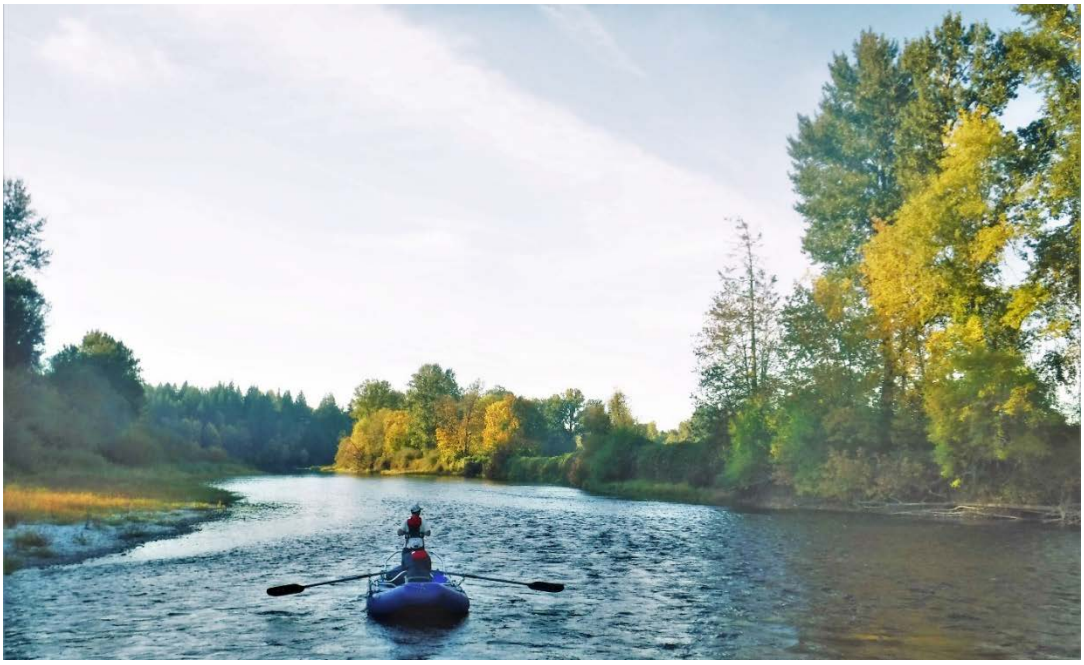
Spring Chinook Salmon Spawning Surveys in the Upper Willamette River Basin in 2018

Final Report



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1 Introduction and Background

Normandeau Associates, Inc. and Environmental Assessment Services (EAS) were contracted by the Portland District of the U.S. Army Corps of Engineers (USACE) to provide monitoring and evaluation services (spawning surveys) for the NWP Hatchery Program related to the mitigation, production, and release of spring Chinook salmon (*Oncorhynchus tshawytscha*) into the Willamette Basin (Figure 1). The upper Willamette River Evolutionarily Significant Unit (ESU) was originally listed as threatened under the Endangered Species Act in 1999 (64 FR 14308, NOAA 1999); the listing was updated in 2005 (70 FR 37159, NOAA 2005). Hatchery stocks are included in the ESU for the upper Willamette River ESU. This study provides information on the status of the spawning populations in the selected rivers and reaches of the Willamette Basin by calculating rates of prespawn mortality (PSM) rates, determining the proportions of hatchery and wild origin fish spawning in the selected reaches, and by assessing the abundance and distribution of redds.

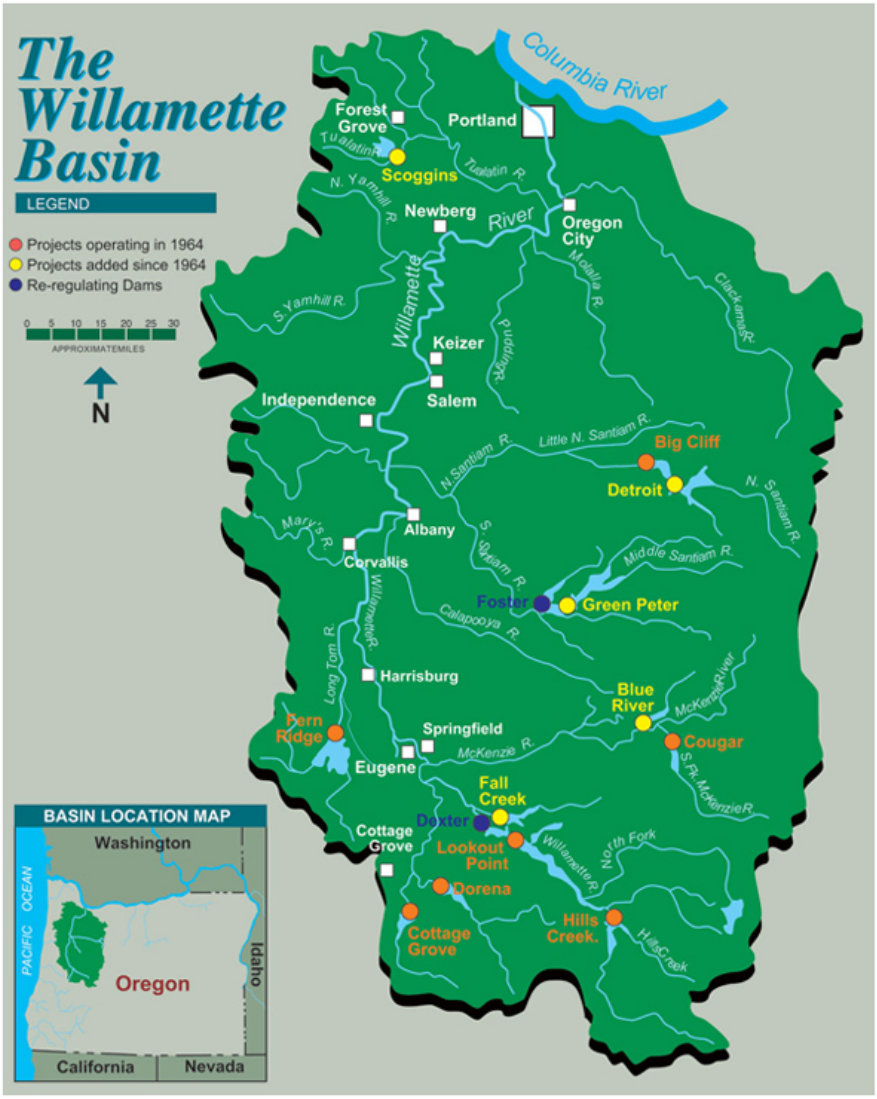

Figure 1. The Willamette River Basin (Source: nwp.usace.army.mil).

Upper Willamette River spring Chinook salmon spawn in the fall. After emerging, smolts follow various life histories; with some leaving their natal streams almost immediately while others reside for more than a year before beginning downstream migration to the ocean (Schroeder et al. 2016). Adult fish return upstream to the lower Willamette River in the late winter and early spring, and then hold in the river system until spawning (Schroeder et al. 2016). According to the Oregon Department of Fish and Wildlife (ODFW), the run forecast for spring Chinook in the Willamette River Basin was 53,820 for 2018; however, the estimated return was 37,441 adults. To reach the upper tributaries of the Willamette River, spring Chinook salmon must first pass the Willamette Falls Dam, located at river mile 26.5. Spring Chinook passage occurs at the Willamette Falls fishway between April and July, typically peaking in mid-May (JCRMS 2019). Fish passing through the Willamette Falls fishway are counted 24 hours per day year-round. According to the ODFW, in 2018 the total (adult + jack) count of spring Chinook salmon at Willamette Falls Dam was 26,542. This included 24,542 adults, with 19,531 clipped fish and 5,012 unclipped fish. This was below the average total count of the previous 10 years of 37,602 (JCRMS 2019, Figure 2).

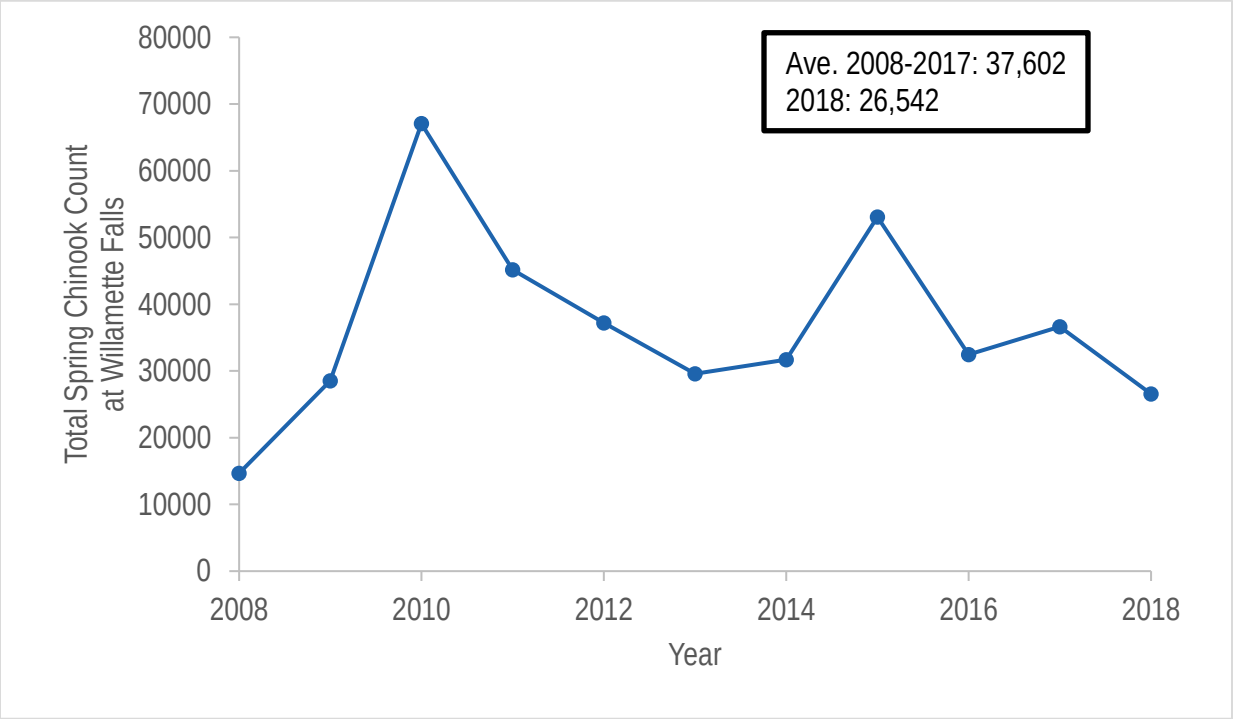

Figure 2. Counts of spring Chinook salmon (adult + jack) at Willamette Falls Dam from 2008-2018 (Source: www.dfw.state.or.us).

2 Methods

2.1 Study Area

Surveys were performed along USACE specified portions of the Santiam River, McKenzie River, Middle Fork Willamette River and selected tributaries (Figures 3, 4, and 5). Each river was divided into sections, termed “reaches”, that typically corresponded to river access points and are also consistent with the reaches surveyed during previously funded USACE spawning

surveys on the subject rivers (Table 1). This study, and the resulting data analysis, is only relevant to the specific rivers and reaches where surveys were conducted. These rivers vary from large, low-gradient, slow moving water in the lower sections, to Class III and IV whitewater in some of the upper reaches. Several of the river sections are located along major roadways while others are in remote areas with limited access.

Table 1. Survey reaches by river.

River & *Reach*	River & *Reach*	River & *Reach*
Middle Fork Willamette	McKenzie cont.	Santiam
Dexter Dam to Pengra Landing	*South Fork McKenzie to Forest Glen*	*Confluence to Jefferson*
Pengra Landing to Jasper	*Forest Glen to Rosboro Bridge*	*Jefferson to I-5 Bridge*
Fall Creek	*Rosboro Bridge to Ben Kay*	*I-5 Bridge to Mouth*
Falls to Gold Creek	*Helfrich to Leaburg Lake*	North Santiam
Gold Creek to 1833 Bridge	*Leaburg Dam to Leaburg Landing*	*Big Cliff Dam to Minto*
1833 to Hehe Creek	*Leaburg Landing to Deerhorn*	*Minto Dam to Packsaddle*
Hehe Creek to 1828	*Deerhorn to Hendricks*	*Packsaddle to Gates Bridge*
1828 to Portland Creek	*Hendricks to Bellinger*	*Gates Bridge to Mill City*
Portland Creek to Bedrock	*Bellinger to Hayden*	*Mill City to Fisherman's Bend*
Bedrock to Johnny Creek Bridge	*Hayden to Armitage*	*Fisherman's Bend to Mehama*
Johnny Creek to Release	South Fork McKenzie	*Mehama to Powerlines*
Release Site to Reservoir	*Cougar to Bridge*	*Powerlines to Upper Bennett*
Fall Creek Dam to Pengra Bridge	*Bridge to Upstream Habitat Restoration*	*North Channel Stayton Is to Stayton*
Pengra Bridge to Fall Creek Mouth	*Upstream Habitat Restoration to Mouth*	*Stayton to Shelburn*
Little Fall Creek	Lost Creek	*Shelburn to Green's Bridge*
Trib Below NFD 400 to NFD 1806	*Spring to Cascade*	*Green's Bridge to Mouth*
NFD 1806 Bridge to NFD 1818	*Cascade to Limberlost CG*	Little North Santiam
NFD 1818 Bridge to Fish Ladder	*Limberlost CG to Split Point*	*Elkhorn Bridge to Salmon Falls*
McKenzie	*Split Pt to Hwy 126 Bridge*	*Salmon Falls to Camp Cascade*
Spawning Channel to Olallie	Horse Creek	*Camp Cascade to Narrows*
Ollalie to Belknap	*Pothole Creek to Trail Bridge*	*Narrows to Golf Bridge*
Belknap to Paradise	*Trail Bridge to Separation Creek*	*Golf Bridge to Bear Creek Bridge*
Paradise to McKenzie Trail	*Separation Creek to Road Access*	*Bear Creek Bridge to Lomkers Bridge*
McKenzie Trail to McKenzie Bridge	*Road Access to Braids*	*Lomkers Bridge to NF Park*
McKenzie Bridge to Hamlin	*Braids to Avenue Creek*	*NF Park to HWY 22 Bridge*
Hamlin to S.F. McKenzie	*Avenue Creek to Horse Creek Bridge*	*Hwy 22 Bridge to Mouth*
	Horse Creek Bridge to Mouth	South Santiam
		Foster Dam to Pleasant Valley
		Pleasant Valley to McDowell Creek
		McDowell Creek to Waterloo
		Gill's Landing to Sanderson's
		Sanderson's to Mouth/Jefferson

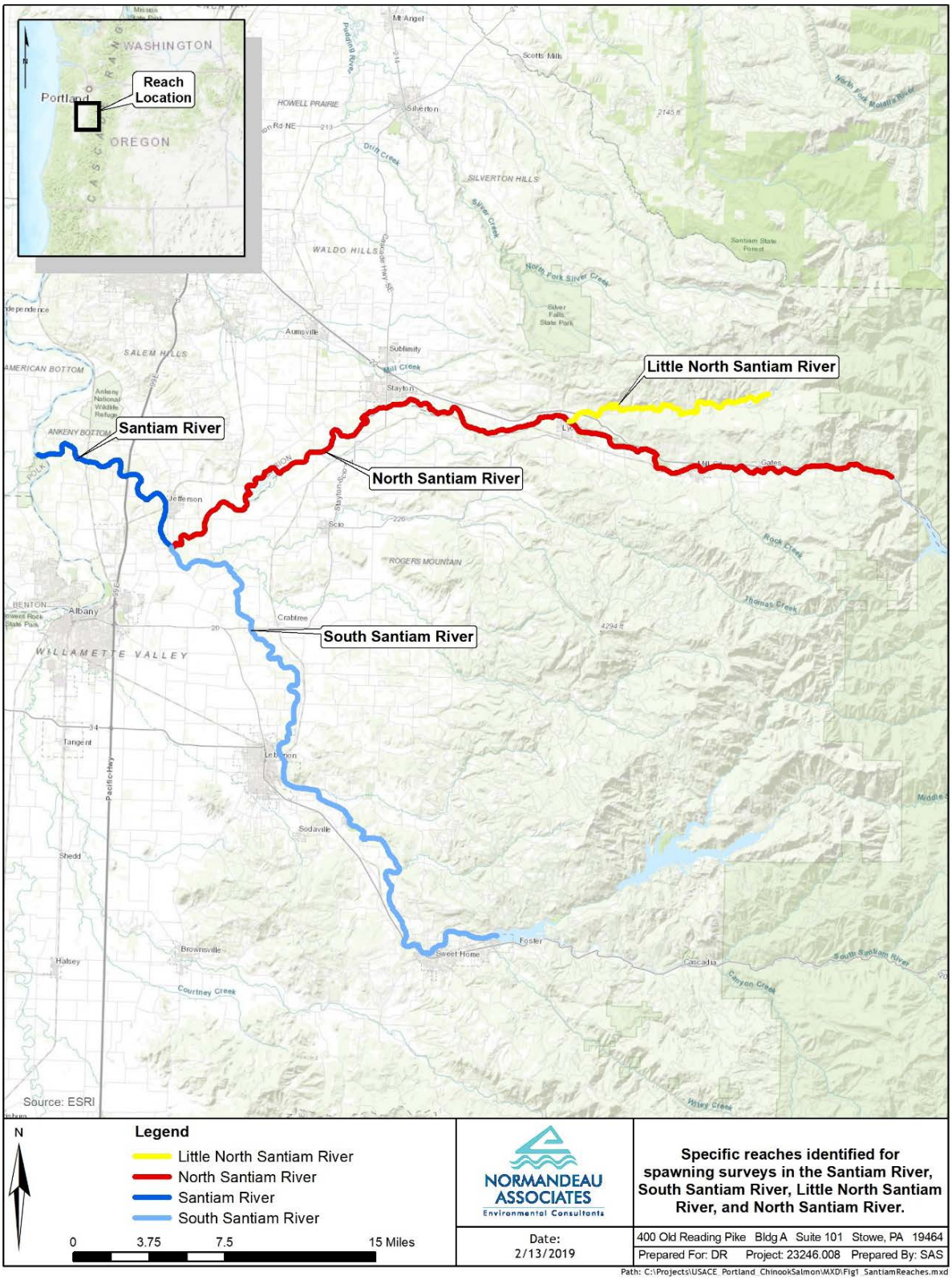

Figure 3. Specific reaches identified for spawning surveys in the Santiam River, South Santiam River, Little North Santiam River, and North Santiam River.

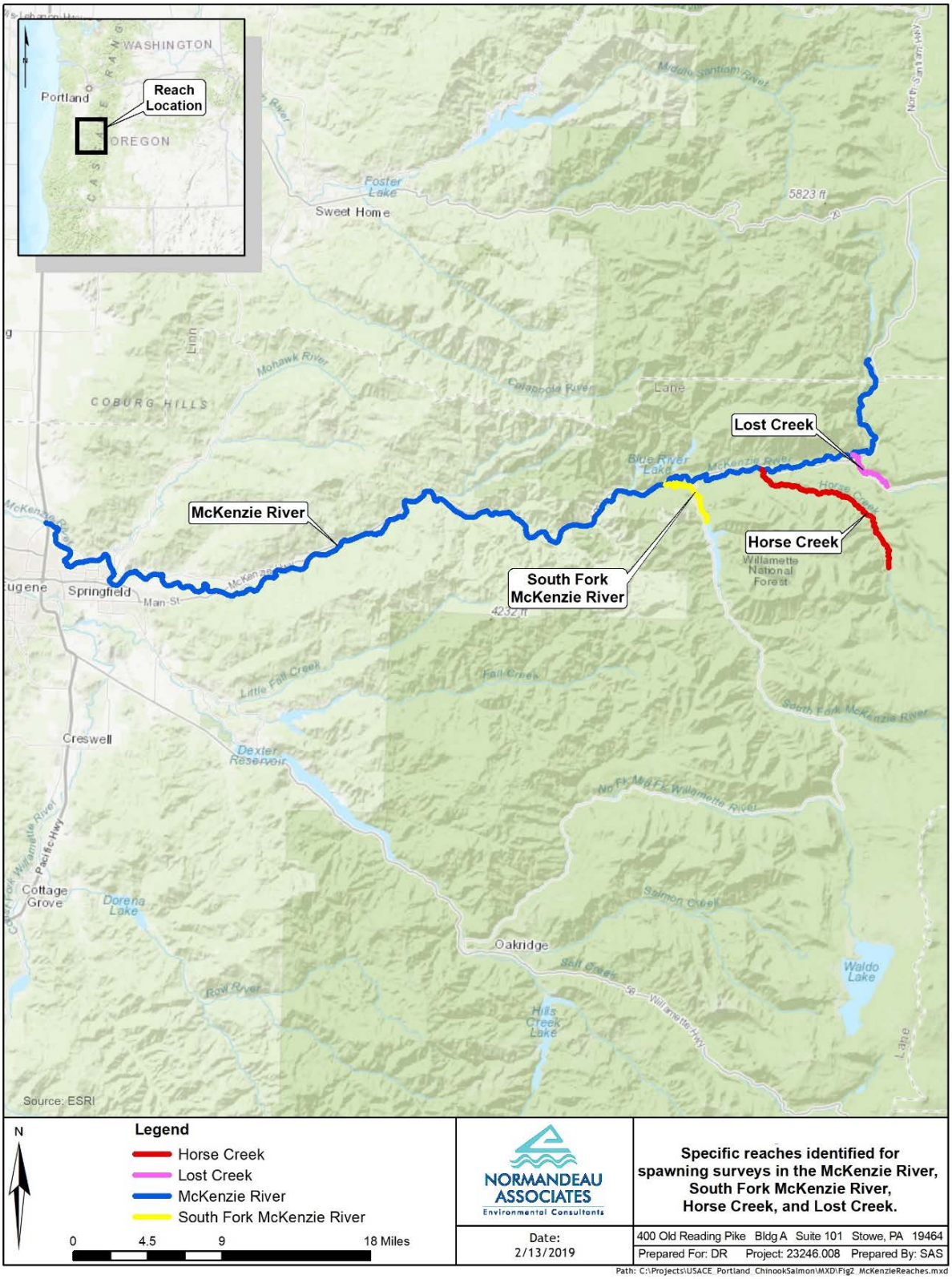

Figure 4. Specific reaches identified for spawning surveys in the McKenzie River, South Fork McKenzie River, Horse Creek, and Lost Creek.

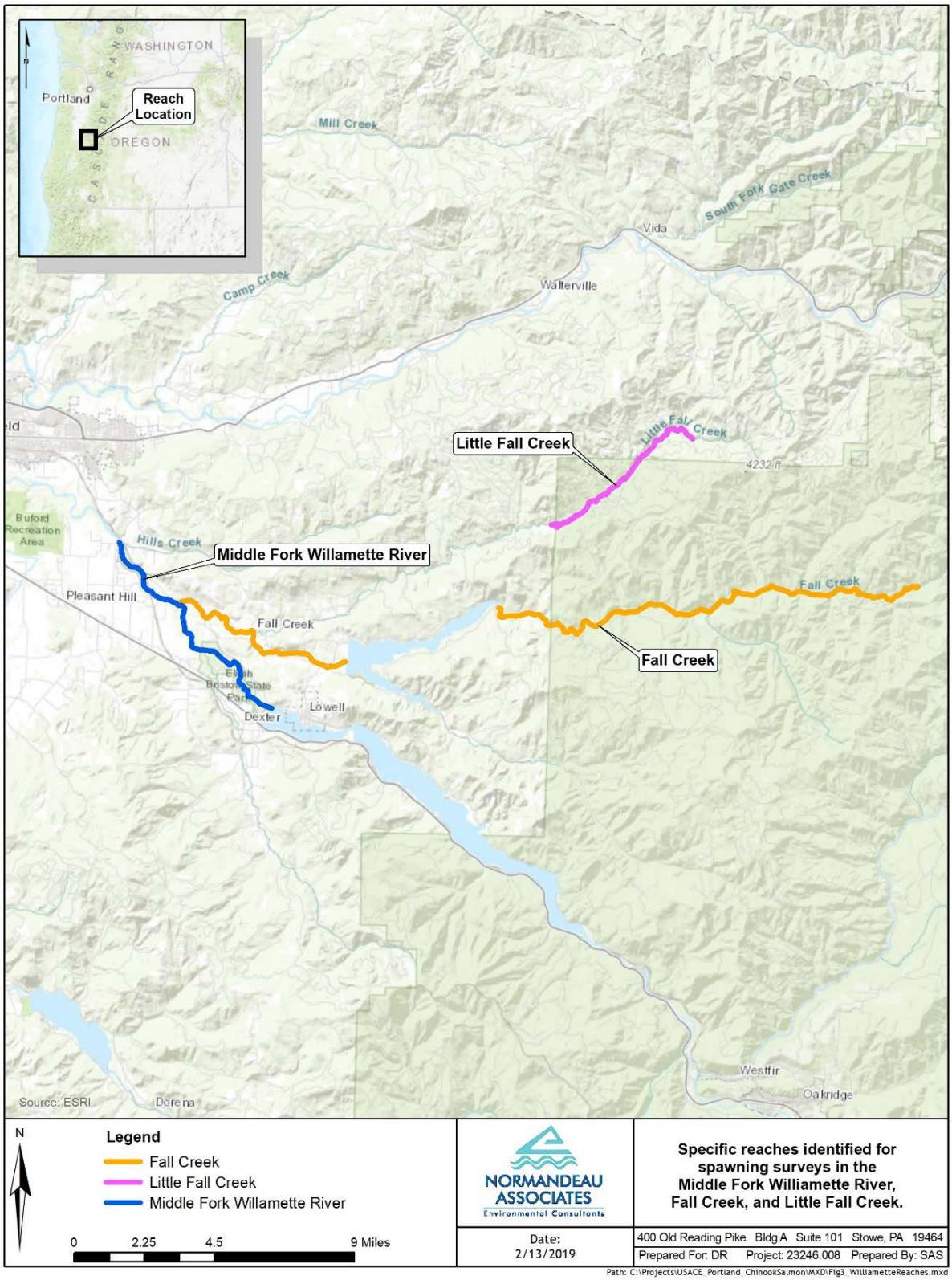

Figure 5. Specific reaches identified for spawning surveys in the Middle Fork Willamette River, Fall Creek, and Little Fall Creek.

2.2 Carcass and Redd Surveys

Prior to beginning field work, all crew members received training in safety procedures, carcass recovery, sample collection methods, and redd counting. Surveys were planned to focus on the river reaches where fish were determined to be most abundant, maximizing carcass collection rates. The level of effort (i.e. number of survey crews) increased over the season due to the increasing number of carcasses approaching peak spawning. Crews always consisted of at least two members, however an additional crew member was added for survey areas with extensive side channels or when abundant carcasses were expected. Some reaches were surveyed by two crews of at least two crew members during peak spawning in anticipation of large carcass numbers, to complete surveys during daylight hours. USACE staff regularly conducted quality assurance assessments of field crews during the season to ensure crews were performing work according to the approved study protocols.

2.2.1 Boat-based Stream Surveys

Crews utilized rafts and inflatable kayaks to navigate the specified river reaches. Catarafts fitted with customized viewing towers (tower boats) were used to increase the area surveyors could effectively see. These tower rafts were used on reaches with Class II and lower rapids and in areas that were wide enough to accommodate the large boats. On reaches where tower boats could not be safely utilized, smaller rafts fitted with fishing frames were used. Inflatable kayaks were used in the smallest creeks or in areas with large rapids, long portages, or where increased maneuverability was needed for safe navigation. All reaches were surveyed for side channels; those reaches that contained side channels with spawning habit were walked by boat crew members or floated separately with an inflatable kayak. During peak spawning in areas of high redd density, two survey crews were used with each focusing on one side of the river to improve carcass recovery and to count redds along both shorelines. Expert boaters were needed to safely navigate the Class III and IV rapids present in several of the reaches.

2.2.2 Walking Stream Surveys

Walking surveys were conducted in reaches where woody debris or very low water prevented boating, including Fall Creek above Fall Creek Reservoir, the Little North Santiam, Lost Creek, and the upper two reaches of Horse Creek. Two-person crews walked the entire stretch of the designated survey reaches and searched for redds and carcasses. The two-person crews separated to survey side channels, when present, to improve carcass recovery rates and redd counts.

2.2.3 Carcass Collection

Crews conducted surveys to estimate the abundance and distribution of both hatchery and natural-origin spring Chinook salmon adults. Surveys were conducted according to the approved study plan and schedule. At the beginning of each survey, field staff recorded the date, reach, and river being surveyed. A water temperature (℃) and a GPS start location were also recorded; GPS position was also recorded at the end of the survey. When a carcass was recovered, field staff recorded the time and assigned a unique fish ID for that carcass. Surveyors examined carcasses for adipose fin clips, measured fork length (in cm.) for size distributions, determined sex, and visually estimated the proportion of eggs remaining in female fish to be used for estimating PSM. Otoliths were collected in the field from carcasses without adipose fin-clips to differentiate hatchery fish with unclipped/regenerated adipose fins from naturally-produced fish; this determination was done in the lab by ODFW due to the presence of thermal markers on the

otoliths of hatchery fish (Volk et al. 1999). Carcasses with adipose fin clips were scanned for coded wire tags (CWT) using either a T-Wand or Blue Wand detector manufactured by Northwest Marine Technologies (NMT). CWT detectors were tested routinely using a test tag provided by NMT to ensure that detectors were functioning properly. The snouts of fish containing CWTs were collected and the CWTs were later removed, identified, and entered into the Regional Mark Information System (RMIS) database (http://www.rmpc.org/). CWT database queries were used to determine rates of hatchery straying, and to cross check scale ages. Scales were collected to determine age and were read by ODFW according to their standard operating procedure (Clemens et al. 2013). Finally, a tissue sample from the dorsal fin was taken and stored for future genetic analysis. When all the samples and measurements were recorded, the carcass was placed back in the stream after the tail was removed to mark that the carcass had been processed. All data was collected, entered into an electronic database, and reviewed according to the approved study plan and quality assurance plan.

2.2.4 Calculating Prespawn Mortality

Crews began conducting carcass surveys early in the season, prior to the initiation of spawning, to improve estimates of PSM (Bowerman et al. 2016). Prespawn mortality was only calculated using data collected from female carcasses due to the uncertainty with determining spawning status of males (Bowerman et al. 2016). Female fish were examined to determine the percentage of eggs retained. For example, a fully spawned fish (i.e., no eggs present) would be recorded as 0% egg retention, while a fish that died prior to initiating spawning would be recorded as 100% egg retention. For consistency with previous survey efforts funded by USACE, fish with greater than 50% egg retention were recorded as PSM (Sharpe et al. 2017). Crews were unable to determine egg retention rates on some carcasses due to scavenging or decay and marked those carcasses as “unknown”. PSM rates were calculated by dividing the number of PSM females by the total number of females collected where egg retention rates were determined (i.e. excluding “unknown” fish). Consistent with previous USACE-funded survey efforts, PSM was categorized as low (<20%), medium (20-50%) and high (>50%). Fisher’s Exact Test was used to determine whether there was a significant difference in the rates of PSM between hatchery and wild fish; as was indicated by Bowerman et al. (2017), who found PSM was greater in hatchery fish in the Willamette Basin.

2.2.5 Redd Counting

After initiation of spawning, all crew members received training in redd identification and enumeration from EAS staff. Our most experienced surveyor also conducted data validation with all crews and completed concurrent counts prior to final redd counts to ensure crews were accurately enumerating redds. Once initiation of spawning was observed, survey crews began counting the total number of redds by reach to become familiar with the redd locations and counts, while also collecting and processing carcasses. Therefore, crews had at least 5 weeks of experience locating spawning habitat, observing redd construction, and counting redds on these specific reaches prior to conducting final redd counts. Surveys were conducted according to the methods outlined in the standard operating procedure for the project, and generally follow the protocols provided in Johnson et al. 2007.

Final redd surveys were conducted, by reach, after live adult fish were no longer visible on redds. During final redd surveys, crews counted redds and took GPS locations of each spawning area, not of each individual redd. Thus, a spawning area was given a GPS point and an associated

number of redds. Spawning area maps were generated from the GPS data using a Geographic Information System (GIS).

2.2.6 Calculating Proportion Hatchery Origin Spawners

All hatchery fish in the Willamette Basin receive an adipose fin clip and some fish also receive a CWT to distinguish them from wild fish and to indicate their hatchery of origin and age. Due to the potential for mis-clipped or regenerated adipose fins that may make a hatchery fish appear wild, all hatchery fish are also put through a process of temperature cycles to induce thermal marks on their otoliths that can be read in the laboratory to distinguish hatchery fish from wild fish. The otoliths of unclipped fish were collected and analyzed for thermal marks to identify and reclassify unclipped hatchery fish; the unclipped hatchery fish were added to the clipped hatchery fish and divided by the total number (hatchery + wild) of carcasses collected, to calculate the proportion of hatchery origin spawners (pHOS).

2.2.7 Calculating Spawner Abundance

The peak count expansion method was used to estimate spawner abundance, consistent with previous USACE-funded survey efforts in the upper Willamette Basin (Sharpe et al. 2017). This calculation utilizes the final redd counts, by reach, multiplied by 2.5, assuming each redd was constructed by one female that spawned with 1.5 males.

2.2.8 Spawner Abundance Estimates by Origin

Spawner abundance estimates were multiplied by pHOS calculations to determine spawner abundance estimates for hatchery-origin and natural-origin fish. This calculation was done after combining data from the 11 rivers (Table 1) into the following eight basin sections: Middle Fork Willamette and Fall Creek below Fall Creek Dam; Fall Creek above Fall Creek Dam; McKenzie above Leaburg Dam including surveyed tributaries (South Fork McKenzie, Horse Creek, and Lost Creek); McKenzie below Leaburg Dam; North Santiam below Minto Dam and Little North Santiam; North Santiam above Minto Dam; South Santiam; and the mainstem Santiam.

3 Results

3.1 Carcass Collections

Crews began conducting carcass surveys on June 27, 10 weeks prior to the initiation of spawning. The first carcass was collected on the first day of surveys. Carcass surveys continued through October 24, with the last carcass of the season collected on October 20. The distribution of the total number of carcass surveys conducted (541) and the total number of carcasses collected (941) is shown in Table 2. Nine jacks, defined as salmon with fork lengths less than 60cm, were collected during the project. The distributions by fork length categories for hatchery and wild fish are shown in Table 3. Age classifications from scale analysis or CWT were applied to the data from the field to determine ages of fish by origin. The distribution of fish by age class is shown in Table 4. Sex ratios of fish in several of the river basins is shown in Table 5.

Table 2. Number of carcass/redd surveys and carcasses collected by river and reach.

River Reach	Total Carcass/Redd Surveys	Carcasses Collected
Middle Fork Willamette	12	10
Dexter Dam to Pengra Landing	7	9
Pengra Landing to Jasper	5	1
Fall Creek	58	8
Falls to Gold Creek	12	0
Gold Creek to 1833	11	1
1833 to Hehe Creek	1	0
Hehe Creek to 1828	1	0
1828 to Portland Creek	1	0
Portland Creek to Bedrock	1	0
Bedrock to Johnny Creek Bridge	1	0
Johnny Creek Bridge to Release Site	7	1
Release Site to Reservoir	7	0
Fall Creek Dam to Pengra Bridge	8	5
Pengra Bridge to Fall Creek Mouth	8	1
Little Fall Creek	0	0
Trib Below NFD 400 to NFD 1806 Bridge	not surveyed	
NFD 1806 Bridge to NFD 1818 Bridge	not surveyed	
NFD 1818 Bridge to Fish Ladder	not surveyed	
McKenzie	147	221
Spawning Channel to Olallie	6	19
Olallie to Belknap	5	5
Belknap to Paradise	5	2
Paradise to McKenzie Trail	6	2
McKenzie Trail to McKenzie Bridge	5	0
McKenzie Bridge to Hamlin	9	7
Hamlin to S.F. McKenzie	9	0
S.F. McKenzie to Forest Glen	13	2
Forest Glen to Rosboro Bridge	22	65
Rosboro Bridge to Ben & Kay	19	14
Helfrich to Leaburg Lake	12	6
Leaburg Dam to Leaburg Landing	16	94
Leaburg Landing to Dearhorn	8	3
Dearhorn to Hedricks	5	2
Hendricks to Bellinger	3	0
Bellinger to Hayden	2	0
Hayden to Armitage	2	0

River Reach	Total Carcass/Redd Surveys	Carcasses Collected
S.F. McKenzie	10	26
Cougar Dam to Bridge	4	9
Bridge to Upstream Habitat Restoration	4	11
Upstream Habitat Restoration to Mouth	2	6
Lost Creek	12	1
Spring to Cascade	3	0
Cascade to Limberlost CG	3	0
Limberlost CG to Split Pt	2	1
Split Pt to Hwy 126 Bridge	2	0
Hwy 126 Bridge to Mouth	2	0
Horse Creek	25	10
Pothole Creek to Trail Bridge	4	0
Trail Bridge to Separation Creek	3	0
Separation Creek to Road Access	4	0
Road Access to Braids	4	1
Braids to Avenue Creek	4	1
Avenue Creek to Horse Creek Bridge	4	3
Horse Creek Bridge to Mouth	2	5
Santiam	29	1
Confluence to Jefferson	9	0
Jefferson to I-5 Bridge	11	1
I-5 Bridge to Mouth	9	0
N. Santiam	143	35
Big Cliff Dam to Minto Dam	7	7
Minto Dam to Packsaddle	9	2
Packsaddle to Gate's Bridge	13	9
Gate's Bridge to Mill City	12	7
Mill City to Fisherman's	13	3
Fisherman's Bend to Mehama	12	4
Mehama to Powerlines	14	0
Powerlines to Upper Bennett	14	1
South Channel Upper Bennett to Stayton	12	0
North Channel Stayton Is to Stayton	10	1
Stayton to Shelburn	9	1
Shelburn to Green's Bridge	9	0
Green's Bridge to Mouth	9	0
Little N. Santiam	40	0
Elkhorn Bridge to Salmon Falls	5	0
Salmon Falls to Camp Cascade	6	0
Camp Cascade to Narrows	6	0

River Reach	Total Carcass/Redd Surveys	Carcasses Collected
Little N. Santiam cont.		
Narrows to Golf Bridge	2	0
Golf Bridge to Bear Creek Bridge	6	0
Bear Creek Bridge to Lomkers Bridge	5	0
Lomkers Bridge to NF Park	5	0
NF Park to HWY 22 Bridge	3	0
Hwy 22 Bridge to Mouth	2	0
S. Santiam	65	629
Foster to Pleasant Valley	31	585
Pleasant Valley to McDowell Creek	14	39
McDowell Creek to Waterloo	14	3
Gill's Landing/Lebanon to Sanderson's	3	2
Sanderson's to Mouth/Jefferson	3	0
Totals	541	941

Table 3. Counts and proportions of hatchery and wild origin fish, by size and river.

Counts	M.F. Willamette		Fall Creek		McKenzie		S.F. McKenzie		Lost Creek	
F.L. (cm)	H	W	H	W	H	W	H	W	H	W
<60	0	0	0	0	0	1	0	0	0	0
60-69	3	0	1	1	26	26	2	4	0	0
70-79	4	2	2	1	51	54	1	12	0	1
80-89	1	0	0	2	21	29	2	5	0	0
90-99	0	0	1	0	3	7	0	0	0	0
≥100	0	0	0	0	0	1	0	0	0	0
Total	8	2	4	4	101	118	5	21	0	1

Proportions	M.F. Willamette		Fall Creek		McKenzie		S.F. McKenzie		Lost Creek	
F.L. (cm)	H	W	H	W	H	W	H	W	H	W
<60	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
60-69	0.38	0.00	0.25	0.25	0.26	0.22	0.40	0.19	0.00	0.00
70-79	0.50	1.00	0.50	0.25	0.50	0.46	0.20	0.57	0.00	1.00
80-89	0.13	0.00	0.00	0.50	0.21	0.25	0.40	0.24	0.00	0.00
90-99	0.00	0.00	0.25	0.00	0.03	0.06	0.00	0.00	0.00	0.00
≥100	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00

Summary	M.F. Willamette		Fall Creek		McKenzie		S.F. McKenzie		Lost Creek	
	H	W	H	W	H	W	H	W	H	W
N	8	2	4	4	101	118	5	21	0	1
Mean	71.9	73.5	74.5	76.8	74.8	76.5	74.2	75.9	n/a	79.0
SEM	2.1	1.5	5.5	3.3	0.7	0.7	2.9	1.2	n/a	n/a

Counts	Horse Creek		Santiam		N. Santiam		S. Santiam		All Rivers	
F.L. (cm)	H	W	H	W	H	W	H	W	H	W
<60	0	0	0	0	0	0	7	1	7	2
60-69	0	0	0	0	1	6	81	10	114	47
70-79	0	6	0	0	10	8	310	27	378	111
80-89	0	3	1	0	6	2	145	21	176	62
90-99	0	1	0	0	1	0	16	3	21	11
≥100	0	0	0	0	0	0	1	0	1	1
Total	0	10	1	0	18	16	560	62	697	234

Proportions	Horse Creek		Santiam		N. Santiam		S. Santiam		All Rivers	
F.L. (cm)	H	W	H	W	H	W	H	W	H	W
<60	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01
60-69	0.00	0.00	0.00	0.00	0.06	0.38	0.14	0.16	0.16	0.20
70-79	0.00	0.60	0.00	0.00	0.56	0.50	0.55	0.44	0.54	0.47
80-89	0.00	0.30	1.00	0.00	0.33	0.13	0.26	0.34	0.25	0.26
90-99	0.00	0.10	0.00	0.00	0.06	0.00	0.03	0.05	0.03	0.05
≥100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Summary	Horse Creek		Santiam		N. Santiam		S. Santiam		All Rivers	
	H	W	H	W	H	W	H	W	H	W
N	0	10	1	0	18	16	560	62	697	234
Mean	0.0	79.4	83.0	n/a	78.3	72.1	76.0	76.7	75.8	76.3
SEM	n/a	1.4	n/a	n/a	1.2	1.5	0.3	1.1	0.3	0.5

Note: fish of unknown origin or length were excluded

Table 4. Counts and proportions of hatchery and wild origin fish, by age and river.

Counts	M.F. Willamette		Fall Creek		McKenzie		SF McKenzie		Lost Creek	
Age	H	W	H	W	H	W	H	W	H	W
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	1	23	0	3	0	0
4	6	0	3	4	42	35	3	5	0	0
5	0	2	1	0	49	43	2	7	0	1
6	0	0	0	0	1	0	0	1	0	0

Proportions	M.F. Willamette		Fall Creek		McKenzie		SF McKenzie		Lost Creek	
Age	H	W	H	W	H	W	H	W	H	W
2	0	0	0	0	0	0	0	0	-	0
3	0	0	0	0	0	0	0	0	-	0
4	1	0	1	1	0	0	1	0	-	0
5	0	1	0	0	1	0	0	0	-	1
6	0	0	0	0	0	0	0	0	-	0

Summary	M.F. Willamette		Fall Creek		McKenzie		SF McKenzie		Lost Creek	
	H	W	H	W	H	W	H	W	H	W
N	6	2	4	4	93	101	5	16	0	1
Mean	4.00	5.00	4.25	4.00	4.54	4.20	4.40	4.38	-	5.00
SEM	0.00	0.00	0.25	0.00	0.06	0.08	0.24	0.22	-	0.00

Counts	Horse Creek		Santiam		N Santiam		S Santiam		All Rivers	
Age	H	W	H	W	H	W	H	W	H	W
2	0	0	0	0	0	0	2	0	2	0
3	0	0	0	0	0	3	3	15	4	44
4	0	0	0	0	7	5	235	25	296	74
5	0	8	1	0	8	8	280	18	341	87
6	0	0	0	0	1	0	8	0	10	1
Proportions	**Horse Creek**		**Santiam**		**N Santiam**		**S Santiam**		**All Rivers**	
Age	H	W	H	W	H	W	H	W	H	W
2	-	0	0	-	0	0	0	0	0	0
3	-	0	0	-	0	0	0	0	0	0
4	-	0	0	-	0	0	0	0	0	0
5	-	1	1	-	1	1	1	0	1	0
6	-	0	0	-	0	0	0	0	0	0
Summary	**Horse Creek**		**Santiam**		**N Santiam**		**S Santiam**		**All Rivers**	
	H	W	H	W	H	W	H	W	H	W
N	0	8	1	0	16	16	528	58	653	206
Mean	-	5.00	5.00	-	4.63	4.31	4.55	4.05	4.54	4.22
SEM	-	0.00	0.00	-	0.15	0.20	0.02	0.10	0.02	0.05

Note: fish of unknown origin or age were excluded

Table 5. Counts and proportions of male and female carcasses collected in selected river basins, including tributaries.

Basin Counts	Female	Male	Unknown
Middle Fork Willamette	7	10	1
McKenzie	157	98	3
Santiam	0	1	0
North Santiam	23	12	0
South Santiam	419	204	6
Total	606	325	10
Basin Proportions	**Female**	**Male**	**Unknown**
Middle Fork Willamette	0.39	0.56	0.06
McKenzie	0.61	0.38	0.01
Santiam	0.00	1.00	0.00
North Santiam	0.66	0.34	0.00
South Santiam	0.67	0.32	0.01
Total	0.64	0.35	0.01

Note: unknown due to scavenging or decay

3.1.1 Prespawn Mortality

Crews collected the first carcass of the season on June 27, over two months prior to the initiation of spawning. Across all rivers, crews determined egg retention rates for 580 female carcasses; of these 104 fish (18%) were recorded as PSM (>50% egg retention), while the remaining 476 (82%) fish spawned successfully. Most fish either retained most of their eggs or were almost fully spawned; only 2% of the carcasses had between 30 and 70% egg retention. Examples of fish with various egg retention levels are shown in Figure 6. The Middle Fork Willamette had high PSM (71%), based on seven carcasses collected. In the North Santiam 19 carcasses were collected and a medium level of PSM was recorded (37%). There were 148 carcasses collected in the McKenzie basin and 406 in the South Santiam, and both rivers had low PSM levels (12 and 18%, respectively).

Results from Fisher's Exact Test showed no significant difference (α=0.05) in the proportion of PSM for hatchery or wild fish for all rivers (0.180 and 0.178, p=1.0), no difference for the South Santiam (0.184 and 0.156, p=0.66), and no difference for the McKenzie and its tributaries (0.068 and 0.173, p=0.07), and no difference for the McKenzie and its tributaries above Leaburg Dam (0.0 and 0.136, p=0.19). A difference was observed in PSM between hatchery and wild fish on the McKenzie below Leaburg Dam, where hatchery fish had a lower PSM rate than wild fish (0.087 and 0.444, p=0.016). PSM data by river and reach are shown in Table 6.

Figure 6. Female with 100% egg retention and intact skeins (A); female with 80% egg retention and broken skeins (B); female with 10% egg retention (C); and a fully spawned female fish with 0% egg retention (D).

Table 6. Prespawn mortality (PSM) results by river and reach.

River Reach	PSM	Spawned	Total Fish	PSM%
Middle Fork Willamette	1	1	2	50%
Dexter Dam to Pengra Landing	0	1	1	0%
Pengra Landing to Jasper	1	0	1	100%
Fall Creek	4	1	5	80%
Gold Creek to 1833 Bridge	1	0	1	100%
Johnny Creek to Release	0	1	1	0%
Fall Creek Dam to Pengra Bridge	2	0	2	100%
Pengra Bridge to Fall Creek Mouth	1	0	1	100%
McKenzie	18	104	122	15%
Spawning Channel to Olallie	0	17	17	0%
Ollalie to Belknap	0	3	3	0%
Belknap to Paradise	0	2	2	0%
Paradise to McKenzie Trail	0	2	2	0%
McKenzie Bridge to Hamlin	0	2	2	0%
South Fork McKenzie to Forest Glen	1	1	2	50%
Forest Glen to Rosboro Bridge	6	16	22	27%
Rosboro Bridge to Ben Kay	1	3	4	25%
Helfrich to Leaburg Lake	1	1	2	50%
Leaburg Dam to Leaburg Landing	8	56	64	13%
Leaburg Landing to Deerhorn	1	0	1	100%
Deerhorn to Hendricks	0	1	1	0%
Below Leaburg Dam	9	57	66	14%
Above Leaburg Dam	9	73	82	11%
South Fork McKenzie	0	17	17	0%
Upstream Habitat Restoration to Mouth	0	2	2	0%
Bridge to Upstream Habitat Restoration	0	8	8	0%
Cougar to Bridge	0	7	7	0%
Lost Creek	0	0	0	n/a
Horse Creek	0	9	9	0%
Road Access to Braids	0	1	1	0%
Avenue Creek to Horse Creek Bridge	0	3	3	0%
Horse Creek Bridge to Mouth	0	5	5	0%
Santiam	0	0	0	n/a
North Santiam	7	12	19	37%
Big Cliff to Minto Dam	1	4	5	20%
Minto Dam to Packsaddle	0	1	1	0%
Packsaddle to Gates Bridge	2	3	5	40%
Gates Bridge to Mill City	0	2	2	0%

River Reach	PSM	Spawned	Total Fish	PSM%
North Santiam cont.				
Mill City to Fisherman's Bend	2	0	2	100%
Fisherman's Bend to Mehama	2	1	3	67%
Upper Bennett to Stayton (North Channel)	0	1	1	0%
Little North Santiam	0	0	0	n/a
South Santiam	74	332	406	18%
Gills Landing to Sandersons	0	2	2	0%
McDowell Creek to Waterloo	2	1	3	67%
Pleasant Valley to McDowell Creek	19	2	21	90%
Foster Dam to Pleasant Valley	53	327	380	14%

Note: data includes only female fish where egg retention rate was available.

3.1.2 Proportion Hatchery Origin Spawners

The proportion of hatchery origin spawners varied from zero in the upper tributaries of the McKenzie (Horse Creek and Lost Creek) to 0.9 in the South Santiam. The mainstem McKenzie River above Leaburg Dam had 0.17 pHOS (27 hatchery fish of 132 total). Two hatchery fish, for a pHOS of 0.29, were collected above Minto Dam, in a reach where only wild fish were expected to be present. The pHOS data by river and reach is shown in Table 7.

Table 7. Proportion hatchery origin spawners (pHOS) by river and reach.

River Reach	Hatchery	Wild	pHOS
Middle Fork Willamette	8	2	0.80
Dexter Dam to Pengra Landing	7	2	0.78
Pengra Landing to Jasper	1	0	1.00
Fall Creek	4	4	0.50
Gold Creek to 1833 Bridge	0	1	0
Johnny Creek to Release	0	1	0
Fall Creek Dam to Pengra Bridge	3	2	0.60
Pengra Bridge to Fall Creek Mouth	1	0	1.00
McKenzie	102	118	0.46
Spawning Channel to Olallie	0	19	0
Ollalie to Belknap	2	3	0.40
Belknap to Paradise	0	2	0
Paradise to McKenzie Trail	0	2	0
McKenzie Bridge to Hamlin	1	6	0.14
South Fork McKenzie to Forest Glen	0	2	0
Forest Glen to Rosboro Bridge	12	53	0.18
Rosboro Bridge to Ben Kay	5	9	0.36
Helfrich to Leaburg Lake	2	4	0.33
Leaburg Dam to Leaburg Landing	76	17	0.82

River Reach	Hatchery	Wild	pHOS
Leaburg Landing to Deerhorn	2	1	0.67
Deerhorn to Hendricks	2	0	1.00
Below Leaburg	80	18	0.82
Above Leaburg	27	132	0.17
South Fork McKenzie	5	21	0.19
Cougar to Bridge	2	7	0.22
Bridge to Upstream Habitat Restoration	2	9	0.18
Upstream Habitat Restoration to Mouth	1	5	0.17
Lost Creek	0	1	0
Limberlost to Split Point	0	1	0
Horse Creek	0	10	0
Road Access to Braids	0	1	0
Braids to Avenue Creek	0	1	0
Avenue Creek to Horse Creek Bridge	0	3	0
Horse Creek Bridge to Mouth	0	5	0
Santiam	1	0	1.00
Jefferson to I5	1	0	1.00
North Santiam	18	17	0.51
Big Cliff to Minto Dam	2	5	0.29
Minto Dam to Packsaddle	1	1	0.50
Packsaddle to Gates Bridge	7	2	0.78
Gates Bridge to Mill City	5	2	0.71
Mill City to Fisherman's Bend	2	1	0.67
Fisherman's Bend to Mehama	1	3	0.25
Powerlines to Upper Bennett	0	1	0
Upper Bennett to Stayton (North Channel)	0	1	0
Stayton to Shelburn	0	1	0
Little North Santiam	0	0	-
South Santiam	564	62	0.90
Foster Dam to Pleasant Valley	528	55	0.91
Pleasant Valley to McDowell Creek	33	5	0.87
McDowell Creek to Waterloo	3	0	1.00
Gills Landing to Sandersons	0	2	0

Note: pHOS estimates included all carcasses collected during the season, except that carcasses of unknown origin were excluded from the analysis.

3.1.3 Coded Wire Tags and Straying

A total of 28 snouts were recovered on four reaches in 2018. Sixteen snouts were collected in the Foster to Pleasant Valley reach, of which eight CWTs were extracted and entered into the RMIS database; eight additional tags were either false positives in the field or lost during processing. The remaining 12 snouts collected were on the McKenzie river, 11 CWTs tags were extracted and entered into the RMIS database; one additional tag was either a false positive in the field or lost during processing. Nine CWTs were read from the Leaburg Dam to Leaburg Landing reach,

while one CWT was recovered from Forrest Glen to Rosboro Bridge, and one from Rosboro bridge to Ben and Kay.

Of the 11 CWTs read in the McKenzie River; one of these fish (9%) was released from the South Santiam Hatchery while the remainder originated from the McKenzie Hatchery. Of the eight CWT read from the South Santiam, two fish (25%) originated from outside the South Santiam (one from the McKenzie, one from the Molalla River). The fish from the Molalla River, a tributary of the lower Willamette River, was reared in the South Santiam but then released in the Molalla.

3.1.4 Otoliths

A total of 228 carcasses had otoliths analyzed for thermal markings; 11 (4.8%) were determined to have been mis-clipped hatchery origin fish. Of these 11 mis-clipped fish, one was found in the Big Cliff to Minto Dam reach of the North Santiam. Four mis-clipped fish were found in the South Santiam, three of those four were recovered from the Foster Dam to Pleasant Valley reach and one was found in the Pleasant Valley to McDowell Creek reach. Six mis-clipped hatchery origin fish were found in the McKenzie River and were distributed as follows; one from Helfrich to Leaburg Lake, one from Rosboro Bridge to Ben and Kay, and four from Leaburg Dam to Leaburg Landing.

3.2 Redd Counts

Survey crews first observed redd construction on September 5; this redd coincided with the first female carcass collected with <50% egg retention, indicating the fish had spawned. Redds were first observed by crews in the South Santiam and McKenzie on September 5, in the North Santiam on September 11, in the South Fork McKenzie and Lost Creek on September 24, in Horse Creek on September 25, and in the Little North Santiam on October 11. Spawning activity peaked around the last week of September, which corresponded to the week when the greatest number of carcasses were recovered for the project. The final carcass was collected in the South Fork McKenzie on October 15, in the McKenzie on October 16, in Horse Creek on October 17, and in the South Santiam on October 18. The final carcass collected for the project was on October 20 in the North Santiam, indicating spawning activity had ended.

Final redd counts began on October 4 and ended on October 24, except for two reaches in the lower McKenzie which had final redd counts completed on November 8. Prior to conducting these two late-season redd counts, crews confirmed redds were still visible on a nearby, previously completed reach. No spawning was documented in Fall Creek upstream of Fall Creek Dam, although crews could not access all reaches due to fire restrictions. No redd counts were conducted on Little Fall Creek due to lack of adult outplanting in 2018. The highest redd densities were recorded on the Foster Dam to Pleasant Valley reach of the South Santiam (79 redds/km). The highest number of redds (108) counted on a single reach on the McKenzie was on the Forest Glen to Rosboro Bridge reach. Redd counts by river and reach, along with the density of redds, are listed in Table 8. The location and number of redds along each river and reach are shown in Appendix A.

Table 8. Reach length, redd counts and number of redds per kilometer by river and reach.

River Reach	Reach Length (km)	# of Redds	Redds/km	Date of Final Count
Middle Fork Willamette	12.7	0	0.0	
Dexter Dam to Pengra Landing	4.3	0	0.0	18-Oct
Pengra Landing to Jasper	8.4	0	0.0	18-Oct
Fall Creek	34.9	1	0.0	
Falls to Gold Creek	1.6	0	0.0	5-Oct
Gold Creek to 1833 Bridge	2.4	0	0.0	5-Oct
1833 to Hehe Creek	1.6		not surveyed	
Hehe Creek to 1828	3.2		not surveyed	
1828 to Portland Creek	2.7		not surveyed	
Portland Creek to Bedrock	1.6		not surveyed	
Bedrock to Johnny Creek Bridge	1.6		not surveyed	
Johnny Creek to Release	7.6		not surveyed	
Release Site to Reservoir	2.1	0	0.0	11-Oct
Fall Creek Dam to Pengra Bridge	8.0	1	0.1	9-Oct
Pengra Bridge to Fall Creek Mouth	2.4	0	0.0	9-Oct
Little Fall Creek	14.2		not surveyed	
Trib Below NFD 400 to NFD 1806 Bridge	6.1		not surveyed	
NFD 1806 Bridge to NFD 1818 Bridge	4.0		not surveyed	
NFD 1818 Bridge to Fish Ladder	4.0		not surveyed	
McKenzie	115.5	374	3.2	
Spawning Channel to Olallie	1.6	15	9.3	9-Oct
Ollalie to Belknap	1.6	29	18.0	9-Oct
Belknap to Paradise	5.3	22	4.1	9-Oct
Paradise to McKenzie Trail	2.4	12	5.0	9-Oct
McKenzie Trail to McKenzie Bridge	2.6	5	1.9	9-Oct
McKenzie Bridge to Hamlin	13.4	22	1.6	9-Oct
Hamlin to S.F. McKenzie	0.5	0	0.0	9-Oct
South Fork McKenzie to Forest Glen	3.9	5	1.3	9-Oct
Forest Glen to Rosboro Bridge	9.2	108	11.8	10-Oct
Rosboro Bridge to Ben Kay	10.5	29	2.8	10-Oct
Helfrich to Leaburg Lake	7.1	15	2.1	16-Oct
Leaburg Dam to Leaburg Landing	9.7	106	11.0	16-Oct
Leaburg Landing to Deerhorn	3.4	1	0.3	11-Oct
Deerhorn to Hendricks	12.2	5	0.4	11-Oct
Hendricks to Bellinger	8.8	0	0.0	8-Nov
Bellinger to Hayden	7.1	0	0.0	8-Nov
Hayden to Armitage	16.4	0	0.0	10-Oct
South Fork McKenzie	7.1	55	7.8	
Cougar to Bridge	3.7	12	3.2	15-Oct
Bridge to Upstream Habitat Restoration	2.4	29	12.0	15-Oct

River Reach	Reach Length (km)	# of Redds	Redds/km	Date of Final Count
South Fork McKenzie cont.				
Upstream Habitat Restoration to Mouth	1.0	14	14.5	9-Oct
Lost Creek	7.7	24	3.1	
Spring to Cascade	3.7	0	0.0	8-Oct
Cascade to Limberlost CG	0.8	5	6.2	8-Oct
Limberlost CG to Split Point	2.4	14	5.8	8-Oct
Split Pt to Hwy 126 Bridge	0.8	5	6.2	8-Oct
Horse Creek	21.7	90	4.1	
Pothole Creek to Trail Bridge	2.7	2	0.7	10-Oct
Trail Bridge to Separation Creek	1.8	0	0.0	10-Oct
Separation Creek to Road Access	2.4	2	0.8	8-Oct
Road Access to Braids	3.4	8	2.4	8-Oct
Braids to Avenue Creek	1.9	6	3.1	8-Oct
Avenue Creek to Horse Creek Bridge	5.6	58	10.3	8-Oct
Horse Creek Bridge to Mouth	3.9	14	3.6	17-Oct
Santiam	19.5	0	0.0	
Confluence to Jefferson	3.4	0	0.0	17-Oct
Jefferson to I-5 Bridge	5.8	0	0.0	17-Oct
I-5 Bridge to Mouth	10.3	0	0.0	17-Oct
North Santiam	74.2	284	3.8	
Big Cliff Dam to Minto	6.4	19	3.0	18-Oct
Minto Dam to Packsaddle	0.3	7	21.8	18-Oct
Packsaddle to Gates Bridge	4.5	48	10.7	19-Oct
Gates Bridge to Mill City	6.1	27	4.4	19-Oct
Mill City to Fisherman's Bend	3.2	31	9.6	19-Oct
Fisherman's Bend to Mehama	10.5	26	2.5	20-Oct
Mehama to Powerlines	5.6	5	0.9	16-Oct
Powerlines to Upper Bennett	5.6	33	5.9	16-Oct
North Channel Stayton Is to Stayton	5.1	73	14.2	20-Oct
Stayton to Shelburn	8.8	12	1.4	17-Oct
Shelburn to Green's Bridge	13.2	3	0.2	17-Oct
Green's Bridge to Mouth	4.7	0	0.0	17-Oct
Little North Santiam	27.8	2	0.1	
Elkhorn Bridge to Salmon Falls	1.6	0	0.0	24-Oct
Salmon Falls to Camp Cascade	1.4	0	0.0	11-Oct
Camp Cascade to Narrows	1.9	0	0.0	11-Oct
Narrows to Golf Bridge	1.4	2	1.4	11-Oct
Golf Bridge to Bear Creek Bridge	5.5	0	0.0	24-Oct
Bear Creek Bridge to Lomkers Bridge	3.1	0	0.0	4-Oct
Lomkers Bridge to NF Park	6.4	0	0.0	4-Oct
NF Park to HWY 22 Bridge	4.0	0	0.0	4-Oct

River Reach	Reach Length (km)	# of Redds	Redds/km	Date of Final Count
Little North Santiam cont.				
Hwy 22 Bridge to Mouth	2.4	0	0.0	4-Oct
South Santiam	54.5	653	12.0	
Foster Dam to Pleasant Valley	7.2	570	78.7	11-Oct
Pleasant Valley to McDowell Creek	8.7	56	6.4	8-Oct
McDowell Creek to Waterloo	6.9	20	2.9	8-Oct
Gill's Landing to Sanderson's	15.6	7	0.4	18-Oct
Sanderson's to Mouth/Jefferson	16.1	0	0.0	18-Oct

3.2.1 Spawner Abundance and Carcass Recovery Rates

Spawner abundance estimates based on redd counts are provided by river and reach in Table 9. This data was then compared to the total number of carcasses collected by river and reach to determine carcass recovery rates, which is the number of carcasses collected out of the estimated spawner abundance. Spawner abundance estimates by origin were calculated for the river sections as shown in Table 10.

Table 9. Carcass recovery rates compared to spawner abundance by river and reach.

River Reach	Spawner Abundance (Redds*2.5)	Total Carcasses	Carcass Recovery Rate (Carc./Spawn.)
Middle Fork Willamette	0	10	n/a
Dexter Dam to Pengra Landing	0	9	no redds
Pengra Landing to Jasper	0	1	no redds
Fall Creek	3	8	320%
Falls to Gold Creek	0	0	none
Gold Creek to 1833 Bridge	0	1	no redds
Johnny Creek to Release	0	1	no redds
Release Site to Reservoir	0	0	none
Fall Creek Dam to Pengra Bridge	3	5	200%
Pengra Bridge to Fall Creek Mouth	0	1	no redds
McKenzie	935	221	24%
Spawning Channel to Olallie	38	19	51%
Ollalie to Belknap	73	5	7%
Belknap to Paradise	55	2	4%
Paradise to McKenzie Trail	30	2	7%
McKenzie Trail to McKenzie Bridge	13	0	0%
McKenzie Bridge to Hamlin	55	7	13%
Hamlin to S.F. McKenzie	0	0	none
South Fork McKenzie to Forest Glen	13	2	16%
Forest Glen to Rosboro Bridge	270	65	24%
Rosboro Bridge to Ben Kay	73	14	19%
Helfrich to Leaburg Lake	38	6	16%
McKenzie cont.			

River Reach	Spawner Abundance (Redds*2.5)	Total Carcasses	Carcass Recovery Rate (Carc./Spawn.)
Leaburg Dam to Leaburg Landing	265	94	35%
Leaburg Landing to Deerhorn	3	3	120%
Deerhorn to Hendricks	13	2	16%
Hendricks to Bellinger	0	0	none
Bellinger to Hayden	0	0	none
Hayden to Armitage	0	0	n/a
South Fork McKenzie	138	26	19%
Cougar to Bridge	30	9	30%
Bridge to Upstream Habitat Restoration	73	11	15%
Upstream Habitat Restoration to Mouth	35	6	17%
Lost Creek	60	1	2%
Spring to Cascade	0	0	none
Cascade to Limberlost CG	13	0	no carcasses
Limberlost to Split Point	35	1	3%
Split Pt to Hwy 126 Bridge	13	0	no carcasses
Horse Creek	225	10	4%
Pothole Creek to Trail Bridge	5	0	no carcasses
Trail Bridge to Separation Creek	0	0	none
Separation Creek to Road Access	5	0	no carcasses
Road Access to Braids	20	1	5%
Braids to Avenue Creek	15	1	7%
Avenue Creek to Horse Creek Bridge	145	3	2%
Horse Creek Bridge to Mouth	35	5	14%
Santiam	0	1	no redds
Confluence to Jefferson	0	0	no carcasses
Jefferson to I-5 Bridge	0	1	No redds
I-5 Bridge to Mouth	0	0	no carcasses
North Santiam	710	35	5%
Big Cliff Dam to Minto Dam	48	7	15%
Minto Dam to Packsaddle	18	2	11%
Packsaddle to Gates Bridge	120	9	8%
Gates Bridge to Mill City	68	7	10%
Mill City to Fisherman's Bend	78	3	4%
Fisherman's Bend to Mehama	65	4	6%
Mehama to Powerlines	13	0	no carcasses
Powerlines to Upper Bennett	83	1	1%
Upper Bennett to Stayton (North Channel)	183	1	1%
Stayton to Shellburn	30	1	3%
Shelburn to Green's Bridge	8	0	no carcasses
Green's Bridge to Mouth	0	0	none
Little North Santiam	5	0	0%

River Reach	Spawner Abundance (Redds*2.5)	Total Carcasses	Carcass Recovery Rate (Carc./Spawn.)
Elkhorn Bridge to Salmon Falls	0	0	none
Salmon Falls to Camp Cascade	0	0	none
Camp Cascade to Narrows	0	0	none
Narrows to Golf Bridge	5	0	no carcasses
Golf Bridge to Bear Creek Bridge	0	0	none
Bear Creek to Lomkers	0	0	none
Lomkers Bridge to NF Park	0	0	none
NF Park to HWY 22 Bridge	0	0	none
Hwy 22 Bridge to Mouth	0	0	none
South Santiam	1633	629	39%
Foster Dam to Pleasant Valley	1425	585	41%
Pleasant Valley to McDowell Creek	140	39	28%
McDowell Creek to Waterloo	50	3	6%
Gills Landing to Sandersons	18	2	11%
Sanderson's to Mouth/Jefferson	0	0	none
Grand Total	3708	941	25%

Note: spawner abundance estimate rounded to the nearest whole number, but decimal places were included when calculating carcass recovery rates.

Table 10. Spawner abundance estimates by origin for specified basin sections.

Basin Sections	Redd Count	Spawner Abundance (Redds*2.5)	pHOS	Spawner Abundance	
				Hatchery-origin	Natural-origin
MF Willamette and Fall Creek below Fall Creek Dam	1	3	0.75	2	1
Fall Creek above Fall Creek Dam	0	0	0.00	0	0
McKenzie below Leaburg Dam	112	280	0.82	229	51
McKenzie above Leaburg Dam (including SF McKenzie, Horse Creek, and Lost Creek)	431	1078	0.17	183	895
Santiam	0	0	1.00	0	0
North Santiam below Minto Dam and Little North Santiam	267	668	0.57	381	286
North Santiam above Minto Dam	19	48	0.29	14	34
South Santiam	653	1633	0.90	1471	162

Note: spawner abundance estimate rounded to the nearest whole number.

4 Discussion

4.1 Prespawn Mortality Estimates

PSM rates observed in 2018 were varied when compared to previous years. On the South Santiam, PSM was higher in 2018 (18%) than in 2015 (12%) and 2016 (4%). Likewise, PSM

was higher on the McKenzie above Leaburg Dam in 2018 (16%) than in 2015 (5%). In contrast, PSM on the McKenzie below Leaburg Dam was lower in 2018 (14%) than in 2015 (35%) and 2016 (17%), it was about half the rate in 2018 (50%) on the Middle Fork Willamette compared to 2015 (99%) and 2016 (96%). These data demonstrate that PSM rates are highly variable among rivers within a year, and among years within individual rivers.

In contrast to the 14-year dataset analyzed in the Willamette Basin by Bowerman et al. (2017), our single season of data did not show higher rates of PSM in hatchery fish. We did not detect a difference in the proportions of PSM between hatchery and wild fish for all rivers, the South Santiam, or for the McKenzie and tributaries. Instead, in McKenzie below Leaburg Dam, PSM was higher in wild fish than in hatchery fish. The reason for these differences is unknown and could warrant further investigation.

Factors that may have influenced the observed PSM values include the frequency and distribution of surveys as well as survey timing. Carcass and redd surveys began early in the season when fish were just arriving in the upper Willamette, thus encompassing most of the time when PSM may potentially occur in the reaches. However, a carcass was collected during the first day of surveys, indicating that carcasses may have been present prior to surveys beginning which could bias PSM estimates low. The surveys focused on areas with the greatest density of fish during the season, to maximize carcass recovery rates. In addition, to compensate for the increased workload during the spawning season, additional crews were brought on to conduct surveys. A spatially and temporally balanced study design may yield more accurate estimates of PSM. Additionally, the presence of ODFW crews may have affected the observed proportions of PSM on the project; analysis of the two datasets combined would be required to determine what effect those collections had on the results in this report.

4.2 Carcass Recovery Rates

A variety of factors may contribute to the observed variability in carcass recovery rates including level of surveyor effort, river conditions, survey timing, spawning timing, and redd count accuracy. Some rivers, such as Horse Creek and Lost Creek, are complex, fast moving rivers which reduces carcass recovery rates (3% and 2%, respectively). Alternatively, the South Santiam is characterized by slower water and lower stream complexity, and carcass recovery rates were much higher (39%). Increased survey effort in this section also contributed to the high recovery rate. Carcass recovery rates on the North Santiam were low overall (5%), and crews located less 5% of the estimated spawner abundance on several of the reaches. Factors that may have contributed to the low carcass recovery rate include lower levels of effort in some of the reaches on the North Santiam, the inability to utilize tower boats in the upper reaches, and fast-moving water.

ODFW conducted carcass surveys on many of the same reaches surveyed by EAS for this project; the full extent and frequency of the ODFW surveys is unknown. In reaches where both crews were collecting carcasses, a carcass collected by one crew would be unavailable to the other crew (both crews marked processed carcasses by removing the tail, which is necessary to avoid double-counting but renders carcasses unavailable for processing by the other crew). EAS staff coordinated with ODFW crews on a weekly basis to attempt to stagger surveys so that crews were not surveying the same reaches on the same days; ODFW and EAS crews surveyed the same reach on the same day on only a few occasions during the season. The presence of the

ODFW crew reduced the overall carcass recovery rate for this project, but the combined carcass recovery rate from the two crews was likely higher overall because the frequency of surveys was increased. An analysis of the combined datasets would be required to determine if and how the collection of carcasses by ODFW affected the results described in this report. A more complete analysis could be performed by combining the datasets from the two carcass crews, in the specific rivers and reaches where ODFW conducted surveys, assuming sampling protocols are comparable.

4.3 Coded Wire Tag Recoveries

In 2018, carcass crews collected 28 snouts that were indicated to contain coded wire tags (CWT's) in the field. Of the 28 snouts collected, 19 tags (68%) were extracted and read; CWT were not successfully extracted from 9 of the snouts (32%). These tags were either lost during extraction due to the extremely small size of the tags or some of the samples may have been collected in the field as false positives. For comparison, the South Santiam hatchery collected 51 snouts, and 44 CWT (86%) were later read.

Field collection percentages for CWT's in the South Santiam by EAS survey crews were similar to the South Santiam hatchery (Foster Trap) collection. Survey crews were testing the readers frequently with a test tag. Survey crews collected 561 non-subadult hatchery carcasses and detected 16 CWT's in the South Santiam reaches below Foster dam (2.8%). The South Santiam Hatchery crews detected 51 coded wire tags at Foster Trap from the 1358 non-subadult Chinook (3.8%). CWT data for 2018 is available at https://www.rmpc.org/.

Straying rates observed in the McKenzie (9%) and South Santiam (25%) may have been affected by low CWT recovery. The small sample size could skew data and may not be representative of true straying rates in the rivers.

4.4 Scale Age Analysis

The rate of agreement between ages from scale reads and ages from the CWT data was 71% in the South Santiam. The rate of agreement was lower in the McKenzie (27%). Both datasets included low numbers of CWT, only 11 CWT were read in the McKenzie and 7 in the South Santiam that also had scale age determinations. A higher recovery of CWT would have been necessary to conduct a meaningful analysis of the rate of agreement between the scale ages and CWT data.

4.5 Factors Affecting Redd Counts

Factors that may influence redd counts include surveyor experience, redd life, boat type, survey timing, spawning timing, experience with habitat locations on individual reaches, frequency of redd counts, and frequency of early of redd construction observations. Crews regularly surveyed reaches beginning in June, prior to spawning, which allowed them to learn whether and where old redds were visible. Crews surveyed most reaches on a weekly basis during the spawning season; this allowed them to become familiar with the location of redds and relative number of live fish remaining in the reaches prior to conducting final redd counts. Personnel observed that some redds that were constructed early in September were becoming more difficult to detect by the end of the survey season, but those redds were still visible during final redd counts; this was observational and no formal method of determining redd life was attempted. Surveyors also noted live fish and redd construction into mid-October.

4.6 Effects of Fire Closures in Fall Creek and Low Flows on the Little North Santiam

The Jones Fire, which burned a portion of the Fall Creek drainage in 2017, caused the U.S. Forest Service to implement access restrictions on a portion of Fall Creek in 2018. Surveyors were not allowed in Fall Creek from the 1833 Bridge to Johnny Creek Bridge. In 2016, the number of Chinook outplanted above Fall Creek Dam was 424, compared to only 94 Chinook in 2018. In 2016 no redds were observed below Johnny Creek Bridge. Of the 98 redds observed above Fall Creek Dam in 2016, 39 redds (40%) were counted from the Falls to 1833 Bridge (Sharpe et al. 2017). The remaining 59 redds (60%) counted in 2016 were found between 1833 Bridge and Johnny Creek Bridge, reaches that EAS was unable to survey in 2018 due to access restrictions relating to recent fires. In 2016, 40% of the fish spawned between the Falls and 1833 Bridge, where no redds were detected in 2018; this could indicate that spawning activity in the unsurveyed area may also have been low or absent in 2018. Surveyors only observed three live Chinook during the season in Fall Creek above Fall Creek Dam; all above Gold Creek. The Falls to Gold Creek was surveyed 12 times with one carcass located early in the season, the 11th of July. Gold Creek to 1833 Bridge was surveyed a total of 11 times with no carcasses recovered. One additional carcass was collected near the release site in early October. Survey efforts that were originally planned in the inaccessible reaches were redistributed to other project reaches.

Two of the drainages surveyed in 2018 were dramatically affected by low water levels. By August, water levels in Fall Creek above Fall Creek Dam and in the Little North Santiam dropped to only a few inches in some areas (Figure 7). The elevation of the headwaters for these two basins are relatively low compared to the rest drainages surveyed, which are either dam controlled or glacially fed. It is highly likely that during the migration season Chinook were unable to navigate Fall Creek and Little North Santiam due to low water levels. Survey crews observed low water levels in bedrock sections and observed water flowing sub-surface in both the Little North Santiam and Little Fall Creek.

Figure 7. Elkhorn Bridge to Bear Creek, Little North Santiam at low water.

4.7 South Fork McKenzie River Habitat Restoration and Fire Closure

In 2018, a habitat restoration project was conducted on the South Fork McKenzie River, from the mouth upstream 0.6 miles, by the United States Forest Service (USFS). The South Fork McKenzie was diverted to a historical floodplain, the main channel was recontoured, and logs were deposited in the restoration area. The restored area was rewatered on August 7.

The amount of woody debris deposited in the habitat restoration made surveying difficult, not only because of difficulty navigating unstable woody debris but the introduction of clean gravels (lacking periphyton) made redds more difficult to identify (Figure 8).

Figure 8. Chinook on redds constructed in the habitat restoration area; redds were difficult see due to the lack of periphyton on the new river substrate.

The South Fork McKenzie was originally broken into two reaches in the survey schedule, Cougar Dam to F.S. 19 bridge and F.S. 19 bridge to the Mouth, both surveyed by boat. This lower reach was split into two reaches, F.S. 19 bridge to the start of the Habitat Restoration was still surveyed by boat, the Habitat restoration to the Mouth was surveyed by climbing over the woody debris (Figure 9). The USFS staff conducted spawning surveys three times a week during the spawning season, the frequency of surveys allowed USFS personnel to observe redd building as it occurred in the newly formed spawning areas. Together with the experienced USFS survey crews, EAS crews conducted carcass surveys and redd count surveys in this reach.

Figure 9. Upstream end of USFS habitat restoration, South Fork McKenzie. EAS surveyor searching woody debris for carcasses.

On August 19, a fire was started at Terwilliger Hot Springs. The Terwilliger fire was active through the completion of the spawning ground survey season. Initially crews were not allowed to access the South Fork McKenzie from the start of the fire until the 24th of September. Consequently, no carcass surveys were conducted in this reach from the 19th of August until the 24th of September, which likely lowered the number of carcasses recovered.

4.8 Little Fall Creek 2018

In 2015 ODFW outplanted 100 adult salmon in Little Fall Creek and conducted spawning surveys in that tributary to assess the potential for recovery of the species; however, no redds were observed (Sharp et al. 2017) and no outplanting occurred in in 2016 or 2018. Because Little Fall Creek appeared to be impassable by fish due to low water levels in 2018, it was not surveyed and instead effort was shifted to Fall Creek below Fall Creek Dam, a reach that was not originally part of the project scope.

5 Acknowledgments

Many people assisted with this project and its successful completion was made possible through their efforts. The project was funded by the U.S. Army Corps of Engineers (USACE). We would like to thank Christopher Walker, Robert Wertheimer, Darren Gallion, Steven Sachs, Devon Mccanna and Richard Piaskowski from USACE Portland District; Greg Taylor, Doug Garletts, Chad Helms, from the USACE Lookout Point office for field help and project coordination. We would also like to thank our survey crew personnel: Matt Paulsen, Peter Spalholz, Larry Javorski, Phoebe Hill, Ethan Prather, Alex Cuda, Brianna Lyons, Dillion Alegre, Courtney Zink, Erica Smith, Emma Juth, Sabina Hagen-Botbol, Katie Humphreys, and Brian Ward. Oregon Department of Fish and Wildlife staff that helped with coordination of field crews included Brian Cannon, Luke Whitman; additional project support was provided by Kurt Kramers, Bret Boyd, Shannon Richardson, and Gabriel Garza. United States Forest Service staff Kate Meyers and Mickey Means-Brous assisted with field work and data collection. Andrew Talabere from the Eugene Water and Electric Board, and Shelly Sherman from Normandeau Associates Inc. also provided support.

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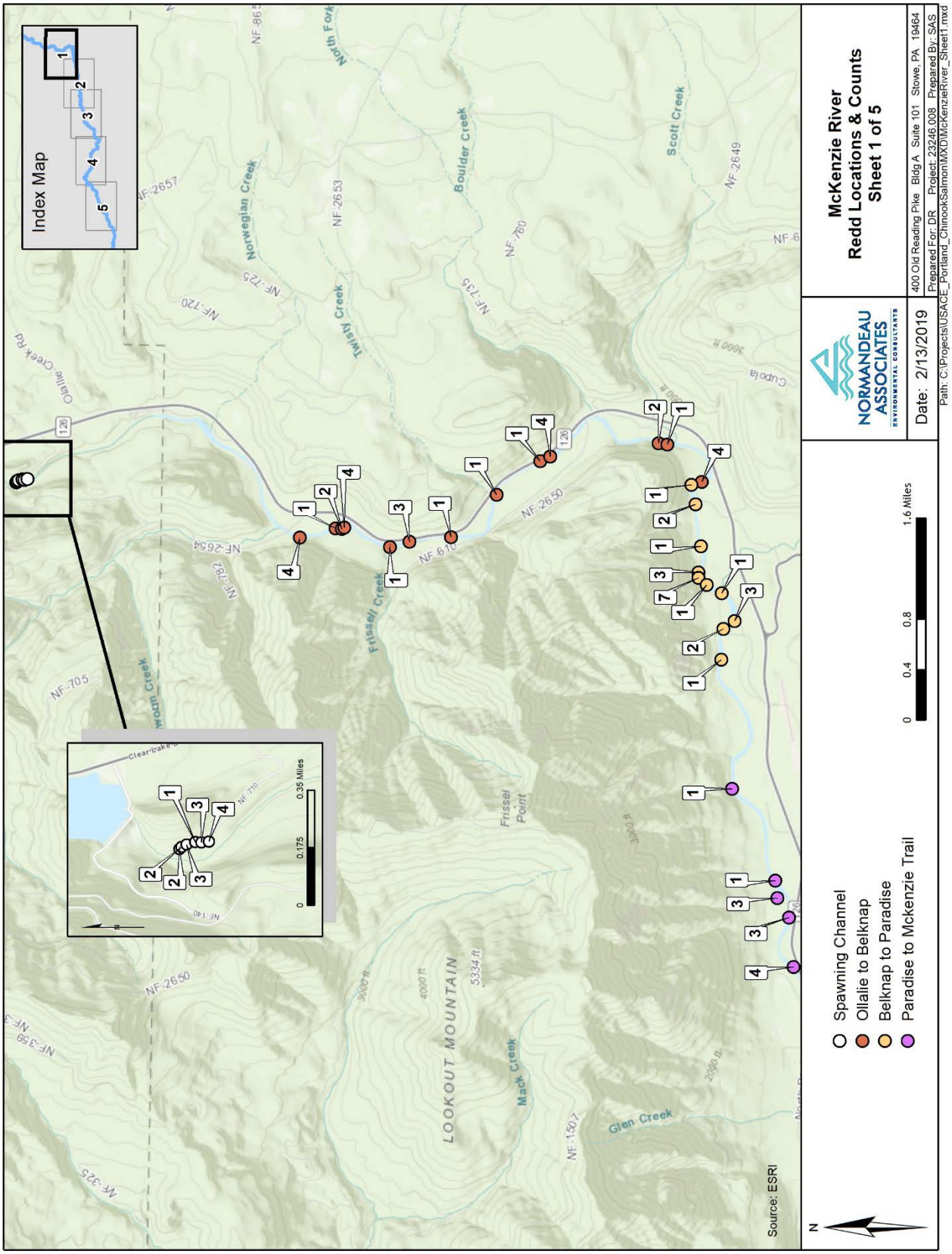
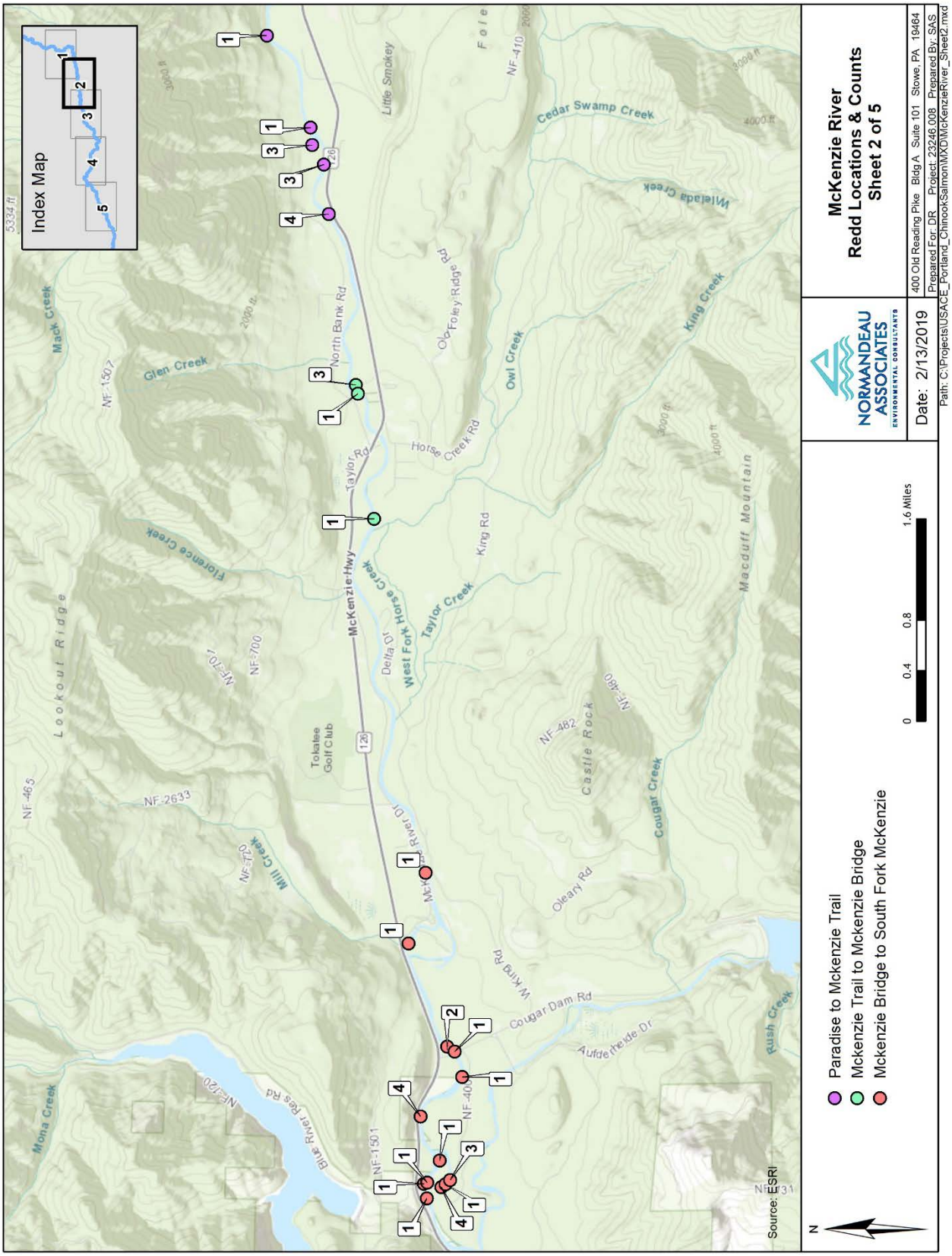
Appendix A: Redd Counts and Locations


Fall Creek
Redd Location & Count
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
400 Old Reading Pike Bldg A Suite 101 Stowe, PA 19464
Prepared For: DR Project: 23246.008 Prepared By: SAS
Date: 2/13/2019
Path: C:\Projects\USACE_Portland_ChinookSalmon\MXD\Fall_Creek.mxd
Fall Creek Dam to Pengra to Mouth
0 0.125 0.25 0.5 Miles
N
Unity
1
Big Fall Creek Rd
Winberry Creek Rd
Winberry Creek Park Rd
Winberry - Fall Creek State Recreation Area
North Shore - Fall Creek State Recreation Area
Reuben Leyh Rd
Church Rd
Jasper Lowell Rd
Little Fall Creek Rd
1132 ft
1175 ft
Source: ESRI


McKenzie River
Redd Locations & Counts
Sheet 1 of 5
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 2/13/2019
400 Old Reading Pike Bldg A Suite 101 Stowe, PA 19464
Prepared For: DR Project: 23246.008 Prepared By: SAS
Path: C:\Projects\USACE_Portland_ChinookSalmon\MXD\McKenzieRiver_Sheet1.mxd
Index Map
Spawning Channel
Ollalie to Belknap
Belknap to Paradise
Paradise to Mckenzie Trail
0 0.4 0.8 1.6 Miles
0 0.175 0.35 Miles
N
Source: ESRI
LOOKOUT MOUNTAIN
Frissel Point
Frissel Creek
Mack Creek
Glen Creek
Twisty Creek
Boulder Creek
Scott Creek
Norwegian Creek
Olallie Creek Rd
NF-2650
NF-2657
NF-2653
NF-2649
NF-760
NF-735
NF-720
NF-725
NF-2654
NF-782
NF-705
NF-1507
NF-325
NF-359
5334 ft
4000 ft
3000 ft
2000 ft


McKenzie River
Redd Locations & Counts
Sheet 2 of 5
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 2/13/2019
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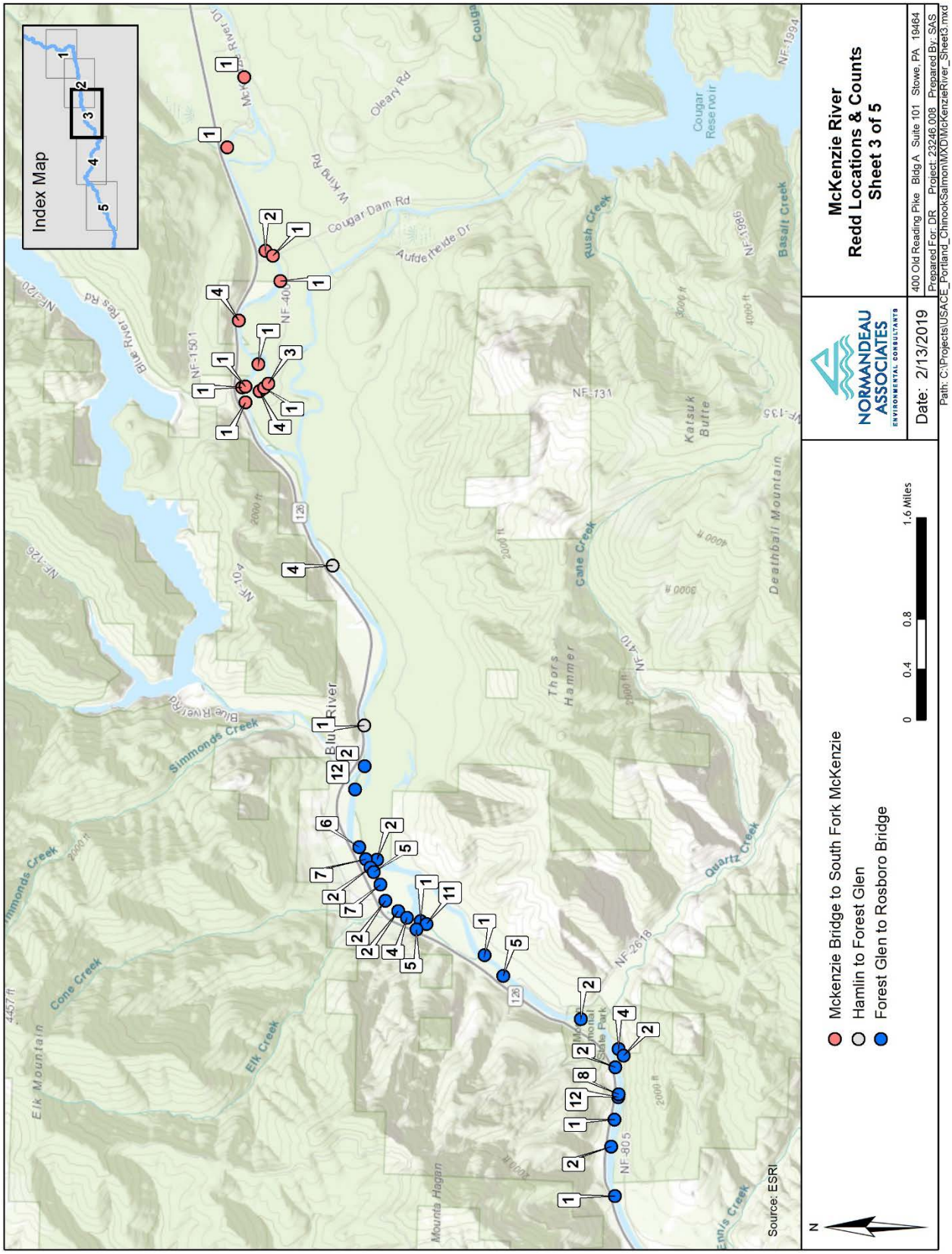
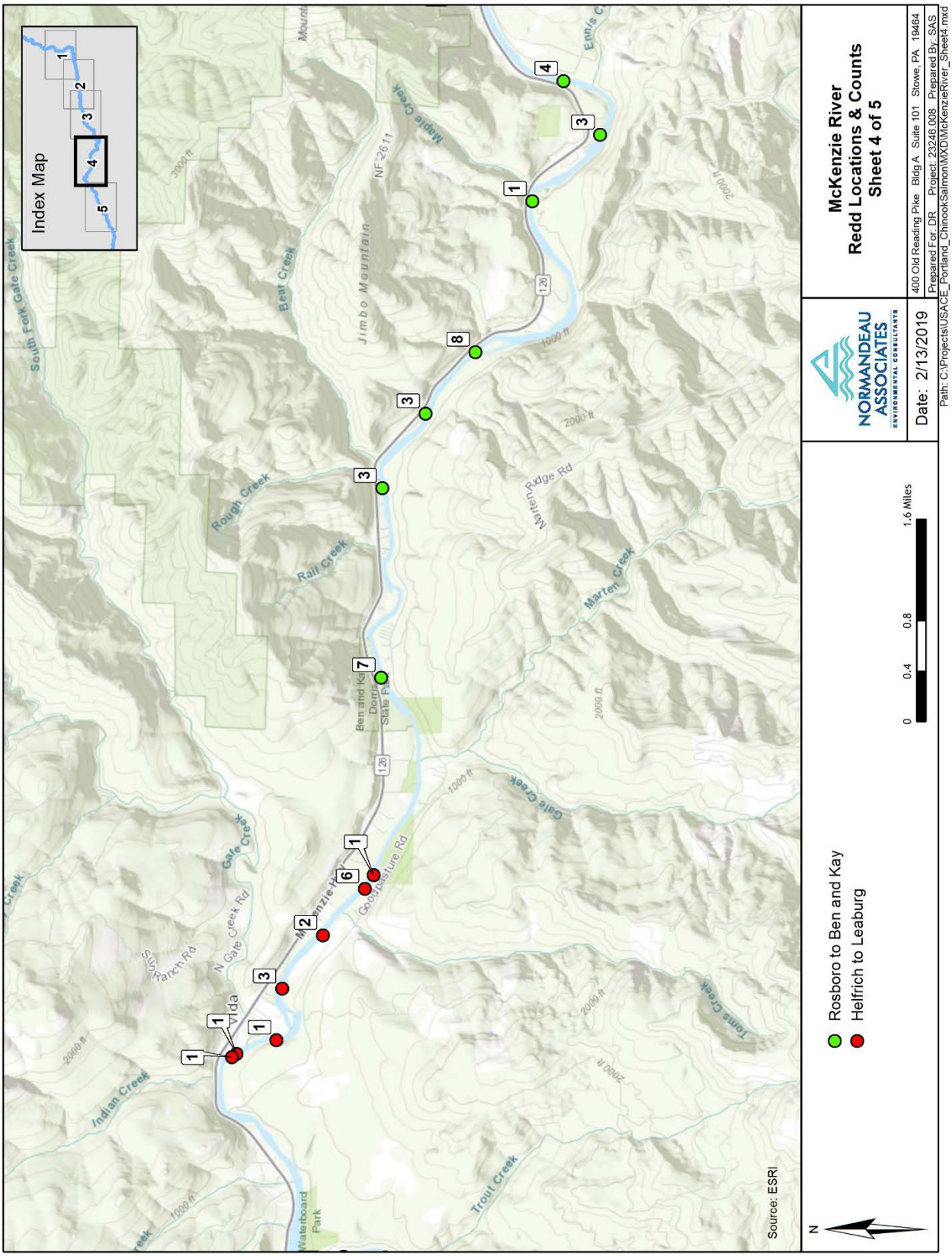
Prepared For: DR Project: 23246.008 Prepared By: SAS
Path: C:\Projects\USACE_Portland_ChinookSalmon\MXD\McKenzieRiver_Sheet2.mxd
Index Map
Paradise to Mckenzie Trail
Mckenzie Trail to Mckenzie Bridge
Mckenzie Bridge to South Fork McKenzie
0 0.4 0.8 1.6 Miles
N
Source: ESRI
McKenzie Hwy
Cedar Swamp Creek
Little Smokey
Mack Creek
Glen Creek
North Bank Rd
Old Foley Ridge Rd
Owl Creek
King Creek
Horse Creek Rd
Taylor Rd
Florence Creek
West Fork Horse Creek
Taylor Creek
King Rd
Delta Dr
Tokatee Golf Club
Lookout Ridge
Macduff Mountain
Castle Rock
Cougar Creek
Oleary Rd
W King Rd
Cougar Dam Rd
Audderheide Dr
Rush Creek
Mona Creek
Mill Creek
Blue River Res Rd
NF-1507
NF-700
NF-2633
NF-465
NF-1501
NF-410
NF-480
NF-482
NF-400
NF-420


Index Map
McKenzie River
Redd Locations & Counts
Sheet 3 of 5
Mckenzie Bridge to South Fork McKenzie
Hamlin to Forest Glen
Forest Glen to Rosboro Bridge
0 0.4 0.8 1.6 Miles
N
Source: ESRI
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 2/13/2019
400 Old Reading Pike Bldg A Suite 101 Stowe, PA 19464
Prepared For: DR Project: 23246.008 Prepared By: SAS
Path: C:\Projects\USACE_Portland_ChinookSalmon\MXD\McKenzieRiver_Sheet3.mxd
Cougar Dam Rd
Cougar Reservoir
Cleary Rd
Rush Creek
Basalt Creek
Deathball Mountain
Katsuk Butte
Cone Creek
Elk Mountain
Elk Creek
Simmonds Creek
Quartz Creek
Mounts Hagan
Ennis Creek
Thors Hammer
Blue River
NF-1501
NF-126
NF-2618
NF-131


Index Map
McKenzie River
Redd Locations & Counts
Sheet 4 of 5
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 2/13/2019
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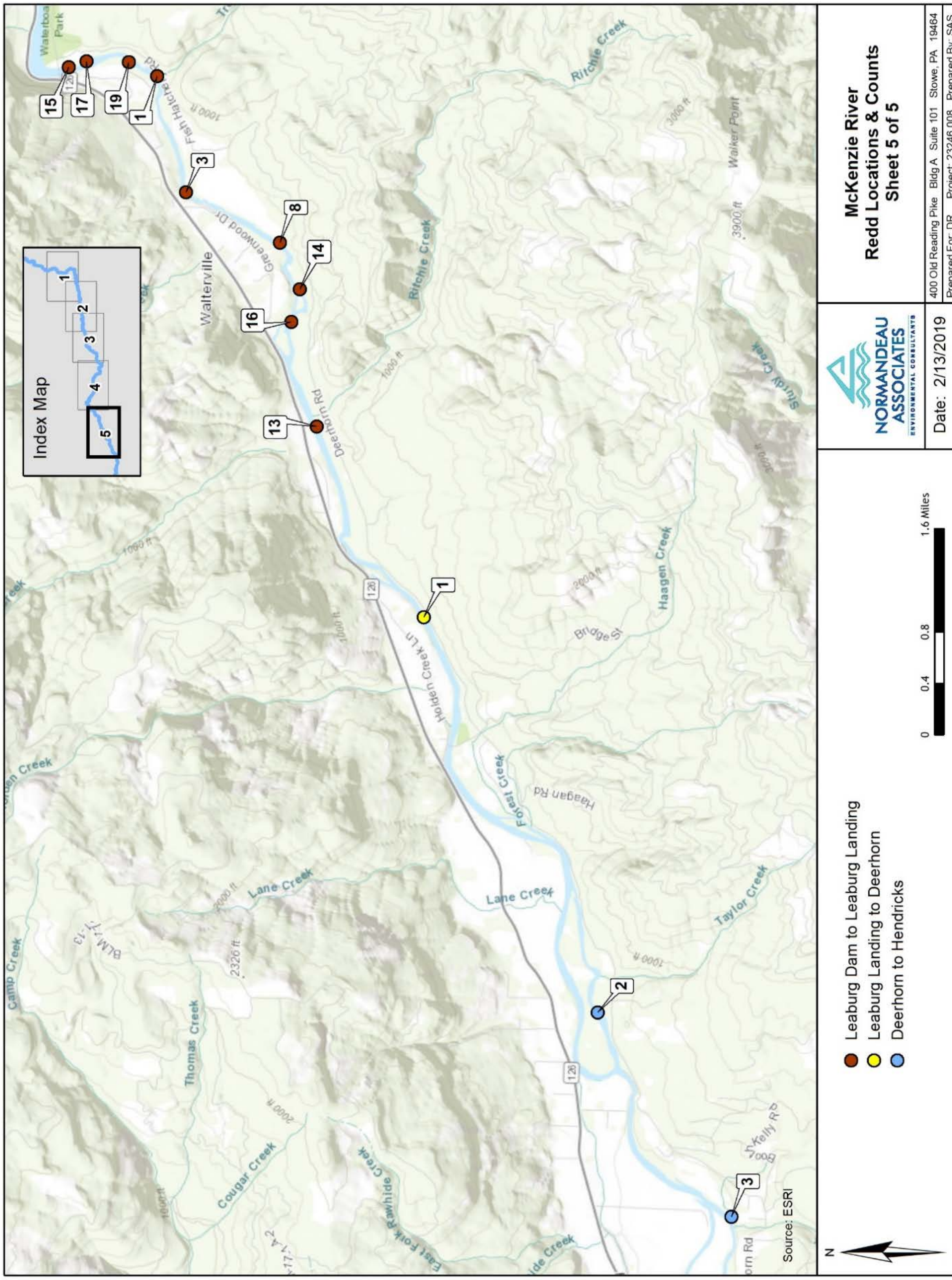
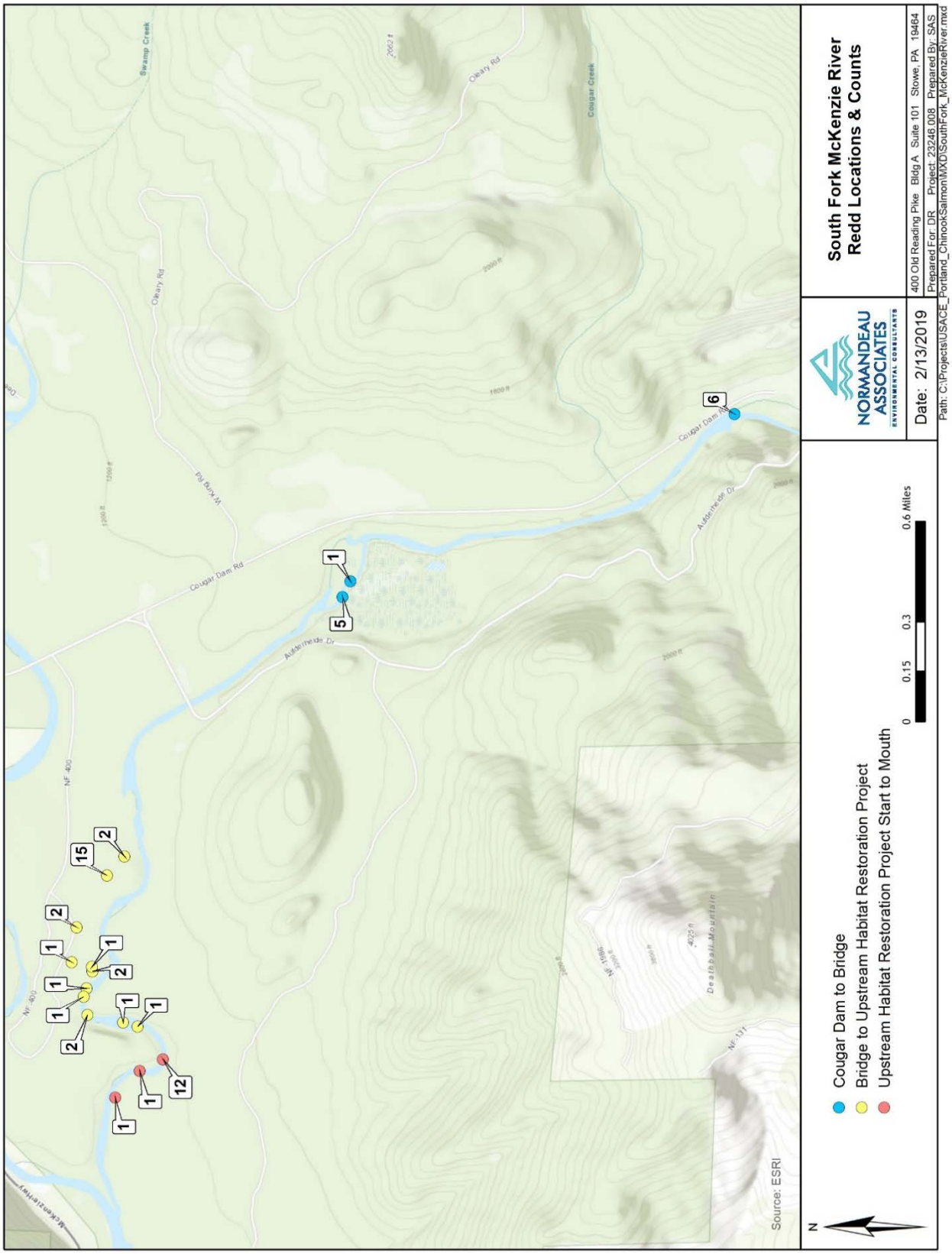
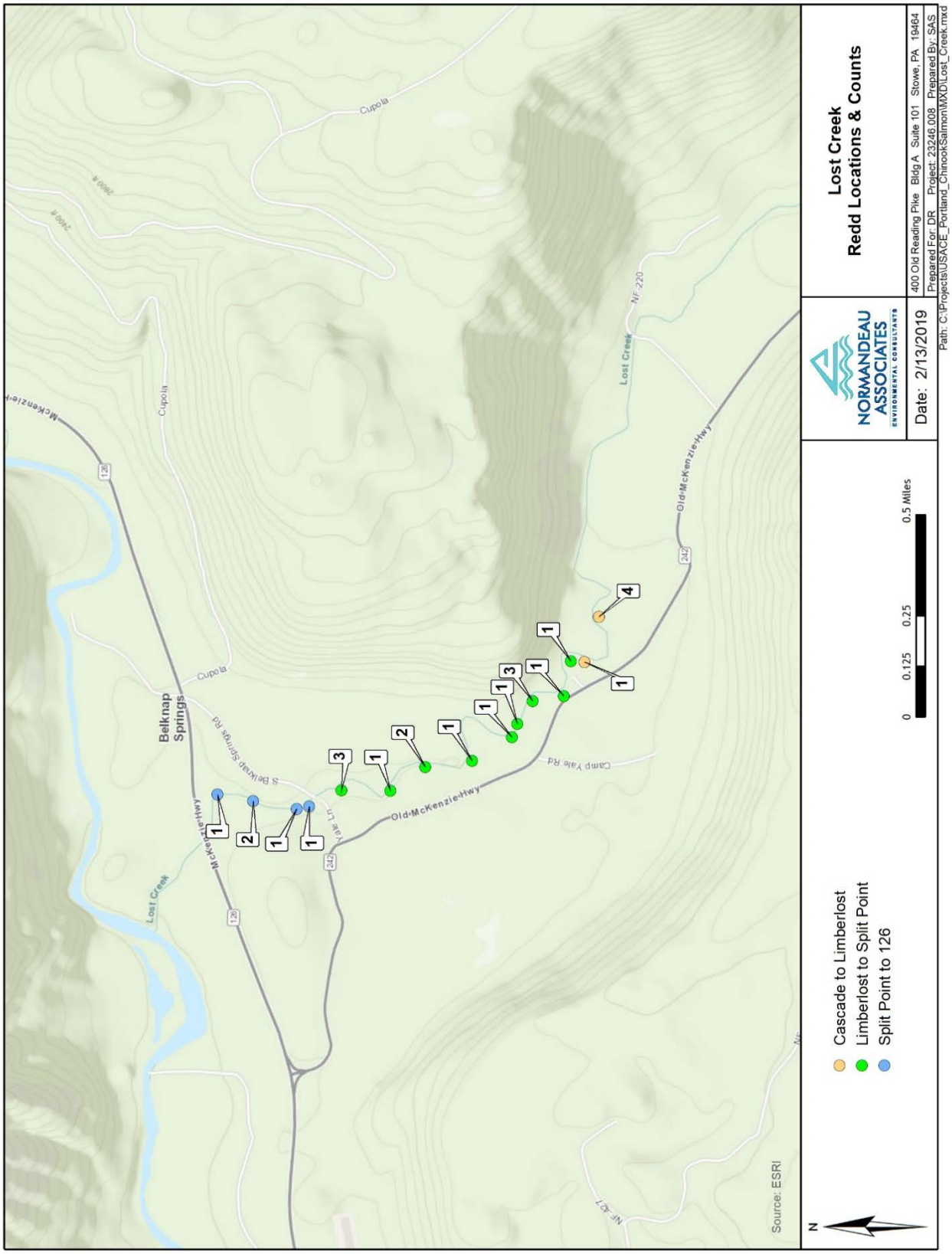
Prepared For: DR Project: 23246.008 Prepared By: SAS
Path: C:\Projects\USACE_Portland_ChinookSalmon\MXD\McKenzieRiver_Sheet4.mxd
Rosboro to Ben and Kay
Helfrich to Leaburg
0 0.4 0.8 1.6 Miles
N
Source: ESRI
Rough Creek
Rail Creek
Gate Creek
Indian Creek
Trout Creek
Gale Creek
Marten Creek
Toms Creek
Beat Creek
Jimbo Mountain
Maple Creek
Ben and Kay Dorris State Park
Waterboard Park
Goodpasture Rd
N Gate Creek Rd
Marten Ridge Rd
Sub Ranch Rd
NF 2611
126


McKenzie River
Redd Locations & Counts
Sheet 5 of 5
Index Map
Leaburg Dam to Leaburg Landing
Leaburg Landing to Deerhorn
Deerhorn to Hendricks
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 2/13/2019
400 Old Reading Pike Bldg A Suite 101 Stowe, PA 19464
Prepared For: DR Project: 23246.008 Prepared By: SAS
Path: C:\Projects\USACE_Portland_ChinookSalmon\MXD\McKenzieRiver_Sheet5.mxd
0 0.4 0.8 1.6 Miles
Source: ESRI
N
Walterville
Deerhorn Rd
Holden Creek Ln
Greenwood Dr
Ritchie Creek
Haagen Rd
Forest Creek
Lane Creek
Taylor Creek
Thomas Creek
Cougar Creek
Camp Creek
Hagen Creek
Bridge St
Walker Point


South Fork McKenzie River
Redd Locations & Counts
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 2/13/2019
400 Old Reading Pike Bldg A Suite 101 Stowe, PA 19464
Prepared For: DR Project: 23246.008 Prepared By: SAS
Path: C:\Projects\USACE_Portland_ChinookSalmon\MXD\SouthFork_McKenzieRiver.mxd
Cougar Dam to Bridge
Bridge to Upstream Habitat Restoration Project
Upstream Habitat Restoration Project Start to Mouth
0 0.15 0.3 0.6 Miles
N
Source: ESRI
Cougar Dam Rd
Okary Rd
Swamp Creek
Cougar Creek
Aufderheide Dr
NF 400
NF 1316
Deathball Mountain
NF 1311
15
12
6
5


Lost Creek
Redd Locations & Counts
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 2/13/2019
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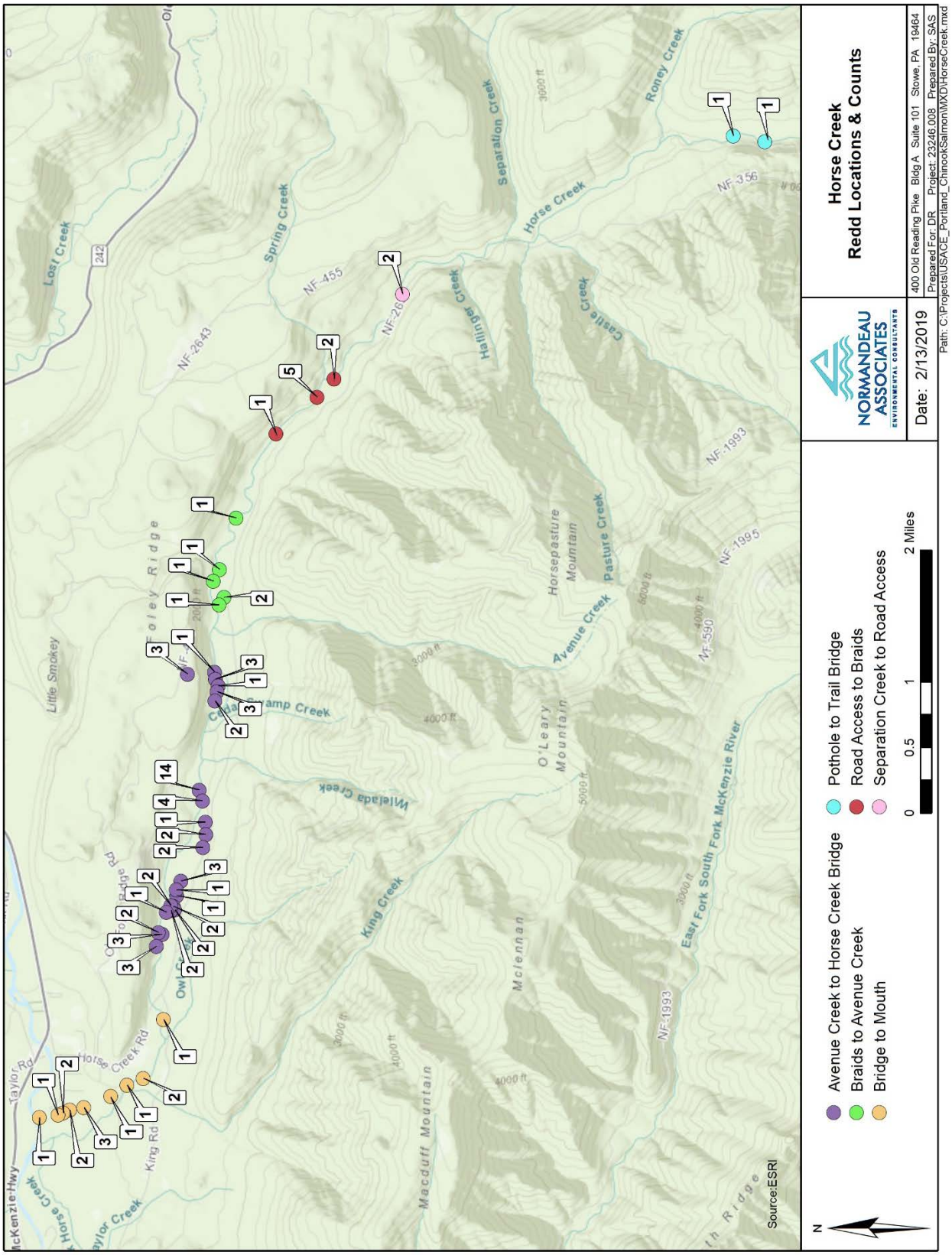
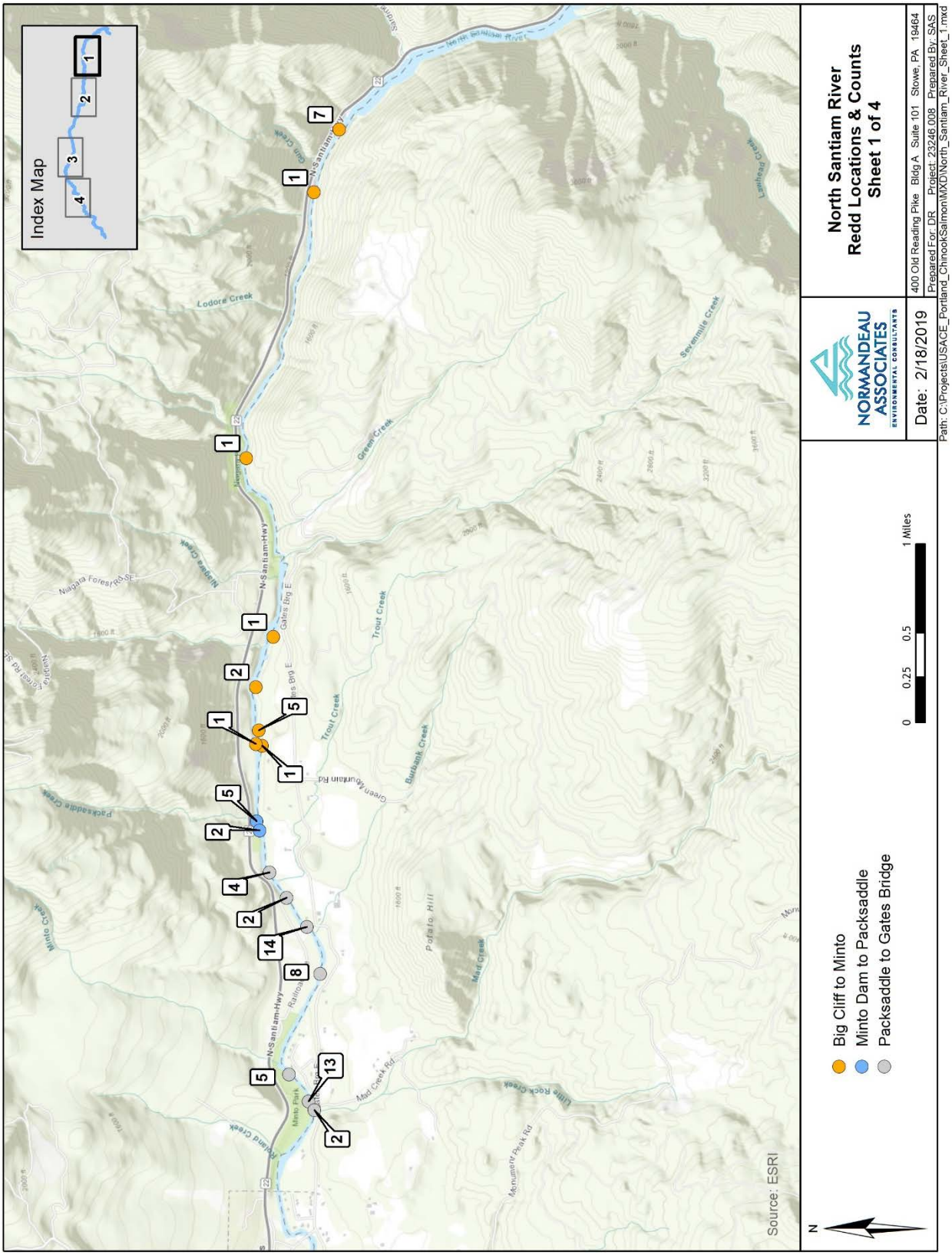
Prepared For: DR Project: 23246.008 Prepared By: SAS
Path: C:\Projects\USACE_Portland_ChinookSalmon\MXD\Lost_Creek.mxd
Cascade to Limberlost
Limberlost to Split Point
Split Point to 126
0 0.125 0.25 0.5 Miles
N
Source: ESRI
Belknap Springs
Old McKenzie Hwy
Lost Creek
Cupola
Camp Yale Rd
S Belknap Springs Rd
McKenzie Hwy
NF 220
NF 427


Horse Creek
Redd Locations & Counts
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 2/13/2019
400 Old Reading Pike Bldg A Suite 101 Stowe, PA 19464
Prepared For: DR Project: 23246.008 Prepared By: SAS
Path: C:\Projects\USACE_Portland_ChinookSalmon\MXD\HorseCreek.mxd
Avenue Creek to Horse Creek Bridge
Braids to Avenue Creek
Bridge to Mouth
Pothole to Trail Bridge
Road Access to Braids
Separation Creek to Road Access
0 0.5 1 2 Miles
N
Source:ESRI
Lost Creek
Spring Creek
Separation Creek
Roney Creek
Horse Creek
Halfinger Creek
Castle Creek
Avenue Creek
Pasture Creek
Horsepasture Mountain
O'Leary Mountain
Foley Ridge
Little Smokey
Camp Creek
Melada Creek
King Creek
Mclennan
Macduff Mountain
East Fork South Fork McKenzie River
Horse Creek Rd
King Rd
Taylor Rd
McKenzie Hwy
NF-2643
NF-455
NF-2660
NF-356
NF-1993
NF-1995
NF-590
242


Index Map
Big Cliff to Minto
Minto Dam to Packsaddle
Packsaddle to Gates Bridge
0 0.25 0.5 1 Miles
N
Source: ESRI
North Santiam River
Redd Locations & Counts
Sheet 1 of 4
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 2/18/2019
400 Old Reading Pike Bldg A Suite 101 Stowe, PA 19464
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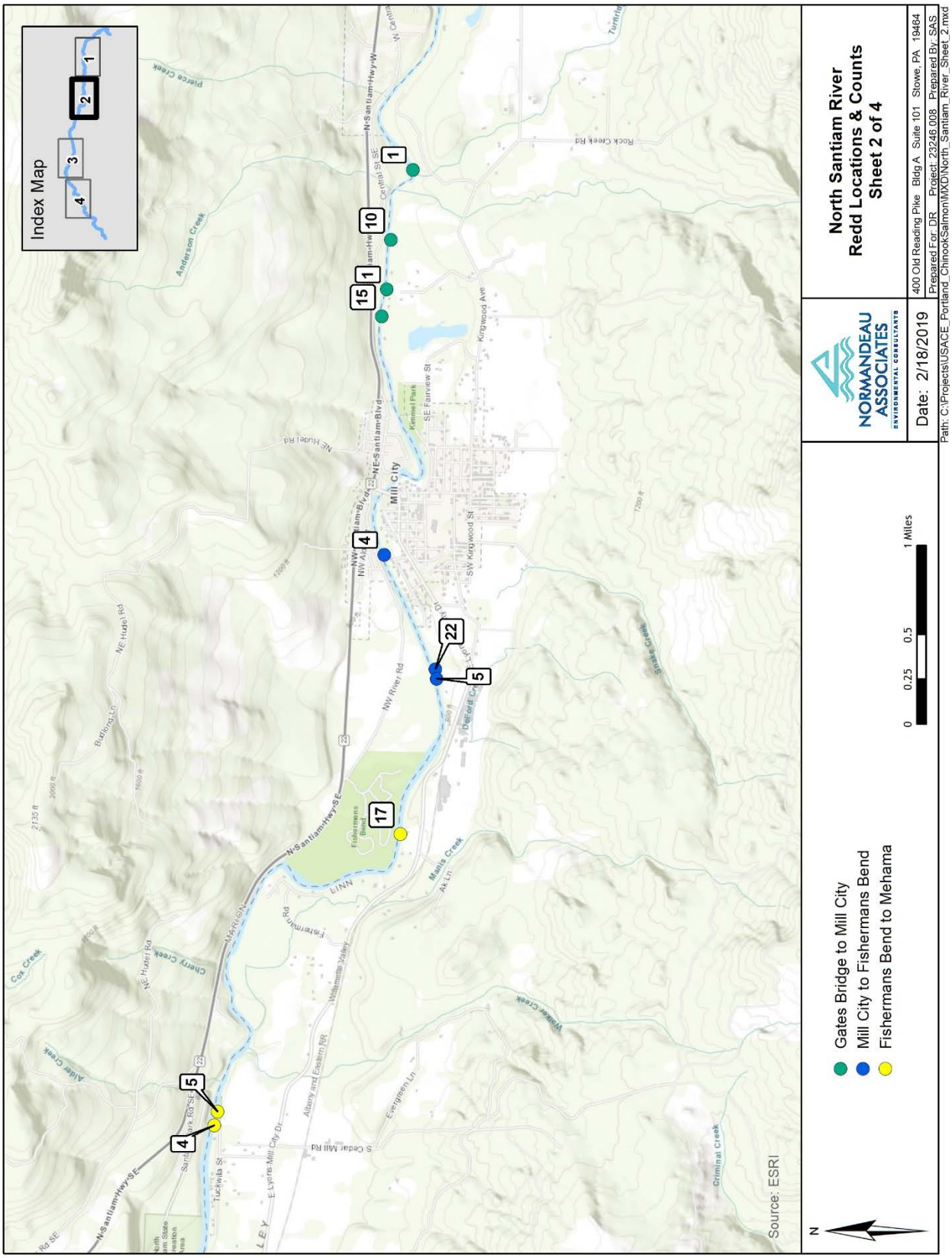
Index Map
1
2
3
4
Gates Bridge to Mill City
Mill City to Fishermans Bend
Fishermans Bend to Mehama
0
0.25
0.5
1 Miles
N
Source: ESRI
North Santiam River
Redd Locations & Counts
Sheet 2 of 4
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 2/18/2019
400 Old Reading Pike Bldg A Suite 101 Stowe, PA 19464
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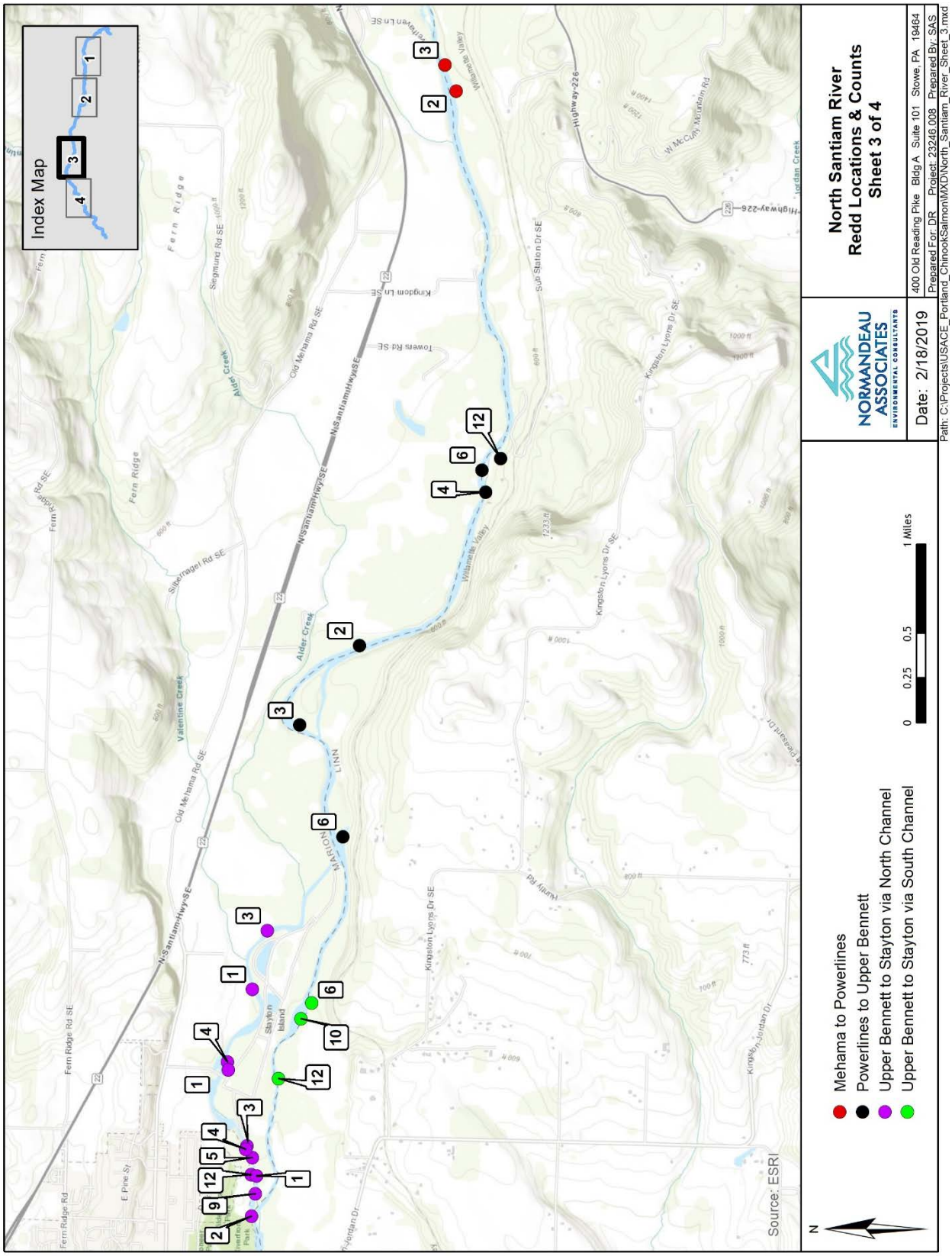
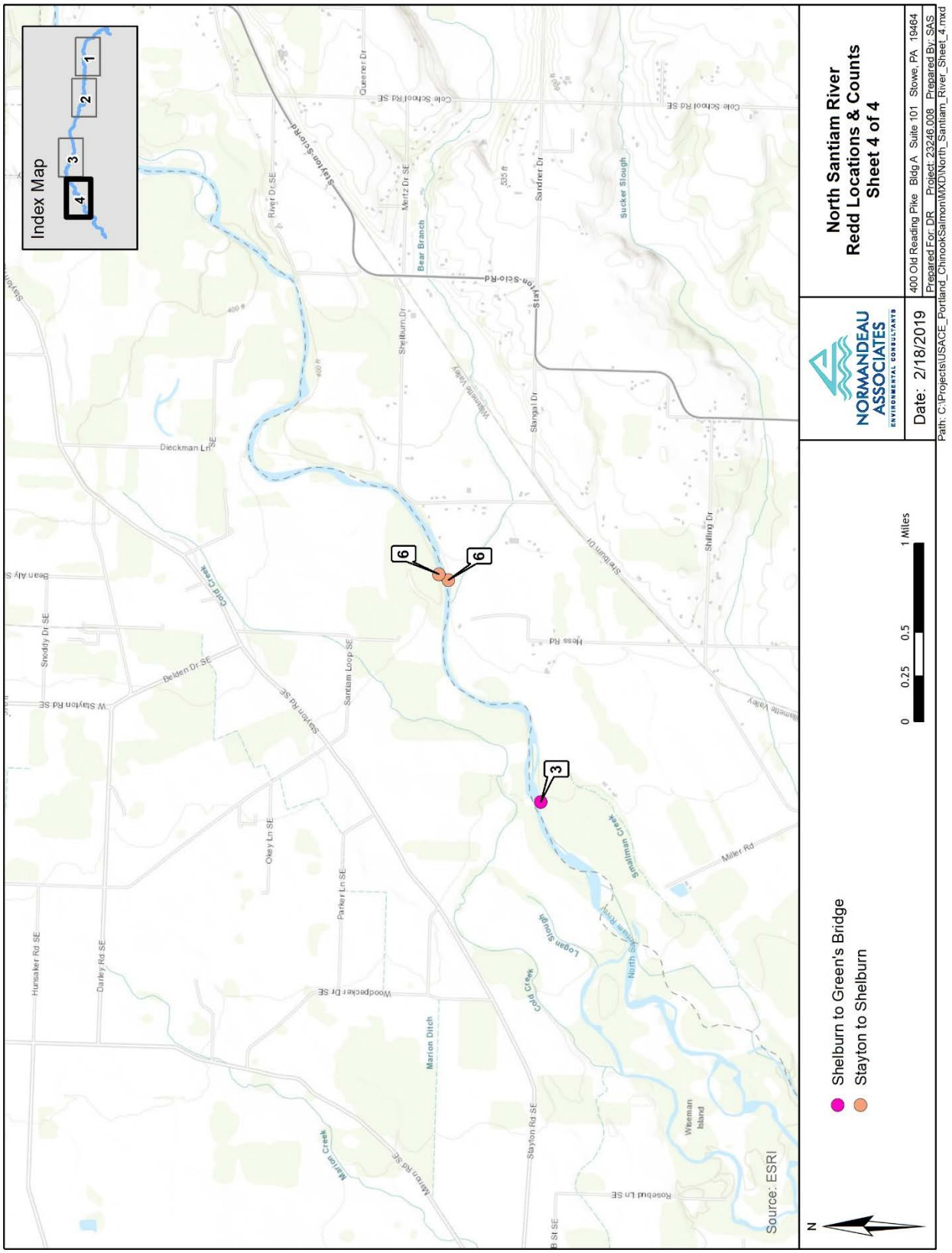

Index Map
North Santiam River
Redd Locations & Counts
Sheet 3 of 4
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 2/18/2019
400 Old Reading Pike Bldg A Suite 101 Stowe, PA 19464
Prepared For: DR Project: 23246.008 Prepared By: SAS
Path: C:\Projects\USACE_Portland_ChinookSalmon\MXD\North_Santiam_River_Sheet_3.mxd
Mehama to Powerlines
Powerlines to Upper Bennett
Upper Bennett to Stayton via North Channel
Upper Bennett to Stayton via South Channel
0 0.25 0.5 1 Miles
N
Source: ESRI
N Santiam Hwy SE
Fern Ridge Rd SE
Old Mehama Rd SE
Alder Creek
Valentine Creek
Kingston Lyons Dr SE
Highway 226
Stayton Island
LINN
MARION


Index Map
1
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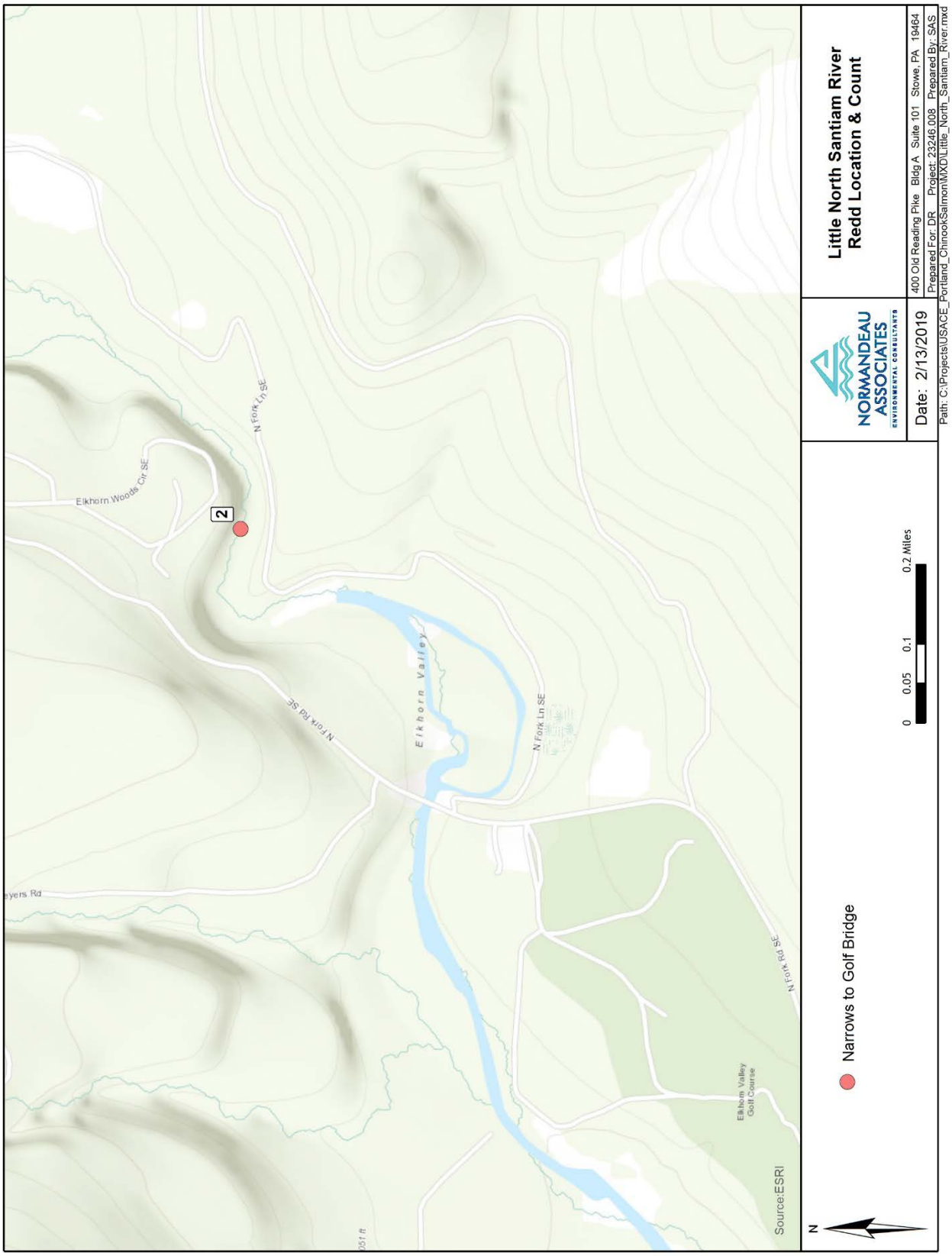
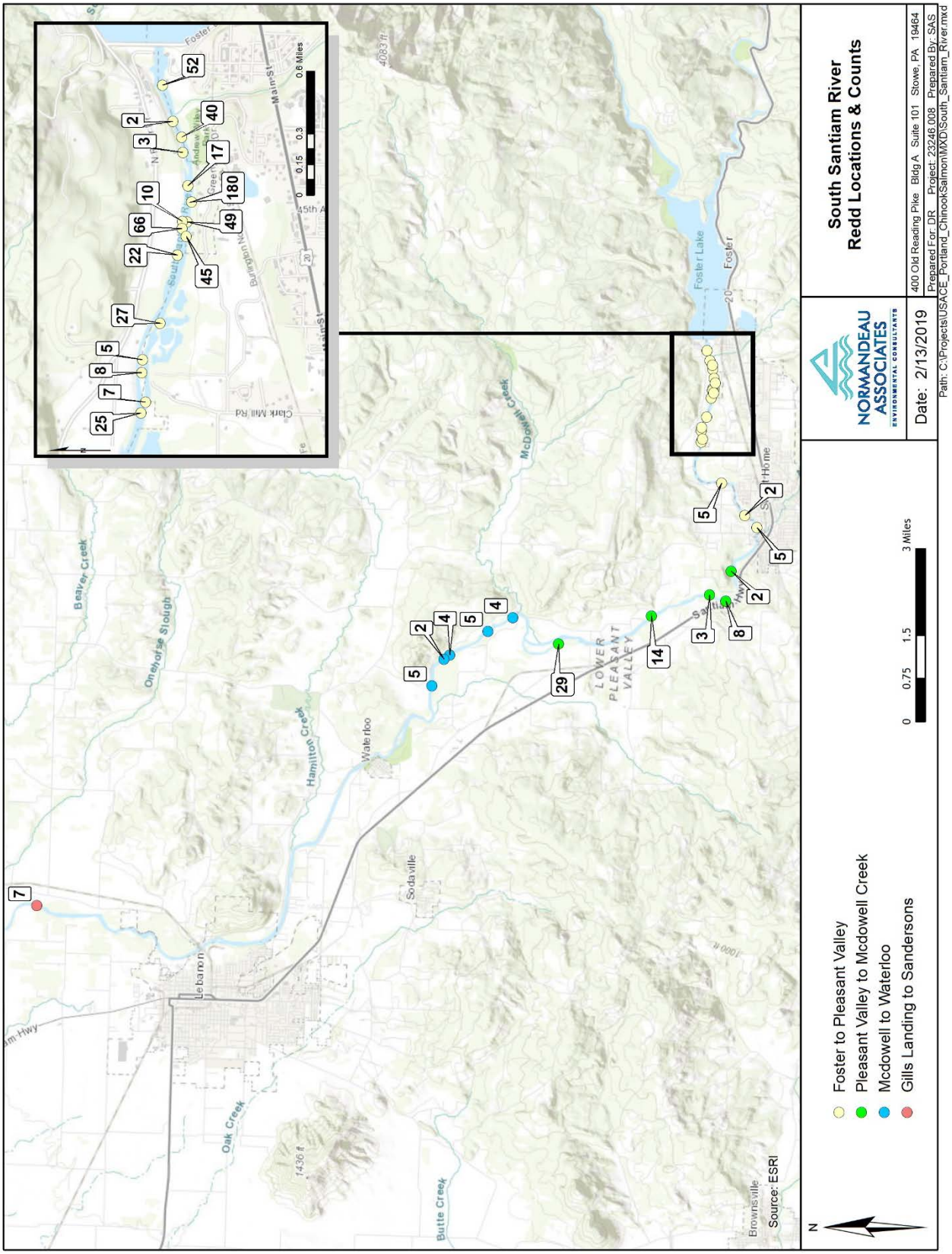
4
North Santiam River
Redd Locations & Counts
Sheet 4 of 4
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 2/18/2019
400 Old Reading Pike Bldg A Suite 101 Stowe, PA 19464
Prepared For: DR Project: 23246.008 Prepared By: SAS
Path: C:\Projects\USACE_Portland_ChinookSalmon\MXD\North_Santiam_River_Sheet_4.mxd
Shelburn to Green's Bridge
Stayton to Shelburn
0 0.25 0.5 1 Miles
N
Source: ESRI
6
6
3
Cole School Rd SE
Queener Dr
Stayton-Scio-Rd
River Dr SE
Mertz Dr SE
Bear Branch
Sandner Dr
Sucker Slough
Shelburn Dr
Wilamette Valley
Stangel Dr
Dieckman Ln SE
Shelburn Ct
Shilling Dr
Bean Aly S
Sneddy Dr SE
Belden Dr SE
W Stayton Rd SE
Santiam Loop SE
Hess Rd
Cobb Creek
Okey Ln SE
Parker Ln SE
Hunsaker Rd SE
Darley Rd SE
Woodpecker Dr SE
Marion Ditch
Stayton Rd SE
Marion Rd SE
Rosebud Ln SE
B St SE
Shelburn Creek
Miller Rd
Logan Slough
North Santiam River
Cox Creek
Weeman Island


Little North Santiam River
Redd Location & Count
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
400 Old Reading Pike Bldg A Suite 101 Stowe, PA 19464
Date: 2/13/2019
Prepared For: DR Project: 23246.008 Prepared By: SAS
Path: C:\Projects\USACE_Portland_ChinookSalmon\MXD\Little_North_Santiam_River.mxd
Narrows to Golf Bridge
0 0.05 0.1 0.2 Miles
N
2
Elkhorn Woods Cir SE
N Fork Ln SE
N Fork Rd SE
Elkhorn Valley
Elkhorn Valley Golf Course
Source:ESRI


South Santiam River
Redd Locations & Counts
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 2/13/2019
400 Old Reading Pike Bldg A Suite 101 Stowe, PA 19464
Prepared For: DR Project: 23246.008 Prepared By: SAS
Path: C:\Projects\USACE_Portland_ChinookSalmon\MXD\South_Santiam_River.mxd
Foster to Pleasant Valley
Pleasant Valley to Mcdowell Creek
Mcdowell to Waterloo
Gills Landing to Sandersons
Source: ESRI
N
0 0.75 1.5 3 Miles
Foster
Foster Lake
Sweet Home
LOWER PLEASANT VALLEY
McDowell Creek
Waterloo
Hamilton Creek
Beaver Creek
Oneholse Slough
Sodaville
Lebanon
Oak Creek
Butte Creek
Brownsville
Clark Mill Rd
Main St
0 0.15 0.3 0.6 Miles