Colville Tribes, Fish & Wildlife Department

2016 Okanogan Subbasin Steelhead Spawning Abundance and Distribution

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Executive Summary

The Okanogan Basin Monitoring and Evaluation Program (OBMEP) monitored summer steelhead (*Oncorhynchus mykiss*) spawner abundance and distribution within the Okanogan River subbasin from 2005 through 2016. Monitoring has been conducted through a combination of redd surveys, underwater video counts, and Passive Integrated Transponder (PIT) tag detections. Over the past 12 years of monitoring, the estimated average total number of steelhead spawners in the Okanogan subbasin was 1,767 (geomean 1,650). The average natural origin spawner abundance (NOSA) was 328 (geomean 291). Spawning estimates were also compared with recovery goals, as outlined by the Interior Columbia Basin Technical Recovery Team (ICBTRT). The Upper Columbia Spring Chinook and Steelhead Recovery Plan states that 500 naturally produced Steelhead adults would meet the minimum abundance recovery criteria within the U.S. portion of the Okanogan subbasin; if the Canadian portion of the subbasin was included, minimum abundance recovery criteria would be 1,000 naturally produced adults (UCSRB 2007).

Results from adult steelhead enumeration efforts in the Okanogan subbasin indicate that the number of spawning steelhead in the Okanogan River, both hatchery and naturally produced, has been increasing since data collection began in 2005. The slope of the trend line from 2005 to 2015 abundance estimates suggests that the number of natural origin spawners increased at an average rate of 27 fish per year. The trend may be driven by a large spawning cohort in 2010. The proportion of hatchery origin spawners (pHOS) from 2005 through 2013 averaged 0.85, but has decreased to an average pHOS of 0.69 in 2014 through 2016. Spawning occurred throughout the mainstem Okanogan River, but was concentrated in distinct areas that contained suitable water velocities and spawning substrates. Steelhead spawning has been documented to be most heavily concentrated below Zosel Dam on the Okanogan River and in braided island sections of the lower Similkameen River. It is likely that distribution of spawning may have been influenced by stocking location as juvenile hatchery steelhead have been released in Omak Creek, Salmon Creek, and the Similkameen River.

Steelhead redd surveys can provide a reasonable depiction of spawning distribution and an estimate of escapement on years when spring runoff occurs post-spawning. Defining the physical location of redds informs managers about which, and to what extent, habitats are being used for spawning and allow for tracking of spatial status and trends through time. However, conducting redd surveys on years with early runoff is not always effective due to poor water clarity. Since OBMEP began collecting steelhead spawning data in 2005, the importance of not relying solely on redd surveys for abundance estimates has become evident. Implementation of Upper Columbia Basin-wide PIT tag interrogation systems (Project # 2010-034-00), coupled with the representative marking of returning adults at Priest Rapids Dam, allowed managers an additional means to estimate abundance on years with poor water visibility, to validate redd survey efficiency, and describe spatial distribution and upstream extent of spawning, where previously unknown. The Fish and Wildlife Program should consider continuing these efforts to allow managers to more accurately describe the spatial extent of spawning in tributaries, to monitor effectiveness of barrier removal projects, and better define escapement estimates.

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1.0 Introduction

Within the Upper Columbia River Basin, the furthest upstream and northern-most extent of currently accessible anadromous habitat is found in the Okanogan River. Summer steelhead (*Oncorhynchus mykiss*) are listed as threatened in the Upper Columbia Evolutionarily Significant Unit (ESU) under the Endangered Species Act (ESA) (NMFS 2009). To recover this ESU requires that all four populations (Wenatchee, Entitat, Methow, and Okanogan) meet minimum adult abundance thresholds, have positive population growth rates, and each population must be widely distributed within respective basins (UCSRB 2007). Within the Okanogan River subbasin, the Okanogan Basin Monitoring and Evaluation Program (OBMEP) monitors adult abundance attributes. OBMEP developed protocols derived from the Upper Columbia Strategy (Hillman 2004) that called for a complete census of all spawning. Preliminary methodologies for implementing redd surveys were developed in 2005 and revised in 2007 (Arterburn et al. 2007). In addition to redd surveys, adult weir traps, Passive Integrated Transponder (PIT) tag arrays, and underwater video counting were combined to improve escapement estimates and coordinate with other on-going data collection efforts. In cooperation with the Washington Department of Fish and Wildlife (WDFW), OBMEP expanded the use of PIT tag arrays to enhance monitoring adult summer steelhead use of small tributaries to the Okanogan River.

This document builds upon knowledge and information gained from preceding years' surveys. A literature review of historic spawning information related to the Okanogan River subbasin can be found in Arterburn et al. 2005. Previous years' data and reports can be accessed at:

https://www.okanoganmonitoring.org/Reports/SteelheadSpawningSurveys

2.0 Methods

OBMEP - Adult Abundance - Redd Surveys (ID:192)
https://www.monitoringmethods.org/Protocol/Details/192
OBMEP - Adult Abundance - Adult Weir and Video Array (ID:6)
https://www.monitoringmethods.org/Protocol/Details/6
Estimate the abundance and origin of Upper Columbia steelhead (2010-034-00) v1.0 (ID:235)
https://www.monitoringmethods.org/Protocol/Details/235

The Okanogan River flows from the northern headwaters near Vernon, BC to the confluence with the Columbia River near Brewster, WA (Figure 1). Counts of summer steelhead spawning occurred downstream of anadromous fish migration barriers in the mainstem Okanogan and Similkameen rivers and tributaries accessible to anadromous fish within the United States (Arterburn et al. 2007, Walsh and Long 2006) following the OBMEP redd survey protocol. The area of the Okanogan River downstream from Chiliwist Creek has very low gradient and is inundated by the Columbia River (Wells Pool/Lake Pateros). Consequently, this lower reach (~23 km) of the Okanogan River was excluded from surveys because it lacks appropriate velocity and substrate needed for summer steelhead to spawn. Mainstem and tributary redd survey reaches are listed in Table 1. Redd surveys were supplemented with adult weir traps, PIT tag arrays, and underwater video counts at locations where habitat was too extensive or when access could not be arranged with private landowners.

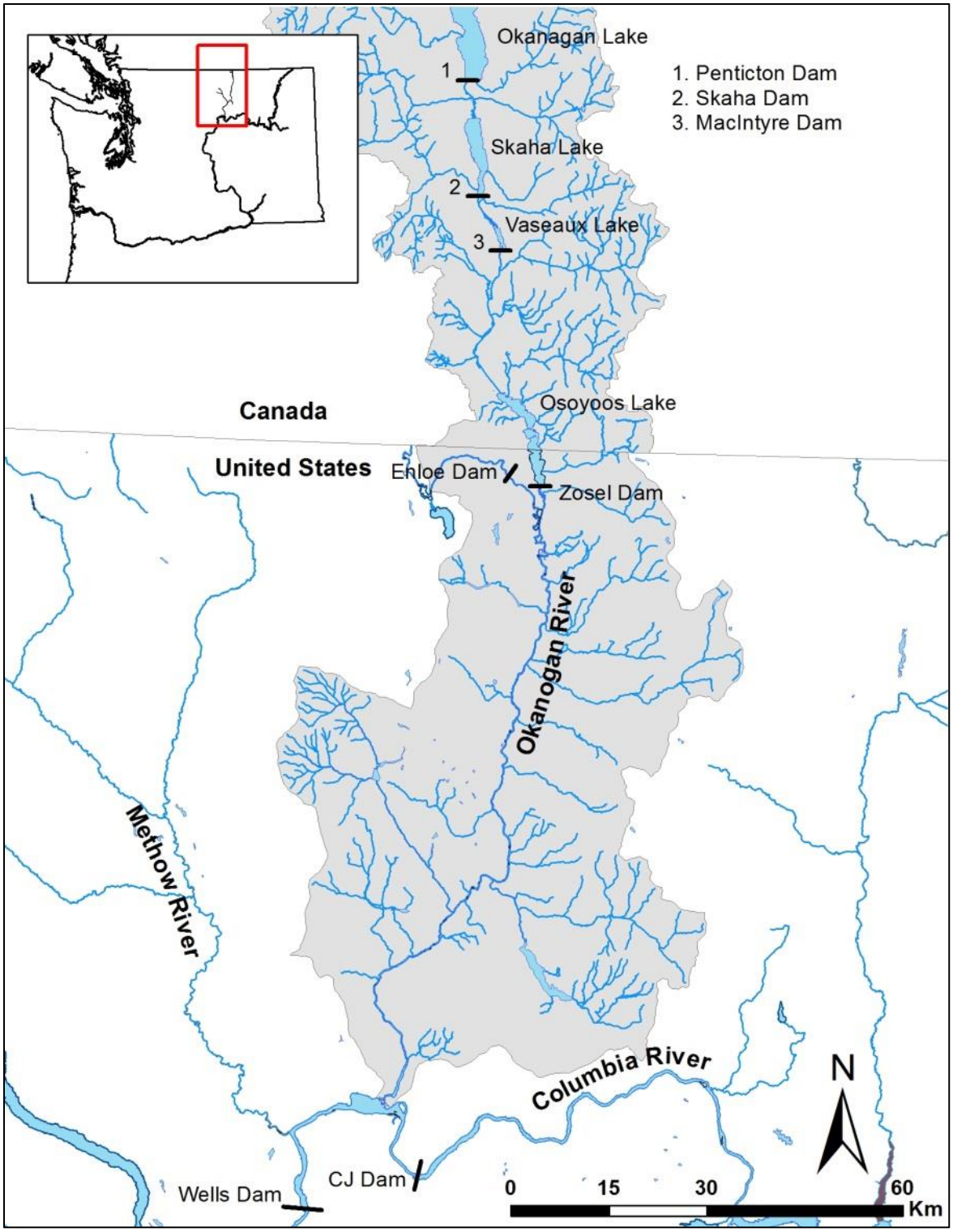

Figure 1. Study area, the Okanogan River subbasin in north-central Washington State and southern British Columbia.

The Okanogan River was divided into seven survey reaches and the Similkameen River was surveyed as two reaches. Survey reaches were determined by access points along the river and directly related to the EDT reach layer, used in habitat monitoring. Discharge data, air and water temperature, and local knowledge of fish movements collected from previous years were used to determine when to begin surveys on the mainstem. Mainstem surveys were conducted from rafts and on foot in a downstream progression. All island sections or other mainstem areas that could not be floated due to limited access and/or obstacles (e.g. wood debris, braided channels, and diversions) were surveyed on foot. Raft surveys were conducted by a minimum of two people using 10' catarafts. Small tributaries were surveyed on foot, walking in an upstream direction, once per week during the steelhead spawning period.

Geographic position of redds were collected with a Trimble GeoXT™ GPS unit and downloaded into GPS Pathfinder® after each survey. The GIS data were reviewed and differentially corrected. To avoid recounting, redds were marked by flagging tied to bushes or trees adjacent to the area where they were observed. Individual flags were marked with the survey date, direction and distance from the redd(s), consecutive flag number, total number of redds represented by the flag, and surveyor initials. Incomplete redds or test pits were not flagged or counted.

Table 1. Okanogan subbasin steelhead redd survey reaches.

Redd Survey Reach	Location and Description	Reach Length (km)
Okanogan River 1	Okanogan River at Loup Loup Creek (26.7) to Salmon Creek (41.4)	14.7
Okanogan River 2	Okanogan River at Salmon Creek (41.4) to the office (52.3)	10.9
Okanogan River 3	Okanogan River at the office (52.3) to Riverside (66.1)	13.8
Okanogan River 4	Okanogan River at Riverside (66.1) to Janis Bridge (84.6)	18.5
Okanogan River 5	Okanogan River at Janis Bridge (84.6) to Tonasket Park (91.4)	6.8
Okanogan River 6	Ok. R. at Horseshoe Lake (112.4) to confluence with Similk. R. (119.5)	7.1
Okanogan River 7	Okanogan River at Similk. R. confluence (119.5) to Zosel Dam (127.0)	7.5
Similkameen River 1	Similkameen/Okanogan Confluence (0) to sewer plant (6.6)	6.6
Similkameen River 2	Similkameen from sewer plant (6.6) Enloe Dam (14.6)	8.0
Loup Loup Cr	Loup Loup Creek/Ok. R. confluence to Loup Loup Creek diversion (2.3)	2.3
Salmon Cr	Salmon Creek/Okanogan River confluence (0) to OID diversion (7.2)	7.2
Omak Cr	Omak Creek/Ok. R. Confluence (0) to Omak Creek trap site (1.5)	1.5
Wanacut Cr	Wanacut Creek/Okanogan River confluence (0) to the falls (2.5)	2.5
Johnson Cr	Johnson Cr./Ok. R. conf. (0) to PIT tag array above Hwy 97 (0.5)	0.5
Tunk Cr	Tunk Creek/Okanogan River confluence (0) to the falls (1)	1.0
Aeneas Cr	Aeneas Creek/Okanogan River confluence (0) to the barrier (0.4)	0.4
Bonaparte Cr	Bonaparte Creek/Ok. River confluence (0) to the falls (1.6)	1.6
Antoine Cr	Antoine Creek/Okanogan River confluence (0) to video weir (1.3)	1.3
Wildhorse Sp Cr	Wildhorse Spring Creek/Okanogan River confluence to barrier (1.1)	1.1
Tonasket Cr	Tonasket Creek/Okanogan River confluence (0) to the falls (3.5)	3.5
Ninemile Cr	Ninemile Creek from Lake Osoyoos (0) to PIT tag array (0.7)	0.7
Foster Cr	Foster Creek/Columbia River confluence (0) to barrier (1.7)	1.7

2.1 Sex Ratio and Number of Fish Per Redd

OBMEP employed a method that has been used by the Washington Department of Fish and Wildlife (WDFW) in the Upper Columbia Basin to extrapolate escapement estimates from redd counts using the sex ratio of fish collected randomly over the run at Wells Dam. A sample of 442 summer steelhead, including 209 males (174 hatchery and 35 natural origin) and 233 females (184 hatchery and 49 natural origin), were sexed at Wells Dam during the 2015 upstream migration by WDFW personnel (Charles Frady, WDFW, pers. comm.). Adjusted proportionally for the run, a sex ratio of 0.897 males per female or 1.897 fish per redd (FPR) was used to expand redd counts on the mainstem Okanogan River into steelhead spawning estimates. All calculations using sex ratio multipliers assume that each female will produce only one redd.

2.2 PIT Tag Expansion Estimates

Permanent and seasonally operated PIT tag arrays were operated near the mouth of all tributaries to the Okanogan River known to contain steelhead spawning, throughout the spring of 2016. The WDFW operates as the lead investigator on project number 2010-034-00 and the study is conducted in conjunction with the CCT. The CCT operates and maintains detection sites in the Okanogan subbasin, along with data collection and management of those datasets. Any expanded PIT tag estimates presented in this document should be considered preliminary estimates as data analyses are currently in progress for the entire Upper Columbia for multiple years of the project. Final analyses of these data will be reported under project number 2010-034-00.

Population estimates derived from PIT tag detections were calculated following Murdoch et al. 2011. In the 2015 up-river migration year, a random representative sample of steelhead were captured at Priest Rapids Dam, two to three days per week over the course of the run, from July through November. A proportion of fish, approximately 19.4%, were tagged and released above Priest Rapids Dam (Ben Truscott, WDFW, pers. comm.). The mark-rate was used to expand the number of detections into escapement estimates for tributaries with PIT tag arrays. For example, if five hatchery and two natural origin steelhead were detected at a given creek in the Okanogan subbasin, the escapement estimate would be 26 hatchery steelhead (26=5/0.194) and 10 natural origin steelhead (10=2/0.194), calculated from the mark-rate at Priest Rapids Dam. This method assumes that marked fish are representative of unmarked fish. Given relatively few detections at many locations (particularly at smaller tributaries) escapement estimate confidence bounds derived from PIT tag detections may be quite wide and the estimate should be considered general. In addition to fish tagged at Priest Rapids, steelhead may have also received PIT tags at other locations (such as out-migrating juveniles, adults returning to Bonneville Dam, Wells Dam, among others); however, it is unknown how representative of the run those fish were. Therefore, any extrapolations from PIT tag detections to an escapement estimate were derived only from the Priest Rapids release group.

3.0 Okanogan Subbasin Summer Steelhead Spawning Estimates

Based on expanded PIT tag detections from project 2010-034-00, it was estimated that a total of 1,566 summer steelhead (1,175 hatchery and 391 natural origin) spawned in the Okanogan subbasin in 2016. From 2005 through 2016, it was estimated that an average of 1,767 steelhead spawned in the Okanogan subbasin (Table 2). The average for natural origin and hatchery origin steelhead was estimated to be 328 and 1,439, respectively. The proportion of hatchery origin spawners (pHOS) from 2005 through 2013 averaged 0.85, but the average pHOS decreased to 0.69 in 2014 through 2016.

Results from steelhead adult enumeration efforts indicate that, in general, the abundance of spawning steelhead in the Okanogan River subbasin, both hatchery and natural origin, has increased since data collection began in 2005. A summary of the estimated number of adult steelhead spawners, distributed by mainstem survey reach and individual tributaries, are presented in Table 3. Detailed results for unique tributaries and mainstem survey reaches are further detailed in sections 3.1 to 3.3 of this document.

Table 2. Okanogan subbasin summer steelhead spawner abundance estimates, 2005-2016.

Year	Hatchery Origin	Natural Origin	Total
2005	1,080	146	1,226
2006	702	197	899
2007	1,116	152	1,268
2008	1,161	225	1,386
2009	1,921	212	2,133
2010	2,768	728	3,496
2011	1,341	333	1,674
2012	2,475	327	2,802
2013	1,687	250	1,937
2014	838	518	1,356
2015	1,009	452	1,461
2016	1,175	391	1,566
Mean	1,439	328	1,767
Geomean	1,324	292	1,650

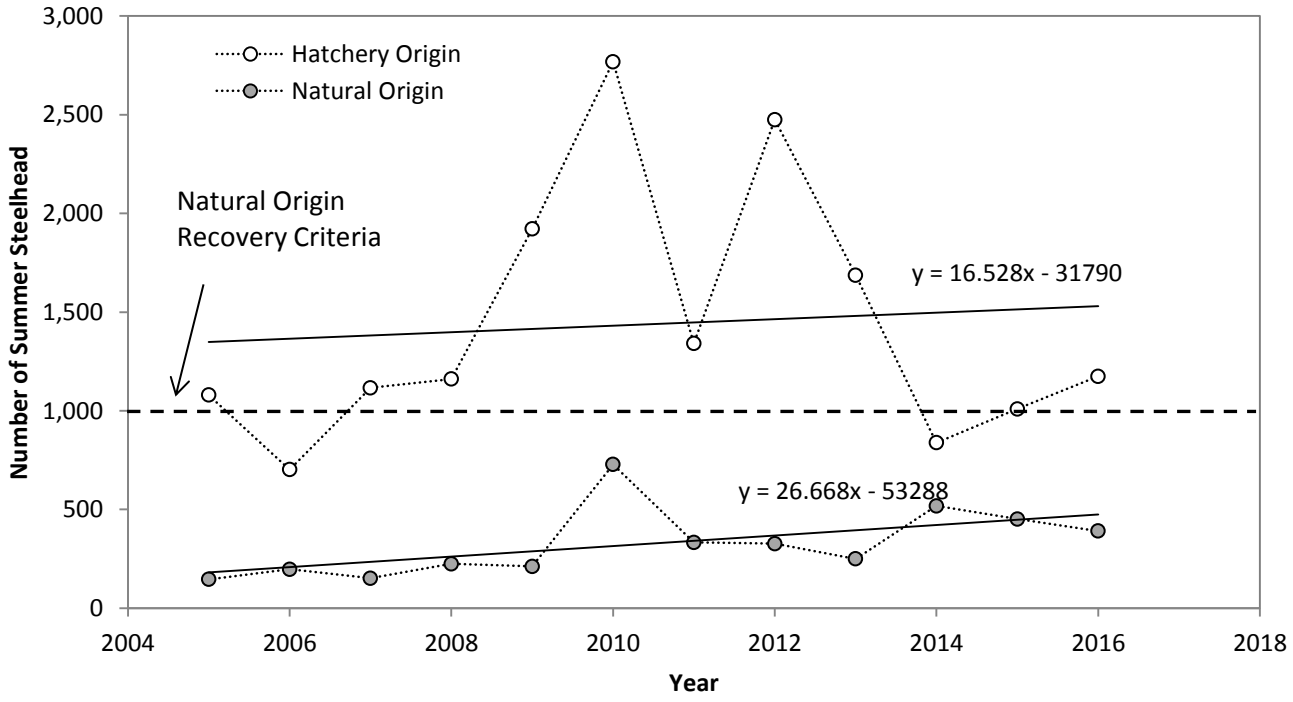

Figure 2. Trend in the estimated number of summer steelhead spawning in the Okanogan River subbasin, 2005 - 2016.

Table 3. Estimated number of hatchery and natural origin steelhead spawning for each sub-watershed or assessment unit in 2016.

Distribution of Steelhead Spawning in the Okanogan Subbasin, 2016

Category	Description/location	Estimated Hatchery Origin Spawner Abundance	Estimated Natural Origin Spawner Abundance
WA Mainstem	Okanogan River 1	5	0
WA Mainstem	Okanogan River 2	16	1
WA Mainstem	Okanogan River 3	4	0
WA Mainstem	Okanogan River 4	14	1
WA Mainstem	Okanogan River 5	23	2
WA Mainstem	Okanogan River 6	6	0
WA Mainstem	Okanogan River 7	147	10
WA Mainstem	Similkameen River 1	50	4
WA Mainstem	Similkameen River 2	37	3
WA Tributary	Loup Loup Creek	121	33
WA Tributary	Salmon Creek	104	79
WA Tributary	Omak Creek	246	80
WA Tributary	Wanacut Creek	8	0
WA Tributary	Johnson Creek	13	7
WA Tributary	Tunk Creek	37	12
WA Tributary	Aeneas Creek	18	0
WA Tributary	Bonaparte Creek	75	34
WA Tributary	Antoine Creek	51	21
WA Tributary	Wild Horse Spring Creek	69	26
WA Tributary	Tonasket Creek	6	23
WA Tributary	Ninemile Creek	16	9
Area	**Washington State Mainstem**	**302**	**21**
Area	**Washington State Tributaries**	**764**	**324**
Area	**British Columbia**	**15**	**15**
Subbasin	**Okanogan**	**1,175**	**391**

*Area spawner estimates do not directly sum to subbasin estimate based on calculation method.

3.1 Steelhead Spawning Estimates: Okanogan and Similkameen River Mainstem

Due to an early onset of runoff and turbid water conditions that began in early April 2016 (Figure 3), documenting the duration and distribution of steelhead spawning activity in the Okanogan River mainstem was mostly unsuccessful. Flows remained high through June, at which time spawning had long since concluded and steelhead redds were indistinguishable. A total of 25 redds were documented in the mainstem on the first pre-peak spawning survey before discharge rates rose. Locations of redds marked in 2016 and on historic surveys (2005-2015) are shown in Figures 4-10 and 13-25.

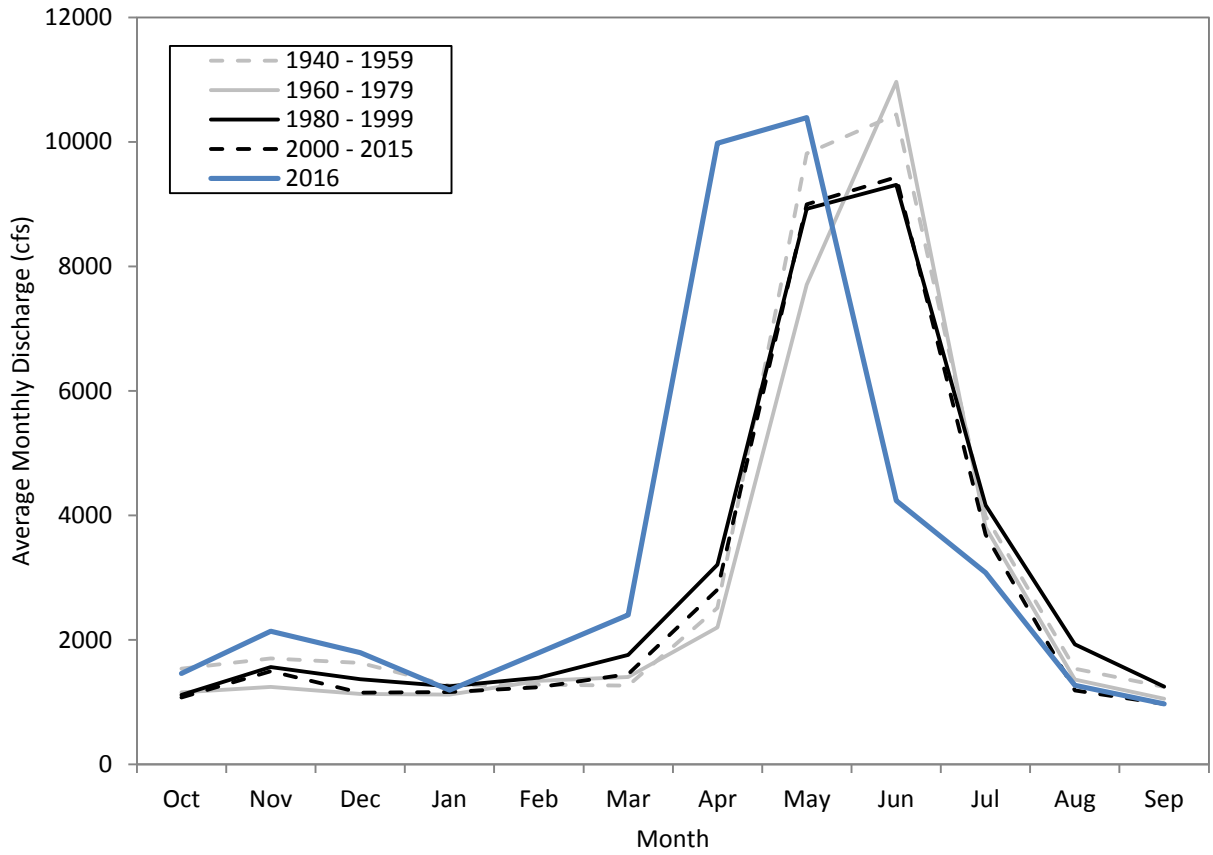

Figure 3. Average monthly discharge of the Okanogan River at Tonasket, WA (USGS Station 12445000, Okanogan River near Tonasket, WA).

Although redd surveys were unable to capture the complete spawning activity of steelhead in the mainstem Okanogan and Similkameen Rivers, an estimate of mainstem spawning by reach was calculated as follows: The proportional distribution of spawning in each mainstem reach was determined for years when successful mainstem spawning surveys occurred (7 years, 2005-2011). The mean each reach-specific proportions was multiplied by the total mainstem spawning estimate for hatchery (302) and natural origin (21) steelhead, as estimated by project 2010-034-00. This calculation assumes that the proportion of spawning in mainstem reaches in 2016 remained similar to the reference time period. Specific calculations are outlined in Table 4.

Table 4. Modeled estimate of mainstem steelhead spawning in 2016.

Mainstem Survey Reach	A. Avg. Proportion of Mainstem Spawning by Reach (2005-2011)	B. Natural Origin Steelhead (B=A*21 [a])	C. Hatchery Steelhead (C=A*302 [b])	D. Total Estimate (D=B+C)
Okanogan River O1	0.015	0	5	5
Okanogan River O2	0.055	1	16	17
Okanogan River O3	0.012	0	4	4
Okanogan River O4	0.047	1	14	15
Okanogan River O5	0.076	2	23	25
Okanogan River O6	0.020	0	6	6
Okanogan River O7	0.486	10	147	157
Similkameen River S1	0.165	4	50	54
Similkameen River S2	0.124	3	37	40
Mainstem Total	1	21 [a]	302 [b]	323

[a] The Okanogan/Similkameen mainstem natural origin spawning estimate of 21 calculated by project 2010-034-00.
[b] The Okanogan/Similkameen mainstem hatchery spawning estimate of 302 calculated by project 2010-034-00.

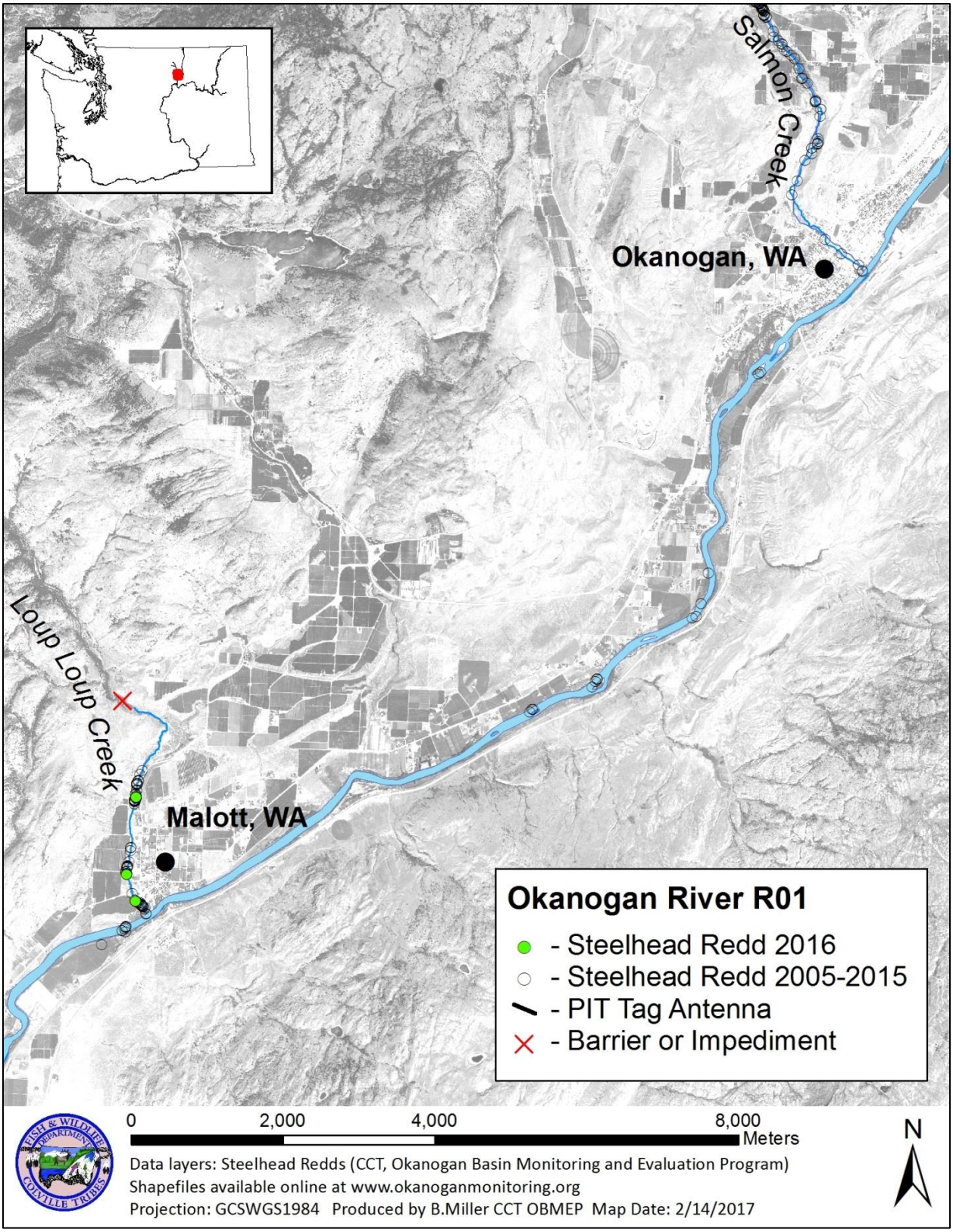

Figure 4. Spatial distribution of summer steelhead redds documented in Okanogan River survey reach RO1, from Salmon Creek to Loup Loup Creek.

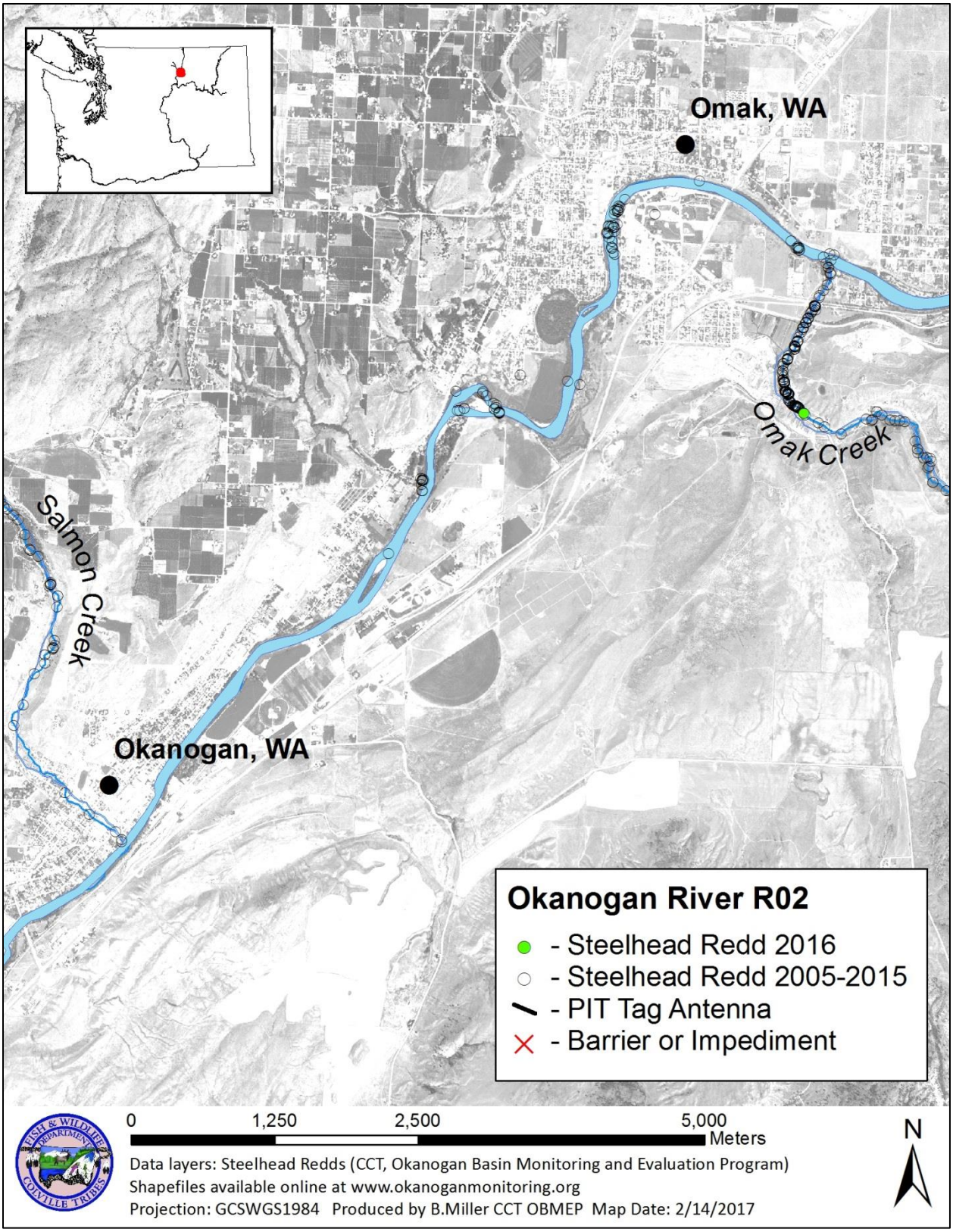

Figure 5. Spatial distribution of summer steelhead redds documented in Okanogan River survey reach RO2, from Omak Creek to Salmon Creek.

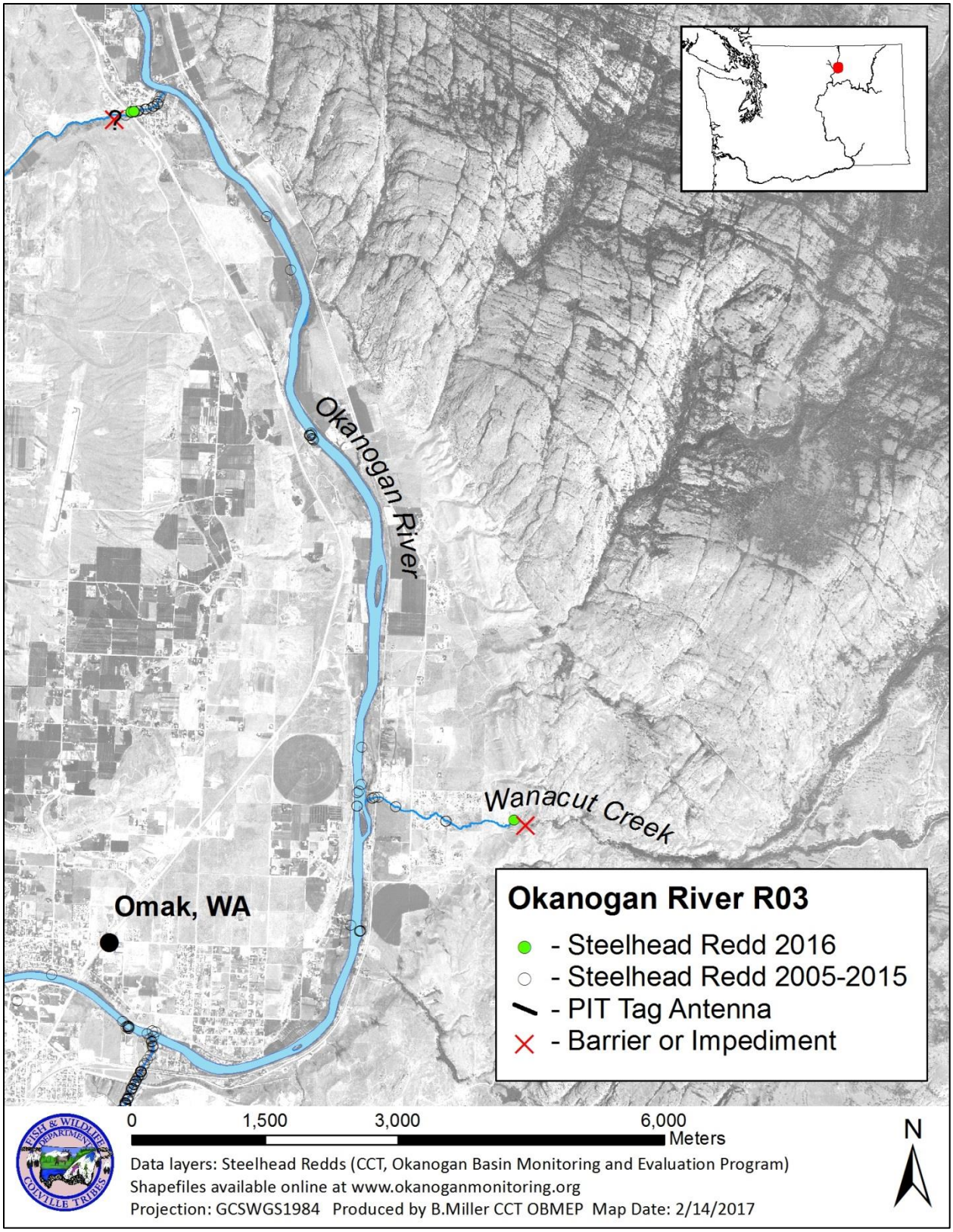

Figure 6. Spatial distribution of summer steelhead redds documented in Okanogan River survey reach RO3, from Johnson Creek to Omak Creek.

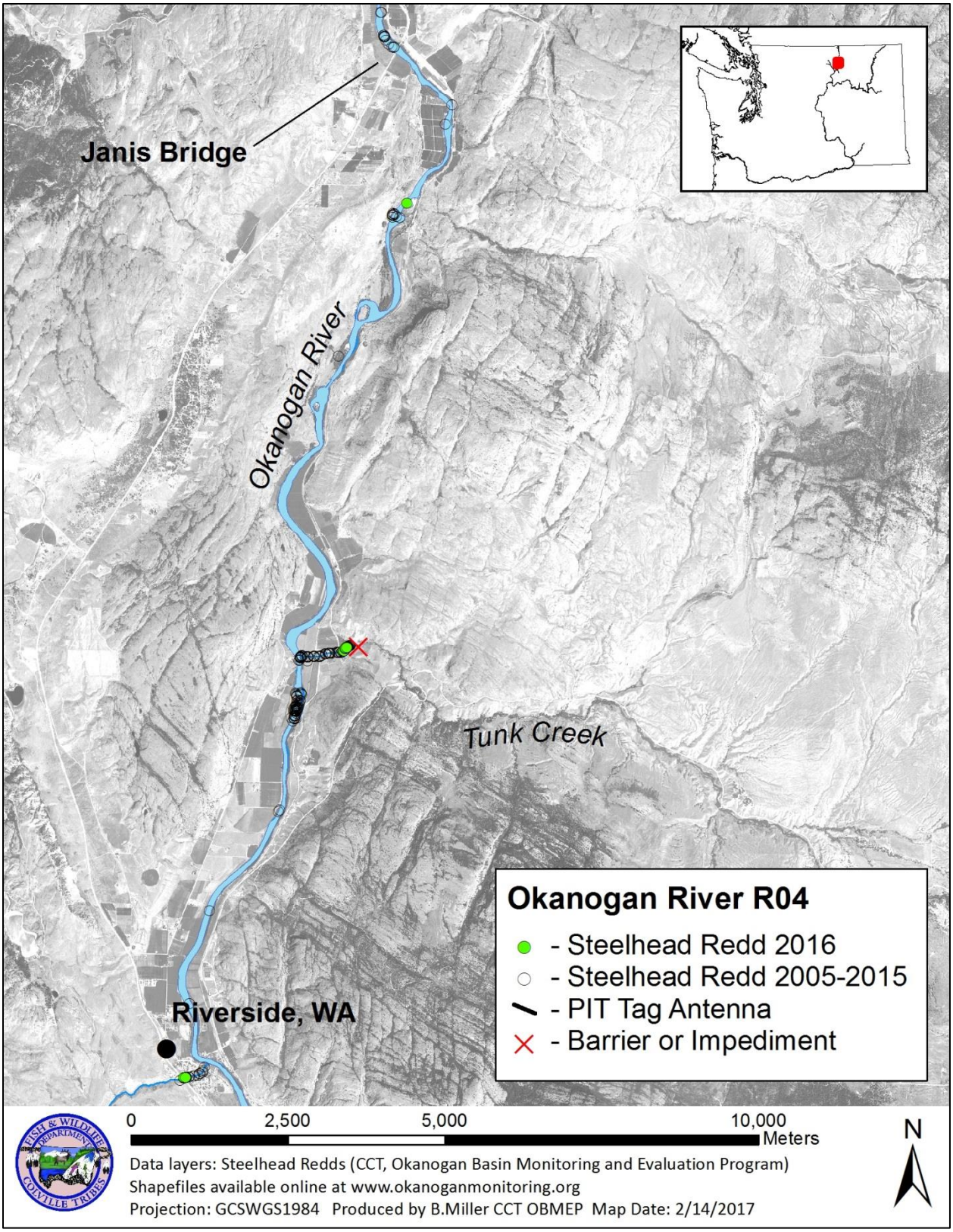

Figure 7. Spatial distribution of summer steelhead redds documented in Okanogan River survey reach RO4, from Janis Bridge to Johnson Creek.

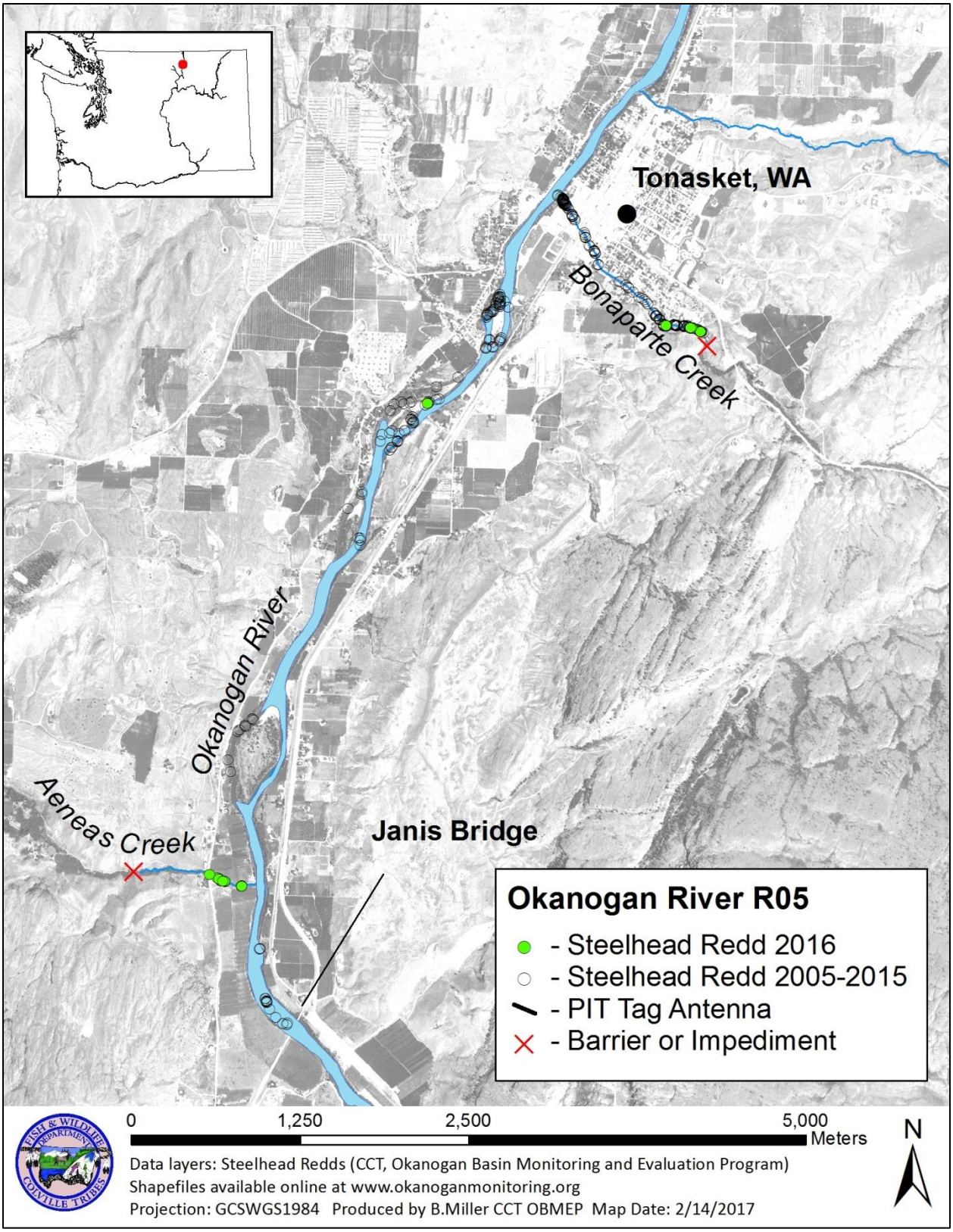

Figure 8. Spatial distribution of summer steelhead redds documented in Okanogan River survey reach RO5, from the Tonasket boat launch to Janis Bridge.

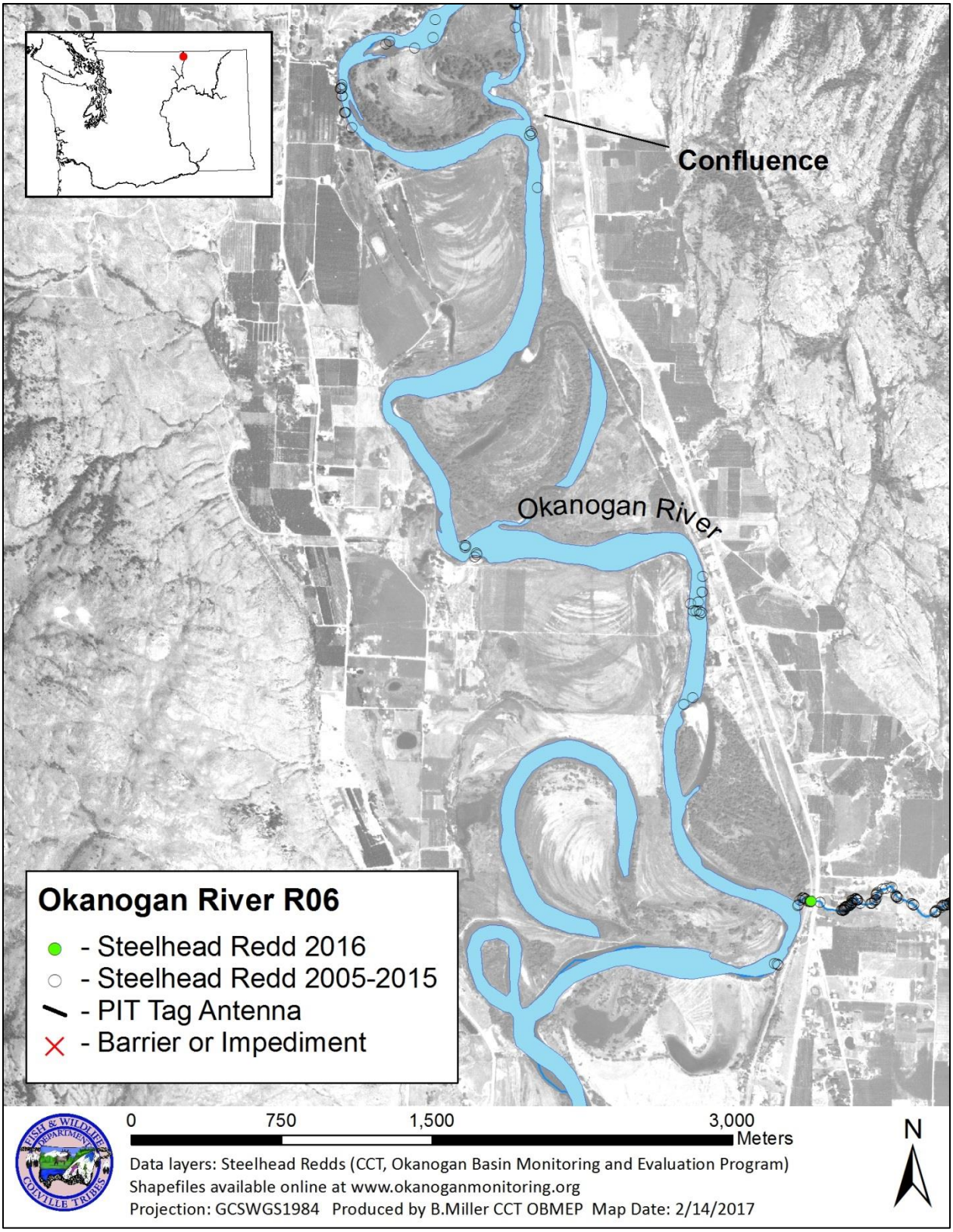

Figure 9. Spatial distribution of summer steelhead redds documented in Okanogan River survey reach RO6, from the confluence of the Similkameen and Okanogan Rivers to Horseshoe lake.

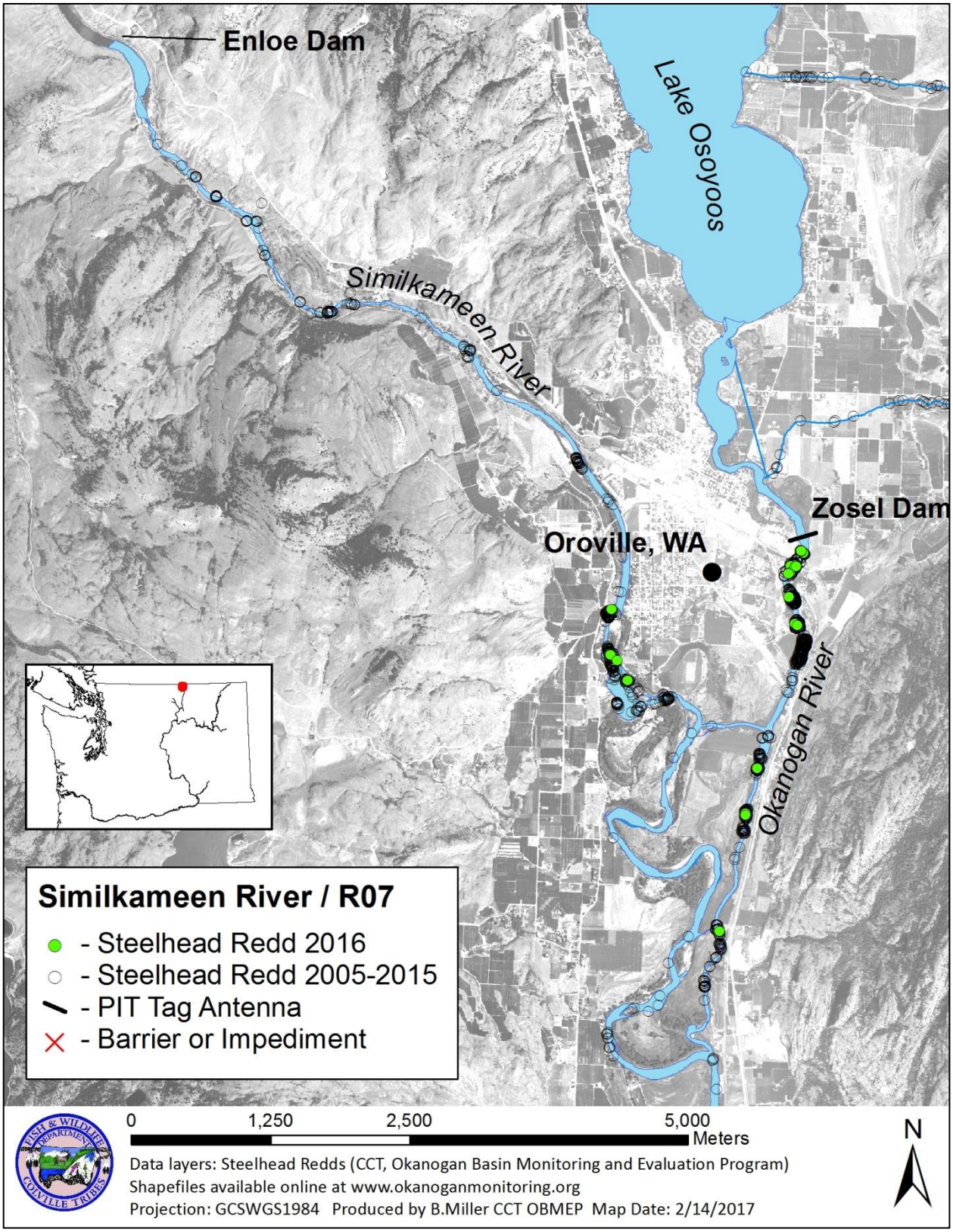

Figure 10. Spatial distribution of summer steelhead redds documented in the Similkameen River, from Enloe Dam to the confluence, and in Okanogan River survey reach RO7, from Zosel Dam to the confluence.

3.2 Steelhead Spawning Estimates: Tributaries to the Okanogan River

Redd surveys on tributaries to the Okanogan River were attempted weekly from March 14 through May 26, 2016. Tributary surveys were also affected by high flows and turbid water conditions from an early runoff period, which began in March in most subwatersheds (Figure 11 and 12). For reference, peak steelhead spawning typically occurs around April 15th. A total of 69 summer steelhead redds were documented in tributaries to the Okanogan River in 2016. Although difficulties existed in documenting redds with visual surveys, spawning estimates were still successfully produced in each subwatershed from PIT tag detections under project # 2010-034-00. In-stream PIT tag interrogation sites were installed and successfully operated on 13 tributaries to the Okanogan River in Washington State.

In the following sections, a summary of spawning estimates for steelhead in tributaries to the Okanogan River are presented, along with spatial distribution information. Detailed maps are presented in the following sections for each subwatershed which outline spatial distribution of redds found in 2016, as well as historic observations from 2005-2015. GIS shapefiles of steelhead redds from 2005-2016 can be downloaded at: www.okanoganmonitoring.org

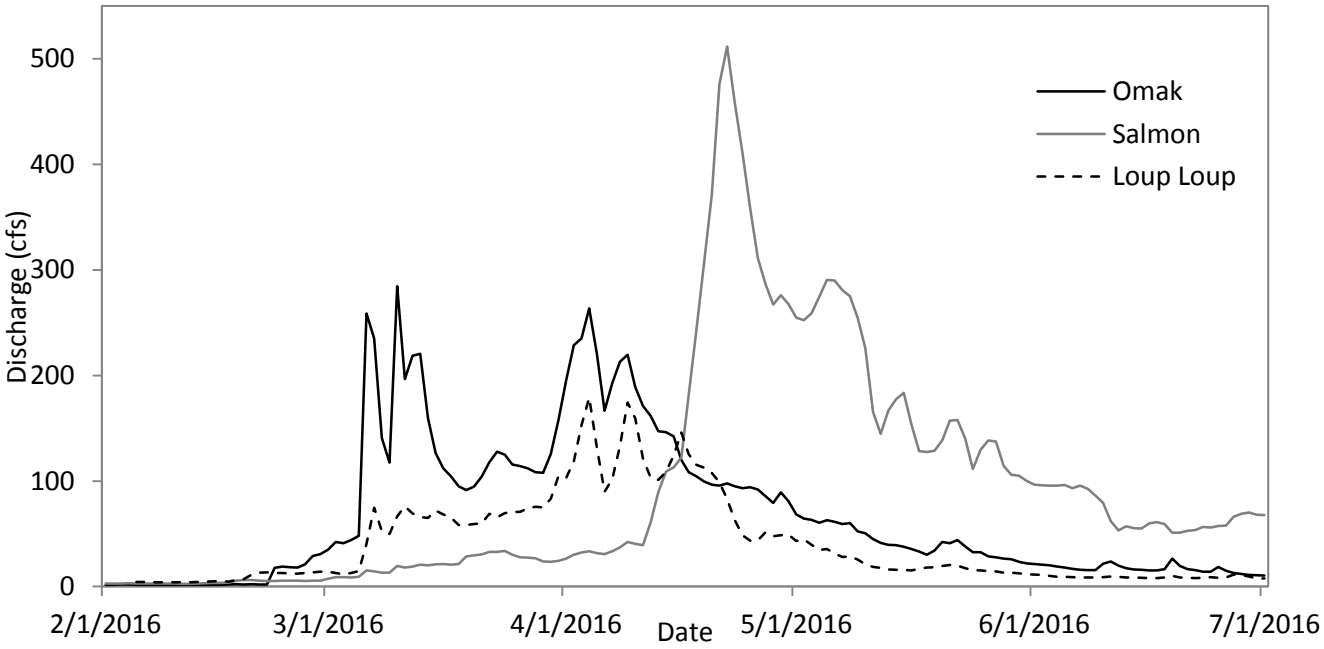

Figure 11. 2016 discharge in three tributaries in the southern Okanogan subbasin.

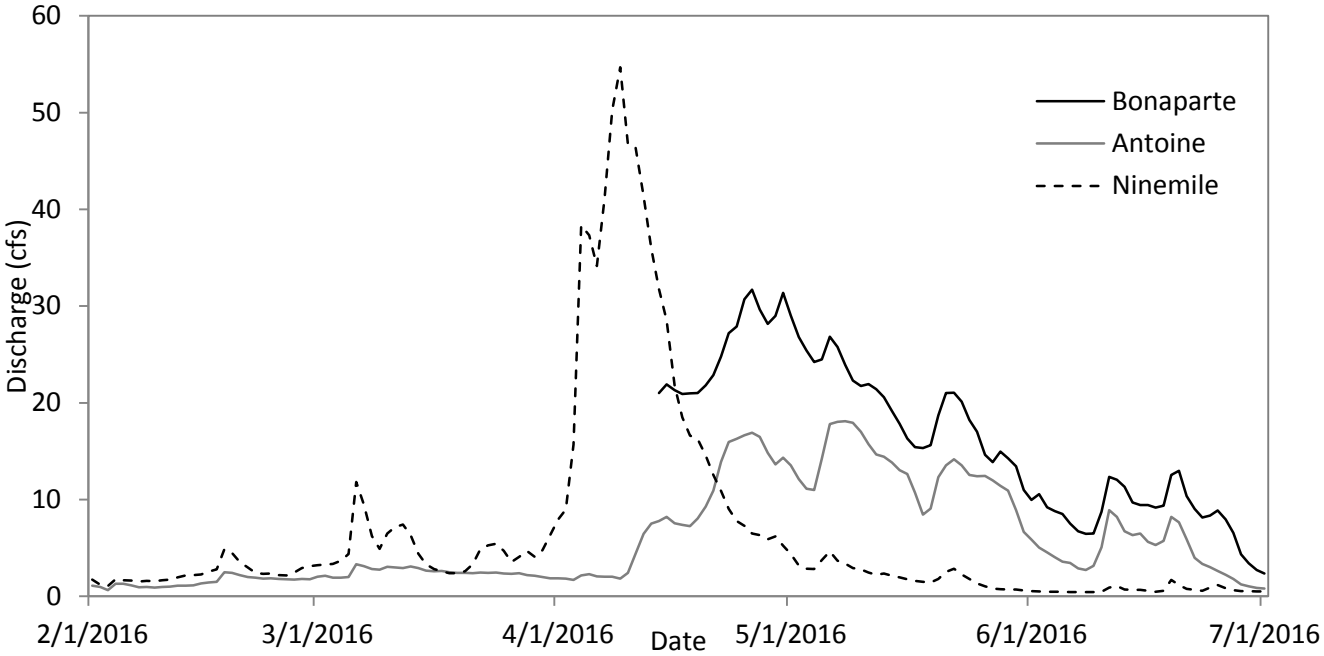

Figure 12. 2016 discharge in three tributaries in the northern Okanogan subbasin.

3.2.1 Loup Loup Creek

Loup Loup Creek is a tributary that enters the Okanogan River at river kilometer (RKM) 24, in the town of Malott, WA. The lower sections of the creek frequently went dry during mid-summer, until 2010, when the point of diversion was transferred to the Okanogan River and the irrigation diversion on Loup Loup Creek was removed. PIT tag interrogation site LLC consists of three pass-over PVC antennas in series is located near the mouth of the creek.

Conditions in Loup Loup Creek were unfavorable to conduct redd surveys throughout most of the spring of 2016. One walking surveys was successfully conducted at the end of the spawning season on May 12 and a total of 7 redds were georeferenced (Figure 13). Two large sections of the creek were not surveyed due to lack of landowner permissions. The estimated spawner abundance in 2016 was 121 hatchery and 33 natural origin, for a total of 154 steelhead. Spawner abundance in 2016 was comparably large when compared to the historic annual mean (2006-2015) of 27 hatchery and 9 natural origin steelhead.

3.2.2 Salmon Creek

Salmon Creek is a highly managed, medium sized tributary that enters the Okanogan River at RKM 41.3, in the city of Okanogan, WA. Since the early 1900's, the majority of water from Salmon Creek had been diverted for irrigation usage. The largely dry stream channel extended from the Okanogan Irrigation District (OID) diversion dam (7.2 km) to the confluence with the Okanogan River. Occasionally, uncontrolled spills occurred downstream of the OID diversion dam in high water years. These spills typically occurred in mid-May to June, which is after summer steelhead have moved into tributaries to spawn. To provide sufficient water during the migration window of spring-spawning steelhead, the Colville Tribes purchased water from the OID and allowed

it to flow down the channel to the Okanogan River. After several years of successful evaluations of steelhead passage, the Tribes negotiated a long term water lease agreement with the OID. Since 2006, the long term water lease has provided a window of water for returning adults and outmigrating juvenile salmonids.

A PIT tag interrogation array (site SA1) is located 2.9 km upstream from the mouth of Salmon Creek. The system arrangement consists of three pass-over PVC antennas grouped in series. A second PIT tag interrogation site (SA0) is located immediately downstream of the OID diversion dam and consists of two rows of pass-over PVC antennas.

Salmon Creek was divided into three reaches, based on survey access points and an irrigation diversion site: (1) from the confluence with the Okanogan River to the PIT tag array located approximately 2.9 km upstream, (2) from the PIT tag array to the Okanogan Irrigation District (OID) diversion, and (3) from the OID diversion to Conconully Dam. Redd surveys were attempted weekly from the confluence to the OID diversion and a PIT tag antenna was operated at the OID diversion to monitor passage past that point. A total of 5 redds were documented between March and early April before high flows made walking surveys impossible. Redd distributions from 2016 and previous years are shown in Figure 14.

3.2.3 Omak Creek

Omak Creek is characterized as a perennial, medium sized tributary that enters the Okanogan River at RKM 51.5, approximately 1.0 km upstream from the city of Omak, WA. Discharge rates in the creek range from a base flow of 2-4 cfs to over 150 cfs during the spring. During the base flow period, wetted widths range from approximately 2 to 8 m. A parallel PIT tag array (site OMK) is located near the mouth of Omak Creek, 0.24 km upstream from the confluence with the Okanogan River. Two additional PIT tag interrogation sites are also operated below (OBF) and above (OMF) Mission Falls to monitor passage rates.

A total of 246 hatchery and 80 natural origin steelhead were estimated to have spawned in Omak Creek in 2016. Due to an early runoff period, Omak Creek discharge rates were elevated from early-March through mid-May and no redd surveys could occur during the peak spawning period. One survey was conducted on May 17th which documented 7 redds (Figure 15). Redd surveys have not been conducted above Mission Falls to date.

3.2.4 Wanacut Creek

Wanacut Creek is a small stream that meets the Okanogan River at approximately RKM 56, between Omak and Riverside, WA (Figure B-4). The 51 km^2 Wanacut Creek drainage stems from Omak Mountain, located on the Colville Reservation. A large natural falls exists a short distance from the confluence with the Okanogan River and the creek frequently flows subsurface in the lower most reaches. A temporary PIT tag antenna (site WAN) is placed seasonally near the mouth of the creek to document PIT tagged steelhead movements.

A handful of adult steelhead have been documented spawning in Wanacut Creek, particularly on years where sufficient runoff occurs in March through May. In 2016, an estimated 8 steelhead spawned in the creek. Although flows were high for much of the early season, one redd was found near the falls (Figure 16). Over the past 9 years of surveys conducted on Wanacut Creek (2007-2015), six years had no steelhead spawning and the remaining 4 years had an average of 8 steelhead spawners. The maximum spawning estimate was 12 in 2012.

3.2.5 Johnson Creek

Steelhead surveys have occurred in Johnson Creek since 2012. As in all previous years, redd surveys occurred weekly in 2016 due to clear water conditions and stable water flows. A total of 8 redds were documented between the mouth and the highway culvert representing a spawner abundance estimate of 15 steelhead (15=8 redds x 1.897 fish/redd) below the highway culvert. The spawning estimate from PIT tag detections was 13 hatchery and 7 natural origin, for a total of 20 spawners. In 2016, only one tag was detected above the gabion weir; the remainder likely spawned below the highway culvert in the town of Riverside, WA. Both the expanded redd and PIT tag methods produced similar estimates.

The distribution of redds documented in Johnson Creek is shown in Figure 17. No redd surveys have occurred above the gabion weir, however a small number of PIT tags have been detected above the structure over the past 5 years; the total spatial extent of anadromous steelhead is unknown above the gabion weir.

3.2.6 Tunk Creek

Tunk Creek is a small tributary that meets the Okanogan River at RKM 72, upstream of Riverside, WA. Although the drainage area of Tunk Creek is approximately 186 km^2, only the lower 1.2 KM are accessible to anadromous fish, due to a natural falls. The creek frequently flows subsurface in the lower reaches during mid-summer. A temporary single PIT tag antenna (site TNK) is installed seasonally near the mouth of the creek.

Redd surveys were attempted weekly, but could only be successfully conducted in March and May. Water clarity was not favorable for visual spawning surveys throughout the month of April. A total of 12 redds were georeferenced. The spawning estimate from PIT tags was 37 hatchery and 12 natural origin steelhead, for a total spawning estimate of 49 fish. From 2005-2015 the average number of estimated steelhead spawning in Tunk creek was 42. The maximum was 109 in 2010. Most of the steelhead spawning in Tunk Creek occurs in a relatively short reach just downstream of the falls (Figure 18).

3.2.7 Aeneas Creek

Aeneas Creek is a small creek that enters the Okanogan River just south of the town of Tonasket, WA (RKM 85). The lower section of the creek was impounded with a series of very large beaver dams that were cemented in with calcified clay. In 2012, many of these structures were removed, allowing adult steelhead passage at the mouth of the creek. The total habitat accessible to anadromous fish is limited by a culvert and steep gradient (Figure 19), although potential passage has not been specifically examined at that location. Weekly spawning surveys were conducted in Aeneas Creek due to low flows and excellent water clarity. Fourteen redds were found for an estimated spawner count of 27 fish (14 redds x 1.897 fish/redd).

A temporary PIT tag antenna was operated near the mouth of the creek to document utilization by adult steelhead. The first adults were detected in the creek in the spring of 2014 (n=3) and no steelhead were found spawning in 2015. In 2016, the spawning estimate was 18 hatchery and zero of natural origin, as determined by PIT tag detections. The expanded PIT tag spawning estimate will be used to maintain inter-agency consistency in the estimates.

3.2.8 Bonaparte Creek

Bonaparte Creek flows out of Bonaparte Lake, near Wauconda, WA, and enters the Okanogan River at RKM 91. The Bonaparte Creek watershed has a drainage area of 396 km^2; discharge ranges from 1 cfs during low flow conditions and may reach 20 to over 40 cfs during peak runoff. During summer base flow, wetted widths range from 1.5 m to 3 m. The total stream kilometers available to anadromous fish is short, totaling only 1.6 km below a natural falls. Only two redd surveys could be completed in the creek before turbid water obscured observations through the remainder of May. The positions of six redds were recorded (Figure 20).

A PIT tag interrogation site (BON) is located just upstream from the confluence with the Okanogan River. Based on tag detection, an estimated 75 hatchery and 34 natural origin steelhead spawned in Bonaparte Creek in 2016. Steelhead surveys have occurred on Bonaparte Creek since 2005; the average number of spawners annually is 100.

3.2.10 Antoine Creek

Steelhead surveys have occurred on Antoine Creek since 2006. The average number of estimated spawners has been low, averaging five per year from 2006-2015. Utilization by adult steelhead has been relatively limited, potentially due to poor accessibility near the mouth of the creek. In 2015 and previous years, there was an approximately 6 foot high cut bank falls with a very shallow plunge pool near the confluence with the Okanogan River. Frequently, wood debris piled up in this slot and likely inhibited upstream passage. In late 2015, habitat modifications were completed near the mouth of Antoine Creek, designed to increase passage success for the 2016 spawning period (Keith Kistler, CCT, pers. comm.). Additionally, a small concrete dam was removed in Antoine Creek in the fall of 2013, which potentially opened up an additional 11 km of habitat in the upper creek.

A permanent PIT tag interrogation site was in operation near the mouth of Antoine Creek (site ANT) and a seasonally operated PIT tag antenna was installed above where the dam was removed to document potential passage above that point. In 2016, an estimated total of 72 steelhead spawned in Antoine Creek, 51 hatchery and 21 natural origin. Redd surveys occurred below the PIT tag interrogation site until mid-April, when the water became turbid from spring runoff. One redd was found (Figure 21).

3.2.11 Wildhorse Spring Creek

Wildhorse Spring Creek is a fairly small watershed the flows off of the west side of Mt. Hull near Oroville, WA. Some years, there is not enough water depth for adult steelhead to access the creek. On years where sufficient water flows to allow for adult steelhead access, it is not uncommon for large numbers of fish to utilize this creek for spawning. Surveys have occurred from 2006-2016 (11 years). On four of the years (2008, 2009, 2014, 2015) zero steelhead were estimated to have entered the creek. In the remaining years, and annual average of 88 steelhead spawned in the creek (max=278 in 2012). In 2016, it was estimated that 95 steelhead spawned in the creek, 69 hatchery and 26 of natural origin. Because a weir trap was placed near the mouth of the creek, no redd surveys were conducted in 2016.

3.2.12 Tonasket Creek

Tonasket Creek enters the Okanogan River at RKM 125, just upstream from Zosel Dam, at the tail end of Lake Osoyoos. The lower reach is known to go dry on an annual basis; however, there is typically some flow in the upper-most reach, below the natural falls. A single seasonal PIT tag antenna is operated near the confluence of the creek with the Okanogan River. The first survey was completed in late March, which located no redds. Subsequently, high turbid water flowed through late April. Three surveys occurred between late April and May which located 7 redds (Figure 23). The mouth of the creek was dry by May 16th. In 2016, an estimated 29 steelhead spawned in Tonasket Creek, 6 hatchery and 23 natural origin. Since 2006, the average number of total annual spawners was 30.

3.2.13 Ninemile Creek

Ninemile Creek enters the eastside of Osoyoos Lake, just south of the British Columbia border (Figure 24). The creek is known to flow sub-surface annually in the middle reach, but surface flows are usually present in the upper and lower reach. A permanent four-antenna PIT tag array is located near the mouth of the creek (site NMC). In 2016, an estimated 25 steelhead spawned in Ninemile Creek, 16 hatchery and 9 of natural origin. Zero redds were found below the PIT tag antenna array during weekly surveys. From 2005-2016, the average number of steelhead in Ninemile creek was 27 (max=77 in 2008).

3.2.14 Foster Creek (located outside the Okanogan subbasin)

Although Foster Creek is not located within the Okanogan subbasin, OBMEP installed a PIT tag antenna and conducted redd surveys every other week in 2016 to further describe the spatial extent of Upper Columbia River steelhead above Wells Dam. Foster Creek was successfully surveyed across the entire 2016 spawning period, due to clear water and stable flows. A total of 13 steelhead redds were observed for an estimated total of 25 steelhead. All redds were located below the Chief Joseph Dam outflow pipe (Figure 25), where water is bypassed from the Chief Joseph Dam forebay into the lower reaches of Foster Creek. No redds surveys were conducted in the upper reach in 2016 due to ongoing construction on a bridge that spanned the creek at Chief Joseph dam; access was not allowed.

The total steelhead spawning estimate for 2016 based on PIT tag detections was 90 steelhead, 77 hatchery and 13 natural origin. During 2016 sufficient water existed for adult steelhead to migrate into the upper reaches. It is likely that redds were constructed at the base of the dam in 2016. Spatial distribution of redds located during previous years surveys are detailed on Figure 25.

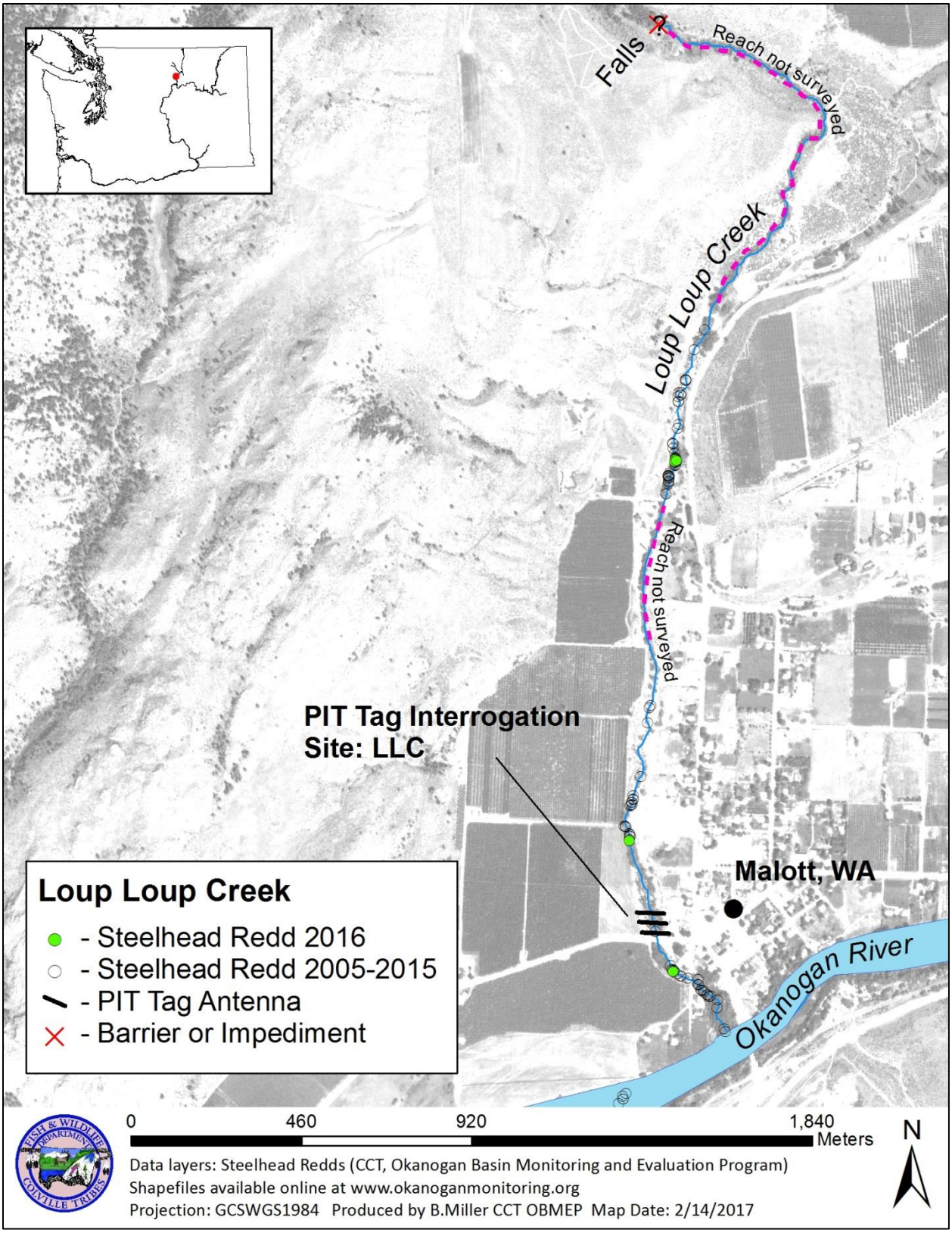

Figure 13. Spatial distribution of summer steelhead redds documented in Loup Loup Creek.

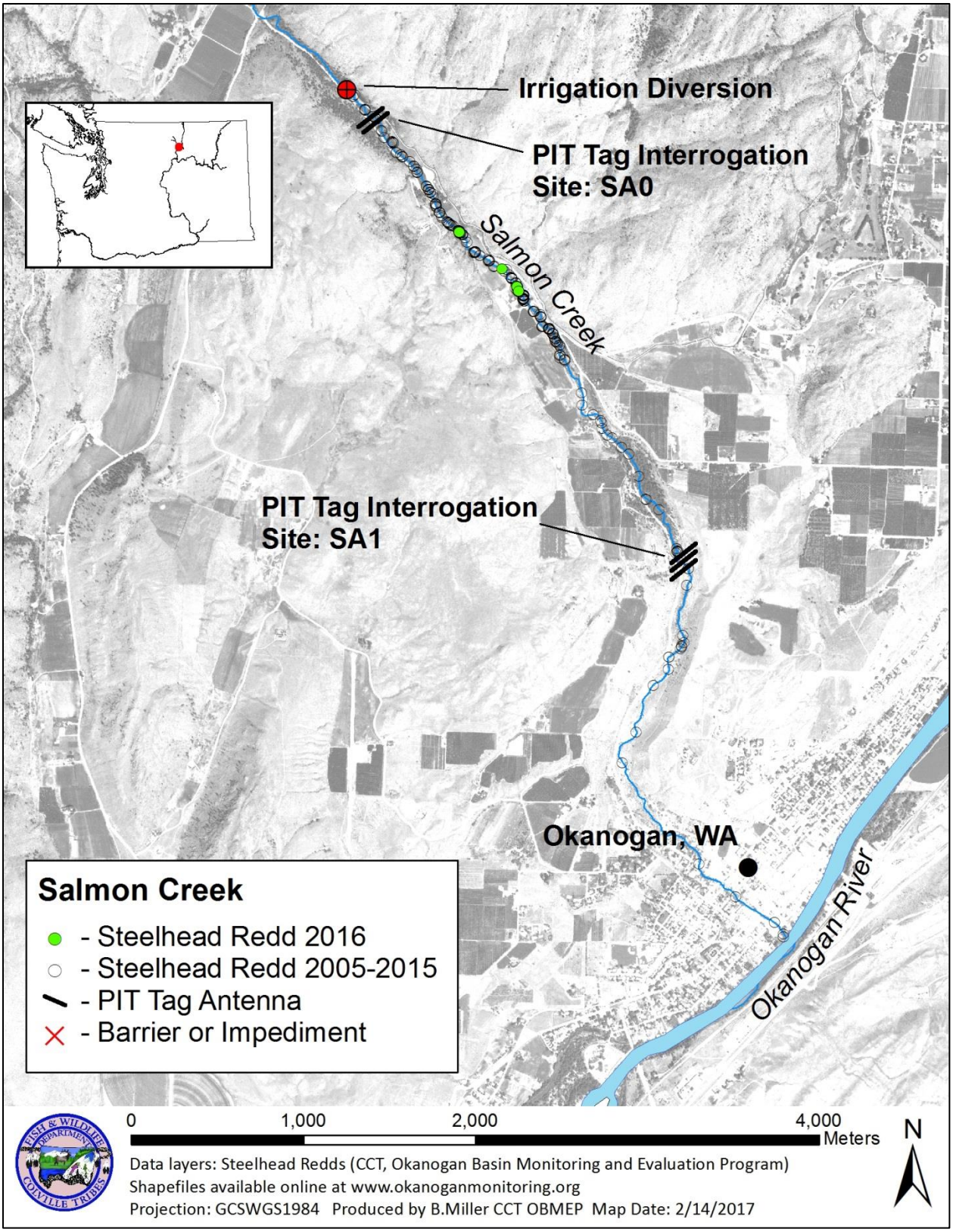

Figure 14. Spatial distribution of summer steelhead redds documented in Salmon Creek, from the confluence to the irrigation diversion.

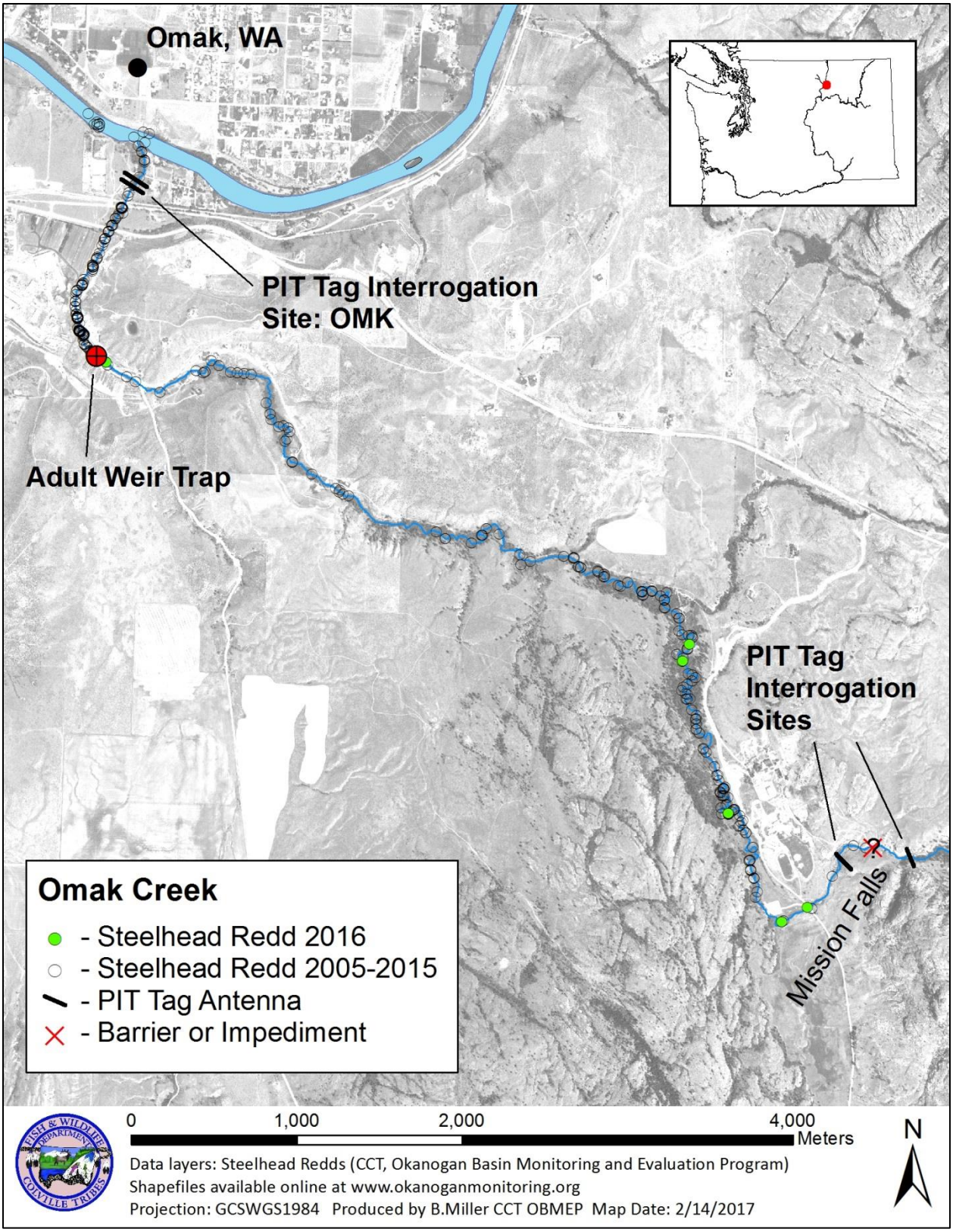

Figure 15. Spatial distribution of summer steelhead redds documented in Omak Creek, from the confluence to Mission Falls.

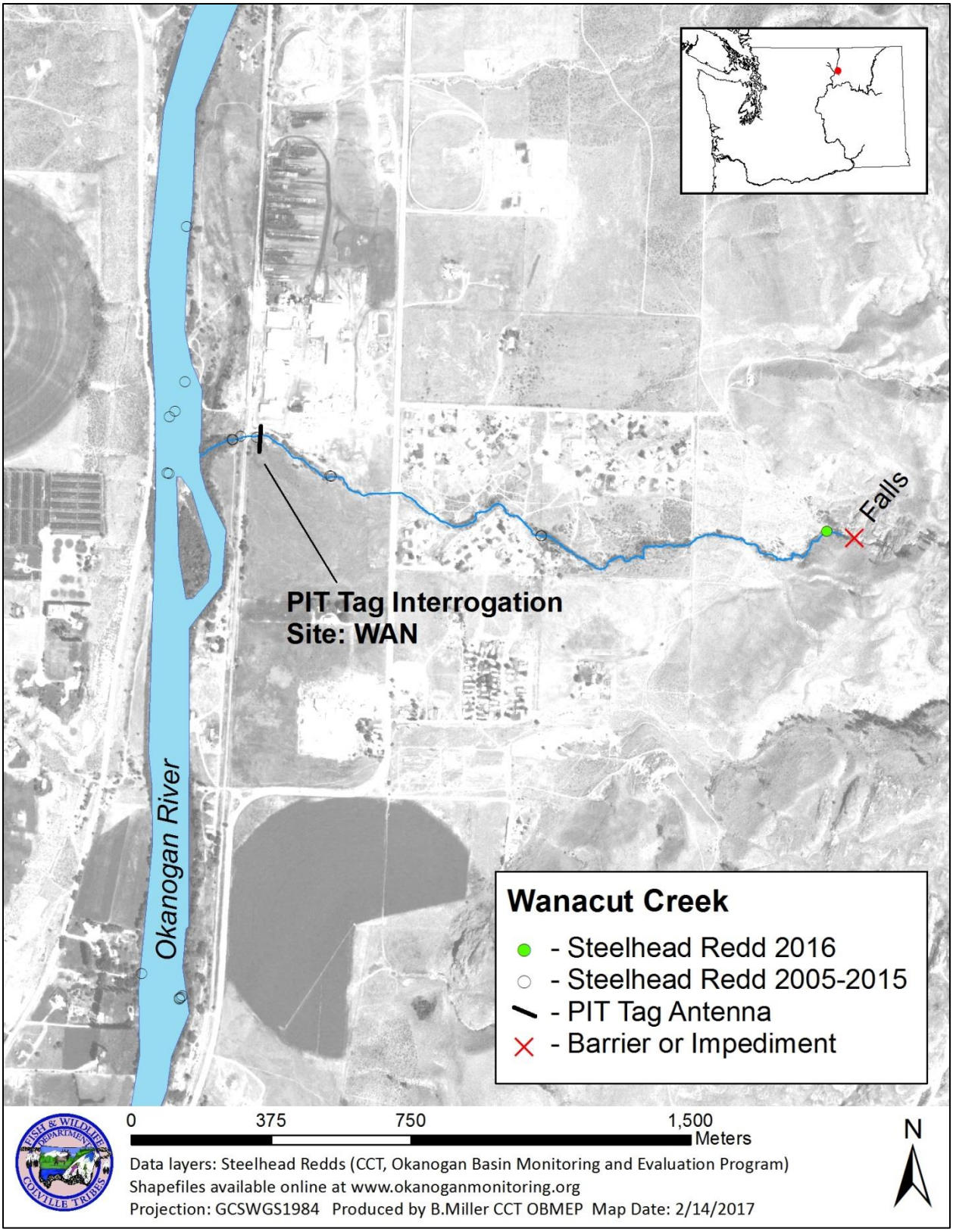

Figure 16. Spatial distribution of summer steelhead redds documented in Wanacut Creek.

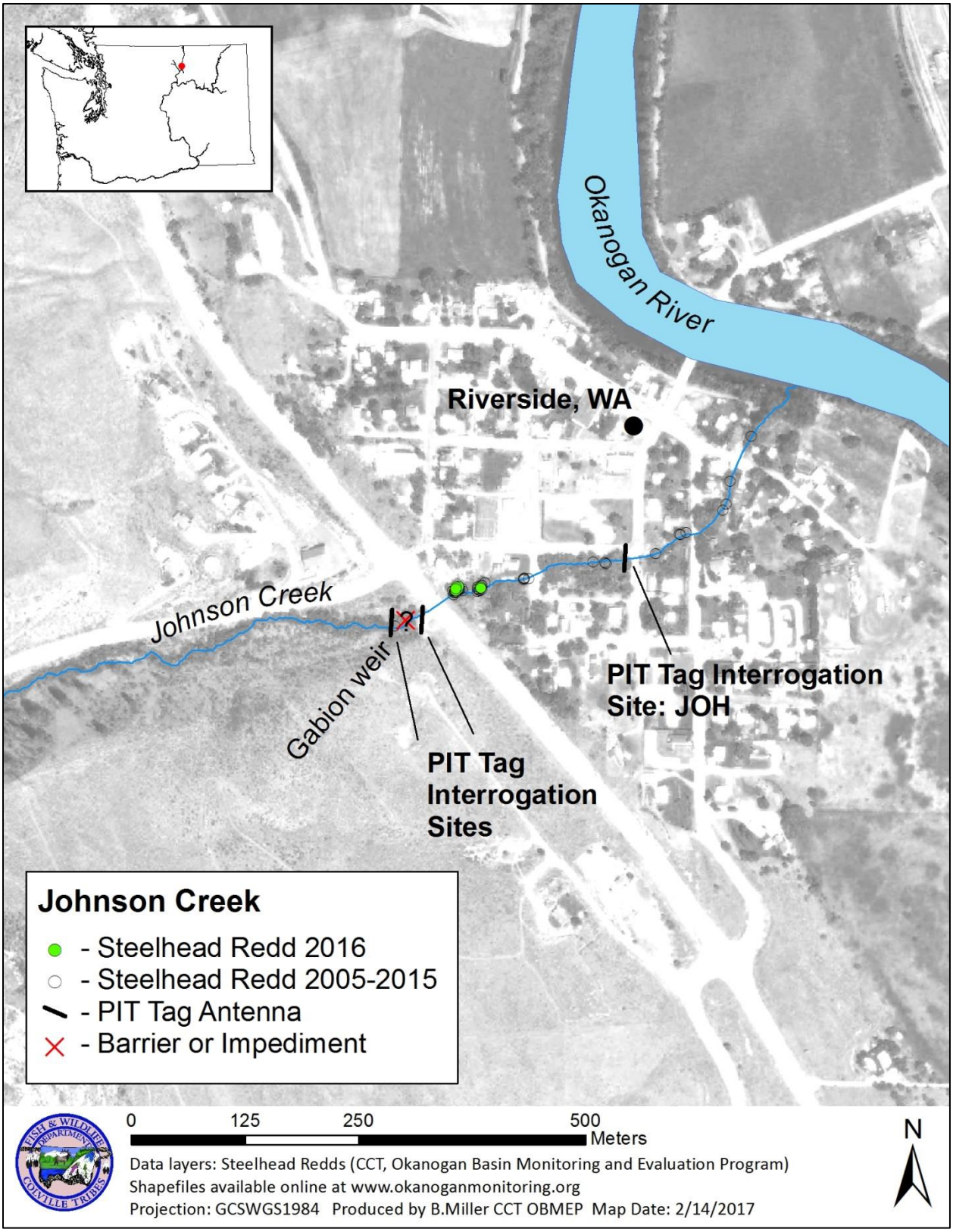

Figure 17. Spatial distribution of summer steelhead redds documented in Johnson Creek, from the confluence to the gabion weir.

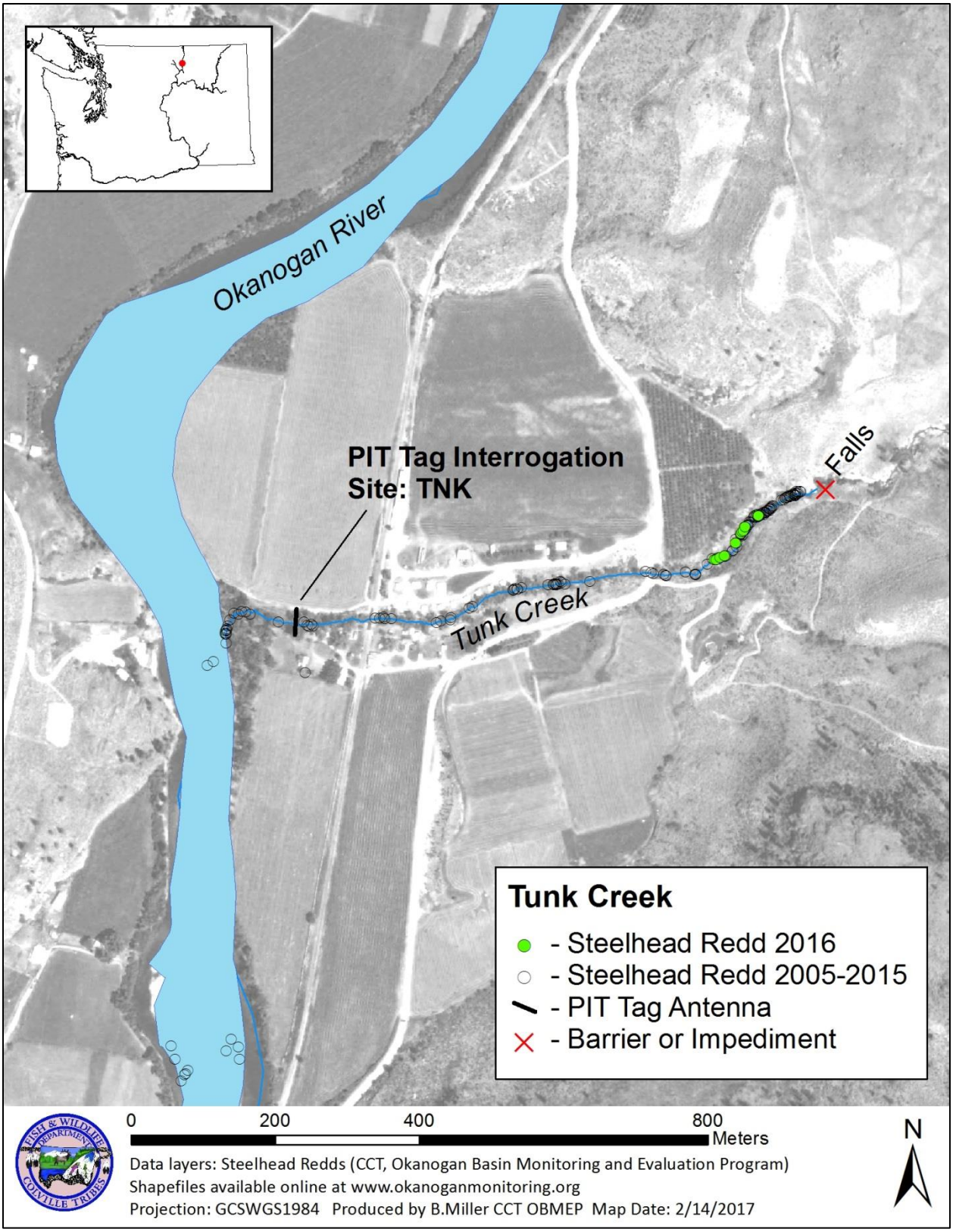

Figure 18. Spatial distribution of summer steelhead redds documented in Tunk Creek.

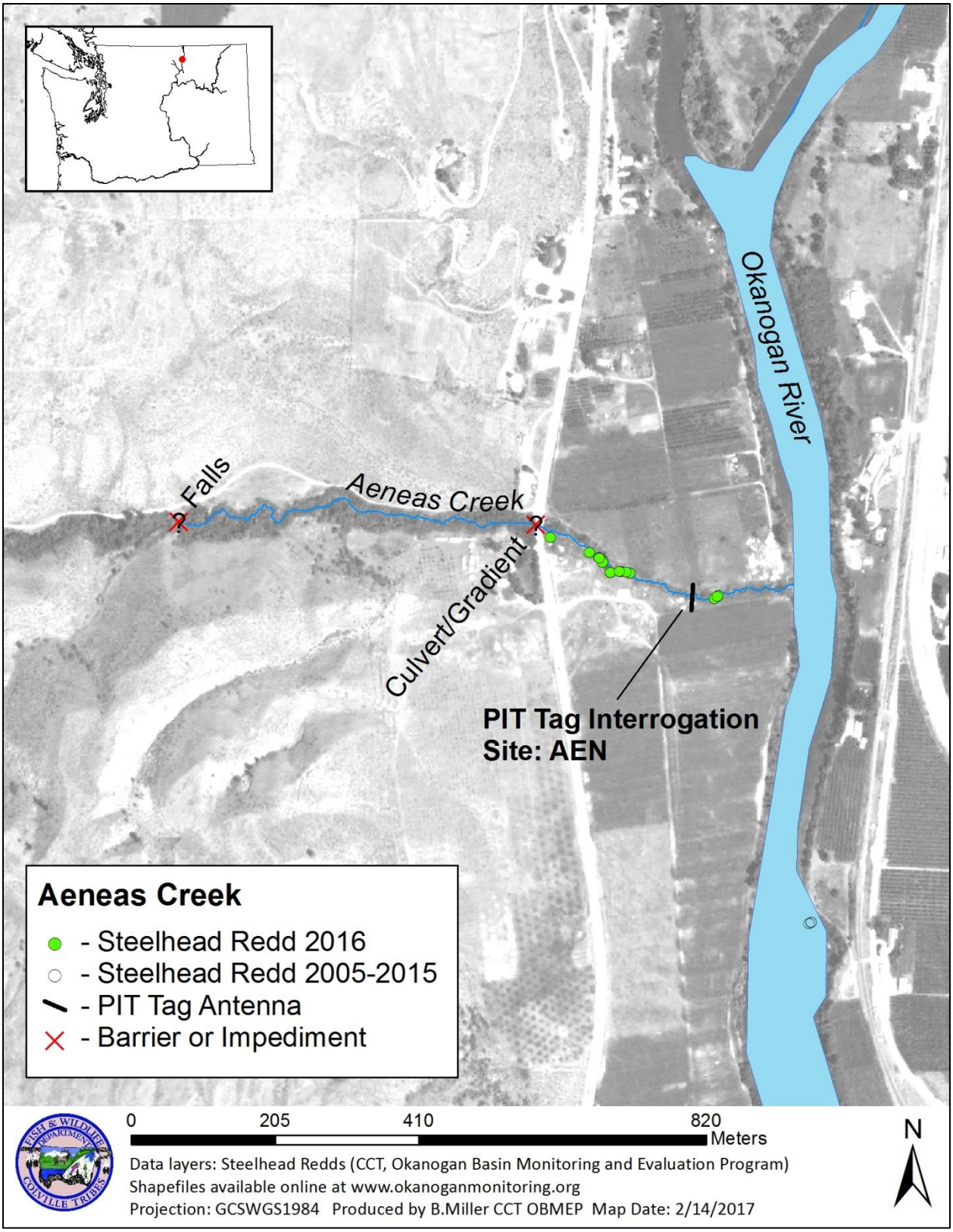

Figure 19. Spatial distribution of summer steelhead redds documented in Aeneas Creek.

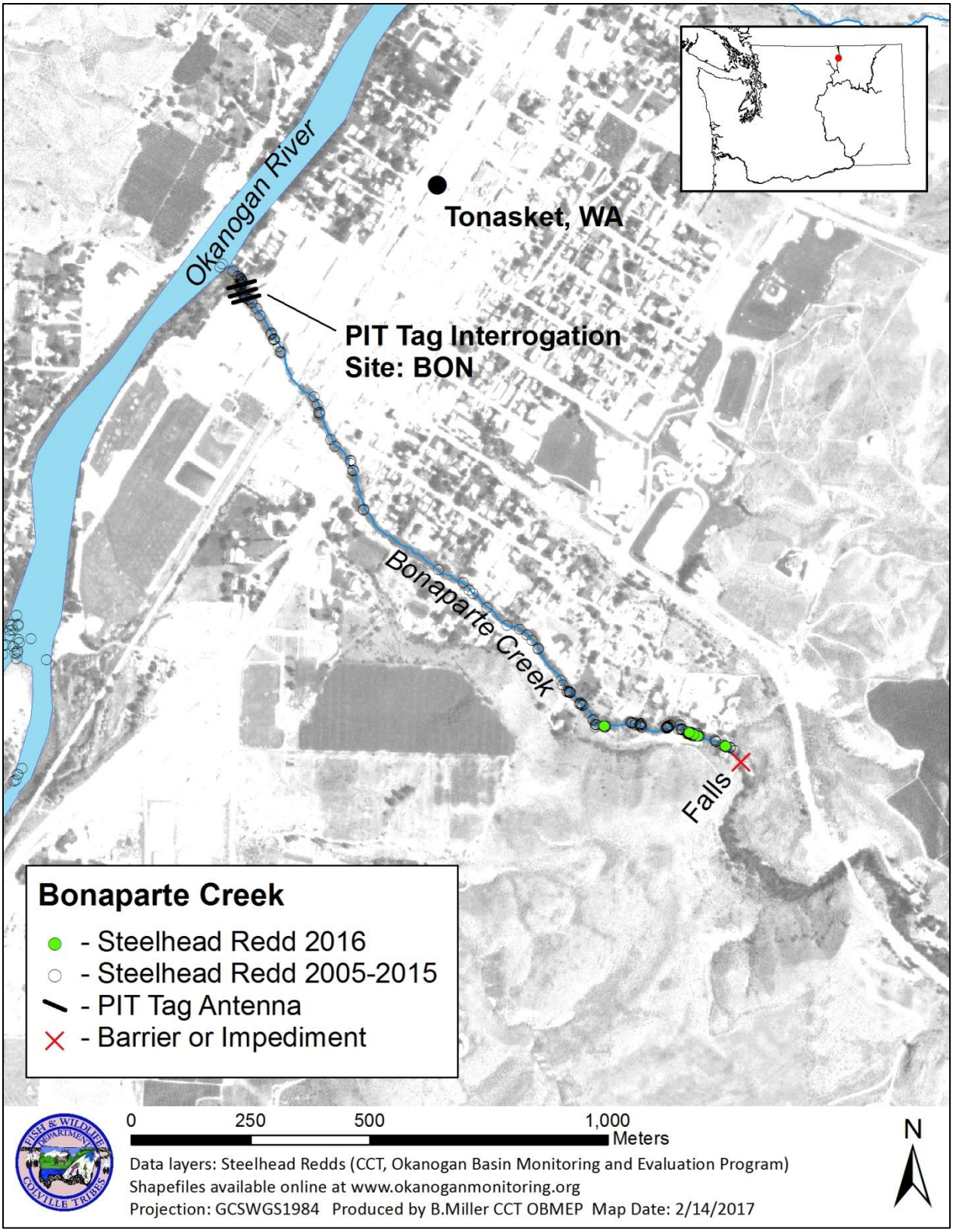

Figure 20. Spatial distribution of summer steelhead redds documented in Bonaparte Creek.

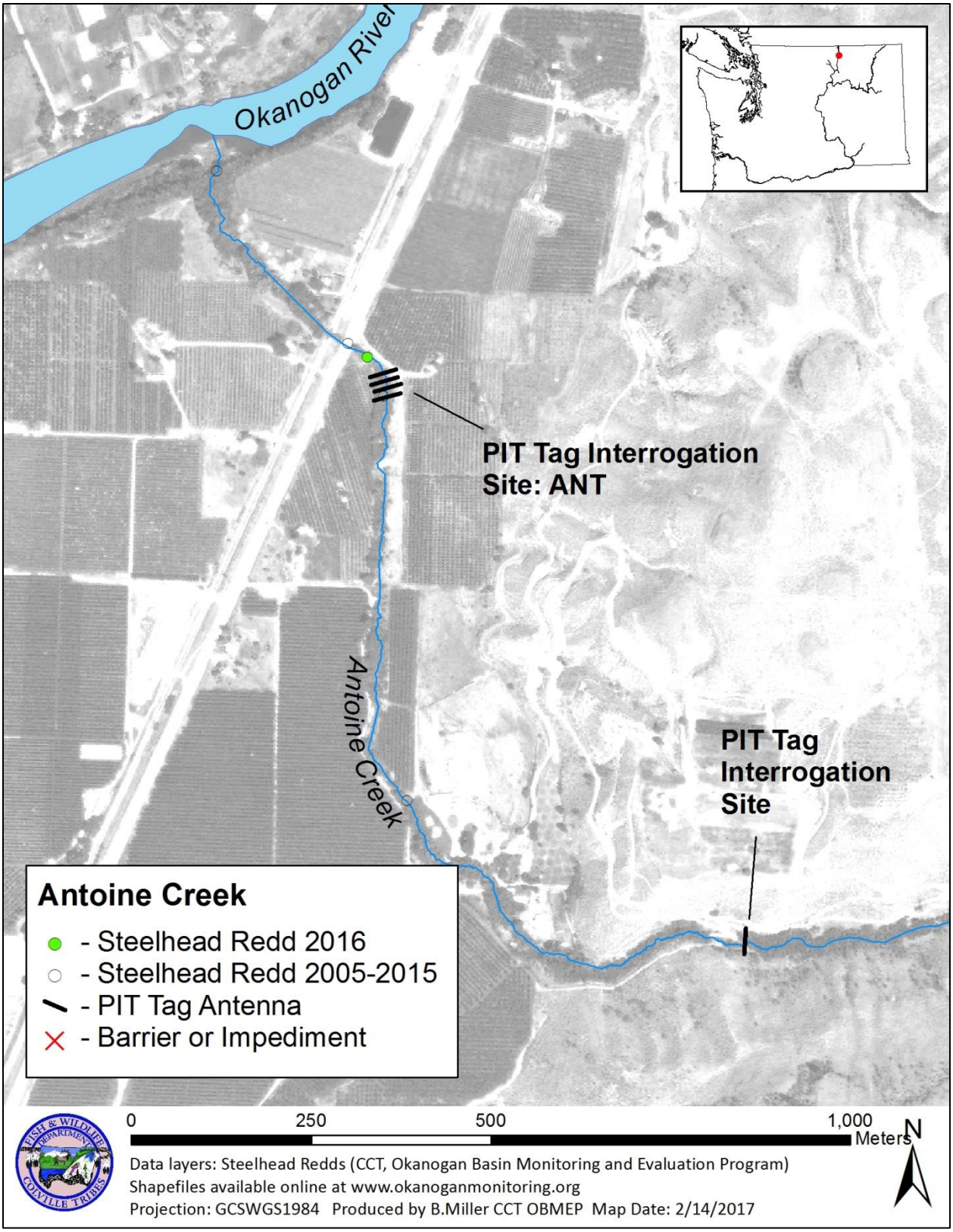

Figure 21. Spatial distribution of summer steelhead redds documented in Antoine Creek.

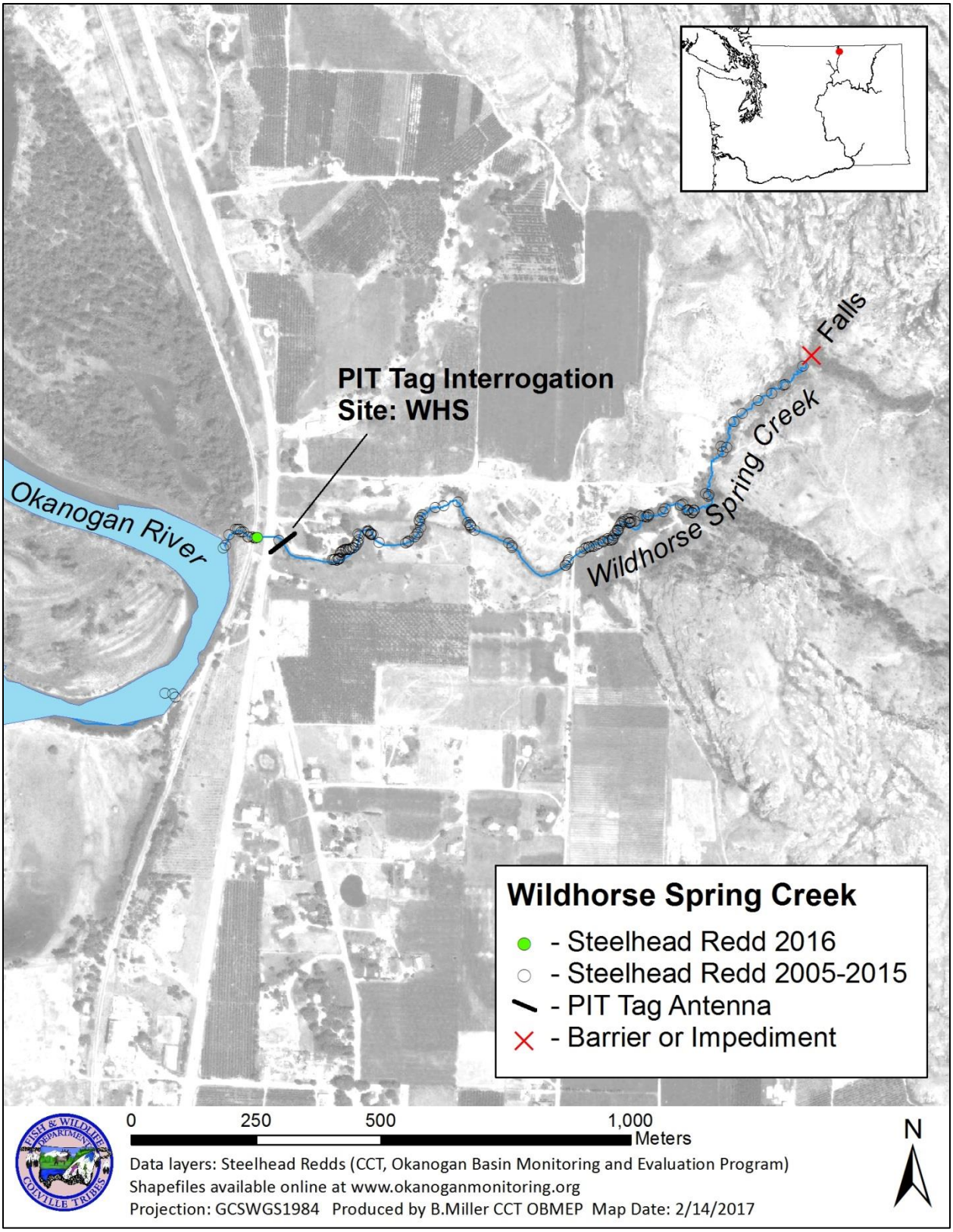

Figure 22. Spatial distribution of summer steelhead redds documented in Wildhorse Spring Creek.

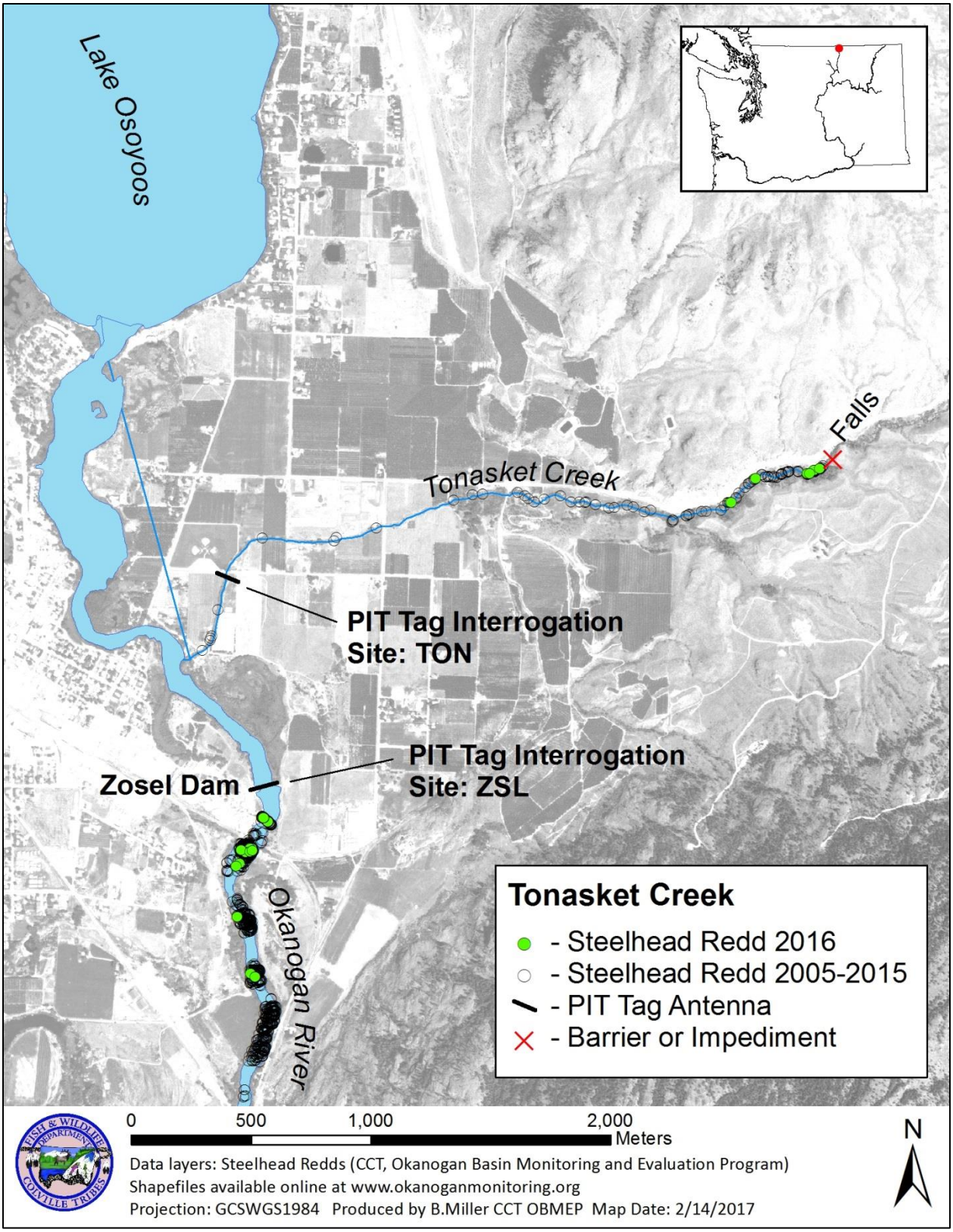

Figure 23. Spatial distribution of summer steelhead redds documented in Tonasket Creek.

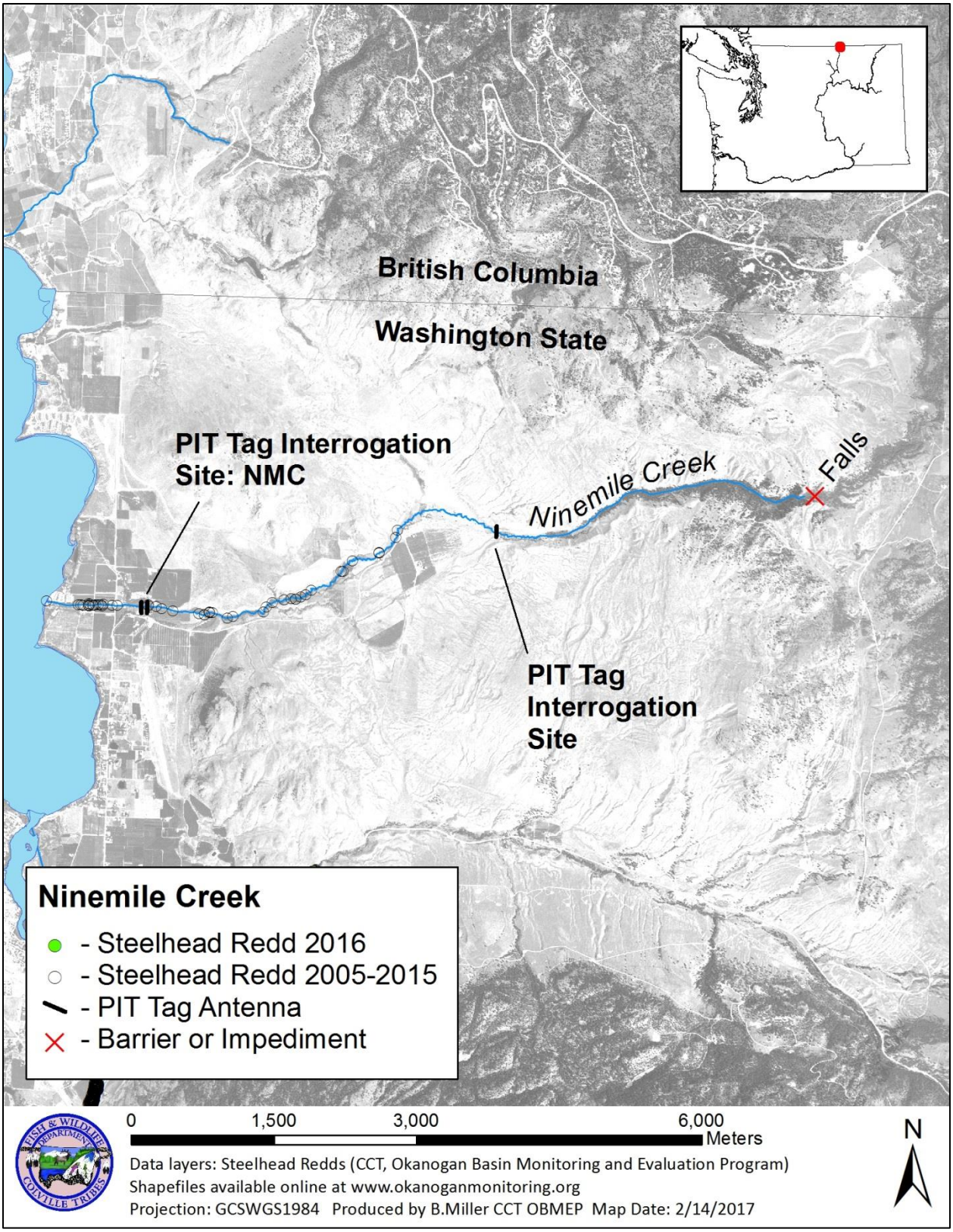

Figure 24. Spatial distribution of summer steelhead redds documented in Ninemile Creek.

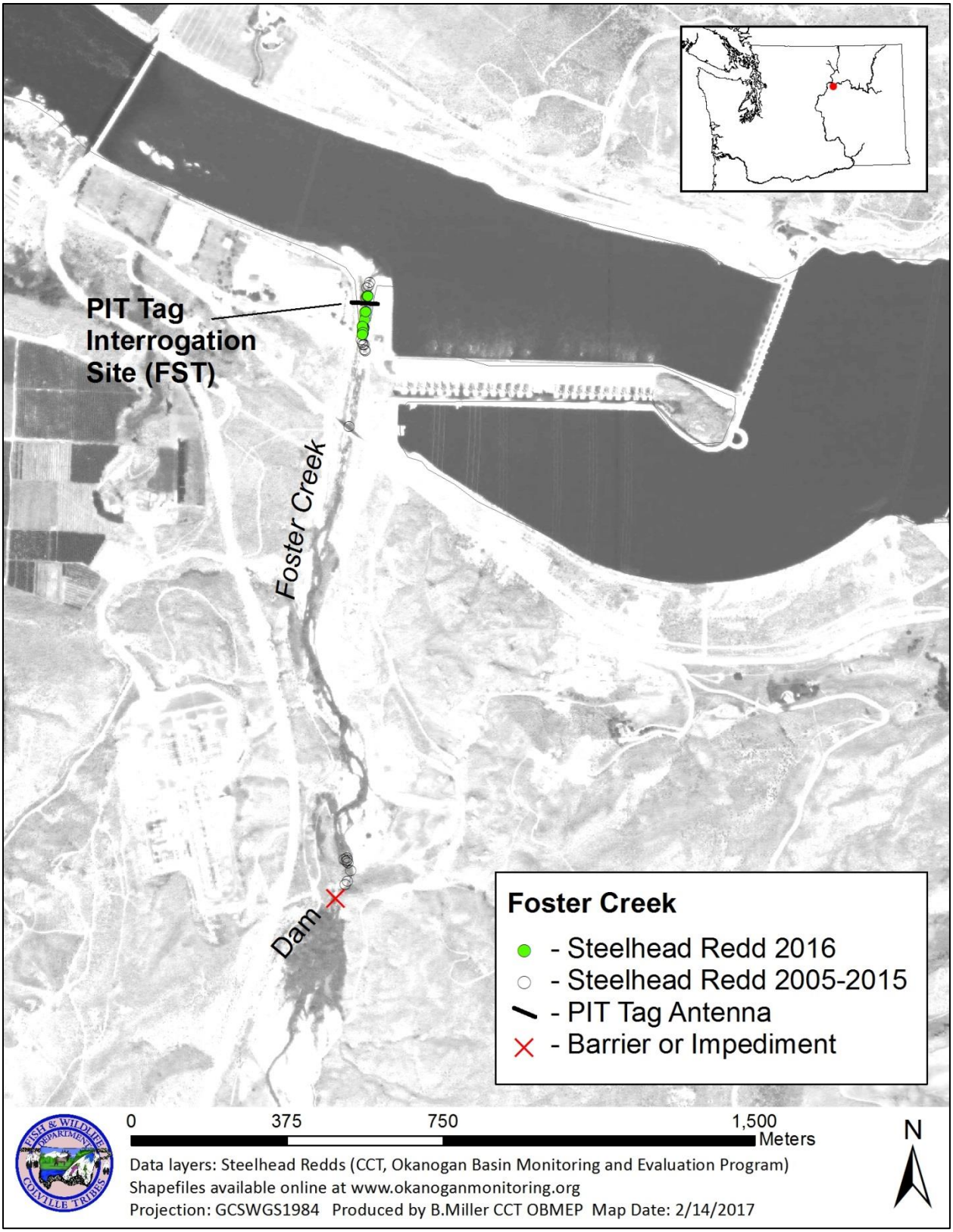

Figure 25. Spatial distribution of summer steelhead redds documented in Foster Creek.

3.3 Zosel Dam and Upstream Locations

Zosel Dam is the outlet of Lake Osoyoos, which extends into the Canadian portion of the subbasin. Besides the mainstem Okanagan River, three other perennial tributaries flow into Lake Osoyoos, two are located on the Washington State side of the border (Ninemile and Tonasket creeks) and one is located in British Columbia (Inkaneep Creek). Both Ninemile and Tonasket creeks have had PIT tag interrogation sites installed for a number of years; additionally, a permanent PIT array was installed in Inkaneep Creek in 2015. Approximately 5 km upstream of Lake Osoyoos, on the Okanagan River mainstem, a permanent PIT array spans the entire channel (site OKC situated at Vertical Drop Structure 3) which has been in operation since 2010. Since all salmon migrating upstream of Lake Osoyoos must cross over OKC, it has been a pivotal detection site for enumerating adult salmon abundance and observing migration timing. PIT arrays were also installed on two other British Columbia tributaries located further up in the subbasin, Shingle and Shuttleworth creeks.

Until 2009, the outlet dam of Vaseux Lake (McIntyre Dam) was the upstream migration barrier for anadromous salmonids. The dam was redesigned in 2009 and, currently, the outlet dam of Okanagan Lake at Penticton, BC is the upstream barrier. A dam also exists at the outlet of Skaha Lake (Okanagan Falls, BC), which had a fish ladder installed in 2014. As well, 17 Vertical Drop Structures (VDS) currently exist along the Okanagan mainstem, 13 between Oliver, BC and Lake Osoyoos, and four between Skaha Lake and Vaseux Lake. The majority of the Canadian portion of the mainstem Okanagan River is characterized as being straightened and channelized. The main tributaries to the mainstem Okanagan River include Shingle Creek, Ellis Creek, McLean Creek, Shuttleworth Creek, Vaseux Creek, and a number of small perennial streams.

Zosel Dam is located at the downstream end of Osoyoos Lake immediately above Okanogan River Reach 7, the largest steelhead spawning area in the Okanogan subbasin. The fall back rate at Zosel Dam is currently unknown, but may be relatively large due to the heavily utilized spawning habitat available in Okanogan Reach 7. Zosel Dam was constructed in its current state in 1987 with undershot spillways. When these spillway gates are raised to a height of more than 12 inches, fish may be able to ascend through the spillways and bypass the fishway monitoring systems. Underwater video counting of steelhead was discontinued at Zosel Dam in 2015 due to sufficient PIT tag detection sites upstream of that point.

4.0 Discussion

OBMEP monitored adult Viable Salmonid Population (VSP) abundance attributes (McElhany et al. 2000) within the subbasin for Okanogan River summer steelhead. Adult monitoring was conducted through redd surveys, underwater video counts, and PIT tag expansion estimates. From 2005 through 2016, the average total number of steelhead spawners in the Okanogan subbasin was 1,767 and the average number of naturally produced spawning steelhead was 328. Summer steelhead spawning estimates were compared with recovery goals outlined by the Upper Columbia Spring Chinook and Steelhead Recovery Plan (UCSRB 2007). The Upper Columbia Spring Chinook and Steelhead Recovery Plan states that 500 naturally produced adult steelhead would meet the minimum abundance recovery criteria within the U.S. portion of the Okanogan subbasin; if the Canadian portion of the subbasin was included, minimum abundance recovery criteria would be 1,000 naturally produced adults (UCSRB 2007).

Results from steelhead adult enumeration efforts indicate that the number of spawning steelhead in the Okanogan River subbasin, both hatchery and naturally produced, increased since data collection began in 2005. Spawning occurred throughout the mainstem Okanogan River, although narrowly focused to distinct areas that

contained suitable spawning substrates and water velocities. Steelhead spawning has been documented to be most heavily concentrated below Zosel Dam on the Okanogan River and in braided island sections of the lower Similkameen River. It is likely that distribution of spawning is influenced by stocking location because juvenile hatchery steelhead have been released in the Similkameen River, Omak Creek, and Salmon Creek where high volumes of spawners are estimated.

Detailed percent-wild information has been provided annually and every attempt has been made to ensure that these estimates are as accurate as stated methods currently allow. However, these data should be used with caution, as it is difficult to define natal origin through visual observation alone (i.e. intact adipose fin) on redd surveys and underwater video. Values presented in this document represent our best estimate from available information, but the variability surrounding point estimates are currently undefined.

Large variations in estimates exist in many reaches from year to year, but often, these accurately reflect real-world situations rather than survey bias or calculation error. Small creeks may have extremely low flows for two years, blocking access with no spawning occurring, and then experience a large run of fish the following year when sufficient flows exist (e.g. Loup Loup Creek escapement of 0, 0, and 125 for 2008, 2009, and 2010, respectively). This irregular nature of small scale population data frequently results in data being scattered loosely around a linear trend line. We have made every effort to ensure that the reported values are as accurate as possible, including using multiple data collection methods for validation, comprehensive on-the-ground surveys, and best scientific judgment based on extensive local experience with the subbasin.

Annual variations in physical habitat and environmental factors can profoundly impact redd distributions in small tributaries to the Okanogan River. Changes in summer steelhead spawning distribution within tributaries appear to be driven by the following four factors: 1) discharge and elevation of the Okanogan River, 2) discharge of the tributary streams, 3) timing of runoff in relation to run timing of steelhead, and 4) stocking location of hatchery fish. The first three factors are largely based upon natural environmental conditions, which can be altered dramatically by such things as water releases from dams, irrigation withdrawals, and variations in climate. Years such as 2006, 2008, and 2009 clearly show how low tributary discharge can dramatically alter spawning location and reduce the available tributary habitat for steelhead to utilize.

The overall outcome of adult steelhead monitoring in the Okanogan subbasin is to guide natural resource managers' decisions to minimize threats to steelhead, choose restoration actions that will have the most positive impact, and set measurable steelhead enhancement objectives to coincide with fiscal investments over multiple jurisdictions. As monitoring efforts proceed, the Okanogan Basin Monitoring and Evaluation Program expects to continually deliver practical status and trend monitoring data and to make those data useful and readily available for use in more comprehensive, broad-scale analyses.

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