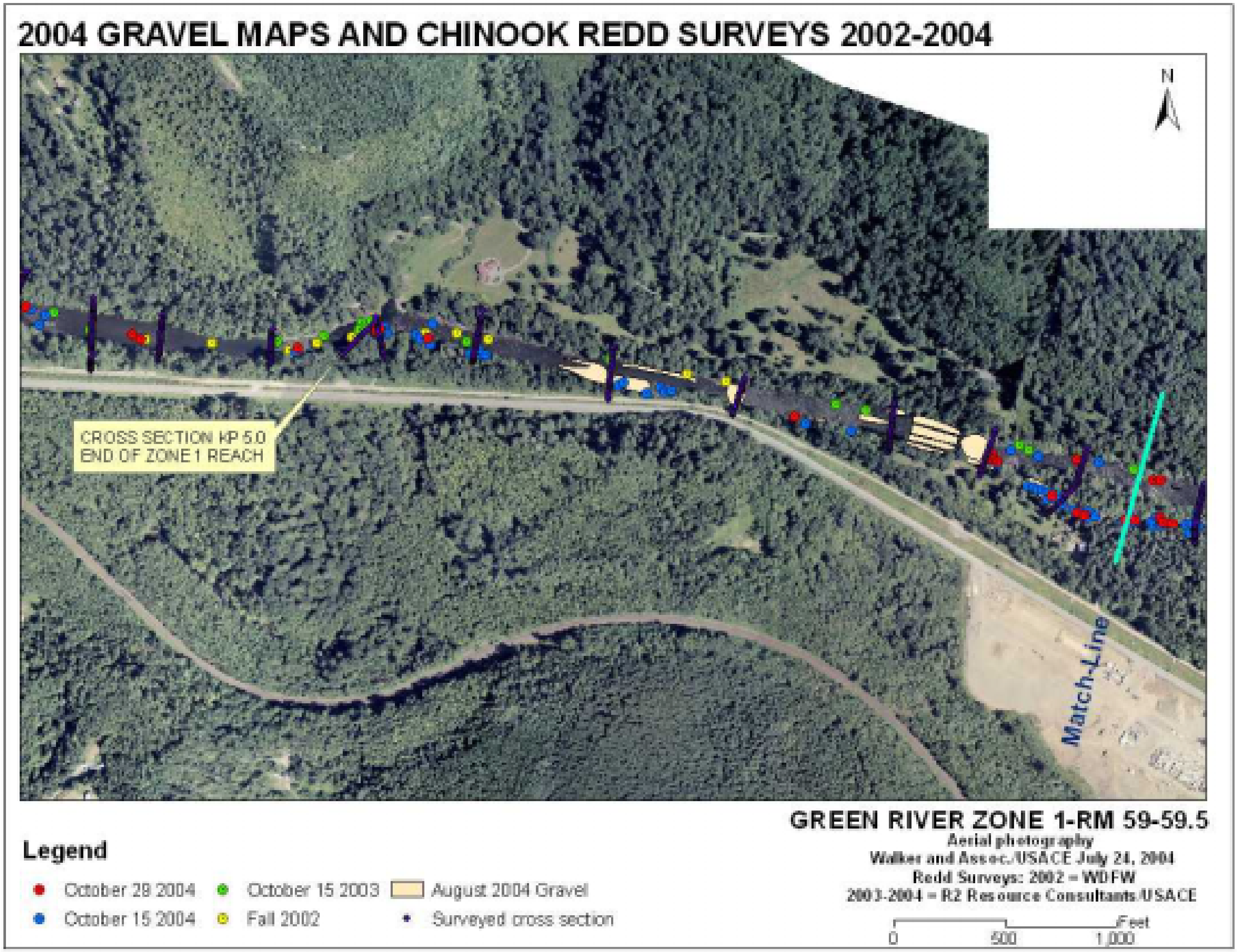


Figure 27. Zone 1 Gravel Patch mapping and 2002-2004 Chinook redd locations, RM 59-59.5

3.5. Adaptive Management

3.5.1. Palmer Stream Gage

Gravel placement at the upper gravel berm caused backwatering of the USGS gage that is immediately upstream. This persisted until the gravel at the upstream end of the berm had eroded. This required the USGS to re-rate the Palmer gage during the period of time where the gravel berms were creating backwater. To address this issue USACE undertook studies to determine the maximum amount of nourishment gravel that can be placed and the configuration of the berm that will eliminate or minimize backwater (USACE 2005a). USACE employed the 2003 calibrated HEC-RAS hydraulic model to perform the analyses. Gravel berms were placed in the model as blocked obstructions within the project work limits. The baseline (without berm) water level was compared to the with berm water level at the uppermost model cross section located at the USGS gage. Since placed gravel erodes immediately after placement, 1,000 cfs was estimated as the upper limit discharge where the berm backwater would still impact the gage. Erosion rates measured in 2003-2004 indicate that higher discharges would not cause backwater at the gage because the berm would be sufficiently eroded. Table 1 below indicates that up to 5,300 yd3 (8,830 tons) could be placed in a modified configuration that would eliminate backwater at the gage. The model predicts that the minimum backwater impact from placing 12,000 yd3 (21,000 tons) in the upper loading zone in the recommended configuration would be about 0.5 ft.

Erosion of the berm gravel during moderate discharges may result in temporary storage of gravel in the upper reach, which may result in local bed elevation increases that are not reflected in the hydraulic models. The annual bedload transport capacity of this reach exceeds 12,000 yd3 (USACE 2004a), although reaches immediately downstream do not have the same transport capacity. The persistence of gravel around the nourishment berms and any associated stage impacts will be based on the total amount of loaded gravel, the berm configuration and location, and the frequency and duration of flows capable of transporting the eroded gravel downstream.

The geomorphic impacts of loading the maximum gravel quantity at the upper loading site (12,000 yd3) should be estimated through observation of changes resulting from annual incremental increases in the loading volume above 5,300 yd3.

Table 9. Gravel berm configurations and volumes for upper loading site to minimize USGS Palmer gage backwater (USACE 2005a)

BERM PLACEMENT OPTION	GRAVEL BERM VOLUME	AVG. BERM TOP WIDTH AT OHW LINE	BERM SIDE SLOPE	BERM HEIGHT ABOVE OHW LINE	BERM LENGTH	NEAREST U/S BERM XS	NEAREST D/S BERM XS	INCREASE IN BACKWATER @ 1,000 CFS
	(CY)	(FT)	(H:V)	(FT)	(FT)	(STA)	(STA)	(FT)
1	5,300	45	2	6	390	27	26.05*	< 0.05
2	8,000	55	2	6	580	27.7*	26.05*	0.13
3	12,000	70	2	7	580	27.7*	26.05*	0.45

3.5.2. 2004 and 2005 Gravel Nourishment

Based on preliminary monitoring data that indicated gravel placed in 2003 was eroded at rates faster than anticipated and concern about trying to retain gravels in the reach, a decision was made to slightly increase the gravel size specifications in 2004. The general rationale for this modification is that the larger gravel size will increase spawning opportunities for salmon by providing increased gravel stability over a broader range of hydraulic conditions compared to placing just the smaller size gravel. Chinook salmon have been reported using this larger gravel (Schuett-Hames and Pleus 1996, Pollock 1969, Burner 1951) and have been reported doing so in the Green River (Malcom 2004). WDFW also recommends spawning gravels up to 6 inches in diameter or larger for this type of project (WDFW 2002). Table 10 is a summary of gravel placed in the river in 2003 and 2004. Gravel monitoring for the 2004 placement will occur in summer 2005.

2004 gravels were slightly coarser at the small end of the range (i.e. few gravels in the one inch range). The specification has been tightened to ensure that a higher percentage of gravels are in the one inch and below range for 2005. The planned 2005 gravel nourishment includes approximately 7000 tons of gravel of the specification indicated in Table 10.

Table 10. Summary of gravel placed in the Green River at RM 60.

	1998 FR/EIS proposed	2003 placed	2004 placed	2005 target
sieve	% finer	% finer	% finer	% finer
6 inch (152 mm)				
5 inch (127 mm)			99.4	100
4 inch (102 mm)	100	100	92.6	85-95
3 inch (76 mm)			76.8	70-90
2 inch (51mm)	70-85	65	55.3	50-70
1 inch (25 mm)	25-50	27	10.9	20-40
0.5 inch (13 mm)	0	6	2.1	0-5
Quantity placed:				
total tons:		7555	7023	7000
tons (not including fines < 0.5 inches):		7102	6876	6650
cubic yards (0.6 cubic yards/ton):		4261	4125	3990

4. LOG JAMS

4.1. Design and Performance Criteria

- Stable to the 100-year flood flow which is 12,500 cfs.
- Top of the log jams will be a minimum 1-foot above the 100-year water surface elevation.
- Create and maintain scour pools.
- Increase flow into downstream side channel.
- Provide habitat for fish.

4.2. Monitoring Activities

The objective of log jam monitoring is to evaluate performance and general effectiveness toward achieving project objectives. In WY 2004, monitoring consisted of an evaluation of structural stability, analysis of side channel flow, survey of scour pools, and fisheries activity. Photographs and analysis were collected during high flow events and during the summer low flow period.

4.2.1. Log Jam Stability

4.2.1.1. High Flow Monitoring

Interim assessments of ELJ performance during high-flow periods were conducted after construction. A detailed analysis of log jam stability was conducted and reported in the Final Design Memorandum for 2004 Construction, May 2004 (USACE 2004b). In WY 2004, the Green River experienced six high flow events with peak discharges greater than 2,000 cfs. Several key observations on ELJ performance were made during these events.

Monitoring indicated that ELJ2 was beginning to overtop at much lower discharges than expected based on the design analysis. On November 18, 2003, ELJ2 was overtopped at a flow of 4,300cfs (Figure 28). This was attributed to several factors including 1) log jam construction was approximately ½ foot lower in elevation than the original design, 2) an underestimate of water surface profile elevations from the hydraulic model, and 3) changes in scour hole conditions. Details regarding factors one and two can be found in the Final Design Memorandum for 2004 Construction.

Figure 28. ELJ 2 Nov 18, 2003 4,300 cfs

Figure 29. ELJ 2 Jan 30, 2004 4,815 cfs

Factor three is the result of the dynamic nature of sediment transport through the reach. Photo analysis indicated that overtopping of ELJ2 occurred at 4,300cfs whereas higher flows on January 30, 2004, resulted in a 1 to 2 feet lower water surface elevation for a 4,815cfs event (Figures 28, 29). In November it is likely that gravel berm erosion and transport resulted in infilling of the ELJ scour holes resulting in the above described conditions. What this information indicates is that the scour holes are highly dynamic and that the influence of the upstream gravel nourishment features will likely mean that the log jams will experience a range of flood stage conditions for a variety of flows, and the flood stage height will be dependent on the amount of gravel in the scour hole. For periods when gravel loading into the scour hole is high, water surface elevations will likely be higher. As gravel is transported through the reach residual sediments in the scour holes will begin to be evacuated, and the scour holes may enlarge. This will increase the cross sectional area resulting in lower water surface elevations.

4.2.1.2. Settlement and Deformation

In 2004, log jams were evaluated visually and compared to 2003 photos. No obvious changes to the log structure of the downstream ELJ 1 (Figures 30 and 31) or the upstream ELJ 2 (Figures 32 and 33) were observed. As mentioned above, overtopping of ELJ did occur at undesired flows and ballast was lost from the structure (section 4.2.1.4). Based on visual observations and photographic comparison, the two ELJs generally appear stable and have not experienced serious settlement or deformation.

Figure 30. ELJ 1 September 3, 2003

Figure 31. ELJ 1 August 2, 2004

Figure 32. ELJ 2 September 3, 2003

Figure 33. ELJ 2 August 2, 2004

4.2.1.3. Wood Loss and Accumulation

Several racking logs that were placed on the front of the log jams were found downstream, presumably removed from the log jams during high flow events. Two logs with USACE tags were reported racked into a wood jam in Kanaskat Palmer state park. On March 19, 2004 USACE verified the presence of two racking logs with USACE tags. Only one tag was visible, #194 that originated from ELJ 1 which is approximately 3.5 miles upstream. Racking log #63 from ELJ 2 was found at about RM 58 during the fall 2004 spawner surveys.

ELJ stability is not at risk from loss of racking members, although ongoing loss of racking members could be indicative of conditions that over time may result in loss of structural stability through erosion of ballast material or structural members.

Minimal new wood debris was recruited and captured on the front of the jams.

4.2.1.4. Ballast Material

As discussed in section 4.2.1.1 above, ELJ 2 was being overtopped at flows less than the bankfull event and was losing unacceptable quantities of ballast. Figure 34 illustrates the amount of ballast lost relative to the as-built condition. Since the continued loss of ballast material would reduce the design safety factor, measures were taken to add ballast to the structure. Additional detail regarding the design analysis for the 2004 retrofit construction can be found in Section 4.4 and the 2004 retrofit design memorandum (USACE 2004b).

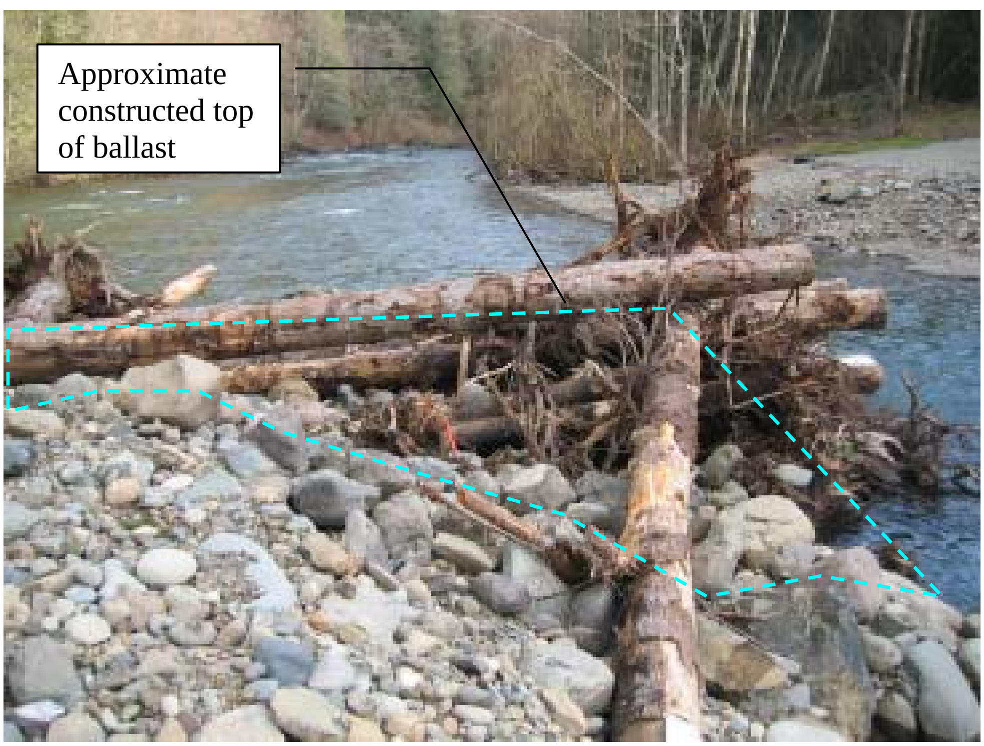


Figure 34. ELJ 2 racking material and eroded ballast, 11 February 2004.

4.2.2. Pool Development

Pool area in front of the log jams was measured by area and depth. The apparent invert of the ELJ 2 scour hole was located at the left corner of the racking material, looking downstream. The surveyed invert elevation was 841.85 ft. The field-surveyed water level at the time was elevation 850 ft. The pool tail-out crest elevation was not surveyed, but was estimated to be about 1-ft below the field water surface for a residual pool depth of 7 ft. The 2003 as-built pool invert for ELJ 2 was around elevation 840.0. The pool depth thus decreased by nearly 2 feet over the year. This is approximately 5 ft less than the 12.0 ft estimated design depth. The left side scour pool around ELJ 1 had nearly filled in (1/2-2/3 full) with nourishment gravel (as-built invert was 838 ft). The invert was not surveyed in 2004. Since scour pool depths are greatest during high flow events, it is not possible to say that the design scour pool depth is being maintained at either jam. Clearly, conditions at the lower jam are different, since the degree of pool infilling is more severe.

Figure 35. Scour hole development at ELJs.

Aerial photo comparison of the as-built pre-excavated pool area in September 2003 with the one year post project area in July 2004 indicate that each scour hole enlarged in area (Figure 35). ELJ 1 pool area increased from 2,670 ft^2 to 2,730 ft^2. ELJ 2 area increased from 1,740 ft^2 to 2,820 ft^2. From visual inspection, ELJ 1 appears to have lost about half to two thirds of its pool volume, where ELJ 2 appears to have moderately enlarged as the scouring flows around the jam flattened the steeply pre-excavated scour hole side slopes.

The constructed scour holes around the front and sides of the jams evolved in response to the high flow events and bedload supplied by the gravel nourishment berms. The scour hole on the front left side of ELJ2 expanded to become an active side channel. During the December high flows it was observed that the pre-excavated scour hole on ELJ1 had completely filled with gravel, most likely derived from upstream gravel nourishment berms and fine gravels turned up during ELJ construction. However, observations after the 6,000cfs event in January found that both scour pools had reformed around the jams and potentially even expanded larger than the original configuration.

Gravel nourishment effects the morphology of the scour hole development. Gravel waves were observed to partially fill in scour holes after flood events where gravel transport was occurring (USACE 2004b). Once the majority of gravel had passed through the reach, the sediment transport capacity around the scour holes increased, and pool sediments were scoured out. This lowered flood levels at comparable discharges (Figure 28 and 29).

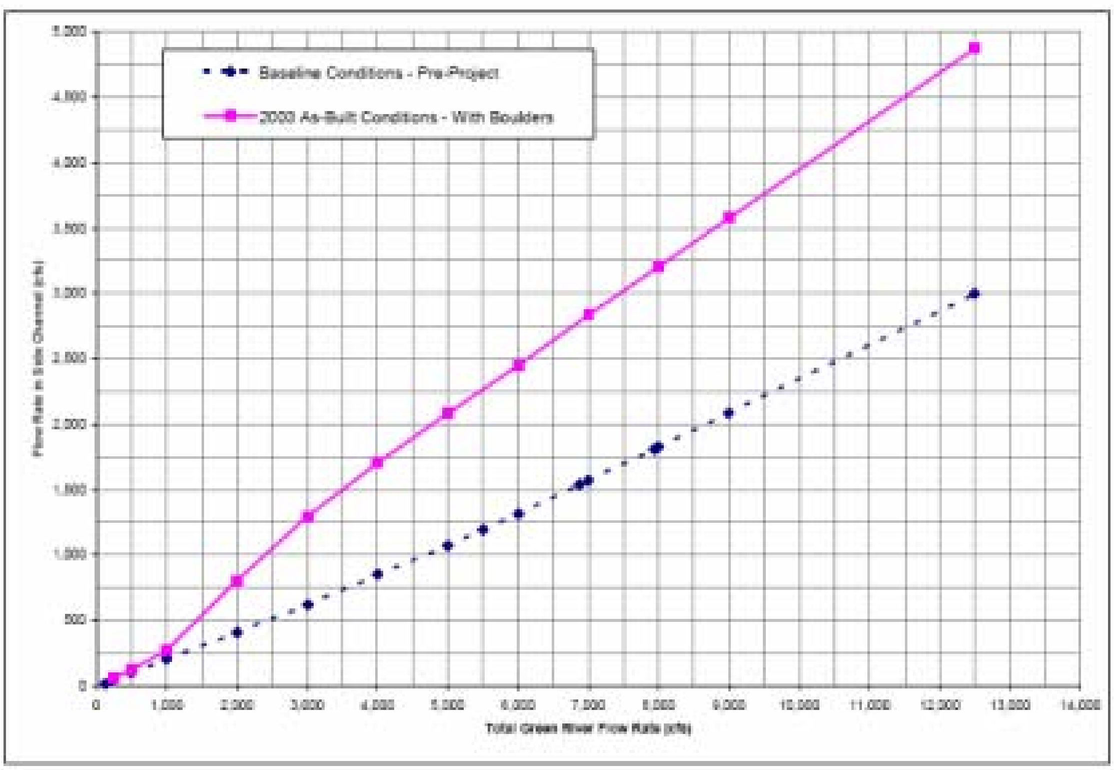


Figure 36. Updated hydraulic model indicating flow into side channel, Baseline vs. 2003 as-built conditions

4.2.3. Side Channel Flow

Based on high flow site visits in October 2003 and January 2004, the river appeared to have more flow in the side channel relative to the baseline condition. During the January 2004 high flow event (6,010 cfs), an estimate was made based on site observations of the flow distribution around the log jams. It was estimated that at the upper end flow is about 60-70% to the right of ELJ 2, and 30-40% to the left. Between the ELJs, about 10-15% of the flow returns to the right main channel. About 25% of the flow enters the side channel, and 75% remains in the main channel.

The updated hydraulic model also indicated an increased flow into the side channel relative to the baseline condition (Figure 36). Based on results of the analyses, the increased roughness caused by placed boulders in the main channel upstream of ELJ 2 and the obstruction created by the ELJs was guiding a higher percentage of flow into the side channel entrance (USACE 2004b). No adverse erosion was reported or observed along the side channel.

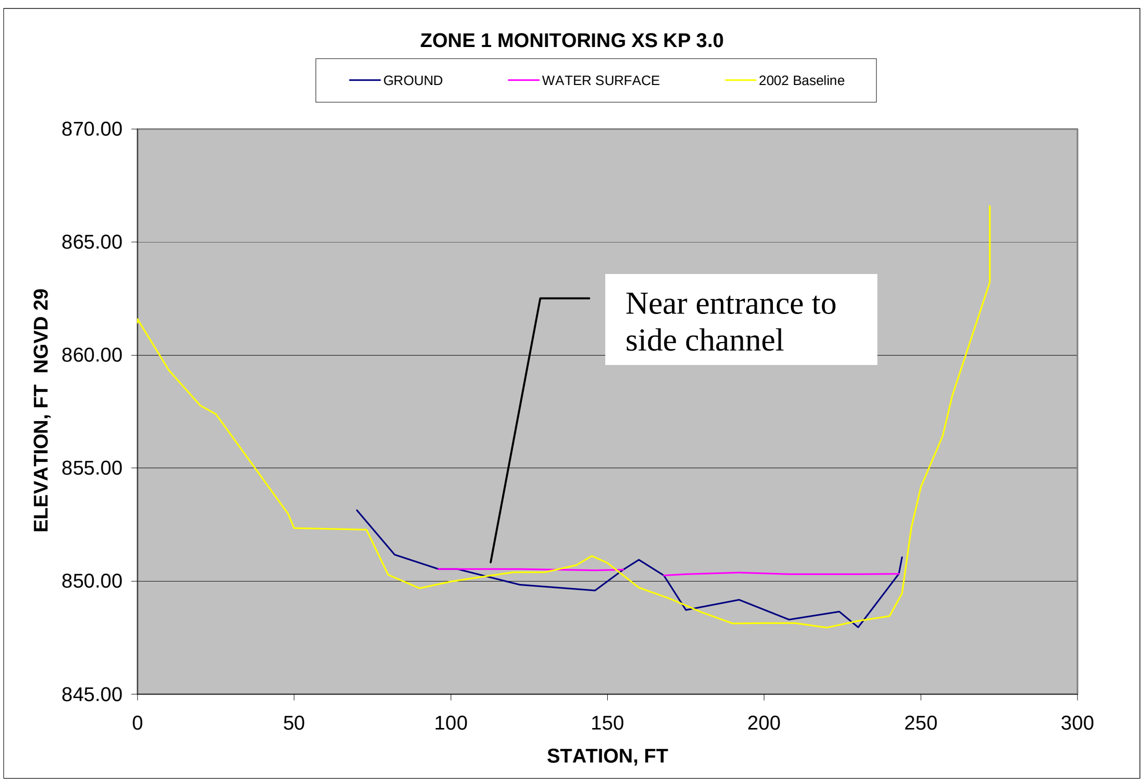


Figure 37. Cross section changes at KP 3.0.

4.2.4. Fisheries Use

Biological surveys were conducted to collect habitat use data on juvenile and adult salmonid abundance at two sites within Restoration Zone 1 where engineered logjams were installed (treatment sites), and at two sites with habitat characteristics similar to the treatment sites, but which have not been identified for habitat manipulation (control sites). The ELJ biological monitoring included the following data modules: pre- and post construction juvenile surveys within the control and treatment sites and post-construction adult surveys within the control and treatment sites. Pre-construction juvenile surveys were conducted on 12 August 2003. In addition to the snorkel surveys, a post-construction fall spawner survey was conducted in 2004 that encompassed both Restoration Zone 1 and the upper Green River downstream to Kanaskat/Palmer State Park (RM 56.5-RM 60.4).

4.2.4.1. Study Design

A post-treatment experimental design was used to determine the response of juvenile salmonids to ELJ construction by comparing densities at control sites to juvenile salmonid densities at treatment sites. Control sites (Figures 39 and 41) with similar habitat characteristics to the treatment sites (Figures 38 and 40) were identified prior to conducting biological surveys on 5 August 2003 in consultation with USACE personnel. Candidate control sites were initially identified using the baseline habitat survey information (USACE 2003a). In order to minimize the effects of non-treatment factors, control sites were located as near as possible to treatment sites.

Each treatment and control site was delineated into a 100 linear ft reach of river channel (linear count) that encompassed the ELJ as well as a footprint site, consisting of only the ELJ and immediate area surrounding it (footprint count) (Figure 42). Control and treatment footprint counts were delineated using an assumed ELJ footprint area of 70- X 50-ft (USACE 2003b). The footprint count was included in the linear foot count but was separated to examine the influence of the ELJ structure itself on juvenile salmonid densities.

In 2004, each treatment and control site was surveyed four times throughout the period of juvenile salmonid emergence. Juvenile salmonid snorkel surveys were conducted on 26 April, 21 May, 25 June, and 28 July 2004. In addition, treatment and control sites were also surveyed on 14 October to evaluate the habitat benefits of the ELJs to not only juvenile salmonids, but also adult salmonids.

Snorkel surveys were conducted by entering the water downstream of the selected sampling site and proceeding upstream until one complete pass was completed within the sampling site. The lateral distance between the snorkeler and the shoreline or adjacent snorkeler was based on underwater visibility and was adjusted at each site to ensure visual coverage of the area below and to each side of the snorkeler. Since the width of the Green River exceeds the visual capability of an individual snorkeler, each snorkeler covered separate visual lanes. The alignment and position of each snorkeler in the channel was maintained by verbal communication by an onshore observer.

Figure 38. Upstream pre-construction view of ELJ Treatment Site 1, 5 August 2003.

Figure 39. Downstream pre-construction view of ELJ Control Site 1, 5 August 2003.

Figure 40. Upstream pre-construction view of ELJ Treatment Site 2, 5 August 2003.

Figure 41. Downstream pre-construction view of ELJ Control Site 2, 5 August 2003.

Figure 42. Location of treatment and control snorkel sites with the restoration zone.

Three snorkel counts occurred at each control and treatment site on each survey date. Fish were identified and reported by species and size class (fry, overyearling, and adult). The onshore observer delineated snorkel counts obtained from the footprint from those of the linear counts at each site. Observations of non-salmonids were recorded but will not be used to evaluate the effects of treatment measures. Fish abundance was calculated using the formula:

$$N = 2N_m - N_{m-1}$$

where:

N	=	fish abundance;
N_m	=	largest count; and
N_{m-1}	=	second largest count.

The bounded count methodology is used when a number of divers obtain independent counts within a site (Regier and Robson 1967). The abundance estimate was converted to a density estimate by dividing by the area of each site. The linear count estimate is inclusive of the footprint estimate; the footprint estimate was calculated to measure the number of fish within the immediate influence of the treatment (i.e., ELJ). The wetted width and length of the linear and footprint count from each control and treatment site was measured with a Bushnell® Compact rangefinder. The rangefinder was calibrated using a 500 ft tag line. Flow conditions, as measured by the USGS gage near Palmer (USGS No. 12106700), were also recorded on field notes. Water temperature to the nearest 0.5°C (measured using a handheld thermometer) and underwater visibility (measured using a Secchi disk) were recorded for each site during pre- and post-construction surveys. Pre- and post-construction photographs were taken at each control and treatment site. All data were entered electronically using MS Excel™ and cross-referenced with original field data forms for QA/QC purposes. Unless otherwise noted, all statistical analyses were performed using SigmaStat™.

4.2.4.2. Juvenile Salmonids

Total juvenile salmonid abundance at both ELJs was greater at the Treatment Site compared to the Control Site during all survey dates (Figure 43). The differences observed between the treatment and control sites were not significant, however ($P > 0.05$). Juvenile salmonid abundance peaked at both ELJ 1 control and treatment on 25 June when 926 and 859 juvenile salmonids were observed per 1,000 ft^{-2}, respectively. Likewise, total juvenile salmonid abundance at ELJ 2 was greater at the Treatment Site when compared to the Control Site during all survey dates (Figure 44) ($P > 0.05$). Juvenile salmonid abundance also peaked at ELJ 2 control and treatment sites on 25 June when 650 and 114 juvenile salmonids were observed per 1,000 ft^{-2}, respectively. Overall, mean juvenile salmonid abundance was greater at ELJ 1 (421•1,000 ft^{-2}) when compared to ELJ 2 (174•1,000 ft^{-2}).

Age-0 juvenile Chinook salmon abundance peaked on the first survey date of 26 April and decreased throughout the study period at all treatment and control sites (Table 11; Figure 45). Overyearling Chinook were observed only once at ELJ 1 control site (Table 11). Mean age-0

Chinook abundance was the highest at ELJ 1 Test Site (64.70•1,000 ft^{-2}), followed by ELJ Test 2 (40.86•1,000 ft^{-2}), ELJ Control 2 (25.66•1,000 ft^{-2}), and ELJ Control 1 (16.50•1,000 ft^{-2}) (Table 11). Overall, age-0 rainbow trout (185.29•1,000 ft^{-2}) were the most abundant species/age cohort at each site location, followed by age-0 coho salmon (67.62•1,000 ft^{-2}), age-0 Chinook salmon (36.93•1,000 ft^{-2}), age-1+ rainbow trout (5.73•1,000 ft^{-2}), and age-1+ coho salmon (0.64•1,000 ft^{-2}) (Table 11; Figures 45-47). Juvenile salmonid abundance estimates were consistently greater from within the footprint of ELJ Test sites compared to overall lineal abundance from the site (Figures 48 and 49). Juvenile salmonids (age-0) appeared to identify with the shallow water interface with the large and small woody debris within the footprint of the test sites whereas age-1+ salmonids usually resided ate the interface of large logs and deeper (>2.0 ft) water.

Other fish species observed during the juvenile snorkel surveys in order of decreasing frequency of occurrence include; largescale sucker (*Catostomus macrocheilus*), longnose dace (*Rhinichthys cataractae*), three-spine stickleback (*Gasterosteus aculeatus*), coastrange sculpin (*Cottus aleuticus*), and mottled sculpin (*C. bairdi*). Each of these species were observed at densities less than 0.05 fish·1,000 ft^{-2} at each site on each survey occasion.

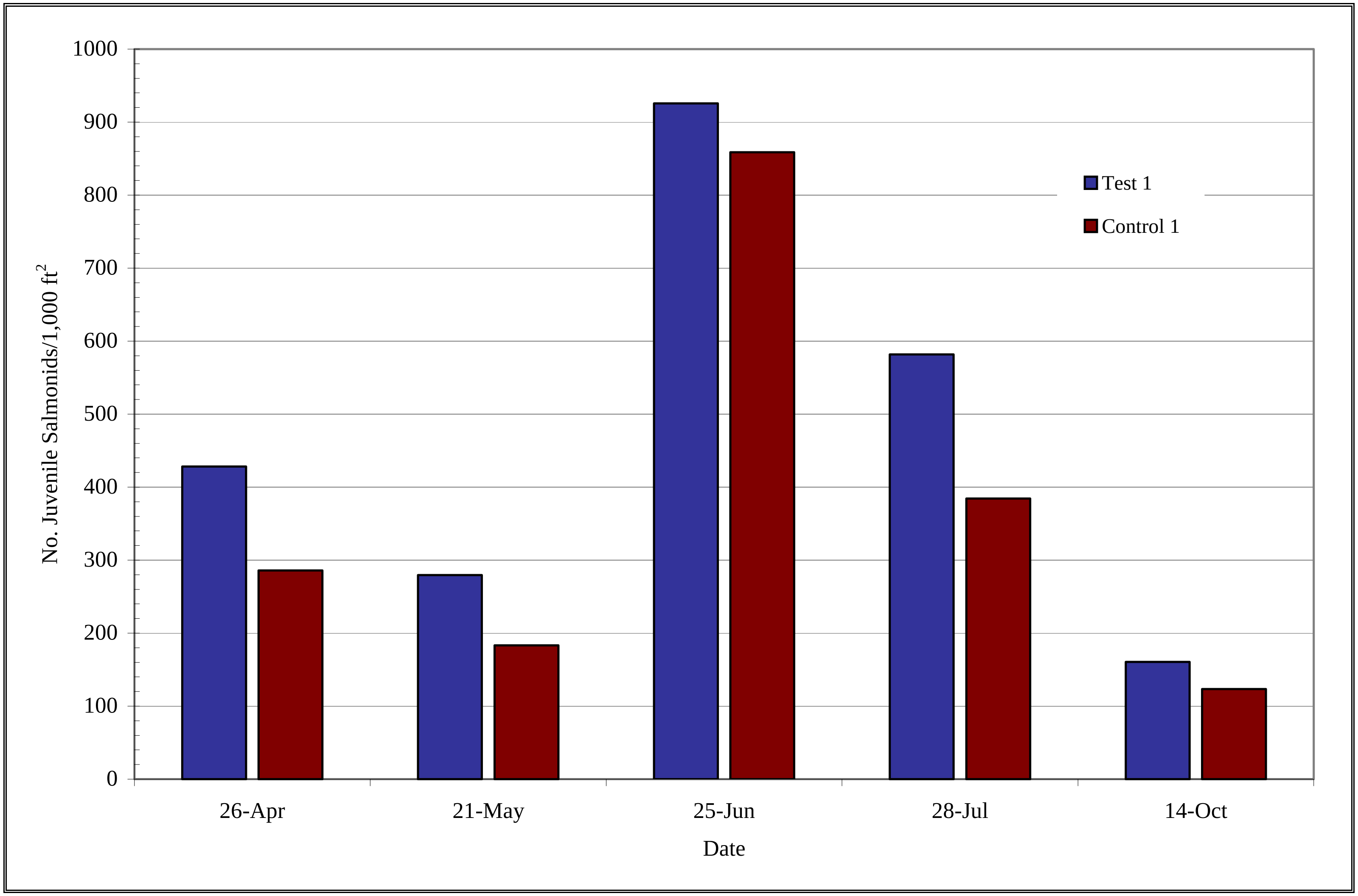


Figure 43. Juvenile salmonid abundance (no. fish 1,000 ft-2) at test and control sites of Engineered Log Jam Site 1.

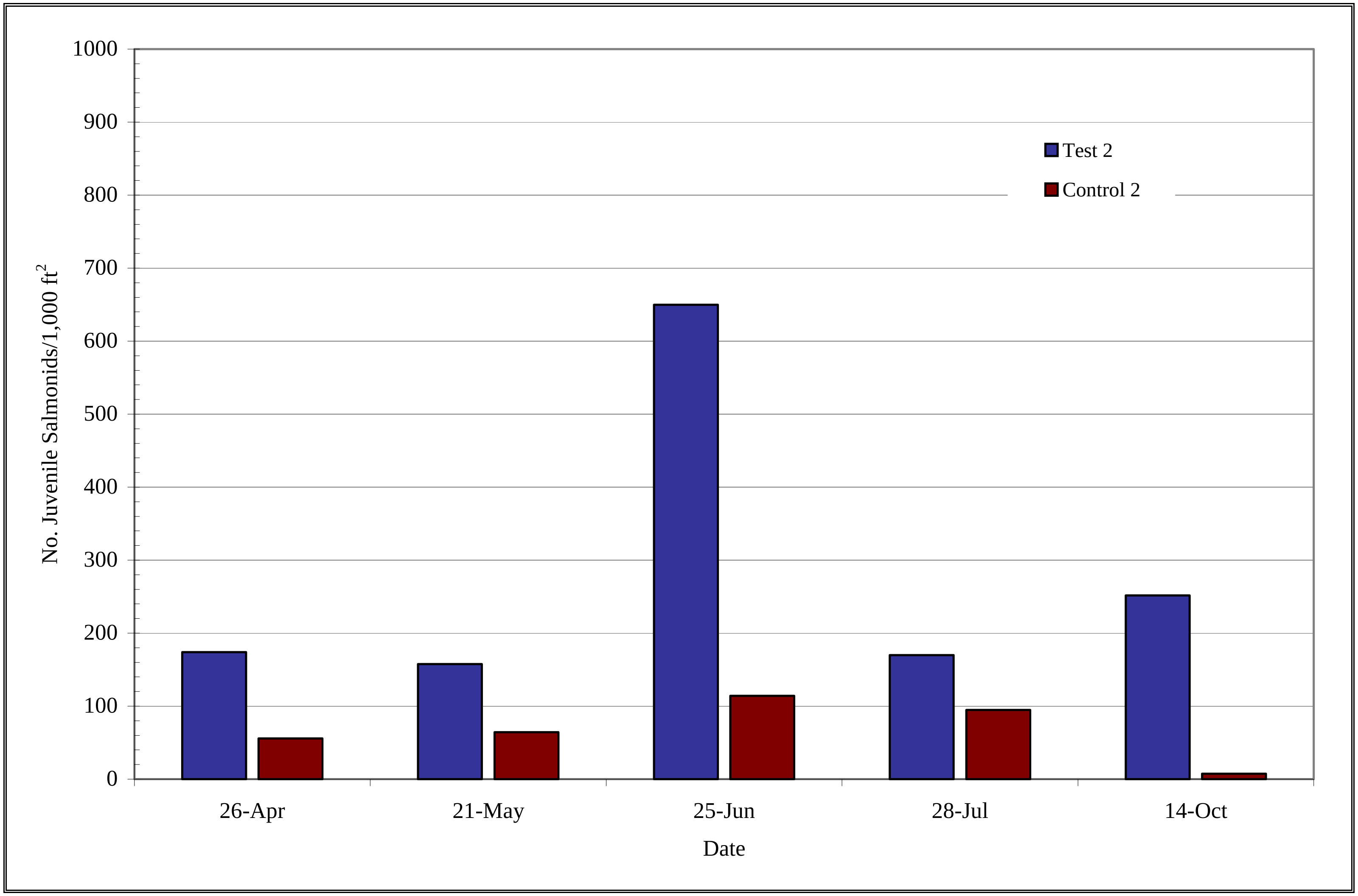


Figure 44. Juvenile salmonid abundance (no. fish·1,000 ft-2) at test and control sites of Engineered Log Jam Site 2.

Table 11. Juvenile salmonid population estimates (number of fish•1,000 ft^{-2}) obtained from snorkel surveys conducted at Engineered Log Jam sites in Restoration Zone 1, upper Green River, King County, Washington, 2004 (Chin = Chinook salmon, RBT = rainbow trout, MWF = mountain whitefish).

		Number •1,000 ft^{-2}					
		26-Apr	**21-May**	**25-Jun**	**28-Jul**	**14-Oct**	**Mean**
Test 1	Age 0+ Chin	223.33	93.69	6.45	0.00	0.00	64.70
	Age 0+ Coho	202.78	182.18	60.53	116.15	99.27	132.18
	Age 0+ RBT	0.00	0.00	854.18	464.73	46.35	273.05
	Age 1+ Chin	0.00	0.00	0.00	0.00	0.00	0.00
	Age 1+ Coho	1.11	1.74	0.00	0.00	0.00	0.57
	Age 1+ MWF	1.02	1.90	0.36	0.09	0.00	0.67
	Age 1+ RBT	0.00	0.00	4.18	1.60	15.09	4.17
Control 1	Age 0+ Chin	83.42	44.89	0.00	0.00	0.00	25.66
	Age 0+ Coho	202.29	133.24	23.42	11.56	13.22	76.75
	Age 0+ RBT	0.00	0.00	830.60	371.22	63.50	253.06
	Age 1+ Chin	0.00	0.00	0.09	0.00	0.00	0.02
	Age 1+ Coho	0.17	0.54	2.82	0.00	0.00	0.71
	Age 1+ MWF	0.00	1.17	1.45	1.78	5.00	1.88
	Age 1+ RBT	0.09	3.31	0.40	0.00	41.72	9.10
Test 2	Age 0+ Chin	111.98	92.31	0.00	0.00	0.00	40.86
	Age 0+ Coho	58.18	52.12	2.24	13.18	135.00	52.15
	Age 0+ RBT	0.00	0.00	644.55	155.60	74.24	174.88
	Age 1+ Chin	0.00	0.00	0.00	0.00	0.00	0.00
	Age 1+ Coho	0.16	6.19	0.00	0.00	0.00	1.27
	Age 1+ MWF	3.80	4.94	1.20	1.00	1.67	2.52
	Age 1+ RBT	0.00	2.08	1.74	0.09	40.95	8.97
Control 2	Age 0+ Chin	44.54	37.97	0.00	0.00	0.00	16.50
	Age 0+ Coho	11.19	24.75	7.17	2.18	1.82	9.42
	Age 0+ RBT	0.00	0.00	106.50	92.45	1.82	40.15
	Age 1+ Chin	0.00	0.00	0.00	0.00	0.00	0.00
	Age 1+ Coho	0.00	0.00	0.00	0.00	0.00	0.00
	Age 1+ MWF	0.05	1.60	0.39	0.00	0.55	0.52
	Age 1+ RBT	0.00	0.05	0.22	0.00	3.09	0.67

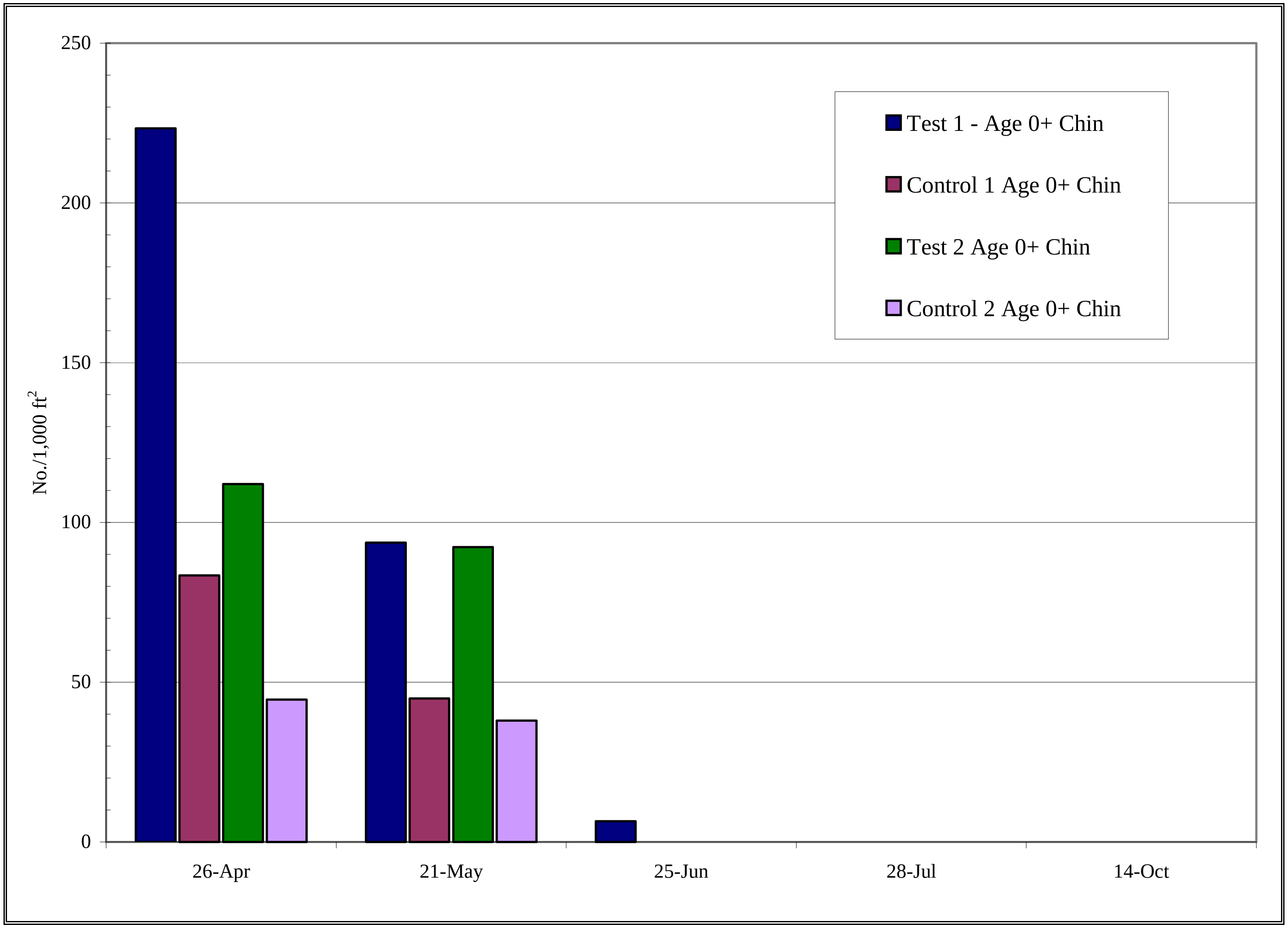


Figure 45. Age 0+ Chinook salmon abundance (no. fish·1,000 ft-2) observed at Engineered Log Jams.

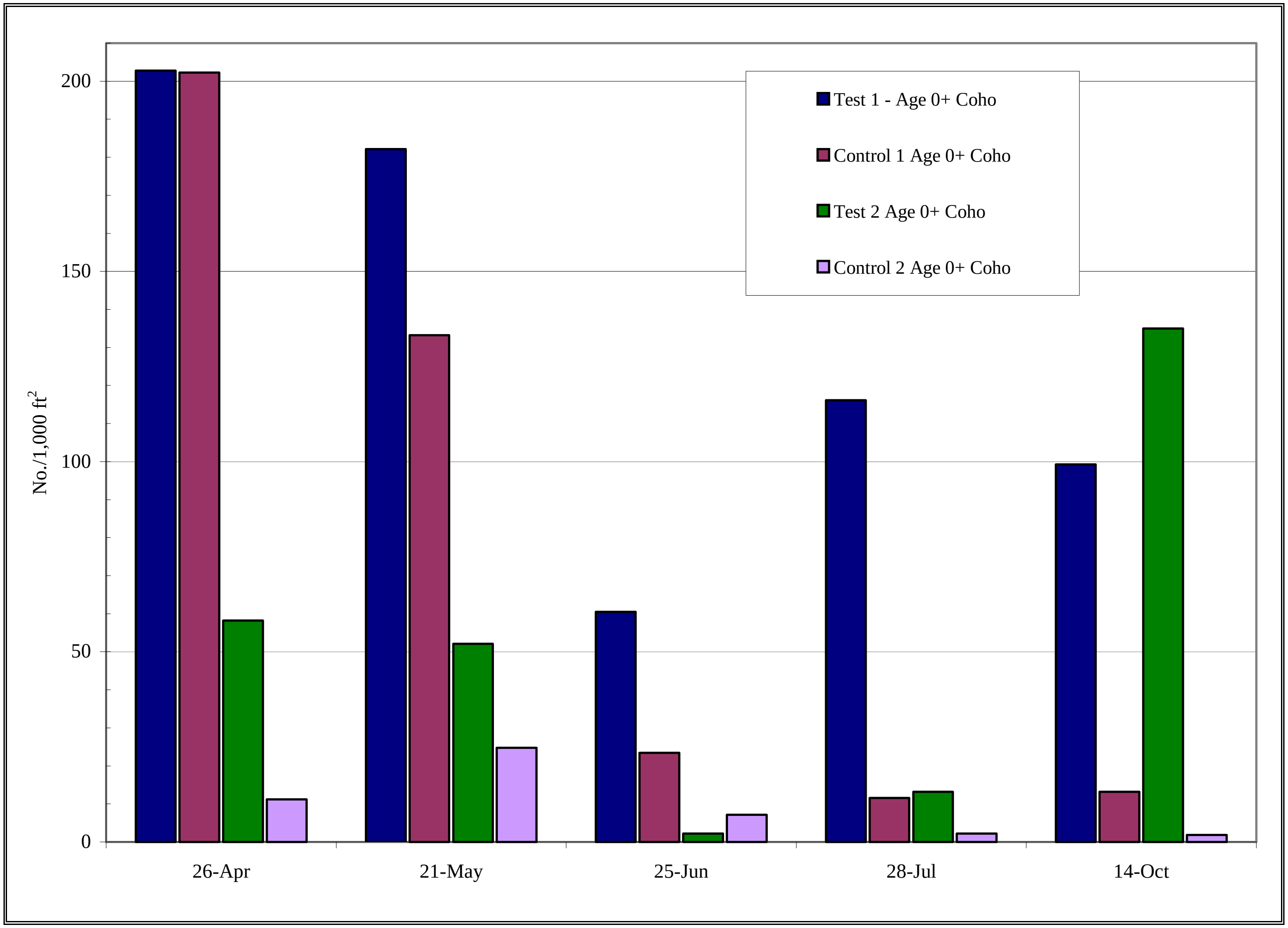


Figure 46. Age 0+ coho salmon abundance (no. fish·1,000 ft-2) observed at Engineered Log Jams.

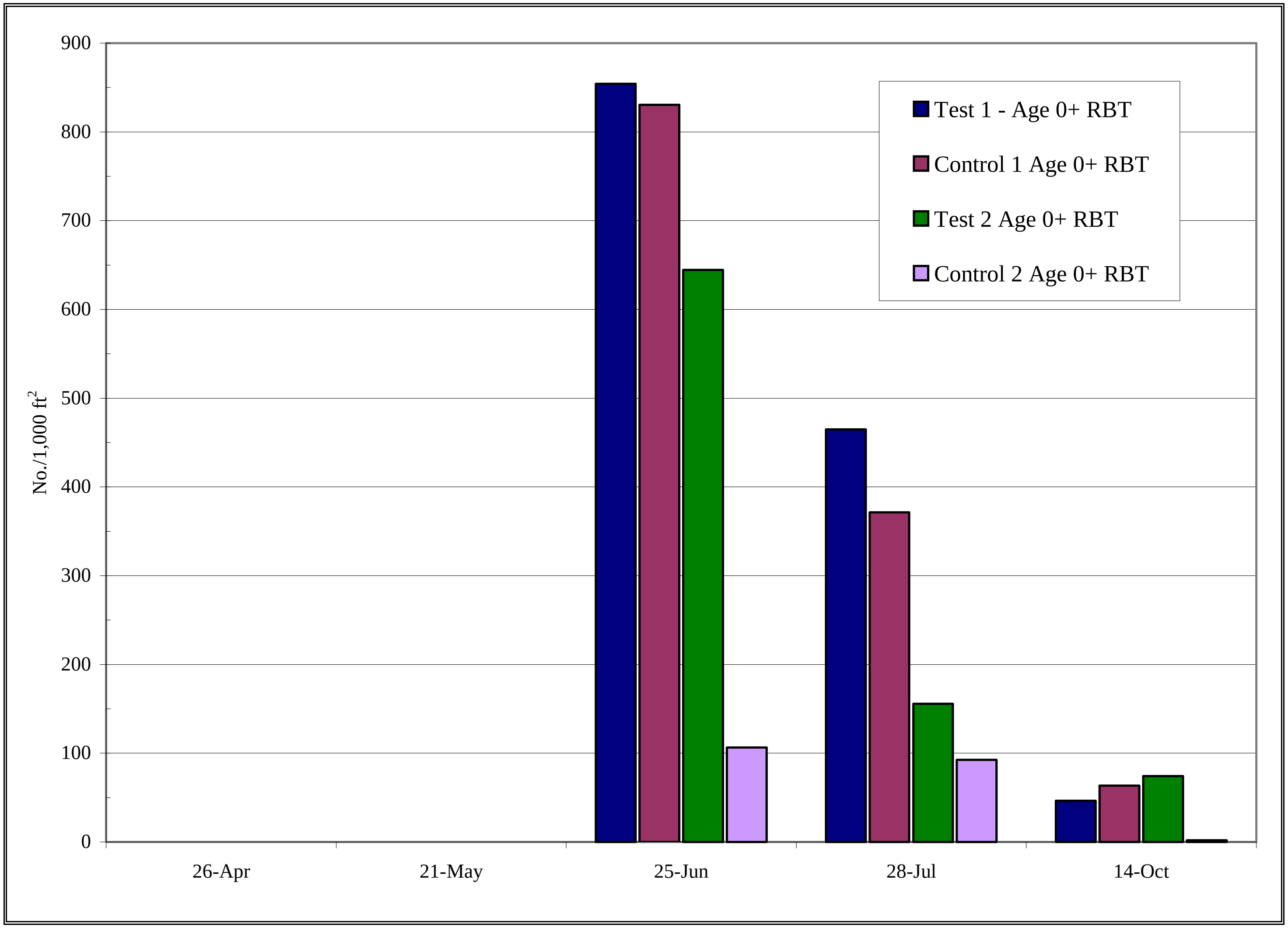


Figure 47. Age 0+ rainbow trout salmon abundance (no. fish·1,000 ft-2) observed at Engineered Log Jams.

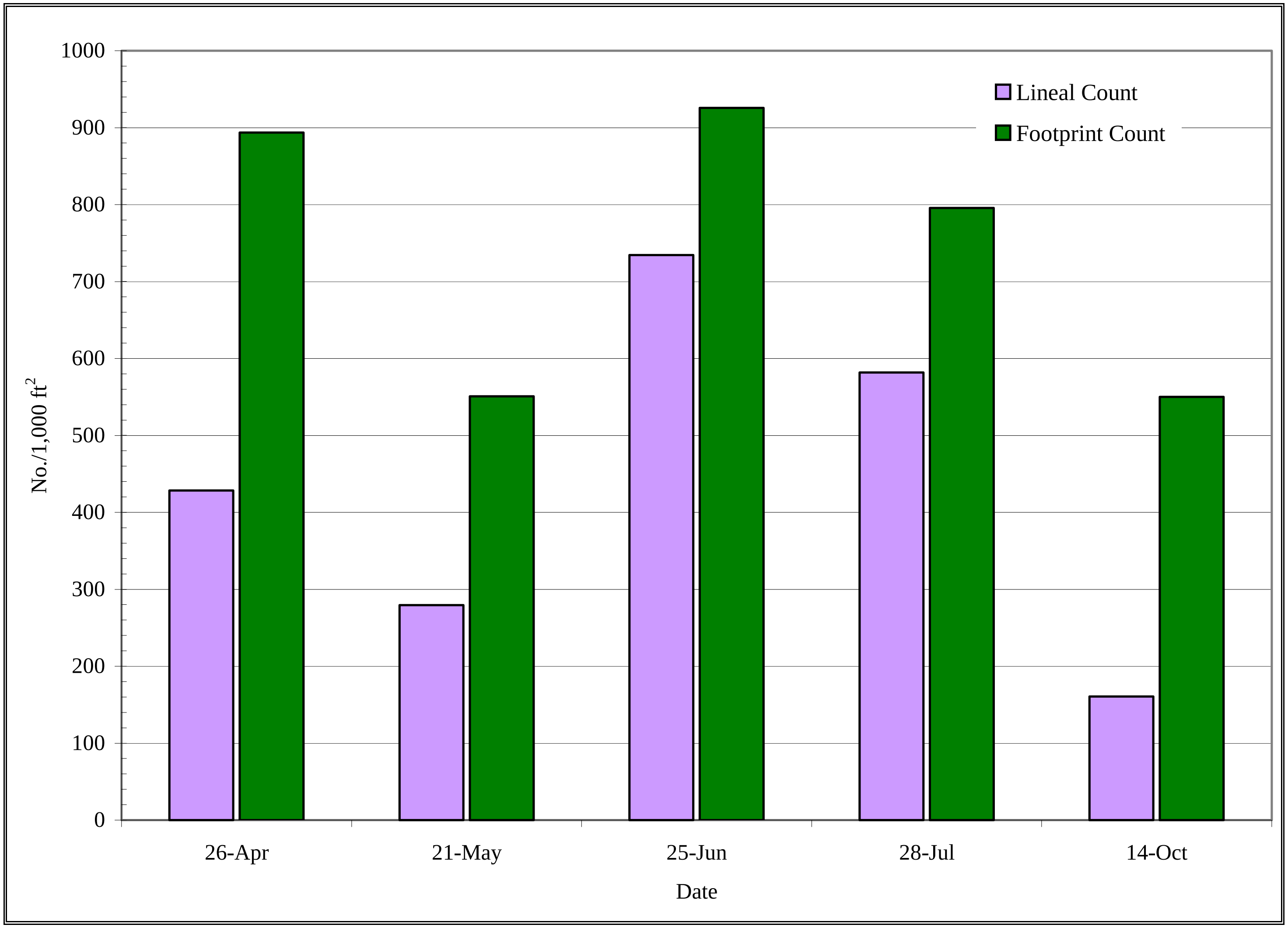


Figure 48. Footprint and lineal juvenile salmonid abundance (no. fish·1,000 ft-2) observed at Engineered Log Jam Site 1.

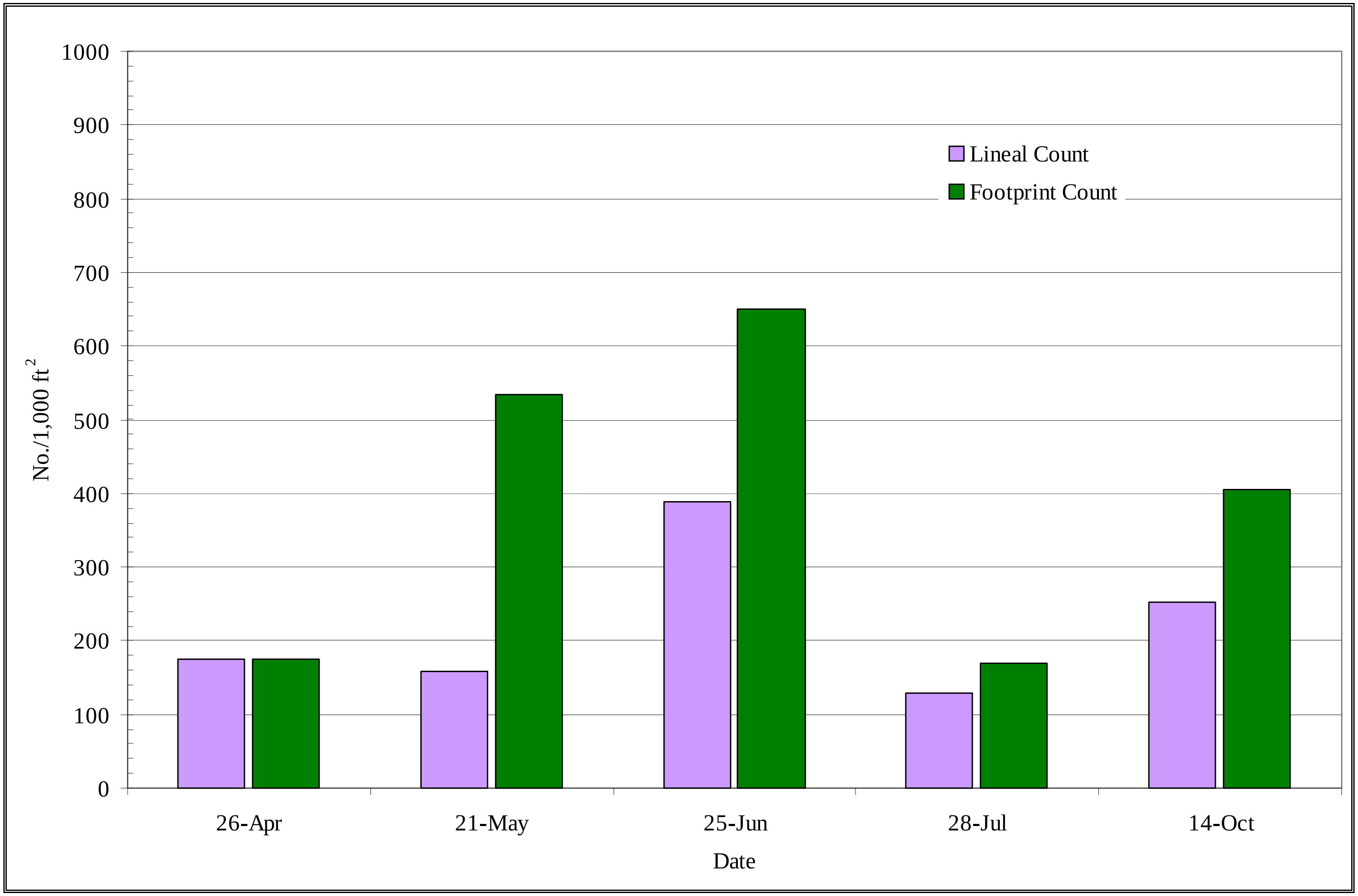


Figure 49. Footprint and lineal juvenile salmonid abundance (no. fish·1,000 ft-2) observed at Engineered Log Jam Site 2.

4.2.4.3. Adult Salmonids

Adult snorkel surveys were conducted in concert with juvenile surveys on 14 October 2004, coinciding with the expected peak of Chinook salmon spawning. Adult Chinook abundance was greater at both treatment sites compared to the controls (Tables 12 and 13). Chinook spawner abundance was greatest (5.5 Chinook•1,000 ft^{-2}) within the ELJ 1 Treatment footprint count, where numerous Chinook were holding in the deep pool associated with large woody debris. In addition to adult Chinook salmon, adult rainbow trout were observed holding in the restoration test sites during spring juvenile salmonid surveys conducted on 21 May 04 (Tables 12 and 13). Like Chinook, the highest adult rainbow trout density (7.3•1,000 ft^{-2}) was observed in the ELJ 1 Treatment footprint count followed by ELJ 2 Treatment footprint count (3.6 rainbow•1,000 ft^{-2}).

Table 12. Adult Chinook salmon and rainbow trout population estimates (number of fish observed•1,000 ft^{-2}) from snorkel surveys conducted at off-channel (side channel) and mainstem portions of ELJ 1, Restoration Zone 1, upper Green River, King County, Washington, 2004.

TREATMENT 1				CONTROL 1			
Species/Age	**Off Channel**	**Mainstem**	**Total**	**Species/Age**	**Off Channel**	**Mainstem**	**Total**
LINEAL COUNT							
Adult Chinook	3.2	0.5	3.7	Adult Chinook	0.0	0.0	0.0
Adult Rainbow	1.7	0.3	2.0	Adult Rainbow	0.0	0.0	0.0
FOOTPRINT COUNT							
Adult Chinook	0.0	5.5	5.5	Adult Chinook	0.0	0.0	0.0
Adult Rainbow	6.4	0.9	7.3	Adult Rainbow	0.0	0.0	0.0

Table 13. Adult Chinook salmon and rainbow trout population estimates (number of fish observed•1,000 ft^{-2}) from snorkel surveys conducted at off-channel (side channel) and mainstem portions of ELJ 2, Restoration Zone 1, upper Green River, King County, Washington, 2004.

TREATMENT 2				CONTROL 2			
Species/Age	**Off Channel**	**Mainstem**	**Total**	**Species/Age**	**Off Channel**	**Mainstem**	**Total**
LINEAL COUNT							
Adult Chinook	0.9	0.7	1.6	Adult Chinook	0.0	0.0	0.0
Adult Rainbow	1.3	0.4	1.7	Adult Rainbow	0.0	0.0	0.0
FOOTPRINT COUNT							
Adult Chinook	0.0	0.0	0.0	Adult Chinook	0.0	0.0	0.0
Adult Rainbow	0.9	2.7	3.6	Adult Rainbow	0.0	0.0	0.0

4.3. Performance Summary

- ELJ1 lost at least 1 racking log and minimal ballast. It generally appears to be stable. ELJ2 also lost at least 1 racking log. ELJ2 was overtopping at relatively low flows which caused concern that this may lead to gradual erosion of ballast and instability of the structure. This issue was addressed with structural modifications to the jam in 2004.

- Each log jam has functioned to maintain a scour pool, however, pool dimensions appear to be highly dynamic as gravel from the nourishment berms fills in and is scoured from the pools. This is expected to be a continual phenomenon. The log jams have successfully increased flow into the immediate downstream side channel during all flows.

- The jams were also successful at providing habitat for multiple fish species and year classes including adult and juvenile Chinook salmon.

- The primary difference observed in the juvenile snorkel surveys was the distribution of juvenile salmonids in the side channel located at ELJ 1. Previous to construction, this side channel was only partially wetted under low flow conditions. Juvenile salmonids appeared to be attracted to the side channel, even under extreme low flow conditions.

4.4. Adaptive Management

As described above, ELJ 2 was constructed below the design elevation which resulted in the overtopping of the jam at unacceptably low flows. Figure 34 indicates the river was eroding ballast material at the top of the jam at about 1/3 of the design flow. Because of concerns that

ELJ 2 was losing more ballast material than was desired, and was at risk of being overtopped frequently, it was decided by USACE to add two additional structural layers (rows of wood and ballast rock) to raise the jam above the expected design flood elevation 860.0 ft (@ 12,000 cfs) and to armor the top front of the jam with large river rock. A design report and construction plans were produced for the modifications that included updates to the HEC-RAS model to calibrate to observed conditions, a structural stability analysis of the ELJ, and a ballast material erosion analysis (USACE 2004b). The construction work was completed in August 2004. The final constructed top elevation of ELJ 2 was 861.0 feet as shown in the construction plans. The final construction report should be consulted for additional detail.

5. CHANNEL GEOMORPHOLOGY

The influence of ELJ construction and gravel nourishment on localized and reach scale morphology was generally evaluated using aerial photography, field observations, and cross section surveys.

5.1. Planform Analysis

Following final grading of the ELJ ballast and in-river construction site in summer 2003, the area along the left bank between the head of the island side channel and ELJ 2 was relatively flat and smooth, interspersed with several large boulders that were placed on top of the streambed. The tail of the ballast placed on ELJ 2 extended downstream nearly 2/3 of the distance between the ELJs. As flows increased ELJ 2 forced the river into this area and a new channel thread quickly developed and continues to evolve. The invert of the left side channel at the head of the island appears to be a hydraulic control, as the water slope is somewhat flat here, and water can be seen crossing back to the main channel in front of (and through) ELJ 1. Backwater from ELJ 2 and ELJ 1 appears to have resulted in gravel bar deposits just upstream of the jams, and deposits in the lee of the jams. Gravel bars are especially apparent upstream of ELJ 2 (KP 2.0), in the lee of ELJ 2 near cross section KP 3.0 (Figure 12), near the left bank at the head of the flow split around the island, and in the ELJ 1 constructed scour hole (left side only) (Page A-26, Appendix A). It is conceivable that gravel could continue to deposit at the head of the side channel resulting in intermittent disconnection of surface flows. It is also conceivable that enough gravel could deposit in the lee of ELJ 2 that an island would form between ELJ 2 and ELJ 1, and the head of the side channel would effectively begin upstream near ELJ 2.

Of note was the presence of large gravel bars in front of both ELJs. These bars are a function of the local backwater effect of the ELJ. Continued deposition in the front of the jams will result in a flow split around the jams that begins father upstream. The increased bed elevation may result in overtopping of the ELJs that is not accounted for in the calibrated hydraulic model. It is recommended that cross sections KP 3.2, 3.0, 2.0, and 1.9 be updated as needed in the HEC-RAS hydraulic model to capture any significant changes.

5.2. Channel stability

The channel has remained stable throughout the monitoring period. The ELJ2 scour hole along the left bank has at times enlarged resulting in some bank erosion. However, this location is at the end of the gravel nourishment road that is armored with riprap. As a result, no additional bank erosion is expected at this location.

The immediate downstream side channel is receiving much higher flows than prior to log jam construction. No changes to side channel banks have been observed or reported.

5.3. Gravel Storage

Visual inspection indicates that gravel is temporarily stored upstream and between the ELJs, and in the scour pools. The percentage of incoming gravel stored near the ELJs and the residence time of the stored gravel is not presently known. The original with-project and newly calibrated hydraulic models suggest that KP 3.0 (area between the log jams) should experience gravel storage (aggradation) over time (USACE 2003a, 2004a). Per the models, the observed gravel deposits were more pronounced in this area implying that the models are predicting relative differences in gravel storage potential. Ongoing monitoring should focus on volumetric changes in this reach as measured by cross section changes to track changes in bed elevation and sediment transport capacity.

6. SUMMARY

6.1. Gravel Nourishment

- 95% of the constructed gravel berms were eroded by the river.
- Gravel was effectively transported to downstream locations.
- Size of downstream substrate was measurably decreased relative to the prior year.
- Chinook salmon and Steelhead spawning in 2004 was more widespread in the zone of gravel influence relative to the prior pre-gravel nourishment year. This was most noticeable in the immediate downstream side channel.

6.2. Log Jams

- ELJ1 was relatively stable throughout the monitoring period. ELJ2 was considered stable, but due to water overtopping the structure below the design flood there was concern that this may lead to loss of ballast and log jam instability.
- Log jams have effectively increased flow to the immediate downstream side channel. This has resulted in gravel transport to and deposition in the side channel and relatively high levels of spawning activity.
- Log jams are maintaining scour pools.
- Multiple fish species and size classes are using the habitat created by the log jams.

6.3. Geomorphology

- Construction of the log jams extended a flow split upstream from a large island located downstream of the log jams. This increased the wetted perimeter of the reach and side channel length.
- In areas where gravel deposits were observed, comparisons with baseline conditions indicate that the bed sediments are finer, theoretically decreasing hydraulic roughness when bed load transport is not occurring (low-moderate flow).
- Log jams are creating backwater conditions upstream resulting in higher water surface elevations over baseline conditions. This is encouraging gravel bar formation mid-channel and along the left bank.
- No channel migration or bank instability has been observed that is attributable to the log jams or gravel loading.
- Gravel storage is primarily observed near the log jams (upstream and downstream), behind large obstructions, upstream of riffles, downstream of pool tail-outs, and in the interstices of large bed material (boulders).
- With the exception of the log jam reach, no changes to the baseline geomorphic reach types have been observed.
- Wood displaced from the log jams has not been reported to have resulted in the formation of significant log jams or channel obstructions downstream, but has contributed to the size of existing log jams.

6.4. Adaptive Management Activities in 2004

- Gravel size specifications were modified in 2004 compared to the 2003 specifications to include a percentage of 5 inch gravels.

- Two layers of logs were added to ELJ2 to increase the height of the jam above the 12,500 cfs water surface elevation (100 year flood).

7. RECOMMENDATIONS FOR FUTURE MONITORING

The following recommendations for improving the data quality and data gathering efficiency for the physical monitoring project are based on the experience of the monitoring staff and comments received on the draft monitoring report. Unless otherwise noted these recommendations are supplemental to the monitoring activities contained in this report.

7.1. Gravel

- Obtain aerial photos in spring leaf-off period if river discharge at Palmer is at or below 200 cfs.
- Use 2-person team to perform photo-point and gravel patch mapping concurrently for the entire study reach. Perform pebble counts and cross section surveys separately using same team. This will improve data quality and efficiency.
- Conduct Wolman pebble counts along cross sections evaluated during baseline study.
- Visually classify the d10, d50, and d90 sediment grain size at all locations where gravel patches are mapped.
- Take grid photos to supplement gravel visual classifications at two representative locations per deposit. Record grid photo location with handheld GPS waypoint.
- Use the GPS track feature to delineate the location and shape of gravel deposits. Tape off average length, width, height of bar. Sketch bar shape on map, include average dimensions, estimates of sediment d10, d50, d90 grain size. Sketch a typical bar cross section.
- Use gridded mylar overlays to record gravel mapping data. Scale latest orthorectified aerial photos to 1-in: 50-ft, print and laminate the maps for field use. Include field maps in report appendix.
- Establish permanent measuring pins at the gravel nourishment loading zone to aid in high flow erosion assessments.
- Cross section surveys will be a primary method by which gravel deposition will be evaluated in future years. Additional methods that may be considered include regular topographic reach surveys, using technologies that provide quick absolute depth measurements, or installing some distinguishing features in the gravel that allow easy identification of the source of the deposit (coloration, magnetization, or tracking tags). The monitoring study should also investigate simple means of checking depths of deposits in the field that are not labor intensive.

7.2. Log Jams

- Use total station instead of level/rod to survey perimeter of scour pools, ELJ monitoring pins, scour pool inverts, pool tail-out crest elevations, and scour pool invert elevations.

7.3. Geomorphic Change

- Re-establish all cross section endpoints using metal fence posts between KP 3.2 and KP 1.7. Include USACE section 1.9.
- Focus survey effort between KP 3.2 and 1.7. Extend cross section surveys downstream if adverse deposition or erosion is suspected.
- Survey main channel and side channel invert between KP 3.2 and KP 1.7. Compare with baseline, as-built, and 2004 data.
- Use baseline photos contained in the 2003 construction report at photo points in field to ensure photo points are properly re-established.

7.4. Fisheries

- Multiple spawning surveys within the season will indicate the proportion of Chinook spawning in this reach of the upper Green River over the season as well as provide information on redd scour during the spawning season.
- Conduct a redd scour study. This could be accomplished by burying marked stones as a surrogate for eggs/redds and determining the fate of the stones with respect to flow. Alternatively scour chains or rebar driven into the stream bed could be monitored to determine changes in bed elevation in response to flow.
- Future monitoring efforts should attempt to tease out the level of increased production that may be attributed to restoration processes.
- In an effort to show ecosystem response, biological monitoring could be extended to macroinvertebrates as well as fish species other than salmonids (Kauffman et al. 1997).

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