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Hanford Site Steelhead Redd Monitoring Report for Calendar Year 2015



Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-09RL14728



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Mission Support Alliance

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1.0 Introduction

The U.S. Department of Energy, Richland Operations Office (DOE-RL) conducts ecological monitoring on the Hanford Site to collect and track data needed to ensure compliance with an array of environmental laws, regulations, and policies governing DOE activities. Ecological monitoring data provide baseline information about the plants, animals, and habitats under DOE-RL stewardship at Hanford required for decision-making under the *National Environmental Policy Act* (NEPA) and *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA). The *Hanford Site Comprehensive Land Use Plan* (CLUP, [USDOE 1999](#)), which is the Environmental Impact Statement that evaluates the potential environmental impacts associated with implementing a comprehensive land-use plan for the Hanford Site for at least the next 50 years, helps ensure that DOE-RL, its contractors, and other entities conducting activities on the Hanford Site are in compliance with NEPA.

The *Hanford Site Biological Resources Management Plan* (BRMP, [USDOE 2013](#)) is identified by the CLUP as the primary implementation control for managing and protecting natural resources on the Hanford Site. According to the CLUP, the BRMP

“provides a mechanism for ensuring compliance with laws protecting biological resources; provides a framework for ensuring that appropriate biological resource goals, objectives, and tools are in place to make DOE an effective steward of the Hanford biological resources; and implements an ecosystem management approach for biological resources on the Site. The BRMP provides a comprehensive direction that specifies DOE biological resource policies, goals, and objectives.”

DOE-RL places priority on monitoring those plant and animal species or habitats with specific regulatory protections or requirements, that are rare and/or declining (federal or state listed endangered, threatened, or sensitive species), or are of significant interest to federal, state, or tribal governments or the public. The BRMP ranks wildlife species and habitats (Levels 0-5), providing a graded approach to monitoring biological resources based on the level of concern for each resource. Steelhead (*Oncorhynchus mykiss*) and their critical habitat are ranked as Level 5 resources, the highest ranking level in BRMP. According to BRMP, *“resources classified as Level 5 are the rarest and most sensitive habitats and species and are considered irreplaceable or at risk of extirpation or extinction.”* The management goal of Level 5 resources is preservation, and these resources require a high level of status monitoring. While the BRMP provides overall biological resource management policies, objectives, and goals, the *Threatened and Endangered Species Management Plan: Salmon, Steelhead, and Bull Trout* ([USDOE 2015a](#)) provides specific management activities for stocks of Upper Columbia River steelhead found within the Hanford Reach of the Columbia River.

1.1 Objectives for Current Steelhead Monitoring

Aerial and follow-up boat surveys for steelhead redds are conducted in Hanford Reach in the spring of each year to identify potential spawning areas and timing as well as to provide an annual index of relative

abundance among spawning areas. These surveys serve to document any change in the status of steelhead spawning in the Hanford Reach and are used to help plan project activities to avoid redds, if any are identified.

1.2 Regulatory Drivers

A prized recreational fishery exists for steelhead throughout the Pacific Northwest, and steelhead constitutes a primary component of tribal fisheries in the Columbia Basin. Steelhead use the Hanford Reach for rearing as juveniles, as a migratory corridor as both juveniles and adults, and for spawning as adults. Upper Columbia River summer-run steelhead use the Hanford Reach and are currently listed as threatened under the [Endangered Species Act of 1973](#) (ESA). Because of their ESA listing status and importance to recreational and tribal fisheries, steelhead are monitored by the Mission Support Alliance (MSA) Public Safety and Resource Protection Program (PSRP).

On August 18, 1997, Upper Columbia River summer-run steelhead were listed as endangered under the ESA, with an effective date of October 17, 1997 ([62 FR 43937](#)). This status was upgraded to threatened on January 5, 2006; reinstated to endangered status per U.S. District Court decision in June 2007; and upgraded to threatened again per U.S. District Court order in June 2009. National Oceanic and Atmospheric Administration (NOAA) Fisheries issued results of a five-year review on August 15, 2011, and concluded that this species should remain listed as threatened ([76 FR 50447](#)). Steelhead covered under this listing include all naturally-spawned anadromous steelhead populations and their progeny below natural and man-made impassable barriers in streams in the Columbia River Basin upstream from the Yakima River, Washington, to the United States-Canada border. Also covered are artificial propagation programs: the Wenatchee River, Wells Hatchery (in the Methow and Okanogan Rivers), Winthrop National Fish Hatchery, Omak Creek, and the Ringold steelhead hatchery programs. Critical habitat for this Evolutionarily Significant Unit (ESU) within the Hanford Site includes the entire Hanford Reach ([65 FR 7764](#); [70 FR 52630](#)).

1.3 Steelhead Biology

Steelhead are the anadromous (sea-run) form of the rainbow trout. Steelhead migrate from their natal streams to the ocean as juveniles and return to their natal streams as mature adults to spawn. They can survive spawning (iteroparity), whereas all pacific salmon die after spawning (semelparity). Although steelhead can survive spawning to spawn a second time, the repeat spawning rate in the state of Washington is low (4 to 15 percent [Wydoski and Whitney 1979]). In addition, adults encounter four mainstem Columbia River dams on their way to and from the Hanford Reach; therefore, repeat spawning in the Hanford Reach by a significant number of steelhead is unlikely.

Steelhead build nests, termed “redds”, in gravel or cobble substrate and spawn in the spring; the steelhead fry emerge from the gravel later that same spring. A typical steelhead red covers approximately 4.4 to 5.4 m² (47.4 to 58.1 ft²) ([Bjornn and Reiser 1991](#)). Adult steelhead generally utilize smaller tributary habitat and substrate than Chinook salmon, but will spawn in larger mainstem rivers, such as the Columbia, where suitable habitat exists. In Idaho’s Clearwater and Salmon Rivers, the preferred gravel

size for nesting was 1.3 to 10.2 cm (0.5 to 4 in), water depth 0.2 to 1.5 m (0.75 to 5 ft), and water velocity 0.70 to 0.76 m/s (2.3 to 2.5 ft/s); these habitat conditions are available within the Hanford Reach (Orcutt 1968). In 2007, steelhead spawning habitat suitability surveys were conducted at multiple sites contained within three key contaminant plumes resulting from Hanford Site operations (Stables and Tiller 2007). Habitat suitability was assessed based upon depth, velocity, substrate size, and substrate embeddedness. Eleven of the 72 sites surveyed were found to be entirely suitable to support steelhead spawning at the flows present during the time of the surveys.

1.4 Steelhead Occurrence in the Hanford Reach of the Columbia River

Steelhead occur in the Hanford Reach all year; however, most adults move into the Hanford Reach from August to November, peaking in September (Watson 1973; [Becker 1985](#)). Most steelhead that enter the Hanford Reach hold in the immediate vicinity for 6 to 8 months. A limited tagging study in 1967 found adults migrated near shorelines at depths less than 3 m (10 ft) (Coutant 1973).

Spawning within the Hanford Reach occurs between February and early June, with peak spawning in mid-May (Eldred 1970; Watson 1973; [Becker 1985](#)). Little is known about the quality and quantity of steelhead spawning, rearing, and adult holding habitat in the Hanford Reach. Watson (1973) estimated that from 1962 to 1971, an annual average of 35,000 steelhead that passed McNary Dam did not pass Priest Rapids Dam on the Columbia River or Ice Harbor Dam on the Snake River ([USDOE 2015a](#)). After taking into account reductions due to migration into the Yakima and Walla Walla Rivers, sport catch, and natural mortality, he estimated that 10,000 of these fish were potential spawners in the Hanford Reach. Counts from 1977 to 1996 indicated an average of 20,000 steelhead that annually passed McNary Dam did not pass Priest Rapids or Ice Harbor dams, and approximately 9,000 of these could potentially spawn in the Hanford Reach ([USDOE 2015a](#)).

Gray and Dauble (1976) provide other evidence of steelhead spawning ([USDOE 2015a](#)). They collected gravid and ripe females in late April and early May and collected spent males in August within the Hanford Reach. However, information on the quantity and location of steelhead spawning is difficult to assess because aerial surveys of steelhead spawning are often hampered by highly turbid spring runoff that obscures visibility. Prior to 2015, historical information on steelhead spawning primarily existed from the late 1960s and early 1970s during unusually low flow conditions. Low flow conditions at that time were 1104 to 2209 m³/s [39 to 78 thousand cubic feet per second (kcfs)] when normal average flow is approximately 3398 m³/s (120 kcfs). Key spawning areas reported from aerial surveys conducted in 1968 and 1970 included Vernita Bar, Coyote Rapids, Locke Island, 100-F islands, and Ringold (Tony Eldred, personal communication with D. R. Geist PNNL 9-28-89). A total of 220 redds were counted in 1968 and 95 in 1970; total steelhead spawning was estimated by Eldred (1970) to be approximately 2,200 to 25,000 in 1968 and 950 to 7,800 in 1970. Fickeisen et al. (1980) indicated steelhead likely spawned at Vernita Bar, Coyote Rapids, Locke Island, and Ringold. An aerial survey conducted on April 30, 1998, identified up to 75 redds in the Hanford Reach, with the area from Wooded Island to Ringold having 14 redds and the 100-F Area islands having 61 (Dauble 1998; [USDOE 2015a](#)).

Until 2015, few recent steelhead spawning events were documented in the Hanford Reach. A comprehensive study was conducted in spring 1999 to survey likely spawning areas near Locke Island, but no steelhead redds were found ([Mueller and Geist 1999](#)). In the spring of 2005, the 100-N Area shoreline was investigated by aerial and boat surveys to search for spawning areas ([Poston 2010](#)). Results of these surveys showed only limited spawning near the Ringold Hatchery Creek (near United States Geological Survey (USGS) River Mile 355) in certain years. One verified steelhead redd was found near the 300 Area in spring 2003, and surveys in the spring of 2005 identified a single location where steelhead redds occurred downstream of Ringold at Island 15 ([Poston 2010](#)). Aerial steelhead redd counts were conducted during years 2007 through 2009, but only a single redd was observed in 2008, which was located near the upper portion of Locke Island. Aerial surveys conducted during 2012 along the entire length of the Hanford Reach detected no steelhead redds ([Wagner et al. 2012](#)). Four steelhead redds were located near the tip of Homestead Island (Island 13) during aerial surveys in 2013 ([Wagner et al. 2014](#)). No steelhead redds were observed during aerial surveys in 2014 ([USDOE 2015b](#)). Forty-three steelhead redds were recorded this year (2015) marking the first time in seventeen years that a sizeable number of steelhead redds were observed in the Hanford Reach.

2.0 Methods

2.1 Aerial Surveys

Aerial surveys of steelhead redds were conducted in 11 areas of the Hanford Reach (Figure 1), with the number of redds being totaled by section, consistent with past survey efforts and the historical data set. Eight sub-sections (100-B/C, 100-K, 100-N, 100-D, 100-H, 100-F, Dunes, and 300 Areas) were added in 2012 to better monitor the abundance and distribution of steelhead redds in areas of the Columbia River adjacent to contaminated groundwater plumes of the Hanford Site ([USDOE 2011](#)) (Figure 2). These eight new sub-sections do not affect direct comparisons to historical records in the original areas.

Survey flight altitudes ranged from approximately 244 to 366 m (800 to 1200 ft) with air speeds of 120 to 161 km (75 to 100 miles) per hour. Redds, when observed, were counted individually. Flight cancellation could occasionally be necessary due to either adverse weather conditions (i.e., wind, fog, or low clouds) or excessively high river flows. Excessively high flows resulting from spring run-off can flood areas typically characterized by terrestrial vegetation and lacking steelhead spawning habitat, and leave previously usable habitat with flows too swift for spawning and too deep to be observed from the air. Sustained flows in excess of 4531 m³/s (160 kcfs) were considered too high to survey.

Redd count surveys began near Richland at Nelson Island and ended at Priest Rapids Dam. Flights were normally conducted near noon with the intent to bracket the highest angle of the sun for optimum viewing conditions. Observers wore polarized glasses as necessary to reduce glare. Any redds observed were documented by survey area on large format printed maps.

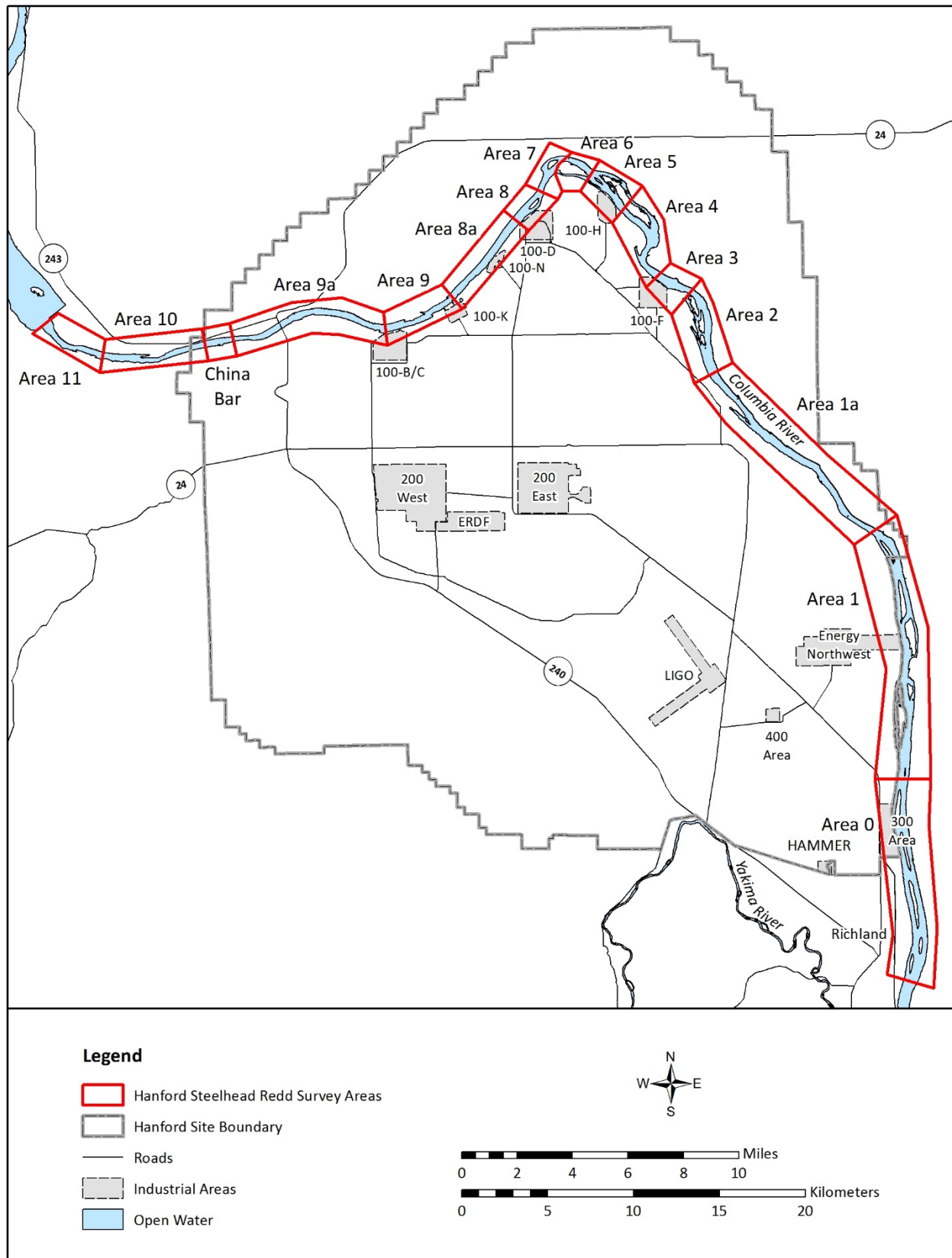


Figure 1. Aerial Survey Areas for Steelhead Redds Used Historically and in 2015

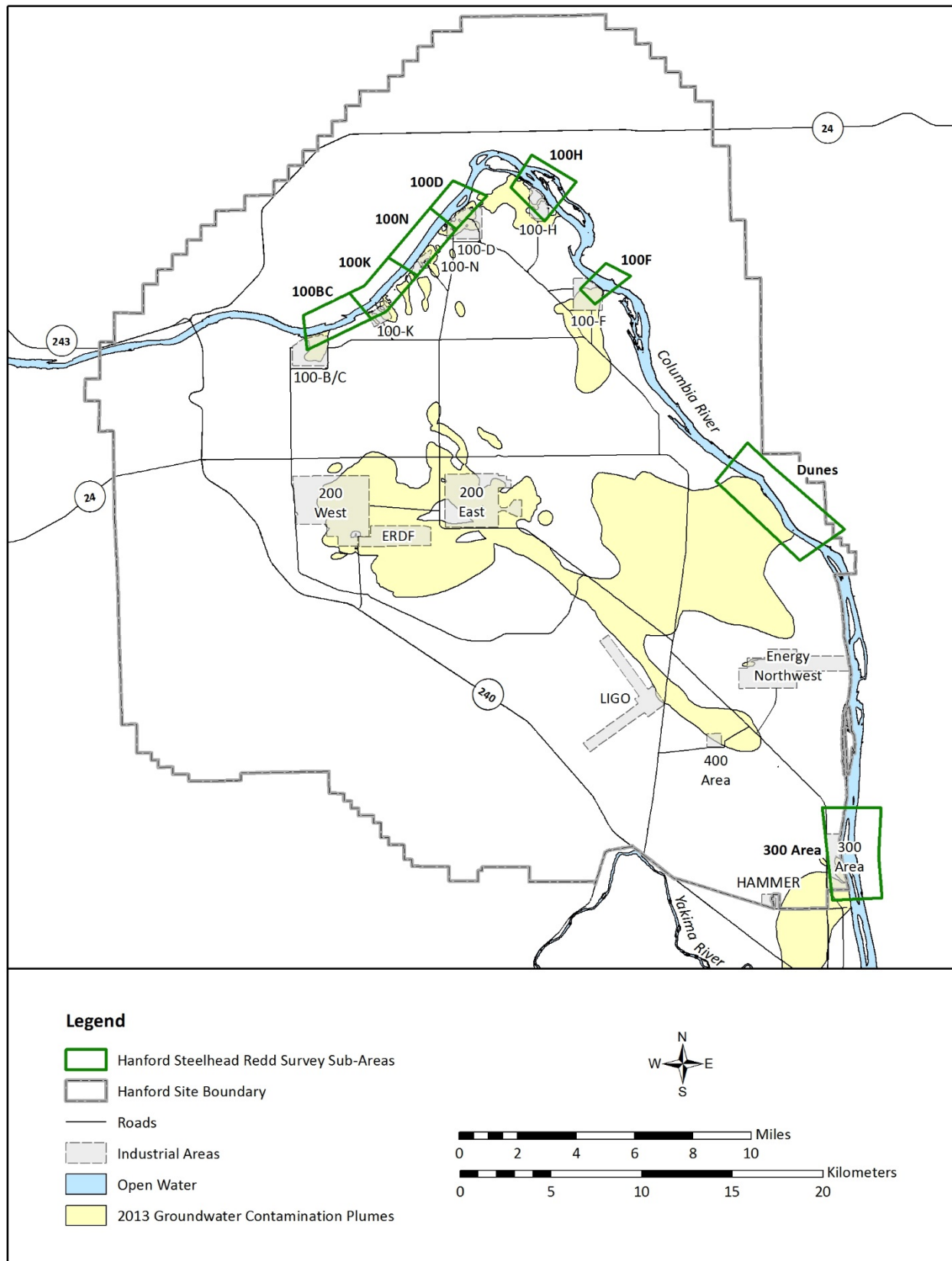


Figure 2. Survey Sub-areas where Groundwater Upwelling May Contain Contamination from the Hanford Site

The primary physical factors influencing the accuracy of aerial counts includes depth of water over redds and water clarity. Wind action, available light, orientation of the river, and direction of the current can also affect visibility. Because it is seldom possible to view all redds from the air, these counts provide an index of relative abundance and distribution of steelhead spawning in the Hanford Reach.

2.2 Boat Survey

After the first aerial survey in which redds were observed, a follow-up boat survey was conducted to verify redds seen from the air. The areas seen from the air were examined for evidence of spawning (clean swept gravel), the presence of live steelhead, and if general environmental conditions (depth of water, water velocities, substrate size and embeddedness) were suitable for spawning.

3.0 Results

Three steelhead aerial redd count surveys were completed along the length of the Hanford Reach during the 2015 spawning season. The first survey was performed on April 7, the second survey on May 6, and the third survey on May 21. River flows during the 2015 steelhead spawning season were higher than the 50-year average for the first half of the season (February 15 through April 15), but were much lower for the second half of the season (April 16 through June 15) (Figure 3).

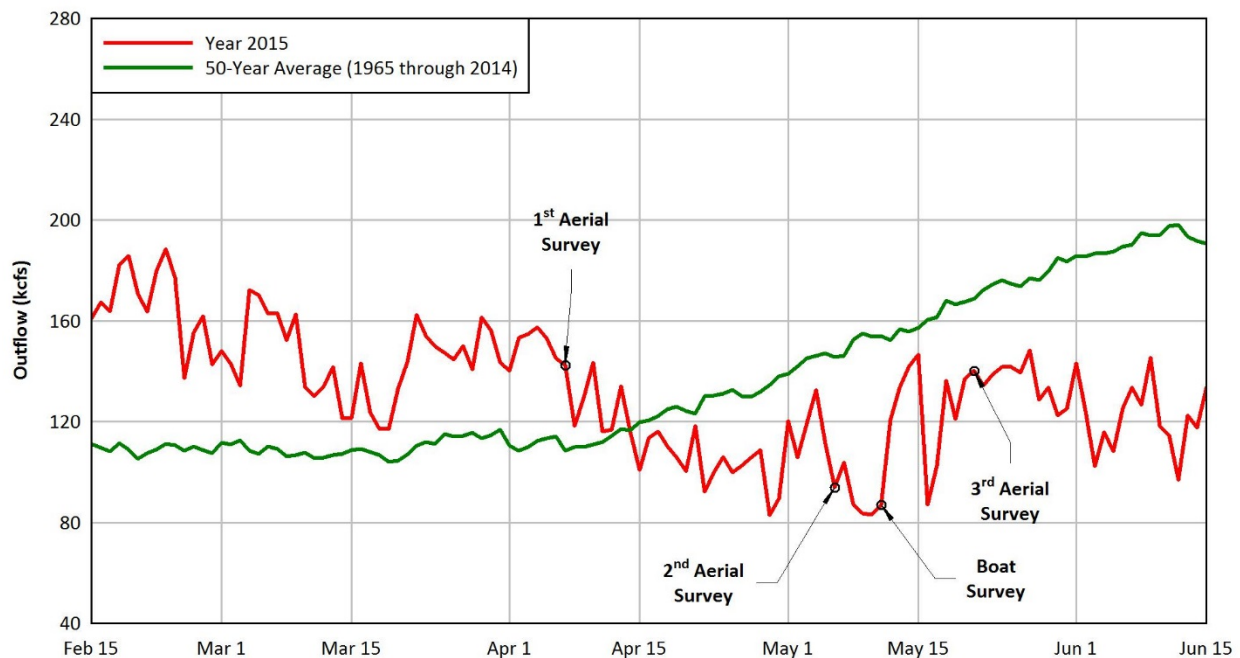


Figure 3. Daily Average Priest Rapids Dam Outflow February 15, 2015 through June 15, 2015 Compared to 50-Year Average

The first steelhead aerial redd count survey was conducted on April 7. Weather was partly cloudy with light and variable winds. Viewing conditions were good. Volumetric flow rates in the Hanford Reach during the survey, reflected by discharge from Priest Rapids Dam for the eight hours prior to the survey, ranged from 3370 to 4134 m³/s (119 to 146 kcfs). No steelhead redds were observed during the April 7 Flight.

The second steelhead aerial redd count survey was performed on May 6. Weather was sunny with some clouds and light winds. Viewing conditions were very good. Discharge from Priest Rapids Dam for the eight hours prior to the survey ranged from 2265 to 2549 m³/s (80 to 90 kcfs). A total of 28 steelhead redds were observed during the May 6 Flight (Table 1). None of these redds were located in areas adjacent to Hanford Site operations (Table 2).

A boat survey was conducted on May 11 to validate the aerial observations. Discharge from Priest Rapids Dam during the boat survey ranged from 2237 to 2379 m³/s (79 to 84 kcfs). Although measurements were not taken, environmental conditions (depth of water, water velocities, substrate size and embeddedness) at the three major areas where steelhead redds were observed during the May 6 aerial survey (downstream end of Locke Island, downstream end of 100-F Islands, and upstream end of Homestead Island) appeared suitable for steelhead spawning. Two steelhead were observed at the Locke Island location and one steelhead was observed at the 100-F Islands location. Several redds at the Homestead Island location were located by boat and verified as recently established steelhead redds.

The third steelhead aerial redd count survey was conducted on May 21. Weather was sunny with high clouds and light winds. Viewing conditions were moderate. Discharge from Priest Rapids Dam for the eight hours prior to the survey ranged from 3511 to 4191 m³/s (124 to 148 kcfs). A total of 35 steelhead redds were observed during the May 21 Flight (Table 1). Six redds were located in areas adjacent to Hanford Site operations (Table 2).

Table 1 describes the counts performed by survey area for each flight. The maximum count describes the highest number of redds documented in a survey area within a single flight. Table 2 shows the number of redds occurring within the newly defined sub-sections, coinciding with areas of potential upwelling of contaminated groundwater. The number and the approximate location of all steelhead redds observed during the 2015 spawning season are shown in Figure 4.

Table 1. Summary of Steelhead Redd Counts by Areas for the 2015 Aerial Surveys in the Hanford Reach of the Columbia River

Area	Description				Maximum
		4/7/2015	5/6/2015	5/21/2015	Count
0	Islands 17-21 (Richland)	0	0	0	0
1	Islands 11-16	0	15	7	15
1a	Savage Island/Hanford Slough	0	0	0	0
2	Islands 8-10	0	6	6	6
3	Near Island 7	0	0	0	0
4	Island 6 (lower half)	0	7	16	16
5	Island 4, 5 and upper 6	0	0	6	6
6	Near Island 3	0	0	0	0
7	Near Island 2	0	0	0	0
8	Near Island 1	0	0	0	0
8a	Upstream of Island 1 to Coyote Rapids	0	0	0	0
9	Near Coyote Rapids	0	0	0	0
9a	Upstream of Coyote Rapids to China Bar	0	0	0	0
China Bar	China Bar/Midway	0	0	0	0
10	Near Vernita Bar	0	0	0	0
11	Upstream of Vernita Bar to Priest Rapids Dam	0	0	0	0
Total		0	28	35	43

Table 2. Summary of Steelhead Redd Counts by Sub-areas adjacent to Hanford Site Operations for the 2015 Aerial Surveys in the Hanford Reach of the Columbia River

Sub-area				Maximum
	4/7/2015	5/6/2015	5/21/2015	Count
300 Area	0	0	0	0
Dunes	0	0	0	0
100F	0	0	0	0
100H	0	0	6	6
100D	0	0	0	0
100N	0	0	0	0
100K	0	0	0	0
100BC	0	0	0	0
Total	0	0	6	6

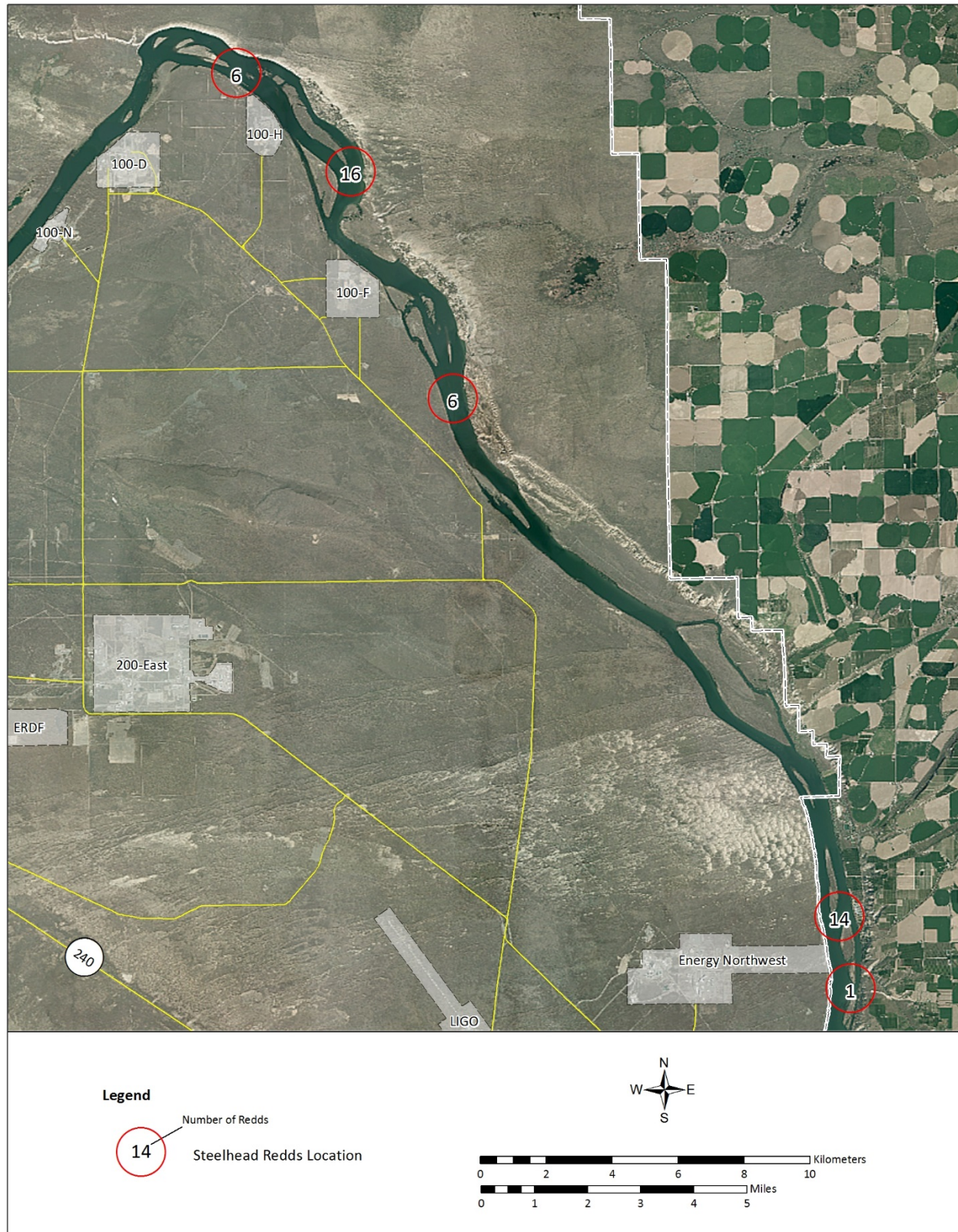


Figure 4. The Number and the Approximate Location of All Steelhead Redds Observed in the Hanford Reach of the Columbia River during the 2015 Spawning Season

4.0 Discussion

The maximum count of 43 steelhead redds in 2015 were the most redds recorded in the Hanford Reach of the Columbia River since 1998 when 75 redds were documented (Dauble 1998, [USDOE 2015a](#)). Steelhead redds observed in 2015 were first detected in early May. Lower than normal flows in late April and early May were likely the reason for the increase in steelhead redds detected. It is unclear whether the higher number of redds detected was due to increased spawning in the reach or to better conditions for observation during 2015. Past records of elevated numbers of steelhead redds in the Hanford Reach also coincided with low flow periods during the spawning season (Table 3). It is assumed, although it has not been quantified, that more high-quality spawning habitat occurs at lower flow levels.

Table 3. River Flows in the Hanford Reach of the Columbia River during Years with Elevated Numbers of Steelhead Redds

Year	Number of Redds	Outflow (kcfs)							
		Late February	Early March	Late March	Early April	Late April	Early May	Late May	Early June
1968	220	60.1	108.6	109.4	95.4	105.2	94.4	157.6	253.6
1970	95	80.0	81.7	88.5	91.7	91.8	78.8	177.2	196.7
1998	75	144.2	116.8	121.0	72.2	96.1	176.6	166.3	194.5
2015	43	161.2	142.5	139.0	132.3	104.0	113.6	134.9	127.1
Average (1965 to 2014)	-	108.9	108.3	111.0	112.5	128.6	149.8	172.8	191.0

5.0 Conclusion

River flows in the Hanford Reach during the steelhead spawning season (February through early June) normally begin to slowly rise in March with greater increases in May and June. In years where higher steelhead redds numbers were observed in the Hanford Reach, lower flows [$<3398 \text{ m}^3/\text{s}$ (120 kcfs)] were recorded in April and early May (Figure 5). Managing steady flows below $3398 \text{ m}^3/\text{s}$ (120 kcfs) in April and early May could be an approach for increasing steelhead spawning in the Hanford Reach.

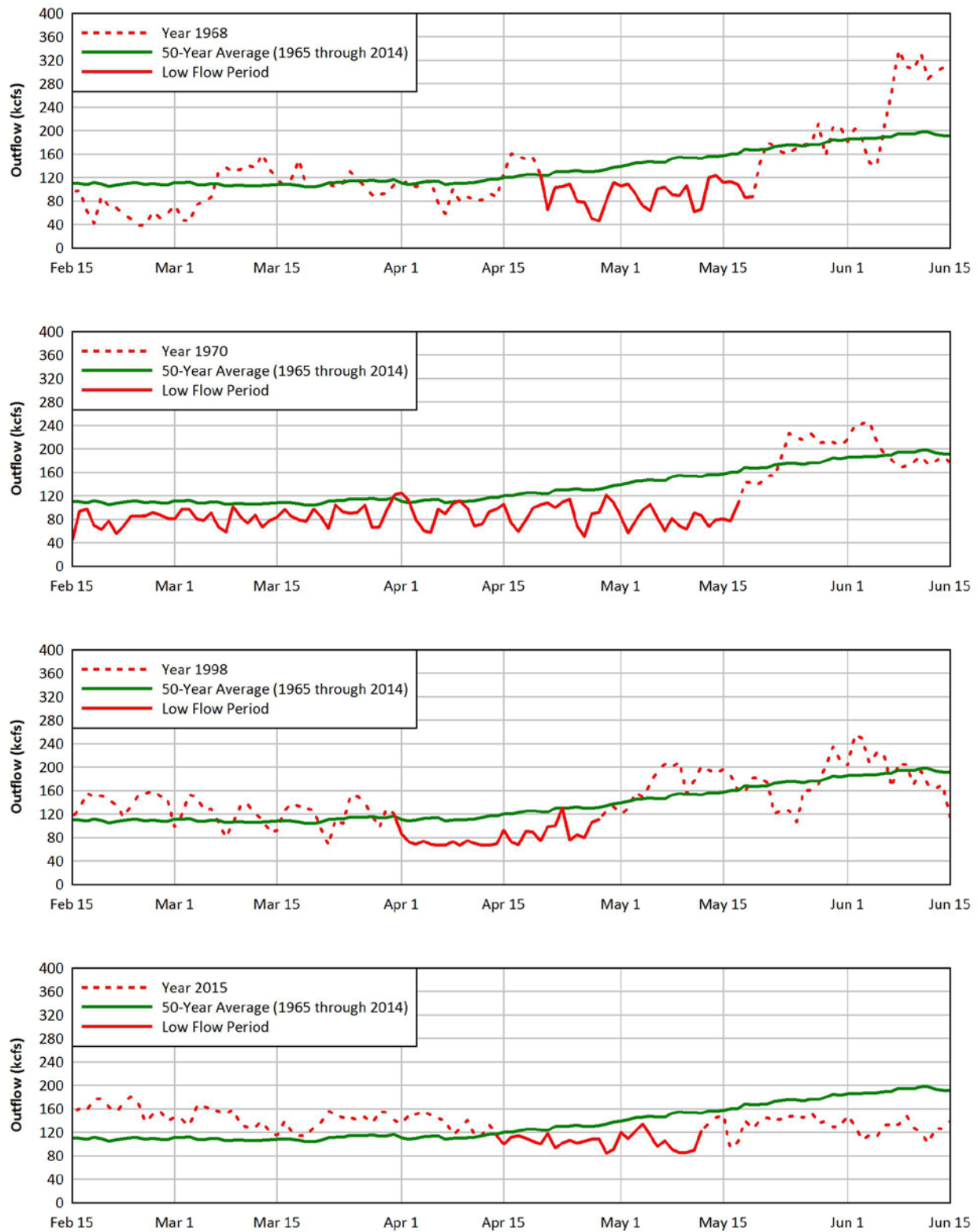


Figure 5. River Flows in the Hanford Reach of the Columbia River during Years when Elevated Numbers of Steelhead Redds were Observed

6.0 References

- 62 FR 43937. National Marine Fisheries Service. "Endangered and Threatened Species: Listing of Several Evolutionarily Significant Units of West Coast Steelhead." August 18, 1997. *Federal Register*. Online at: <http://www.westcoast.fisheries.noaa.gov/publications/frn/1997/62fr43937.pdf>.
- 65 FR 7764. National Marine Fisheries Service. "Designated Critical Habitat: Critical Habitat for 19 Evolutionarily Significant Units of Salmon and Steelhead in Washington, Oregon, Idaho, and California." Final Rule. February 16, 2000. *Federal Register*. Online at: <http://www.westcoast.fisheries.noaa.gov/publications/frn/2000/65fr7764.pdf>.
- 70 FR 52630. National Marine Fisheries Service. "Endangered and Threatened Species; Designation of Critical Habitat for 12 Evolutionarily Significant Units of West Coast Salmon and Steelhead in Washington, Oregon, and Idaho." September 2, 2005. *Federal Register*. Online at: <http://www.westcoast.fisheries.noaa.gov/publications/frn/2005/70fr52630pre.pdf>.
- 76 FR 50447. National Marine Fisheries Service. "Endangered and Threatened Species; 5-Year Reviews for 5 Evolutionarily Significant Units of Pacific Salmon and 1 Distinct Population Segment of Steelhead In California." Notice of availability of 5-year reviews. August 15, 2011. *Federal Register*. Online at: <http://www.westcoast.fisheries.noaa.gov/publications/frn/2011/76fr50447.pdf>.
- Becker, C. D. 1985. *Anadromous Salmonids of the Hanford Reach, Columbia River: 1984 Status*. PNL-5371, Pacific Northwest Laboratory, Richland, Washington. Online at: http://www.osti.gov/energycitations/product.biblio.jsp?query_id=5&page=0&osti_id=5222130.
- Bjornn, T. C., and D. W. Reiser. 1991. *Habitat requirements of salmonids in streams*. In: W. R. Meehan (Ed.), *Influences of forest and rangeland management on salmonid fishes and their habitats*. American Fisheries Society Special Publication 19: 83-138. Online at: https://www.for.gov.bc.ca/hfd/library/ffip/Bjornn_TC1991.pdf.
- Comprehensive Environmental Response, Compensation, and Liability Act of 1980*. 42 U.S.C. 9601-9675 (P.L. 96-510).
- Coutant, C. C. 1973. *Behavior of Ultrasonic Tagged Chinook Salmon and Steelhead Trout Migrating Past Hanford Thermal Discharges (1967)*. BNWL-1530, UC-48, Battelle Pacific Northwest Laboratories, Richland, Washington.
- Dauble, D. D. 1998. Letter Report to Keith Wolf, Washington Department of Fish and Wildlife, October 22, 1998.
- Eldred, D. 1970. Steelhead Spawning in the Columbia River, Ringold to Priest Rapids Dam, September 1970 Progress Report. Washington Department of Game, Ephrata, Washington. 4 pp.
- Endangered Species Act of 1973*. 16 U.S.C. 1531-1544 (P.L. 93-205).
- Fickeisen, D. H., D. D. Dauble, D. A. Neitzel, W. H. Rickard, R. L. Skaggs, and J. L. Warren. 1980. *Aquatic and Riparian Resource Study of the Hanford Reach, Columbia River, Washington*. Battelle Pacific Northwest Laboratories, Richland, Washington.

- Gray, R. H., and D. D. Dauble. 1976. "Synecology of the Fish Community Near Hanford Generating Project and Assessment of Plant Operational Impacts," pp. 5.1 to 5.55. In: *Final Report on Aquatic Ecological Studies Conducted at the Hanford Generating Project, 1973-1974*. WPPSS Columbia River Ecology Studies Vol. 1. Prepared for Washington Public Power Supply System under Contract No. 2311201335 with United Engineers and Constructors, Inc., by Pacific Northwest National Laboratory, Richland, Washington. 216 pp.
- Mueller, R. P., and D. R. Geist. 1999. *Steelhead Spawning Surveys Near Locke Island, Hanford Reach of the Columbia River*. PNNL-13055, Pacific Northwest National Laboratory, Richland, Washington. Online at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-13055.pdf.
- National Environmental Policy Act of 1969, 42 U.S.C. 4321, et seq. (P.L. 91-190).
- Orcutt, D. R., B. R. Pulliam, and A. Arp. 1968. *Characteristics of Steelhead Trout Redds in Idaho Streams*. Transactions of the American Fisheries Society 97: 42-45.
- Poston, T. M. 2010. *Assessment of Apatite Injection at 100-NR-2 for Potential Impact on Threatened and Endangered Species*. PNNL-SA-75348, Pacific Northwest National Laboratory Richland, Washington. Online at: <http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0084235>.
- Stables, T. B., and B. L. Tiller. 2007. *Suitability of Aquatic Habitat for Steelhead Spawning at Selected Sites in the Hanford Reach of the Columbia River, Measured February 21-25, 2007*. Environmental Assessment Services, Richland, Washington.
- USDOE (U. S. Department of Energy). 1999. *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*. DOE/EIS-0222-F. U.S. Department of Energy, Washington, D.C. Online at: <http://energy.gov/nepa/downloads/eis-0222-final-environmental-impact-statement-0>.
- USDOE (U. S. Department of Energy). 2011. *Hanford Site Environmental Report for Calendar Year 2011*. DOE/RL-2011-119, Rev. 0. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at: http://msa.hanford.gov/files.cfm/2011_DOE-RL_2011-119_HanfordSiteEnviroReport4CY2011.pdf.
- USDOE (U. S. Department of Energy). 2013. *Hanford Site Biological Resources Management Plan*. DOE/RL-96-32, Rev. 1. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at: <http://www.hanford.gov/files.cfm/DOE-RL-96-32-01.pdf>.
- USDOE (U. S. Department of Energy). 2015a. *Threatened and Endangered Species Management Plan: Salmon, Steelhead, and Bull Trout*. DOE/RL-2000-27, Rev. 2. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at: http://www.hanford.gov/files.cfm/DOE-RL-2000-27_Rev_02.pdf.
- USDOE (U. S. Department of Energy). 2015b. *Hanford Site Environmental Report for Calendar Year 2014*. DOE/RL-2014-52, Rev 0. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at: <http://msa.hanford.gov/files.cfm/DOE-RL-2014-52.pdf>.
- Wagner, P. G., C. T. Lindsey, and J. J. Nugent. 2012. *Steelhead Redd Monitoring Report for Calendar Year 2012*. HNF-53665, Rev. 0. Mission Support Alliance, Richland, Washington. Online at: http://www.hanford.gov/files.cfm/HNF-53665_-_Rev_00.pdf.

Wagner, P., J. Nugent, and C. Lindsey. 2014. *Hanford Site Steelhead Redd Monitoring Report for Calendar Year 2013*. HNF-56705, Rev. 0. Mission Support Alliance, Richland, Washington. Online at: [http://www.hanford.gov/files.cfm/HNF-56705 - Rev_00.pdf](http://www.hanford.gov/files.cfm/HNF-56705_-_Rev_00.pdf).

Watson, D. G. 1973. *Estimate of Steelhead Trout Spawning in the Hanford Reach of the Columbia River*. Battelle Pacific Northwest Laboratories, Richland, Washington.

Wydoski, R. S., and R. R. Whitney. 1979. *Inland Fishes of Washington*. University of Washington Press, Seattle, Washington.