U.S. Fish and Wildlife Service

Pilot project to develop a long-term aquatic monitoring program at National Wildlife Refuges in Region 1 for climate change

FY2014-FY2015 Progress Report

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On the cover: *Fisheries and Refuges personnel investigate aquatic monitoring sites at Little Pend Oreille NWR in 2014. (Photo: S. Lohr)*

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PILOT PROJECT TO DEVELOP A LONG-TERM AQUATIC MONITORING PROGRAM AT NATIONAL WILDLIFE REFUGES IN REGION 1 FOR CLIMATE CHANGE
FY2014—FY2015 PROGRESS REPORT

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Executive Summary – The U.S. Fish and Wildlife Service has developed and is implementing a strategic plan to help ensure the sustainability of natural resources (i.e., fish, wildlife, plants, and their habitats) under conditions expected from climate change and other environmental stressors. To support the strategic plan in Region 1, Service programs are collaborating to develop and implement a long-term aquatic monitoring program for evaluating effects of climate change at National Wildlife Refuges (NWRs). The goal of the monitoring program is to evaluate evidence of climate change in physical attributes at NWRs and associated changes in aquatic communities. Specific objectives are to: 1) establish long-term sentinel sites representing mainland NWRs across the range of ecoregions in Region 1; 2) describe how physical attributes vary through time; 3) describe how biological attributes vary through time; 4) analyze for potential temporal change in attributes by ecoregion; and 5) assess relationships in physical and biological attributes by ecoregion. A three-year pilot project presently is underway to assess implementation of the aquatic monitoring program. This progress report presents background information leading to development of the program, including a chronology of activities, rationale for the program, considerations in its development, appropriate field methods, and process used to select five sentinel sites. The progress report also describes implementation of the pilot project, which includes preparation, and reconnaissance activities that began in FY2014, initial field surveys that were conducted in FY2015, and ongoing data management activities. This report concludes with preliminary conclusions and recommendations for continued implementation of the pilot project.

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Introduction

Effects of accelerating climate change on natural resources and associated ramifications for people represent an unprecedented conservation challenge. In response, the U.S. Fish and Wildlife Service (Service) has developed and is implementing a strategic plan (USFWS 2010) to help ensure the sustainability of natural resources (i.e., fish, wildlife, plants, and their habitats) under conditions expected from climate change and other environmental stressors. The Strategic Plan for Climate Change acknowledges considerable uncertainties in the specific conditions and rate of change for habitat attributes anticipated to result from climate change, and describes three strategies, adaptation, mitigation, and engagement, that the Service will use to address conservation under predicted environmental conditions and accompanying uncertainties.

To support implementation of the Service's Strategic Plan for Climate Change relative to fisheries and aquatic resources in Region 1, Fisheries Project Leaders identified areas of emphasis during their coordination meeting in 2011. These areas were National Fish Hatchery programs and operation, key aquatic species, and aquatic resources at National Wildlife Refuges (NWRs). All areas of emphasis were intended to support actions primarily addressing a better understanding of the status and trends of aquatic species and their habitats relative to climate change, potential adaptation strategies, and inventory and monitoring. For the third area, the primary action was for Fisheries to assist NWRs in designing and implementing a long-term aquatic monitoring program for evaluating effects of climate change.

This report documents the development and implementation of a long-term aquatic monitoring program for climate change at Region 1 NWRs. The goal of the monitoring program is to evaluate evidence of climate change in physical attributes at NWRs and associated changes in aquatic communities. Specific objectives are to:

1. Establish long-term sentinel[1] sites representing mainland NWRs across the range of ecoregions in Region 1.
2. Describe how physical attributes vary through time.
3. Describe how biological attributes vary through time.
4. Analyze for potential temporal change in attributes by ecoregion.
5. Assess relationships in physical and biological attributes by ecoregion.

In general, the monitoring program relies on temporal analyses at each sentinel site using time series of physical attributes (i.e., air temperature, water temperature, and stream discharge, which are continuously recorded, and habitat, which is periodically surveyed) and biological attributes (i.e., metrics describing aquatic assemblages, which are periodically surveyed). We intend to implement the program during a three-year period as a pilot project to assess its sustainability, logistical constraints, and likely performance for long-term implementation.

[1] As used here, sentinel sites are NWRs where a stream reach has been identified and standardized methods to describe and measure physical and biological attributes are applied through time, allowing assessment of temporal changes and associations among attributes at each reach.

The report is organized by: 1) Background, which is a narrative describing a brief chronology, rationale, considerations, methods, and sentinel site selection process used in developing the program; and 2) Pilot Implementation, which reports the activities and results from the initial year of implementation, 2015, at each sentinel site.

Background

Brief Chronology

The approach used to develop the program primarily relied on the annual NWR-Fisheries Meeting, which is a forum to exchange information and coordinate activities among Service programs and various workgroups. The concept of developing an aquatic monitoring program was initially introduced during the 2011 NWR-Fisheries Meeting and further discussed during the 2012 meeting (see Lohr et al. 2014, Appendices). A brief questionnaire concerning potential goals, issues, attributes, and sites that could be addressed was distributed prior to the latter meeting to help facilitate discussion so that the desire for and scope of a monitoring program could be further defined.

A Fisheries workgroup (i.e., representatives from the CRFWCO, Idaho Fish and Wildlife Conservation Office (IFWCO), Mid-Columbia Fish and Wildlife Conservation Office (MCFWCO), Western Washington Fish and Wildlife Conservation Office (WWFWCO)) developed a proposal identifying the goal, objectives, considerations, and methods of the monitoring program, as well as potential sentinel sites, which were primarily based on previous work history between Fisheries and NWRs. The proposal was presented during the 2013 NWR-Fisheries Meeting. A recommendation on the proposal was to conduct an explicit, systematic assessment of various attributes at NWRs (e.g., watershed conditions, prevalence of non-climate-related stressors, relative length of stream reaches on NWRs, fish species present) to assist in selecting sentinel sites. A cross-program workgroup (i.e., Fisheries, R1 Refuges Branch of Biology and Inventory and Monitoring Initiative, and Water Resources) conducted the assessment, and recommended the establishment of sentinel sites at these five refuges: Kootenai NWR; Little Pend Oreille NWR; Malheur NWR; William L. Finley NWR; and Willapa NWR.

A joint presentation on the monitoring program and sentinel site assessment was made by Fisheries and Refuges Branch of Biology during the 2014 NWR-Fisheries Meeting and to the Regional Climate Board. The Natural Resource Program Center-Water Resources, provided funding to purchase equipment (e.g., temperature and pressure/temperature loggers) for the program and conduct reconnaissance visits to each sentinel site. Aquatic surveys were conducted in 2015 with funding provided by the R1 Inventory and Monitoring Initiative, and 2016 surveys were planned with funding provided by the Natural Resource Program Center-Water Resources.

Rationale for Implementation

Climate change is expected to affect multiple attributes influencing habitat and its suitability for various species in aquatic systems (e.g., Haak et al. 2010; National Wildlife Federation 2011). Specifically, climate change is anticipated to alter patterns of air temperature and precipitation, which will directly affect water temperature and hydrologic regime of streams and rivers

(Environmental Protection Agency (EPA) 2012). Direct effects of altered water temperature and hydrologic regimes on native aquatic species may consist of conditions that exceed physiological thermal tolerances or produce incompatible disturbance regimes for certain life history stages. Indirect effects may consist of altered processing rates of nutrients, modified habitat structure, or conditions conducive to establishment of invasive non-native species.

Evaluating evidence of climate change at NWRs is of particular importance in that NWRs represent the principal land base managed by the Service, and the mission of the NWR system is to administer a national network of refuges for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats for the benefit of present and future generations of Americans. Thus, evaluating evidence of climate change on physical and biological attributes through a long-term aquatic monitoring program would provide information to assist in conservation at NWRs. Examples of how information may contribute to conservation include: 1) providing an early indication of climate change effects on aquatic habitats and species; 2) detecting changes in status of non-native species indicative of climate change or presence of new invasive species; 3) characterizing conditions so that adaptive management strategies can be considered in a timely manner: and 4) providing basic information to meet inventory and monitoring needs. Such contributions to aquatic conservation also support objectives in the Region 1 Fisheries Program Strategic Plan and the National Fish and Aquatic Conservation Program Strategic Plan (USFWS 2008; 2016). Moreover, detecting effects of climate change may contribute to strategic habitat conservation, for example by indicating new aquatic habitat conditions that should be incorporated into biological planning (e.g., revising maps describing ranges in stream temperatures) or appropriate approaches for conservation delivery (e.g., incorporating hydrologic changes in determining the sizes of culverts to accommodate fish passage and transport of bed materials).

Considerations

Major considerations in developing the program concerned the type of analysis (i.e., spatial or temporal comparisons of physical and biological variables) to use and criteria for selection of individual NWRs to include as sentinel sites. Questions of climate change primarily focus on long-term patterns in temperature, precipitation, stream flow, aquatic habitats, and biotic variables (EPA 2012). Thus, the analytic approach selected in the design of the monitoring program consists of temporal trend analyses at individual sentinel sites.

Selection of individual NWRs for sentinel sites relied on representing at least one NWR in each of the three Level I EPA ecoregions (see Commission for Environmental Cooperation 1997) encompassing Region 1 that possessed wadeable stream reaches, and considering ongoing or previous monitoring activities, presence of naturally-maintained aquatic habitats, and other activities occurring off of the NWR that may affect aquatic habitat and species. Landownership and cover upstream of NWRs also were assessed to identify streams considered relatively resistant to non-climate related stressors (e.g., development, water diversion) that could confound our ability to detect a long-term climate trend.

An additional consideration in the design of the monitoring program was the likelihood that activities could be sustained in the long-term. That is, once the necessary infrastructure was in place at each sentinel site (e.g., stream temperature and pressure/temperature loggers), cost of

infrastructure maintenance, field crews, and data analyses would not be overly prohibitive into the foreseeable future. Ability of a trained crew of three individuals to complete field work at a site in a week (i.e., one week for each NWR during a year) was used as a minimum guide in considering methods appropriate for the monitoring program. A consideration for implementation was that each of the four R1 FWCOs would lead monitoring activities for at least one sentinel site within their geographic area of responsibility.

Methods

The approaches selected for collection of physical and biological attributes in the monitoring program are largely based on methods recommended or developed by the EPA. The EPA has developed a document providing guidance for continuous monitoring of temperature and flow in wadeable streams, which assists in the agency's work to establish regional monitoring networks (EPA 2014). The EPA's guidance is being applied at all sentinel sites for temperature (e.g., use of temperature loggers set to record at 30-minute intervals) and ungauged sites for flow (e.g., use of pressure/temperature loggers set to record at 15-minute intervals) for the monitoring program. Flow data generated at gauge stations maintained by Water Resources are used at two sentinel sites.

Methods developed for wadeable streams under EPA's Environmental Monitoring and Assessment Program (EMAP; Peck et al. 2006) are being used to monitor biological attributes and habitat at sentinel sites. The EMAP manual describes standardized field methods for which results of regional pilot applications throughout the United States have successfully characterized ecological conditions using multiple biological assemblages in conjunction with physical and chemical habitat characteristics (Hughes et al. 2000). The EMAP approach identifies nine ecological indicators for assessing chemical, physical, and biological conditions of streams. Measurements are made during the typical low-flow period relative to stream reaches of standardized length (40 channel widths) that are selected using a Generalized Random-Tessellation Stratified (GRTS) design to identify spatially-balanced random points in a stream network.

Various aspects of the EMAP approach (e.g., scope, reach selection, and component indicators) are modified, or not used, in employing its methods for the monitoring program to address our goal, objectives, and considerations. Whereas EMAP survey design allows extrapolation of conditions observed at sites to a broader target population (e.g., streams in a state or region), the scope of the monitoring programs focuses on conditions at specific sites through time. A GRTS design was not used to select stream reaches at sentinel sites; rather, stream reaches for the monitoring program were selected based on a variety of considerations (e.g., proximity to existing gauge stations and physical constraints, such as locations of tributaries, channel conditions, and landownership). The following is a subset of EMAP's component indicators selected to be included in the monitoring program to increase the likelihood for the program's long-term sustainability: water chemistry (pH, conductivity, and dissolved oxygen, all point measurements made during a survey); physical habitat characterization (thalweg profile; woody debris; channel and riparian measurements; and assessment of channel constraint, debris torrents, and recent floods); and aquatic vertebrates (electrofishing survey, for which total length and weight are recorded from a subsample of fish).

We intend to implement the monitoring program as a pilot project during a three-year period in order to evaluate its sustainability, logistical constraints, and likely performance for long-term implementation. During the pilot application, we plan to characterize physical habitat once each year, and survey aquatic vertebrates three times annually, which will allow an assessment of variability in assemblage metrics (e.g., species richness, relative abundance, ecological and physiological traits of taxa) during the course of a field season. Subsampling fish length and weight will allow calculation of condition factor, facilitating an assessment of evidence potentially indicative of environmental stress or presence of pathogens. In addition, benthic macroinvertebrates will be collected, according to EMAP methods, and preserved for processing in the future.

Sentinel Site Selection

In response to recommendations made during the 2013 NWR-Fisheries Meeting, a two-phased approach involving an initial screening and a geospatial assessment was used in a systematic assessment of NWRs. The goal of the assessment was to identify streams at NWRs that were potentially suitable for long-term monitoring given the scope of the monitoring program. The cross-program workgroup conducting the assessment identified a number of attributes of streams, NWRs, and associated watersheds to consider, which are listed below with desirable conditions in parentheses.

- Stream habitat (non-tidal and wadeable)
- Fish fauna diversity (relatively high)
- Prevalence of non-climate-related stressors (relatively unlikely to be severely affected by water diversion, development, logging)
- Stream length and watershed within NWR (substantial portion of stream and watershed on a NWR)
- Existing information or ongoing data collection (substantial amount of relevant information exits or currently being generated)
- NWR location (at least one suitable sentinel site represented in each of the three Level I ecoregions on the mainland of Region 1)
- Interest to pursue monitoring (NWR and Fisheries in agreement)

The intent of the first phase was to reduce the number of potential candidate sites on which a geospatial assessment would be conducted during the second phase. Each workgroup member was queried whether or not to further assess each of the 45 NWRs occurring on the mainland of Region 1, and to provide justification for their response, and note specific areas of interest at a NWR appropriate for further assessment. Members' responses were largely based on their familiarity with areas, available information, and information provided to members by NWR managers and biologists. No candidate NWR was eliminated from consideration if one member recommended that it should be further assessed or was uncertain. Results of the query were discussed over the course of two meetings, and ultimately 13 NWRs were selected to be further assessed in the second phase (Table 1, see Appendix A).

Table 1. Results of the two-phased assessment to select sentinel sites at R1 NWRs (X under phase 1 screening indicates that the NWR was excluded from further consideration).

NWR	Areas of Interest	Phase 1-Screening	Phase 2-Geospatial Assessment Comments concerning selections
		Marine West Coast Forest Ecoregion	
Bandon Marsh	Fahys Creek		Not selected—short stream reach on NWR, high proportion of private ownership in watershed
Grays Harbor		X	
Julia Butler Hansen		X	
Lewis and Clark		X	
Nestucca Bay		X	
Siletz Bay		X	
Willapa	Streams east of 101, Porters Point and Bear River Units		Selected to represent Marine West Coast Forest Ecoregion—two streams (Headquaters and Omeara) had the highest proportion of federal ownership in the ecoregion (66% and 45%, respectively), Omeara Creek selected after reconnaissance field visit
Cape Meares		X	
Copalis		X	
Flattery Rocks		X	
Oregon Island		X	
Quillayute Needle		X	
Three Arch Rocks		X	
Dungeness	Dean Creek		Not selected—short stream reach on NWR, concerns with passage and development in watershed
Nisqually	Nisqually River	X	
Protection Island		X	
San Juan Island		X	
Ankeny		X	
Baskett Slough		X	
Ridgefield	Gee Creek	X	
Steigerwald Lake		X	
Tualatin River	Chicken Creek	X	
William L.Finley	Muddy Creek, others on main unit		Selected to represent Marine West Coast Forest Ecoregion—extensive reach (13.6 km) of Muddy Creek occurs on NWR, third highest proportion of federal ownership in ecoregion (18%), contains ODEQ survey site (considered "least disturbed" relative to similar valley streams), represents interior portion of ecoregion compared to Willapa NWR
		Northwestern Forested Mountains Ecoregion	
Franz Lake	Indian Mary Creek		Not selected—concerns with passage to watershed
Pierce	Hardy Creek		Not selected—short stream reach on NWR
Conboy Lake		X	
Kootenai	Myrtle Creek		Selected to represent Northwestern Forested Mountains Ecoregion—Myrtle Creek had a high proportion of federal ownership in the watershed (82%), history of work by Idaho FRO, fish species considered sensitive to climate change
Little Pend Oreille	Bear Creek, Little Pend Oreille River		Selected to represent Northwestern Forested Mountains Ecoregion—extensive reach (10 km) of Little Pend Oreille River occurs on NWR, relatively high proportion of federal ownership in watershed (43-56% depending on reach, West or at Blacktail Road), FWS Water Resources gauge station operated in the West reach, West reach selected after reconnaissance field visits
Grays Lake		X	

NWR	Areas of Interest	Phase 1-Screening	Phase 2-Geospatial Assessment Comments concerning selections
		North American Deserts Ecoregion	
Cold Springs		X	
Columbia		X	
McKay Creek		X	
McNary		X	
Saddle Mountain		X	
Toppenish	Toppenish Creek		Not selected—substantial water diversions and management activities in watershed upstream
Turnbull	Pine Creek		Not selected—concerns with effects of water impounds on the NWR
Umatilla		X	
Camas	Camas Creek	X	
Deer Flat		X	
Minidoka		X	
Hart Mountain	Willow, Rock, and Guano creeks		Not selected—low fish diversity (1 or 2 species present) in each stream
Malheur	Blitzen River, Bridge Creek		Selected to represent North American Deserts Ecoregion—Bridge Creek possesses high proportion of federal ownership (76%) and a relatively diverse fish fauna compared to other NWR in the ecoregion, FWS Water Resources gauge station operated in the reach
Sheldon	Virgin and Fish creeks		Not selected—low fish diversity (1 or 2 species present) in each stream
Oxford Slough		X	
Bear Lake		X	

The intent of the second phase was to conduct a systematic geospatial assessment of the 13 NWRs to facilitate selection of suitable sentinel sites for the monitoring program. Water Resources performed the assessment using regional and national datasets (USGS Streamstats application, BLM Federal Ownership layer, National Land Cover Dataset). The workgroup identified the lowermost point for a potential stream survey reach for each area of interest at the 13 NWRs. These points were typically at the NWR boundary, a stream gauge station, or upstream of inappropriate stream reaches (e.g., those subject to tidal influence). Variables, which were calculated or summarized relative to these points, included: 1) stream length to the NWR boundary upstream; 2) total watershed area upstream; 3) landownership in watershed upstream (i.e., percent private, Service, Federal); 4) land cover in watershed upstream (13 categories); and 5) basin characteristics (mean annual precipitation, mean maximum/minimum air temperatures, mean and maximum elevations). All variables were presented in a spreadsheet, and landownership and cover displayed in figures that included aerial photos of each NWR.

The workgroup considered landownership and cover as primary indicators for the prevalence of non-climate-related stressors, and used aerial photos to indicate areas most susceptible. All variables were discussed among members relative to our considerations to select sentinel sites (Appendix A). Five sites were selected, Kootenia NWR, Little Pend Oreille NWR, Malheur NWR, Willapa NWR, and William L. Finley NWR (Table 1). Survey reaches were based on field visits and collaboration with NWR personnel.

Pilot Implementation

Pilot implementation of the monitoring program began in 2014, and consisted of three general activities. These were: 1) preparation and reconnaissance; 2) field surveys; and 3) data management.

Preparation and Reconnaissance

Preparation for implementing the program included procuring equipment and conducting accuracy checks on temperature and pressure/temperature loggers. Sets of equipment needed by FWCOs were purchased during summer 2014, which included such items as hand-held water quality meters, data loggers (temperature, pressure/temperature), pocket thermometers, and associated supplies. All meters were manufactured by YSI, Inc. (EcoSense DO200A for dissolved oxygen, EC30A for conductivity/TDS, pH10A for pH), and all data loggers were manufactured by Onset Computer Corp. (TidbiT v2 for temperature, HOBO U20 water level logger for pressure/temperature).

Accuracy of temperature readings were checked for all loggers and pocket thermometers at the CRFWCO. A multi-point pre-deployment accuracy check (EPA 2014) was performed to assess temperature by placing groups of loggers and thermometers in a water bath (after launching to record at 30-minute intervals for temperature loggers and 15-minute intervals for pressure/temperature loggers). Over the course of 3—4 days, groups were placed on a laboratory bench at room temperature and in a refrigerator, alternating for a minimum of four hours each, during which water temperature was periodically recorded with four National Institute of Standards and Technology (NIST)-certified digital thermometers. Temperature readings from all loggers were downloaded (HoboWarePro version 3.7.4). The difference between mean temperature of individual loggers and the overall mean of all loggers in a group was calculated for the entire period of the accuracy check, as well as the difference between mean temperature of individual loggers and mean temperature of the four NIST-certified thermometers during the times that recordings were made. Temperature readings of pocket thermometers were recorded when the temperature of the water bath was recorded with NIST-certified thermometers. These data were used to calculate differences in mean temperature of individual thermometers and the overall mean for the group, as well as the mean of NIST-certified thermometers. Accuracy was assessed by comparing mean differences of individual temperature loggers, pressure/temperature loggers, and pocket thermometers to accuracy provided by the manufacturer (i.e., 0.2, 0.4, and 0.5°C, respectively). Essentially all loggers and pocket thermometers were considered accurate, and they were distributed to the FWCOs.

For water level, the accuracy of pressure/temperature loggers was assessed by suspending groups of loggers near the base within a plastic column (3 m height) while loggers were recording pressure and temperature. The column was filled with water, after which water was incrementally removed over a 3-hour period resulting in four water levels recorded by the loggers (~0.3—3.0 m, two readings per water level). Pressure was converted to water level using HoboWarePro (Version 3.7.4), and differences between readings for each logger and water levels were used to assess accuracy. Accuracy was assessed by comparing mean differences between loggers and water levels in the column to accuracy provided by the manufacturer (i.e.,

0.3—0.6 cm). Pressure/temperature loggers were considered accurate, and they were distributed to the FWCOs.

Reconnaissance included discussions among FWCOs and NWRs about the monitoring program, and visits to assess the suitability of candidate sentinel sites. Meetings and site visits were conducted during September—October 2014.

- Bridge Creek within Malheur NWR was inspected to a point about 1 km upstream of the gauge station, and the area was considered suitable for establishing a survey reach for the sentinel site. Temperature loggers were installed in the stream about 150 m downstream of the gauge station and 500 m upstream on September 23, 2014. Specific location of the survey reach was established during the initial field survey in August 2015.
- Muddy Creek was inspected at various areas on the 14-km length within William L. Finley NWR. Although the lower portions of the stream were not wadeable, suitable conditions for wading were located in the vicinity of McFadden's Marsh, downstream of Bruce Road. In addition, abutments of the Bruce Road Bridge, owned by Benton County, Oregon, were the most appropriate locations observed for the installation of a staff gauge and pressure/temperature logger. We received a county permit the following spring, and installed a staff gauge and loggers on July 29, 2015. Specific location of the survey reach was established during the initial field survey in August 2015.
- The reach selected in the Little Pend Oreille River at Little Pend Oreille NWR was within an area of the highest fish species diversity (five species) during the 1996 MCRFWCO fish and habitat survey (Kelly Ringel 1998) and was also within a reach surveyed in 2014 by the MCRFWCO to develop a three-dimensional model useful to monitor change over time (Parrish and Muir 2016). Specific location of the sentinel site reach was established during a field survey in July 2015.
- Myrtle Creek within Kootenai NWR was inspected at an 800 m section from the waterfall at the refuge boundary downstream to the slack-water influence from the Kootenai River. The specific survey reach was selected on September 10, 2014, and encompassed a stream segment from the screened water diversion near the Myrtle Falls Trail footbridge downstream 280 m to a point just upstream from a large pool adjacent to a bedrock outcrop. The Westside Road Bridge is approximately mid reach, and is equipped with a U.S. Forest Service staff gauge on its abutment. A pressure/temperature logger was installed on the bridge abutment on September 10, 2014. Temperature loggers were installed at the diversion at the uppermost transect, and along the west shore of the lowermost transect. Both temperature loggers were lost during ice breakup in the winter of 2014—2015.
- The lower 400 m of Omeara Creek within Willapa NWR was inspected on October 1, 2014. A section of the creek beginning at the refuge boundary located just upstream of tidal influence was considered suitable for establishing a survey reach for the sentinel site. Temperature loggers were installed in five locations within the creek on November 18, 2014. One was installed below the reach, two within it, and two above it. In addition, an air temperature logger was installed in a radiation shield attached to a large tree above the survey reach. The specific location of the survey reach was determined in July of 2015. A staff gauge and pressure/temperature logger were installed within the reach in June 2016.

Field Surveys

The initial field survey was intended to provide a training opportunity to familiarize personnel with EMAP methods so that they could be consistently applied at each sentinel site. During July 16—17, 2015, representatives from each FWCO met at Willapa NWR and participated in establishing the survey reach on Omeara Creek, characterizing aquatic and riparian habitat, and conducting a vertebrate survey (i.e., electrofishing). Thus, the personnel could then use the experience gained at Willapa NWR to guide crews at each of the other sentinel sites.

Bridge Creek

Field surveys were conducted at Bridge Creek during August 4—5, September 2, and September 29 in 2015. Primary activities during the initial survey included establishing the survey reach, characterizing aquatic and riparian habitat, conducting a vertebrate survey, and collecting aquatic macroinvertebrates. Conducting vertebrate surveys were the primary activities during the latter two surveys. During the course of the surveys, an additional temperature logger was installed in the stream downstream of the survey reach (85 m) and two temperature loggers, within a solar radiation shield (EPA 2014), were mounted on a tree upstream of the survey reach (70 m) to record air temperature. Loggers were periodically checked that they were functioning and all were downloaded during the final survey of the year.

The lower limit of the survey reach (transect A) was established 200 m upstream of the gauge station (measured from the weir), and extended 240 m along the channel upstream (transect K, Figure 1). Reach length was based on a mean wetted width of 6 m observed during the reconnaissance trip (reach length=40X mean wetted width, see Peck et al. 2006). Location of the lower limit of the reach attempted to minimize potential influence of the weir on upstream habitat (EPA (2014) recommended avoiding constructed structures by 200 m). The reach contained an active beaver dam and evidence of old beaver dams.

Habitat was assessed at Bridge Creek during the first day of the initial survey in 2015, on August 4. Channel characteristics of the survey reach were mean wetted and bankfull widths of 4.91 and 5.57 m, respectively, with banks incised 0.51 m above the water surface (Table 2). Mean depth of the thalweg was 61.3 cm, with residual pool depth estimated at 21.5 cm. The reach had a sinuosity of 1.87 and water surface slope of 0.65%.

Five substrate classes were observed (Table 3). Fines made up about half of substrate observations, followed by sand, fine gravel, coarse gravel and cobble (proportions of 0.51, 0.21, 0.15, 0.09, and 0.05 respectively). Mean embeddedness was 65.6%. Relative bed stability, $\log_{10}$ transformed, for which high values (e.g., 3.0) indicate highly stable immovable substrate and low values (e.g., -2.5) indicate highly mobile substrate (Kaufmann et al. 1999), was -2.4.

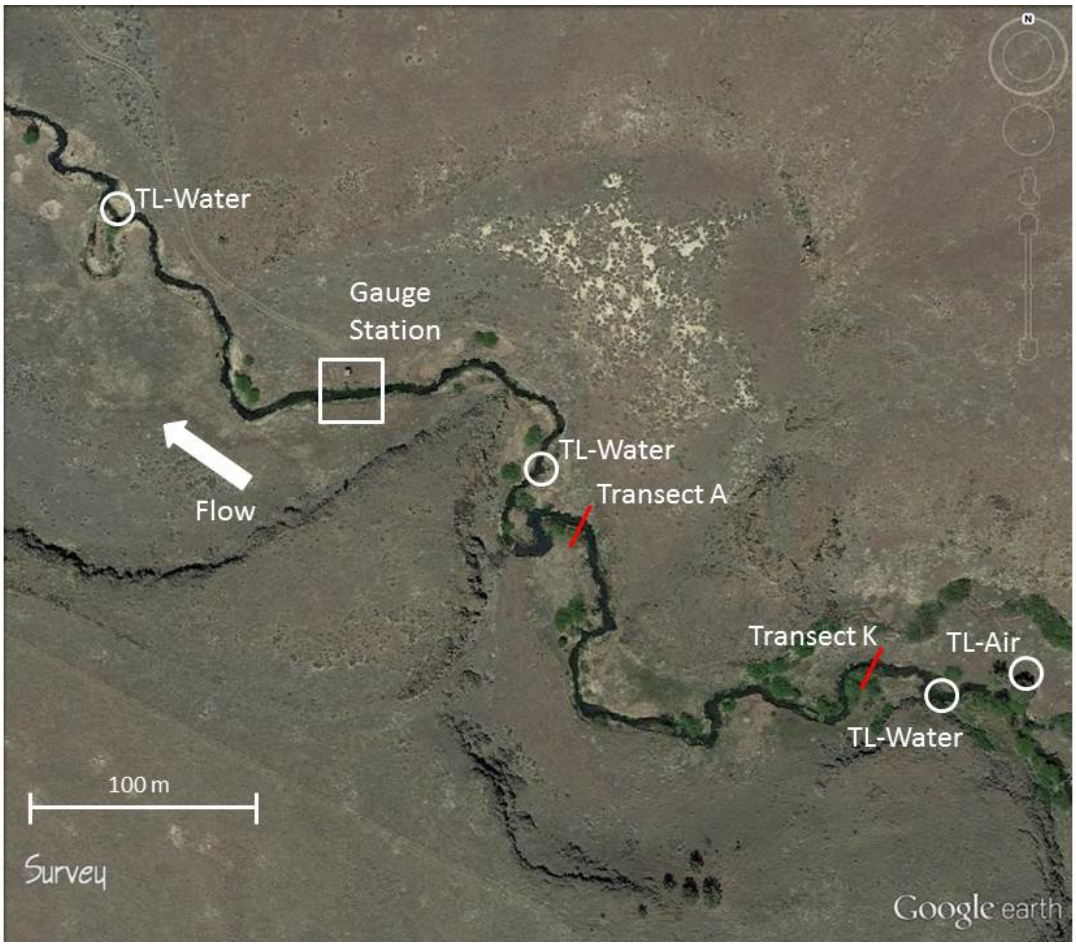

Figure 1. Aerial photograph of Bridge Creek showing direction of stream flow, locations of Water Resources gauge station, survey reach (bounded by transects A and K (red bars)), and temperature loggers (TL) in air and water.

Six categories of fish cover types (out of a total of nine categories) were present (Table 4). The most prevalent category was macrophytes (mean 63.4% cover). These were plants rooted along the stream margins forming extensive mats throughout the survey reach. Overhanging vegetation (mean 44.6%) was the only other category contributing more than a mean of 2% cover. Large woody debris was virtually absent, with less than 1.0 m^3 total volume observed for the entire survey reach.

Riparian vegetation was represented by understory (0.5—5 m height) and ground cover (<0.5 m) plants (Table 5). Thus, canopy cover at mid-channel locations were relatively low (mean 18.6%) compared to cover at stream banks (mean 77.3%) due to the lack of taller trees sufficient for a canopy (>5 m). The understory evenly consisted of both woody and non-woody plants, whereas ground cover was primarily non-woody plants.

Table 2. Stream channel characteristics (SD) of survey reaches in Bridge Creek, Muddy Creek, Little Pend Oreille River, Myrtle Creek, and Omeara Creek during 2015.

Length (m)	Mean width (m)		Mean height (m)		Mean depth (cm)		Water surface slope (%)	Sinuosity	Mean bank angle (deg)	
	Wetted	Bankfull	Bankfull	Incised	Thalweg	Residual pool*			Left	Right
					Bridge Creek					
240	4.91 (1.52)	5.57 (1.43)	0.33 (0.15)	0.51 (0.36)	61.3 (19.6)	21.5	0.65	1.87	50.9 (34.3)	50.5 (34.0)
					Muddy Creek					
320	6.82 (2.07)	9.98 (1.82)	1.06 (0.16)	1.06 (0.16)	32.7 (9.5)	11.1	0.02	1.99	15.7 (6.1)	21.8 (10.8)
					Little Pend Oreille River					
280	7.09 (2.22)	10.57 (2.56)	0.63 (0.94)	0.84 (0.39)	46.7 (20.3)	24.4	0.03	2.36	60.4 (38.9)	40.1 (28.7)
					Myrtle Creek					
280	8.20 (2.70)	14.15 (2.10)	1.01 (0.25)	0.28 (0.07)	32.0 (19.0)	6.5	3.00	1.01	39.1 (53.6)	51.4 (50.3)
					Omeara Creek					
150	1.91 (1.14)	2.98 (1.27)	0.36 (0.07)	0.72 (0.12)	14.5 (11.3)	6.5	1.92	2.28	72.5 (47.1)	57.7 (53.1)

*RP100 in Kaufmann et al. (1999)-equivalent to residual pool vertical profile area per 100 m of reach.

Table 3. Stream substrate characteristics (SD) of survey reaches in Bridge Creek, Muddy Creek, Little Pend Oreille River, Myrtle Creek, and Omeara Creek during 2015.

Proportion substrate class*							Mean embeddedness (%)	Geometric mean particle size (mm)	Log_{10}	
Bedrock	Boulder	Cobble	Coarse gravel	Fine gravel	Sand	Fines			Erodible substrate diameter	Relative bed stability
					Bridge Creek					
0	0	0.05	0.09	0.15	0.21	0.51	65.6 (43.7)	0.2	1.5	-2.4
					Muddy Creek					
0.25	0	0	0	0	0	0.75	74.5 (44.0)	0.2	0.2	-0.9
					Little Pend Oreille River					
0	0	0.01	0.24	0.27	0.37	0.12	71.9 (30.9)	1.5	0.3	-0.1
					Myrtle Creek					
0	0	0.72	0.13	0.01	0.11	0.03	20.8 (33.6)	41.6	2.4	-0.8
					Omeara Creek					
0	0	0.04	0.44	0.22	0.19	0.11	60.3 (35.9)	3.8	1.6	-1.1

*Bedrock (>4000mm, including hard pan), Boulder (250-4000 mm), Cobble (64-250 mm), Coarse gravel (16-64 mm), Fine gravel (2-16 mm), Sand (0.6-2 mm), Fines (<0.6 mm, including silt/clay).

Table 4. Stream fish cover (SD) and large woody debris of survey reaches in Bridge Creek, Muddy Creek, Little Pend Oreille River, Myrtle Creek, and Omeara Creek during 2015.

Fish cover categories (mean %)									Total volume (m^3/reach)	Volume per m^2 (m^3)
Filamentous algae	Macrophytes	Woody debris (>0.3m)	Brushy/woody debris	Live trees/roots	Overhanging vegetation	Undercut banks	Boulders	Artificial structures		
				Bridge Creek						
0	63.4 (28.2)	0	1.8 (2.5)	0.5 (1.5)	44.6 (29.4)	0.9 (2.0)	0.9 (2.0)	0	0.12	0.00009
				Muddy Creek						
0	0	2.7 (2.6)	11.4 (11.0)	0.5 (1.5)	20.7 (15.7)	0	0	0	21.72	0.00680
				Little Pend Oreille River						
0	0	0	10.9 (11.4)	10.0 (12.0)	8.9 (17.7)	3.2 (7.5)	0.9 (2.0)	0	4.04	0.00137
				Myrtle Creek						
4.6 (1.5)	0	0	8.2 (8.5)	0.5 (1.5)	1.8 (2.5)	18.2 (22.1)	36.8 (16.4)	5.5 (9.9)	37.35	0.00942
				Omeara Creek						
0	0	6.4 (9.5)	4.5 (1.5)	3.2 (7.5)	12.1 (17.6)	4.6 (1.5)	0	0	24.80	0.05544

Table 5. Stream canopy cover (SD) and riparian vegetation structure of survey reaches in Bridge Creek, Muddy Creek, Little Pend Oreille River, Myrtle Creek, and Omeara Creek during 2015.

Stream canopy cover (mean %)		Canopy		Understory		Ground cover		
Mid channel	Banks	Big tree	Small tree	Woody	Non woody	Woody	Non-woody	Bare ground
				Bridge Creek				
18.6 (27.9)	77.3 (32.6)	0	0	30.0 (26.3)	22.7 (19.2)	8.3 (19.0)	59.7 (23.4)	10.5 (21.8)
				Muddy Creek				
47.9 (30.7)	82.4 (28.8)	30.5 (32.1)	22.4 (21.5)	47.2 (27.1)	24.0 (21.0)	15.3 (26.7)	33.9 (26.8)	1.1 (2.1)
				Little Pend Oreille River				
43.0 (30.5)	75.1 (33.2)	1.1 (5.3)	16.9 (13.9)	39.8 (21.0)	5.7 (6.6)	7.3 (8.8)	65.1 (25.7)	13.3 (14.8)
				Myrtle Creek				
70.5 (20.2)	73.3 (14.5)	44.1 (26.3)	23.8 (21.0)	18.5 (13.8)	8.2 (9.6)	8.6 (9.3)	13.8 (14.4)	65.7 (26.1)
				Omeara Creek				
76.7 (27.0) 20.4	84.0 (26.3)	6.5 (14.3)	36.1 (36.1)	12.4 (19.0)	3.2 (7.3)	0.7 (1.8)	87.5 (0.0)	0.9 (2.0)

*Heights of vegetation structure categories: canopy (>5 m), understory (0.5-5 m), and ground cover (<0.5 m).

Three vertebrate surveys were conducted in Bridge Creek during 2015, August 8, September 2, and September 29. Water temperatures prior to beginning the surveys were 11.0—13.5°C and dissolve oxygen levels were ≥ 99.4% saturation (Appendix B). A total of four species were collected (Table 6). Three species, Redband Trout (*Oncorhynchus mykiss*), Malheur Sculpin (*Cottus bendirei*), and Speckled Dace (*Rhinichthys osculus)*, were collected during each survey, whereas Longnose Dace (*Rhinichthys cataractae*) were only collected during the initial survey. Relative abundance of species was similar among all surveys, with Speckled Dace as the most abundant, followed by Redband Trout, Malheur Sculpin, and Longnose Dace. Electrofishing effort in the 240-m survey reach appeared adequate for application of EMAP methods based on values of Jaccard's coefficient comparing species collected in even and odd numbered subreaches (i.e., values ≥0.7, Peck et al. 2006). A wide range of fish sizes were collected as indicated by the relatively high variability of total length and weight of individuals that were haphazardly subsampled throughout the survey reach (Table 7). Stream flow, measured near the gauge station, was 7.7—11.1 cfs during the surveys.

Table 6. Numbers of fish and species collected during each vertebrate survey and all surveys combined in Bridge Creek during 2015 (percent of total individuals) and Jaccard's coefficient for each survey*.

Species	Survey date			Total all surveys
	August 5	September 2	September 29	
Longnose Dace	3 (0.5)			3 (0.2)
Malheur Sculpin	55 (8.8)	40 (6.3)	24 (7.3)	119 (7.5)
Redband Trout	78 (12.4)	85 (13.5)	96 (29.2)	259 (16.3)
Speckled Dace	491 (78.3)	507 (80.2)	209 (63.5)	1,207 (76.0)
---total per survey	627	632	329	1,588
---number species per Survey	4	3	3	4
---Jaccard's coefficient	1.0	1.0	1.0	

*Jaccard's coefficient was used as an index to gauge adequacy of sampling species composition by comparing species common to both even and odd numbered subreaches to total number of species collected during a survey (Peck et al. 2006).

Table 7. Number (n), mean length (mm), and mean weight (g) of fish subsampled during each vertebrate survey in Bridge Creek during 2015 (SD).

Species	August 5			September 2			September 29		
	n	Length	Weight	n	Length	Weight	n	Length	Weight
Longnose Dace	3	78.3 (16.5)	4.90 (2.70)	0			0		
Malheur Sculpin	39	72.6 (24.1)	6.41 (5.88)	26	82.5 (20.1)	15.55 (11.14)	24	72.8 (23.0)	13.25 (12.88)
Redband Trout	47	120.5 (42.2)	22.49 (22.08)	46	136.2 (49.6)	61.72 (82.89)	48	124.9 (42.7)	50.34 (50.71)
Speckled Dace	53	62.3 (9.0)	2.48 (0.94)	51	62.6 (5.5)	4.00 (1.47)	50	60.8 (5.5)	4.76 (1.32)

Muddy Creek

Field surveys were conducted at Muddy Creek during August 17—18, September 15, and October 14 in 2015. Primary activities during the initial survey included establishing the survey reach, characterizing aquatic and riparian habitat, and collecting aquatic macroinvertebrates. A vertebrate survey was not conducted due to warm water temperatures (>18°C) that exceeded limits for safely collecting and handling fish. Conducting vertebrate surveys were the primary activities during the latter two surveys. Thus, only two vertebrate surveys were completed in 2015. During the course of the surveys, additional temperature loggers were installed in the stream immediately upstream of the survey reach (<5 m) and downstream (30 m). Loggers were periodically checked that they were functioning and all were downloaded during the final survey of the year.

The upper limit of the survey reach (transect K) was established 100 m downstream of the largest water control structure between McFadden's Marsh and Muddy Creek, and extended 320 m along the channel downstream to (transect A, Figure 2). Reach length was based on a mean wetted width of 8 m observed during the reconnaissance trip (reach length=40X mean wetted width, see Peck et al. 2006). Locations of the survey reach limits were established so that it was in the vicinity of the area inspected during the reconnaissance trip and found most conducive to wading, and was not directly associated with a water control structure along its length.

Habitat was assessed at Muddy during the initial survey 2015. Channel characteristics of the survey reach were mean wetted and bankfull widths of 6.82 and 9.98 m, respectively, with equal bankfull and incised heights, 1.06 m above the water surface (Table 2). Mean depth of the thalweg was 32.7 cm, with residual pool depth estimated at 11.1 cm. The reach had a sinuosity of 1.99 and water surface slope of 0.02%.

Two substrate classes were observed (Table 3). Fines made up three-quarters of substrate observations and the bedrock category, which was composed of hard pan, made up the remainder. Mean embeddedness was 74.5%. Relative bed stability, $\log_{10}$ transformed, was -0.9.

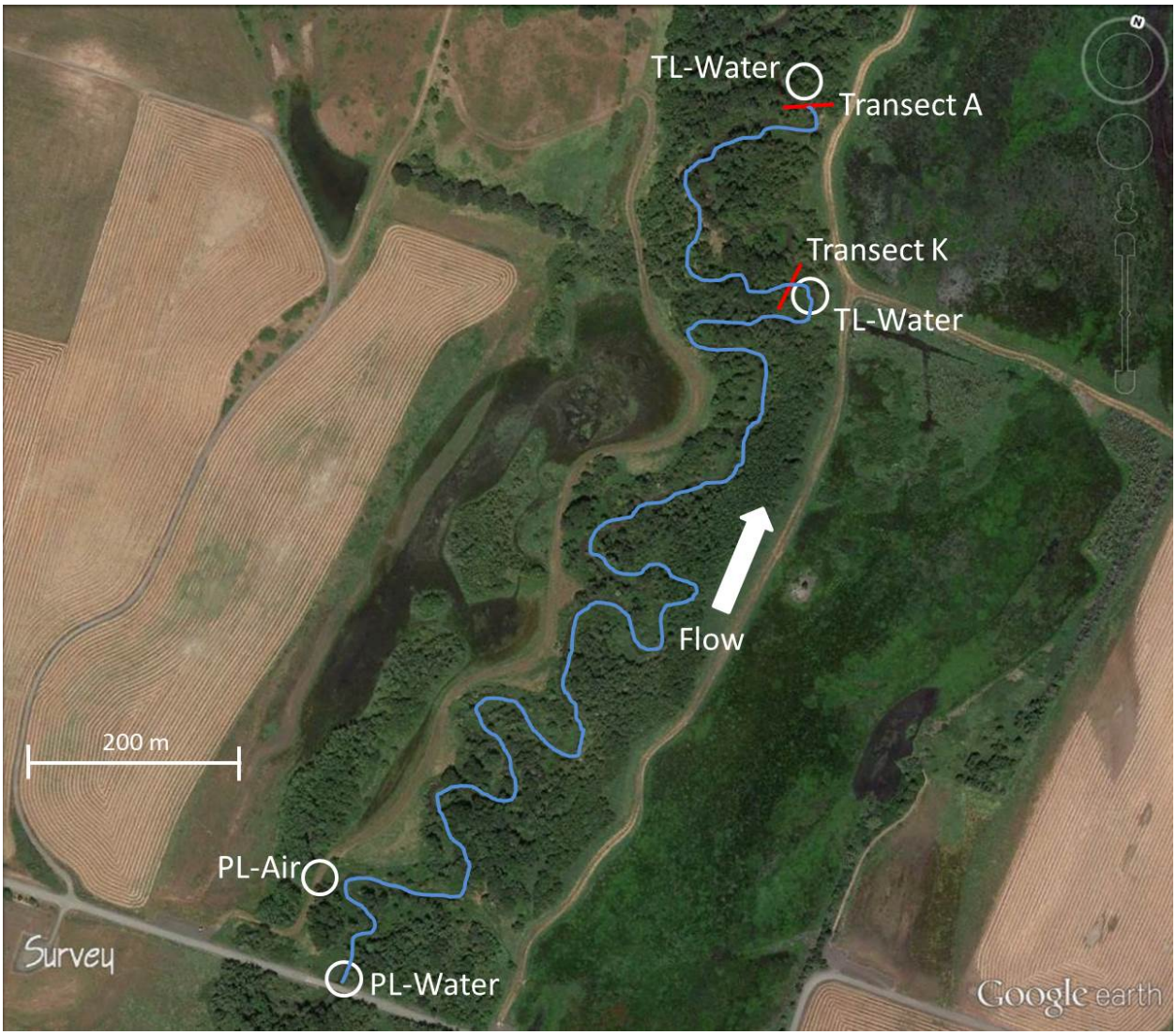

Figure 2. Aerial photograph of Muddy Creek (blue) showing direction of stream flow, locations of the survey reach (bounded by transects A and K (red bars)), and temperature loggers (TL) in water, and pressure/temperature loggers (PL) in air and water.

Four categories of fish cover types (out of a total of nine categories) were present (Table 4). The most prevalent category was overhanging vegetation (mean 20.7% cover). Brushy/woody debris (mean 11.4%) and woody debris (>0.3 m, 2.7%) were the only other categories contributing more than a mean of 2% cover. Total volume of large woody debris was 21.72 m^3 for the entire survey reach.

Riparian vegetation was represented by canopy (>5 m height), understory (0.5—5 m height), and ground cover (<0.5 m) plants (Table 5). Mean canopy cover at mid-channel and bank locations were 47.9% and 82.4%, respectively, due to a relatively extensive canopy of both large and small trees. The understory was primarily woody plants, whereas ground cover was primarily non-woody plants.

Two vertebrate surveys were conducted in Muddy Creek during 2015, September 15 and October 14. Water temperatures prior to beginning the surveys were 13.0 and 13.5°C and dissolve oxygen levels were 50.9% and 63.7% saturation (Appendix B). A total of six species were collected (Table 8). Four species, Western Mosquitofish (*Gambusia affinis*), Northern Pikeminnow (*Ptychocheilus oregonensis*), Redside Shiner (*Richardsonius balteatus*), and Reticulate Sculpin (*Cottus perplexus*)were collected during each survey, whereas Threespine Stickleback (*Gasterosteus aculeatus*) and Western Brook Lamprey (*Lampetra richardsoni*) were only collected during the first and second surveys, respectively. Relative abundance of species was similar between the two surveys, with either Western Mosquitofish or Reticulate Sculpin as the most abundant, followed by Redside Shiner and Northern Pikeminnow. Electrofishing effort in the 320-m survey reach appeared adequate for application of EMAP methods based on values of Jaccard's coefficient comparing species collected in even and odd numbered subreaches (i.e., values ≥0.7, Peck et al. 2006). A wide range of fish sizes were collected as indicated by the relatively high variability of total length and weight of individuals that were haphazardly subsampled throughout the survey reach (Table 9). Stream flow, measured 1.8 km upstream at the staff gauge at Bruce Road, was low during the surveys, 1.0 and 1.9 cfs respectively.

Little Pend Oreille River

Field surveys of the Little Pend Oreille River were conducted three times in 2015: July 27—31, August 26—28, and September 28—29. During the initial survey in July we established the survey reach (Figure 3), characterized aquatic and riparian habitat, conducted a vertebrate survey by electrofishing, and deployed water temperature loggers. During the second visit we conducted the second vertebrate survey, and collected the two composite macroinvertebrate samples. During the third visit we conducted the third vertebrate survey and downloaded the water temperature loggers.

The initial habitat survey was completed during the July 2015 survey. Channel characteristics of the survey reach were mean wetted and bankfull widths of 7.09 and 10.57 m, respectively, with bankfull and incised heights, 0.63 m and 0.84 m, respectively, above the water surface (Table 2). Mean depth of the thalweg was 46.7 cm, with residual pool depth estimated at 24.4 cm. The reach had a sinuosity of 2.36 and water surface slope of 0.03%.

Five substrate classes, from fines to cobble, were observed (Table 3). Sand was the dominant substrate (37%), followed by fine gravel (27%), course gravel (24%), fines (12%) and cobble (1%). Mean embeddedness was 71.9%. Relative bed stability, $\log_{10}$ transformed, was -0.1.

Five categories of fish cover types (out of a total of nine categories) were present but all with less than 11% cover (Table 4). The three most prevalent categories were all vegetation related: brushy/woody debris (mean 10.9 %), live trees/roots (mean 10.0%) and overhanging vegetation (8.9%). There were small amounts of undercut banks (mean 3.2%) and boulders (mean 0.9%). Total volume of large woody debris was 4.04 m^3 for the entire survey reach.

Table 8. Numbers of fish and species collected during each vertebrate survey and all surveys combined in Muddy Creek during 2015 (percent of total individuals) and Jaccard's coefficient for each survey*.

Species	Survey date		Total all surveys
	September 15	October 14	
Northern Pikeminnow	16 (10.7)	4 (6.7)	20 (9.5)
Redside Shiner	24 (16.0)	5 (8.3)	29 (13.8)
Reticulate Sculpin	67 (44.7)	15 (25.0)	82 (39.1)
Threespine Stickleback	1 (0.7)	0	1 (0.5)
Western Brook Lamprey	0	1 (1.7)	1 (0.5)
Western Mosquitofish	42 (28.0)	35 (58.3)	77 (36.7)
---total per survey	150	60	210
---number species per Survey	5	5	6
---Jaccard's coefficient	0.8	0.8	

*Jaccard's coefficient was used as an index to gauge adequacy of sampling species composition by comparing species common to both even and odd numbered subreaches to total number of species collected during a survey (Peck et al. 2006).

Riparian vegetation was represented by canopy (>5 m height), understory (0.5—5 m height), and ground cover (<0.5 m) plants (Table 5). Mean canopy cover, measured with a densiometer, at mid-channel and bank locations were 43.0% and 75.1%, respectively, with small trees and woody brush (mostly alder), providing most of the shading. The understory was primarily woody plants (mean 39.8%), whereas ground cover was primarily non-woody plants (mean 65.1%).

Table 9. Number (n), mean length (mm), and mean weight (g) of fish subsampled during each vertebrate survey in Muddy Creek during 2015 (SD).

Species	September 15			October 14		
	n	Length	Weight	n	Length	Weight
Northern Pikeminnow	8	79.6 (20.8)	4.34 (2.87)	4	103.8 (34.3)	10.95 (8.74)
Redside Shiner	15	89.1 (23.0)	6.49 (3.98)	5	78.2 (25.2)	4.40 (3.98)
Reticulate Sculpin	31	57.0 (14.5)	2.21 (1.31)	14	56.2 (12.1)	2.04 (1.35)
Threespine Stickleback	1	39.0	0.50	0		
Western brook Lamprey	0			1	128.0	2.70
Western Mosquitofish	17	34.9 (5.5)	0.51 (0.38)	10	30.8 (7.4)	0.42 (0.55)

Three vertebrate surveys were conducted in Little Pend Oreille River during 2015, July 28, August 27, and September 28—29. Water temperatures in the morning when surveys started were 12.0 (July and August) and 5.5°C (September) with highs during the surveys of 17, 16.5 and 10.0°C in July, August, and September, respectively. Dissolved oxygen levels taken during the July survey were 89% (Appendix B). Four fish species were collected during all the surveys (Table 10). The dominant species, comprising about half during all surveys was Brook Trout (*Salvelinus fontinalis*). Rainbow Trout (*O. mykiss*) and non-native Brown Trout (*Salmo trutta*) comprised between 3 and 9% each during all surveys. Shorthead Sculpin (*Cottus confuses*) numbers varied and were 28—50% of the total. Electrofishing effort in the 280-m survey reach appeared adequate for application of EMAP methods based on values of Jaccard's coefficient (1.0 in all three surveys) comparing species collected in even and odd numbered subreaches (i.e., values ≥0.7, Peck et al. 2006). A wide range of fish sizes were collected with several large trout captured (Table 11). Size ranges by species were: Brook Trout 49—199 mm, Brown Trout 57—338 mm, Rainbow Trout 61—270 mm, and Shorthead Sculpin 30—107 mm. Stream flow was low during the surveys, 12.4 cfs measured July 28, 2015 at the lower end of the reach.

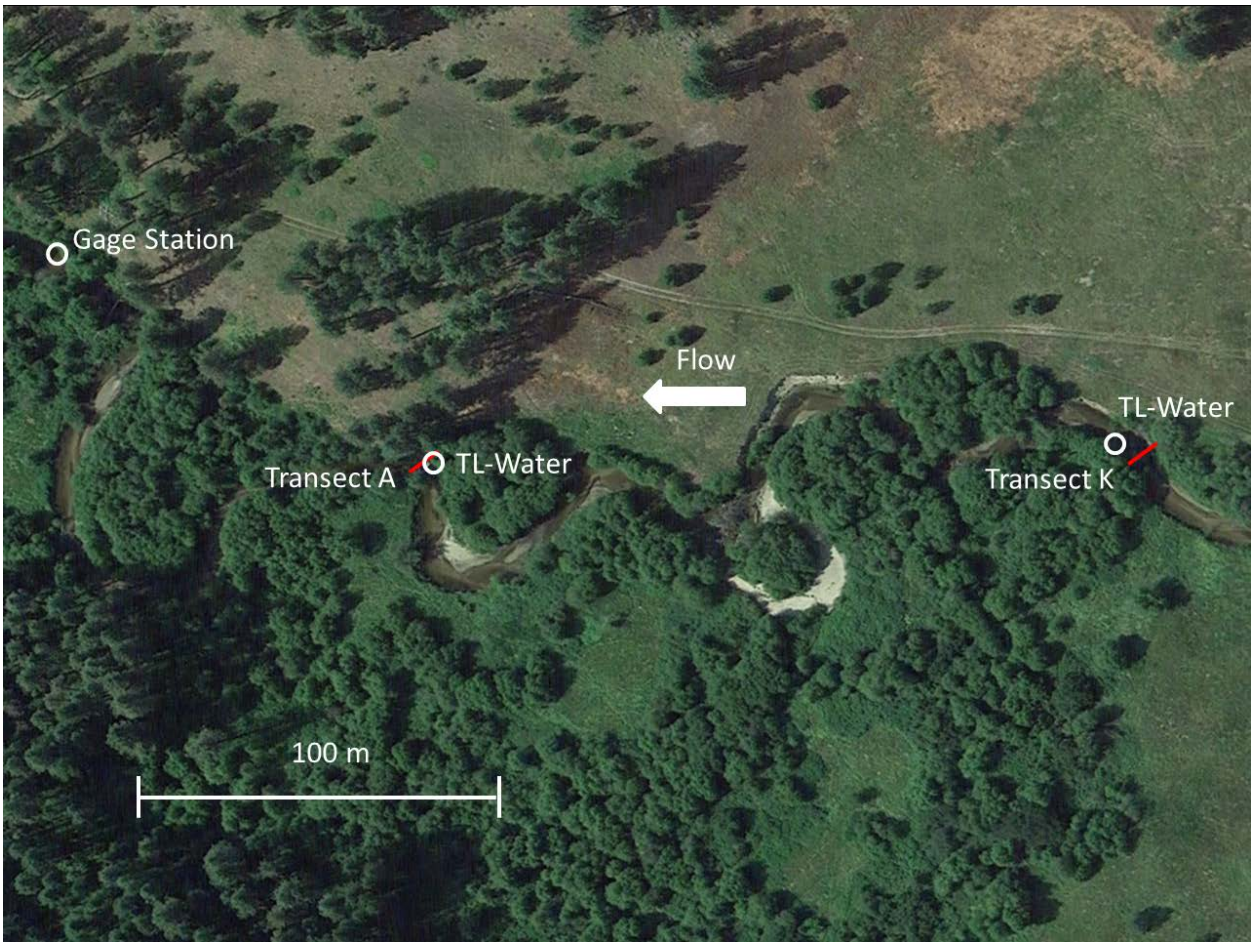

Figure 3. Aerial photograph of Little Pend Oreille River showing direction of stream flow, locations of Water Resources gauge station, survey reach (bounded by transects A and K (red bars)), and temperature loggers (TL) in water.

Myrtle Creek

Field surveys were conducted at Myrtle Creek during July 29—30, August 17, September 2—3, and October 26—27 in 2015. Primary activities during the August survey included characterizing aquatic and riparian habitat. Vertebrate surveys were conducted during the July, September, and October surveys. During the course of the surveys, temperature loggers were re-installed in the stream at the upper and lowermost transects, and a pressure/temperature logger within a solar radiation shield (EPA 2014), was mounted on the west wall of the refuge maintenance shop to record air temperature and atmospheric pressure. Loggers were periodically checked to ensure they were functioning, and all were downloaded during the final survey of the year.

Table 10. Numbers of fish and species collected during each vertebrate survey and all surveys combined in Little Pend Oreille River during 2015 (percent of total individuals) and Jaccard's coefficient for each survey*.

Species	Survey date			Total all surveys
	July 28	August 27	September 28-29	
Brook Trout	70 (50.0)	64 (41.6)	55 (55.5)	189 (48.1)
Brown Trout	11 (7.9)	9 (5.8)	7 (7.1)	27 (6.9)
Rainbow Trout	10 (7.1)	4 (2.6)	9 (9.1)	23 (5.9)
Shorthead Sculpin	49 (35.0)	77 (50.0)	28 (28.3)	154 (39.2)
---total per survey	140	154	99	393
---number species per Survey	4	4	4	4
---Jaccard's Coefficient	1.0	1.0	1.0	

*Jaccard's coefficient was used as an index to gauge adequacy of sampling species composition by comparing species common to both even and odd numbered subreaches to total number of species collected during a survey (Peck et al. 2006).

Table 11. Number (n), mean length (mm), and mean weight (g) of fish subsampled during each vertebrate survey in Little Pend Oreille River during 2015 (SD).

Species	August 5			September 2			September 29		
	n	Length	Weight	n	Length	Weight	n	Length	Weight
Brown Trout	11	124 (97)	63.0 (135.6)	9	145 (63)	55.6 (50.9)	7	151 (84)	72.1 (106.2)
Brook Trout	70	82 (31)	9.0 (12.7)	64	101 (37)	16.6 (20.2)	55	102.5 (30.2)	15.1 (17.8)
Rainbow Trout	10	156 (70)	65.1 (66.8)	4	187 (62)	89.5 (91.6)	9	182 (45)	75.7 (46.4)
Shorthead Sculpin	49	52 (16)	2.1 (1.6)	77	54 (14)	2.2 (2.3)	28	58 (12)	2.5 (2.4)

The lower limit of the survey reach (transect A) was established 280 m downstream of the refuge Myrtle Creek water diversion. The uppermost transect (transect K) is at the downstream edge of

refuge Myrtle Creek water diversion (Figure 4). Reach length was based on a mean wetted width of 7 m observed during the reconnaissance trip (reach length=40X mean wetted width, see Peck et al. 2006). The reach is crossed by a road bridge (Westside Road) at transects D-E.

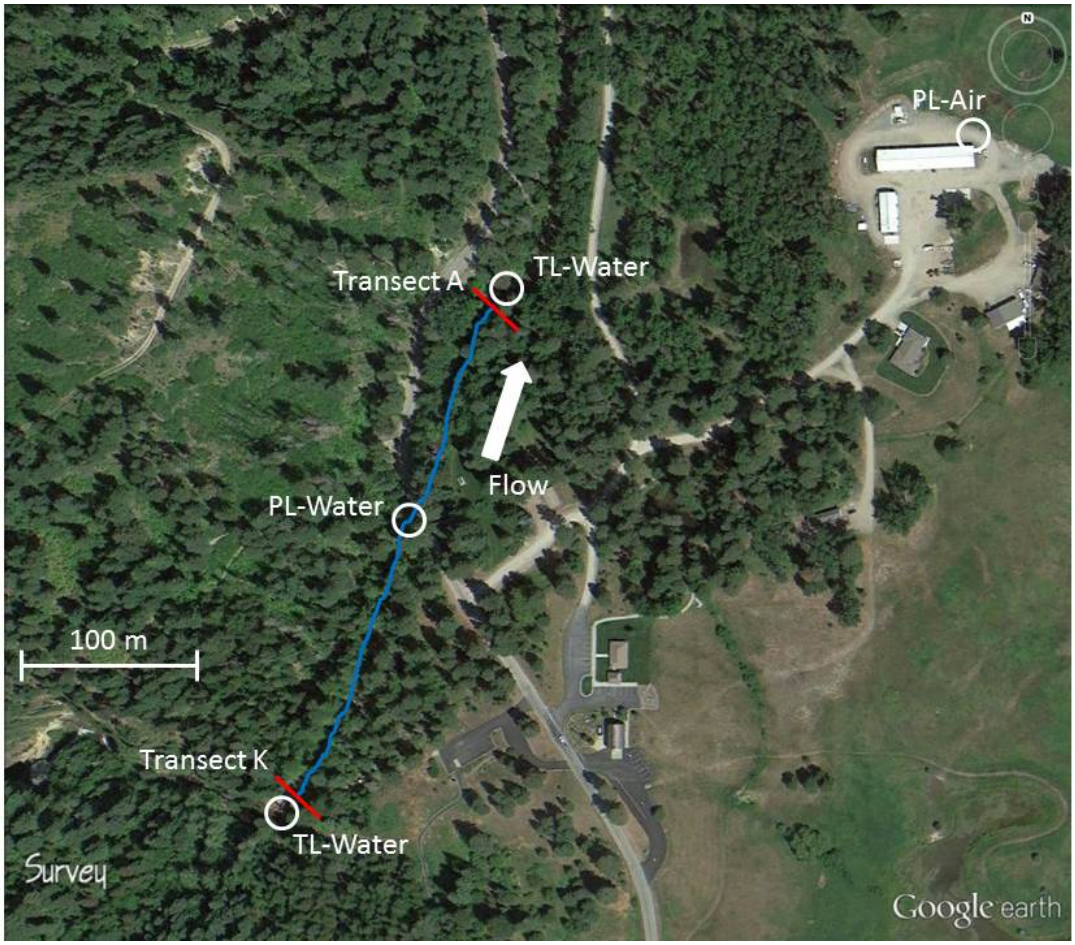

Figure 4. Aerial photograph of Myrtle Creek (blue) showing direction of stream flow, locations of the survey reach (bounded by transects A and K (red bars)), and temperature loggers (TL) in water, and pressure/temperature loggers (PL) in air and water.

Habitat was assessed at Myrtle Creek on August 17, 2015. Channel characteristics of the survey reach were mean wetted and bankfull widths of 8.20 and 14.15 m, respectively, with banks incised 0.28 m above the water surface (Table 2). Mean depth of the thalweg was 32.0 cm, with residual pool depth estimated at 6.5 cm. The reach had a sinuosity of 1.01 and water surface slope of 3.00%.

Five substrate classes were observed (Table 3). Cobble made up about 3/4 of substrate observations, followed by coarse gravel, fine gravel, sand and fines (proportions of 0.72, 0.13, 0.01, 0.11, and 0.03, respectively). Mean embeddedness was 20.8%. The geometric mean particle size was 41.6 mm, and is classified as coarse gravel. Relative bed stability, $\log_{10}$ transformed, was -0.8.

Seven categories of fish cover types (out of a total of nine categories) were present (Table 4). The most prevalent category was boulders (mean 36.8% cover). Undercut banks (18.2%) and brushy/woody debris (8.2%) were the only other categories contributing instream cover in appreciable amounts. Large woody debris was virtually absent, but smaller, brushy/woody debris was moderately abundant contributing a total reach volume of 37.35 m^3 for the entire survey reach.

Riparian vegetation along Myrtle Creek could be characterized as a mature forest, and was represented by canopy (>5 m in height) understory (0.5—5 m height) and ground cover (<0.5 m) plants (Table 5). As a result, canopy cover at mid-channel locations was similar (mean 70.5%) to canopy cover at stream banks (mean 73.3%). The understory and ground cover consisted of both woody and non-woody plants, but the coverage was sparse, ranging from 8.2 to 18.5%.

Three vertebrate surveys were conducted in Myrtle Creek during 2015, July 29—30, September 2—3, and October 26—27. Water temperatures prior to beginning the surveys were 5.0—13.0°C (Appendix B). A total of nine species were collected (Table 12), but only six were collected during each survey. Bull Trout (*Salvelinus confluentus*) were only collected during the second survey, Longnose Sucker (*Catostomus catostomus*) were only collected in the third survey, and Westslope Cutthroat Trout (*O. clarkii lewisi*) were collected during the first and third surveys. Relative abundance of species was similar among all surveys, with Longnose Dace as the most abundant, followed by Rainbow Trout, Slimy and Torrent sculpins (*C. cognatus* and *C. rhotheus*), and Mountain Whitefish (*Prosopium williamsoni*). Electrofishing effort in the 280-m survey reach appeared adequate for application of EMAP methods based on values of Jaccard's coefficient comparing species collected in even and odd numbered subreaches (i.e., values ≥0.7, Peck et al. 2006), with a value slightly less than 0.7 during the final survey. A wide range of fish sizes were collected as indicated by the relatively high variability of total length and weight of individuals that were subsampled throughout the survey reach (Table 13). Stream flow, measured near the gauge station, was 6.5—24.68 cfs during June and July, with corresponding staff gauge measurements of 0.58—0.97 feet, respectively.

Omeara Creek

Field surveys were conducted at Omeara Creek during July 16–17, September 2, and October 15 in 2015. On the initial survey date the reach was identified and marked, and riparian and aquatic habitat characteristics were assessed. We conducted a vertebrate survey on the remaining field dates. Temperature loggers were periodically checked to ensure that they were functioning and all loggers located were downloaded at least once during the surveys.

The lower limit of the survey reach (transect A) was established within 10 m of the lower boundary of the refuge. The reach extended 150 m along the channel upstream of transect A (Figure 5). The minimum reach length of 150 m was used based on a mean wetted width of approximately 2 m observed on July 16, 2015 (see Peck et al. 2006).

Table 12. Numbers of fish and species collected during each vertebrate survey and all surveys combined in Myrtle Creek during 2015 (percent of total individuals) and Jaccard's coefficient for each survey*.

Species	Survey date			Total all surveys
	July 29-30	September 2—3	October 26—27	
Longnose Dace	318 (48.0)	394 (58.6)	67 (28.1)	779 (50.8)
Rainbow Trout	183 (27.6)	188 (28.0)	128 (53.8)	499 (31.7)
Westslope Cutthroat Trout	2 (0.3)	0	1 (0.4)	3 (0.2)
Brook Trout	15 (2.3)	9 (1.3)	6 (2.5)	30 (1.9)
Bull Trout	0	1 (0.1)	0	1 (0.06)
Mountain Whitefish	48 (7.2)	23 (3.4)	1 (0.4)	72 (4.6)
Slimy Sculpin	74 (11.2)	48 (7.1)	27 (11.3)	149 (9.5)
Torrent Sculpin	22 (3.3)	9 (1.3)	7 (2.9)	38 (2.4)
Longnose Sucker	0	0	1 (0.4)	1 (0.06)
---total per survey	662	672	238	1,572
---number species per Survey	7	7	8	9
---Jaccard's Coefficient	0.86	0.86	0.62	

*Jaccard's coefficient was used as an index to gauge adequacy of sampling species composition by comparing species common to both even and odd numbered subreaches to total number of species collected during a survey (Peck et al. 2006).

Habitat was assessed at Omeara Creek during the first day of the initial survey in 2015, July 16. Channel characteristics of the survey reach were mean wetted and bankfull widths of 1.91 and 2.98 m, respectively, with banks incised 0.72 m above the water surface (Table 2). Mean depth of the thalweg was 14.5 cm, with residual pool depth estimated at 6.5 cm. The reach had a sinuosity of 2.28 and water surface slope of 1.92%.

Five substrate classes were observed (Table 3). Coarse gravel made up 44% of substrate observations, followed by fine gravel, sand, fines, and cobble (proportions of 0.22, 0.19, 0.11, and 0.04, respectively). Mean embeddedness was 60.3%. Relative bed stability was -1.1.

Five categories of fish cover types were present (Table 4); however, none were prevalent. The most common category was overhanging vegetation (mean 12% cover). Large woody debris, smaller woody debris, undercut banks, and live trees and roots provided 3.2–6.4% mean cover throughout the reach.

Table 13. Number (n), mean length (mm), and mean weight (g) of fish subsampled during each vertebrate survey in Myrtle Creek during 2015 (SD).

	July 29—30			September 2—3			October 26—27		
Species	**n**	**Length**	**Weight**	**n**	**Length**	**Weight**	**n**	**Length**	**Weight**
Longnose Dace	56	88.5 (26.4)	6.82 (5.18)	51	77.2 (27.8)	6.20 (6.21)	35	77.4 (23.6)	4.99 (4.19)
Rainbow Trout	62	107.0 (54.3)	19.32 (26.15)	52	87.3 (50.6)	14.68 (25.48)	39	84.7 (46.4)	11.36 (24.65)
Westslope Cutthroat Trout	2	239 (0)	130.95 (5.99)	0			1	244 (0)	124 (0)
Brook Trout	11	100.4 (28.2)	10.77 (9.05)	9	86.8 (29.9)	8.58 (9.52)	3	81 (4.6)	4.43 (1.93)
Bull Trout	0			1	170 (0)	49 (0)	0		
Mountain Whitefish	37	82 (23.2)	4.67 (6.69)	23	78.8 (6.2)	3.88 (0.88)	0		
Slimy Sculpin	61	71.1 (12.9)	3.51 (1.81)	42	71.1 (11.8)	3.37 (1.65)	23	74.9 (12.1)	4.31 (1.95)
Torrent Sculpin	22	84.3 (9.7)	7.27 (3.15)	9	87.1 (11.2)	7.43 (3.13)	6	79.5 (10.7)	5.62 (2.59)
Longnose Sucker	0			0			1	84 (0)	5.90 (0)

Riparian vegetation was represented by small trees (36.1%) and non-woody ground cover (87.5%) plants (Table 5). Thus, canopy cover at mid-channel and bank locations were relatively high (mean 76.7% and 84.0%, respectively). Woody plants were more common in the understory (12.4%) than non-woody plants (3.2%), and very little bare ground was observed (<1%) throughout the reach.

Three vertebrate surveys were conducted in Omeara Creek during 2015, July 17, September 2, and October 15. Water temperatures prior to beginning the surveys were 11.9–17.0°C and dissolve oxygen levels were ≥ 91.9% saturation (Appendix B). A total of five fish species were collected (Table 14. Numbers of fish and species collected during each vertebrate survey and all

surveys combined in Omeara Creek during 2015 (percent of total individuals) and Jaccard's coefficient for each survey*.

Three species, Riffle Sculpin (*C. gulosus*), Coho Salmon (*O. kisutch*), and Coastal Cutthroat Trout (*O. clarkii clarkii*), were collected during each survey, whereas steelhead/Rainbow Trout (*O. mykiss*) and Pacific Lamprey (*Entosphenus tridentatus*) were only collected during the initial survey. Relative abundance of species was similar among all surveys, with Riffle Sculpin as the most abundant, followed by Coho Salmon and Cutthroat Trout. A wide range of fish sizes were collected as indicated by the relatively high variability of total length and weight of individuals that were subsampled throughout the survey reach (Table 15). Coastal Cutthroat Trout were the largest fish observed in the reach.

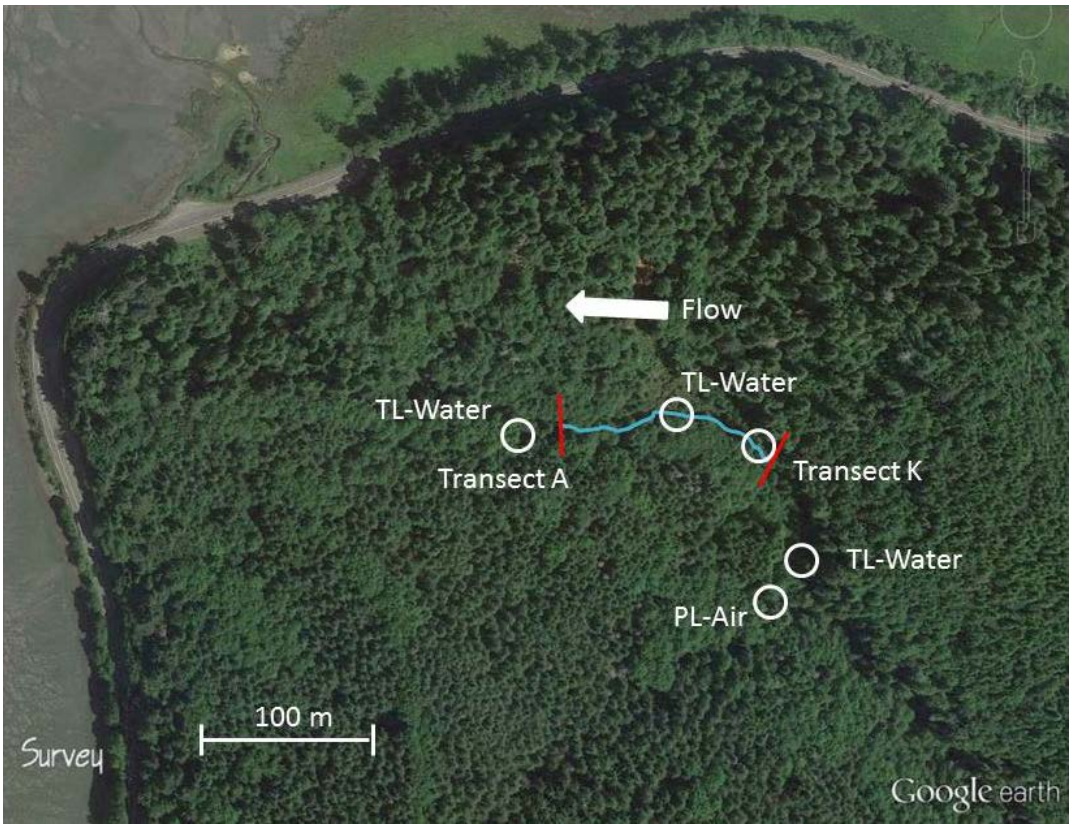

Figure 5. Aerial photograph of Omeara Creek (blue) showing direction of stream flow, locations of the survey reach (bounded by transects A and K (red bars)), and temperature loggers (TL) in air and water, and pressure/temperature logger (PL) in air.

Table 14. Numbers of fish and species collected during each vertebrate survey and all surveys combined in Omeara Creek during 2015 (percent of total individuals) and Jaccard's coefficient for each survey*.

Species	Survey date			Total all surveys
	July 17	September 2	October 15	
Riffle Sculpin	125 (73.1)	146 (76.8)	138 (83.6)	409 (77.8)
Coho Salmon	29 (17.0)	29 (15.3)	13 (7.9)	71 (13.5)
Coastal Cutthroat Trout	15 (8.8)	15 (7.9)	14 (8.5)	44 (8.3)
Steelhead/Rainbow Trout	1 (0.6)	0	0	1 (0.2)
Pacific Lamprey	1 (0.6)	0	0	1 (0.2)
---total per survey	171	190	165	526
---number species per survey	5	3	3	5
---Jaccard's coefficient	0.6	1.0	1.0	

*Jaccard's coefficient was used as an index to gauge adequacy of sampling species composition by comparing species common to both even and odd numbered subreaches to total number of species collected during a survey (Peck et al. 2006).

Table 15. Number (n), mean length (mm), and mean weight (g) of fish subsampled during each vertebrate survey in Omeara Creek during 2015 (SD).

Species	July 17			September 2			October 15		
	n	Length	Weight	n	Length	Weight	n	Length	Weight
Riffle Sculpin	31	55.3 (14.7)	2.6 (2.6)	80	47.7 (17.5)	1.7 (1.9)	129	50.8 (13.2)	1.9 (1.2)
Coho Salmon	27	68.0 (17.5)	4.4 (4.6)	29	67.7 (6.9)	3.5 (1.0)	13	79.4 (8.2)	5.3 (1.5)
Coastal Cutthroat Trout	15	107.3 (42.2)	17.9 (21.4)	14	106.3 (45.7)	19.7 (23.7)	14	118.1 (43.1)	21.1 (21.8)
Steelhead/Rainbow Trout	1	44.0	0.8						
Pacific Lamprey	1	163	-						

Data Management

Assistance with data and database development/management is being provided by expertise within Refuges, Fisheries, and Water Resources. Activities on the pilot project to date have been completion of a data management plan template prior to initiating field surveys in 2015. The template identified the types, sources, and formats of project data, primarily habitat and vertebrate survey data generated during field trips, and water temperature and stream flow data recorded using data loggers. All habitat and vertebrate survey data are recorded on standard forms developed by EMAP. Because habitat data for a relatively small number of survey sites can be efficiently processed using existing agency spreadsheets (P. Kaufmann, EPA, pers. comm.), we modified an Excel spreadsheet developed by Virginia Department of Natural Resources for the pilot project. An Access database has been developed for vertebrate survey data. Files of both the spreadsheet and database have been distributed to each FWCO with instructional materials for their use. After entering data for each sentinel site, files are provided to the CRFWCO where a master copy is compiled and stored with supporting information. A database for temperature and stream flow data is being developed to facilitate data storage, summarization, analysis, and comparisons, such as relative to predicted water temperatures derived for various climate change scenarios (see Appendix C for examples). Whereas all macroinvertebrate collections have been archived for future analyses, samples from the Little Pend Oreille River have been processed to the order level (Appendix D).

Preliminary Conclusions and Recommendations

Activities through FY2015 have provided information for preliminary conclusions and recommendations concerning the physical and biological attributes addressed in the pilot monitoring program. For physical attributes (i.e., temperature, flow, and habitat), deployment of data loggers, since FY2014 at some sites, has indicated conditions that need to be considered for maintaining loggers to generate a time-series for temperature and water level (derived from pressure/temperature loggers). These conditions include presence of anchor ice in winter, extremely low water levels in summer, movement of large wood, and substrate deposition at some of the sentinel sites. We recommend modifying logger deployment location and method, where necessary during pilot implementation of the program, to accommodate these conditions. Temperature and pressure/temperature loggers should be downloaded at annual and six-month intervals, respectively.

The habitat assessment in FY2015 provided a “snap-shot” of conditions during the initial year of pilot implementation, and we found that the assessment could be completed within one day at most sites. We recommend repeating the habitat assessments during FY2016 and FY2017. Assessing habitat during three consecutive years is intended to provide a robust indication of baseline conditions, as well as variability of specific habitat variables, which may be influenced by survey crews’ experience.

For biological attributes, vertebrate surveys indicated that: sentinel sites had relatively simple fish assemblages (i.e., 4—9 taxa encountered for all surveys combined at each site); sampling

was adequate for most surveys (Jaccard's coefficient >0.7 for 12 of 14 surveys); and surveys could be completed within one day at most sites. Because vertebrate surveys were conducted relatively late in FY2015 (July and later), we recommend beginning surveys earlier during the low-flow period during FY2016 and FY2017. Expanding the period over which surveys are conducted will allow us to assess fish assemblage structure over a broader range of conditions and avoid periods when surveys would be precluded due to high water temperatures.

Acknowledgements

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Appendix A. Geospatial assessment and information used in selection of sentinel sites.

Region 1 mainland NWRs in columns by Level I, II, and III ecoregions (first, second, and third rows, respectively) and LCCs. (Ecoregions after Omernik available at http://www.epa.gov/wed/pages/ecoregions.htm).

Marine West Coast Forest			Northwestern Forested Mountains				North American Deserts				
Marine West Coast Forest			Western Cordillera				Cold Desert				
Coast Range	**Puget Lowland**	**Willamette Valley**	**Cascades**	**Eastern Cascades Slopes and Foothills**	**Northern Rockies**	**Middle Rockies**	**Columbia Plateau**	**Snake River Plain**	**Northern Basin and Range**	**Central Basin and Range**	**Wyoming Basin**
Bandon Marsh[1]	Dungeness[1]	Ankeny[1]	Franz Lake[1]	Conboy Lake[2]	Kootenai[2]	Grays Lake[2]	Cold Springs[2]	Camas[3]	Hart Mountain[3]	Oxford Slough WPA[3]	Bear Lake[2]
Gray's Harbor[1]	Nisqually[1]	Basket Slough[1]	Pierce[1]		Little Pend Orielle[2]		Columbia[2]	Deer Flat[3]	Malheur[3]		
Julia Butler Hansen[1]		Ridgefield[1]					McKay Creek[2]	Minidoka[3]	Sheldon[3]		
Lewis and Clark[1]		Steigerwald Lake[1]					McNary[2]				
Nestucca Bay[1]		Tualatin River[1]					Saddle Mountain[2]				
Siletz Bay[1]		William L.Finley[1]					Toppenish[2]				
Willapa[1]							Turnbull[2]				
Cape Meares[1]	Protection Island[1]						Umatilla[2]				
Copalis[1]	San Juan Island[1]										
Flattery Rocks[1]											
Oregon Islands[1]											
Quillayute Needles[1]											
Three Arch Rocks[1]											

[1] North Pacific LCC, [2] Great Northern LCC, [3] Great Basin LCC

Information compiled by R1 Water Resources for the geospatial assessment of 13 NWRs.

	Marine West Coast Forest Ecoregion						Northwestern Forested Mountains Ecoregion					North American Deserts Ecoregion							
ORGNAME	DUNGENESS NATIONAL WILDLIFE REFUGE	WILLAPA NATIONAL WILDLIFE REFUGE	WILLAPA NATIONAL WILDLIFE REFUGE	WILLAPA NATIONAL WILDLIFE REFUGE	WILLIAM L. FINLEY NATIONAL WILDLIFE REFUGE	BANDON MARSH NATIONAL WILDLIFE REFUGE	KOOTENAI NATIONAL WILDLIFE REFUGE	LITTLE PEND OREILLE NATIONAL WILDLIFE REFUGE	LITTLE PEND OREILLE NATIONAL WILDLIFE REFUGE	FRANZ LAKE NATIONAL WILDLIFE REFUGE	PIERCE NATIONAL WILDLIFE REFUGE	TURNBULL NATIONAL WILDLIFE REFUGE	TOPPENISH NATIONAL WILDLIFE REFUGE	HART MOUNTAIN NATIONAL ANTELOPE REFUGE	HART MOUNTAIN NATIONAL ANTELOPE REFUGE	MALHEUR NATIONAL WILDLIFE REFUGE	MALHEUR NATIONAL WILDLIFE REFUGE	SHELDON NATIONAL WILDLIFE REFUGE	SHELDON NATIONAL WILDLIFE REFUGE
LIT	DNG	WLP	WLP	WLP	WMF	BDM	KTN	LPO	LPO	WFZ	PRC	TBL	TPN	HTM	HTM	MLH	MLH	SAR	SAR
STATE	WA	WA	WA	WA	OR	OR	ID	WA	WA	WA	WA	WA	WA	OR	OR	OR	OR	NV	NV
Site_Stream_Nm	Dean Creek	HQ	North Creek	O'Meara Creek	Muddy Creek	Fahey Creek	Myrtle Creek	LPO Blacktail Rd	LPO West	Indian Mary Creek	Hardy Creek	Pine Creek	Toppenish Creek	Guano Creek	Rock Creek	Blitzen R.	Bridge Creek	Fish Creek	Virgin Creek
LENGTH_TO_REFUGE_BNDY_KM	0.45	0.9	0.145	1.6	13.6	0.35	1.3	1.9	10	0.8	0.3	1.3	4.2	10.7	12.2	off-refuge	1.9	9.7	>19 (to reservoir)
DRAINAGE_AREA_SQMILES	2.9	0.2	0.5	0.8	71.3	1.4	38.0	82.8	130.7	2.5	3.0	61.9	493.4	16.9	18.2	209.2	29.5	32.5	147.7
DRAINAGE_AREA_SQKM	7.5	0.5	1.3	2.0	184.6	3.6	98.5	214.3	338.4	6.6	7.9	160.3	1277.8	43.7	47.1	541.8	76.4	84.2	382.5
%PVT	51.1%	33.6%	97.4%	55.5%	81.7%	96.4%	18.4%	50.3%	39.4%	48.7%	10.5%	71.5%	?	0.0%	0.0%	12.4%	29.1%	0.0%	0.0%
%FWS	2.0%	66.4%	2.6%	44.5%	10.7%	3.6%	2.6%	19.1%	39.8%	4.7%	2.0%	28.4%	0.5%	100.0%	100.0%	0.0%	2.1%	100.0%	87.1%
%FED	7.2%	66.4%	2.6%	44.5%	18.2%	3.6%	81.5%	43.2%	55.8%	26.7%	22.9%	28.4%	99% (BIA)	100.0%	100.0%	87.1%	70.9%	100.0%	100.0%
Barren Land	0.0%	0.0%	0.0%	0.1%	1.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.1%
Cultivated Crops	0.0%	0.0%	0.0%	0.0%	10.2%	0.2%	0.9%	0.0%	0.0%	0.0%	0.4%	21.2%	15.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Deciduous Forest	2.0%	3.7%	1.7%	0.3%	1.7%	0.4%	0.2%	0.0%	0.0%	21.9%	7.3%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Developed, High Intensity	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Developed, Low-Med Intensity	1.8%	0.0%	0.0%	0.0%	1.7%	7.7%	0.0%	0.1%	0.1%	0.5%	1.3%	0.5%	2.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Developed, Open Space	1.9%	1.1%	1.5%	0.0%	4.7%	6.7%	0.0%	0.7%	0.5%	5.1%	2.4%	2.6%	1.8%	0.0%	0.0%	0.0%	0.0%	0.6%	0.0%
Evergreen Forest	64.7%	89.6%	74.5%	77.9%	33.9%	60.1%	93.2%	91.8%	91.4%	29.6%	56.6%	32.1%	21.8%	0.7%	0.8%	13.9%	9.9%	0.0%	0.1%
Hay/Pasture	0.0%	0.0%	0.0%	0.0%	19.6%	3.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.3%	3.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Herbaceuous	4.4%	0.0%	1.2%	7.6%	5.5%	12.1%	1.5%	0.3%	0.9%	2.0%	1.8%	18.3%	1.4%	0.4%	0.2%	0.1%	0.0%	0.0%	3.1%
Mixed Forest	10.9%	5.2%	2.4%	1.6%	6.6%	1.1%	0.0%	0.0%	0.0%	20.0%	6.5%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Open Water	0.0%	0.0%	0.0%	0.0%	0.1%	1.3%	0.3%	0.9%	0.7%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Shrub/Scrub	13.9%	0.0%	18.6%	12.5%	7.8%	3.1%	2.8%	5.6%	5.7%	20.0%	22.5%	20.7%	50.0%	95.8%	98.6%	85.5%	90.0%	99.2%	96.4%
Wetlands	0.4%	0.4%	0.2%	0.0%	6.8%	4.4%	0.9%	0.5%	0.6%	0.9%	0.3%	2.6%	2.9%	3.0%	0.3%	0.1%	0.0%	0.1%	0.2%
AVG_ANNUAL_PRECIP_INCHES	32.3	106.4	109.2	110.5	54.58	62.81	36.8	31.5	28.9	82.6	85.8	18.3	21.2	16.79	16.66	26.89	24.45	10.66	11.69
AVGMINTEMP_F	*43.47*	*43.76*	*43.76*	*43.76*	41.72	44.15	*35.21*	*31.66*	*31.66*	*44.24*	*44.47*	*35.77*	*39.86*	28.7	28.89	32.51	32.79	27.43	31.1
AVGMAXTEMP_F	*55.74*	*57.60*	*57.60*	*57.60*	62.27	59.39	*57.41*	*54.11*	*54.11*	*61.72*	*61.47*	*58.07*	*65*	51.93	52.31	54.8	55.69	51	56.2
DRAINAGE_MEAN_ELEV_FT	1553	395	661	472	629	116	4818	3626	3466	1036	1808	2361	5251	6743	6659	6175	5926	6238	~6200
DRAINAGE_ELEVMAX_FT	2446	994	1384	1129	2719	224	7293	5561	5611	2336	3216	2628	5984	8012	7745	9720	7491	7224	*6800*

Data Sources: Drainage Basin Stats - USGS Streamstats application; Ownership - BLM Federal Ownership Layer (Aug 2013); Land Cover - 2006 National Land Cover Dataset (NLCD) (most recent release)

NOTES:

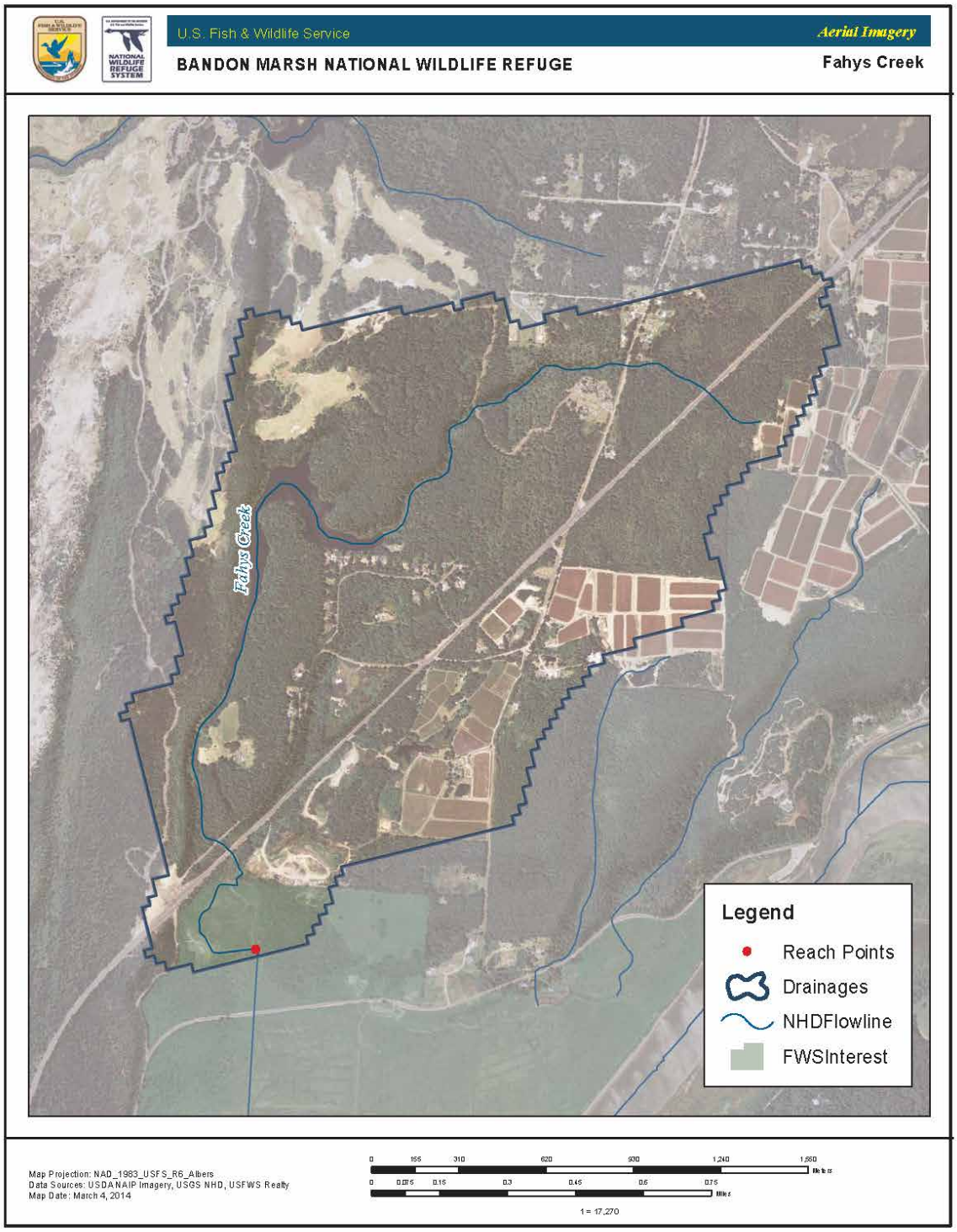
Above data sources are regional/national datasets and as a consequence are relatively coarse, and may contain generalization errors.

Italicized data represents data gathered via different means. For example, Virgin Creek was outside the StreamStats jurisdiction, and PRISM climate data for WA was obtained from a refuge clip rather than drainage as WA Streamstats did not provide climate data.

Drainage delineations for MLH-Bridge Creek, TBL-Pine Creek, and TPN-Toppenish Creek were found to have errors of commission and were hand-edited to better reflect the actual contributing area.

LPO and TBL have substantial private inholdings and ownership metrics were recalculated using R1's Acquired Boundaries (FWSInterest) layer.

Marine West Coast Forest Ecoregion


U.S. Fish & Wildlife Service
Aerial Imagery
BANDON MARSH NATIONAL WILDLIFE REFUGE
Fahys Creek
Fahys Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
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Meters
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Miles
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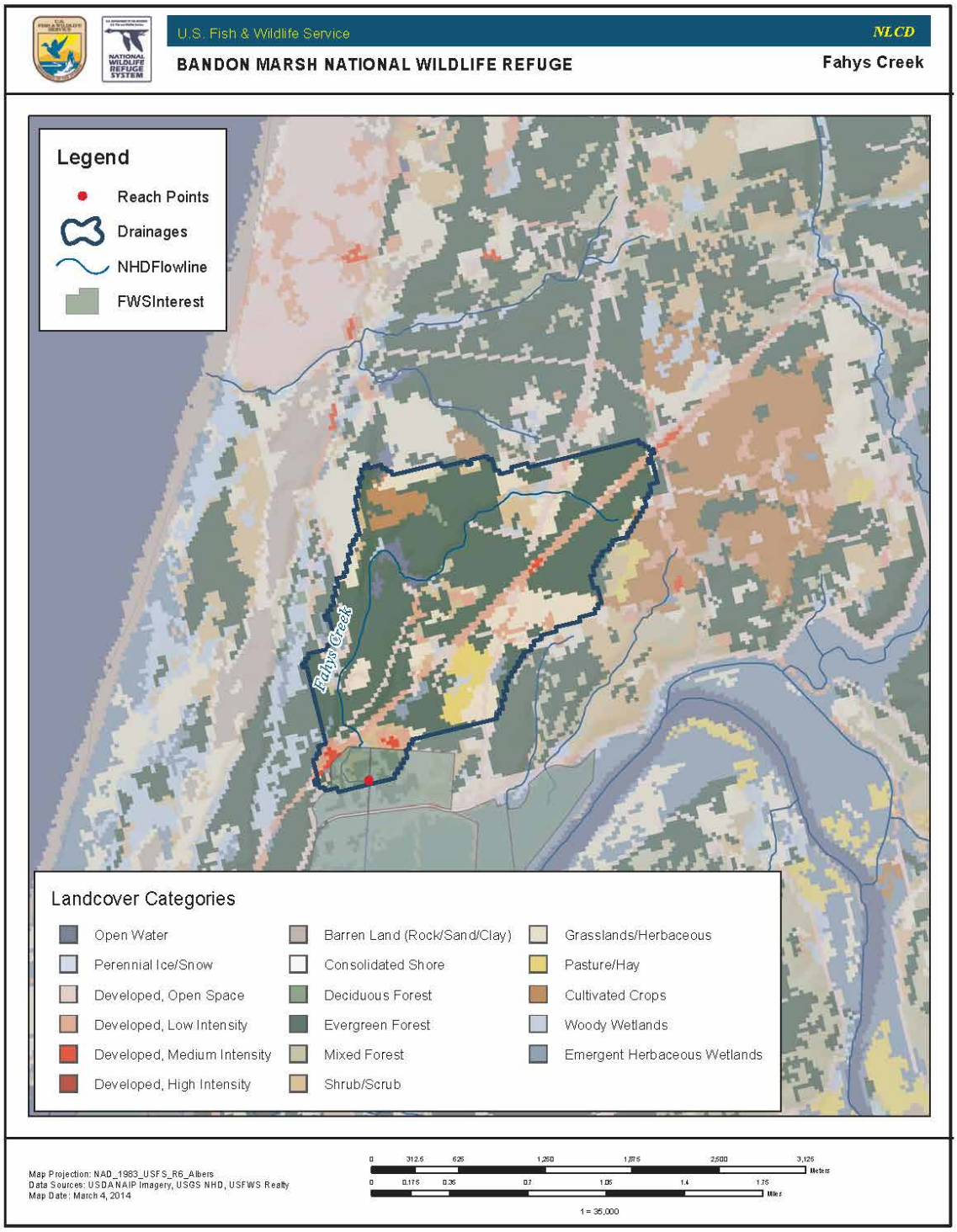
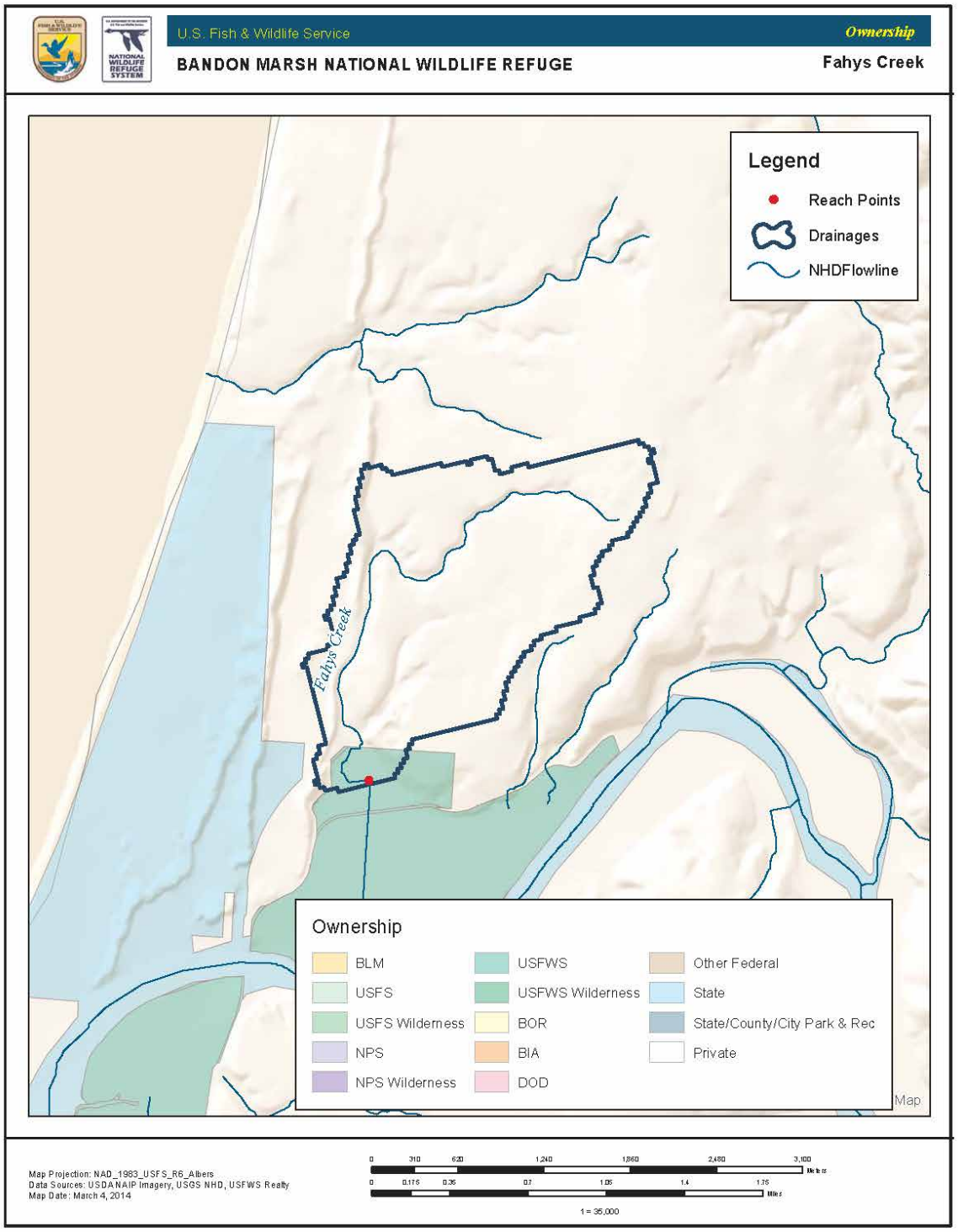
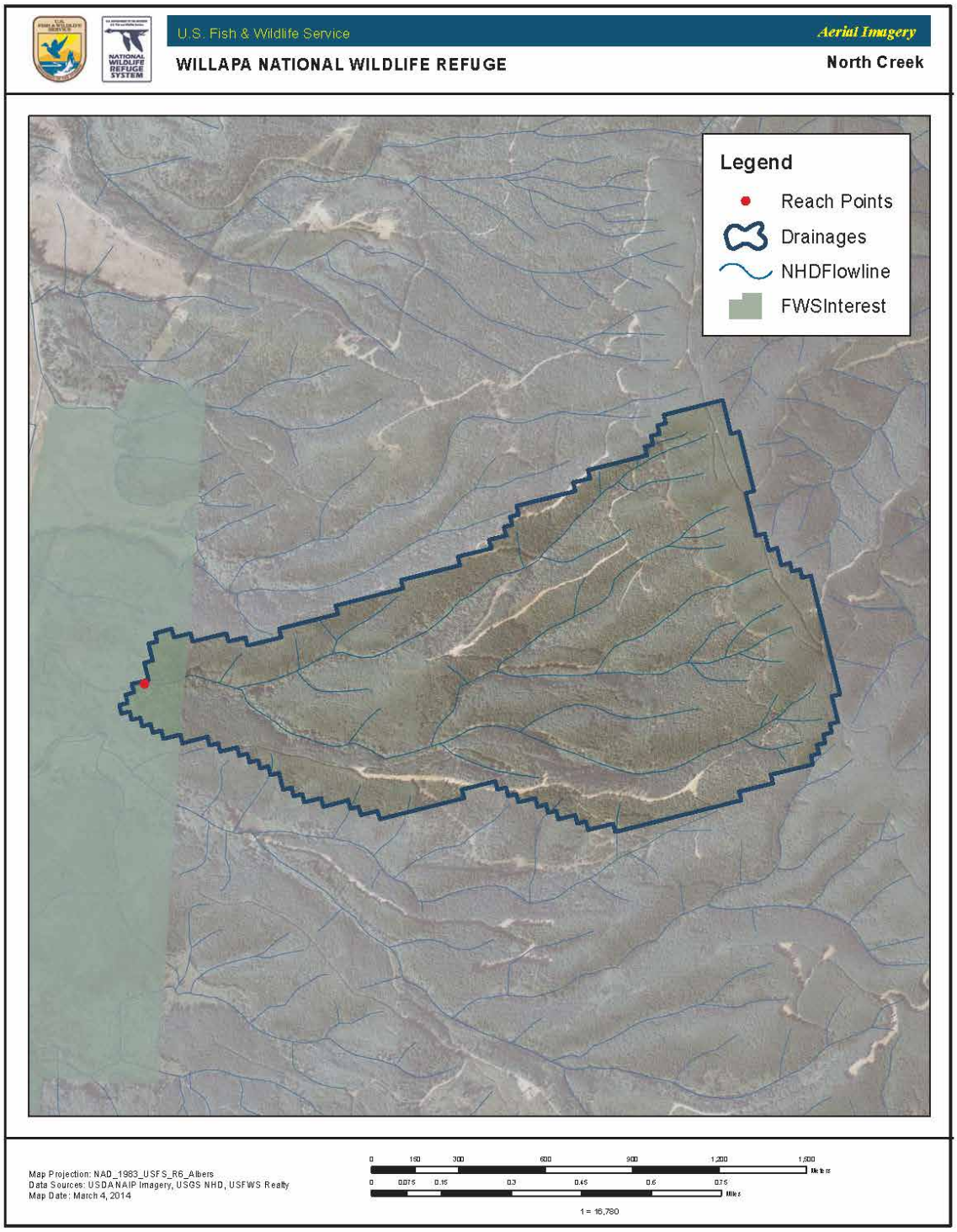
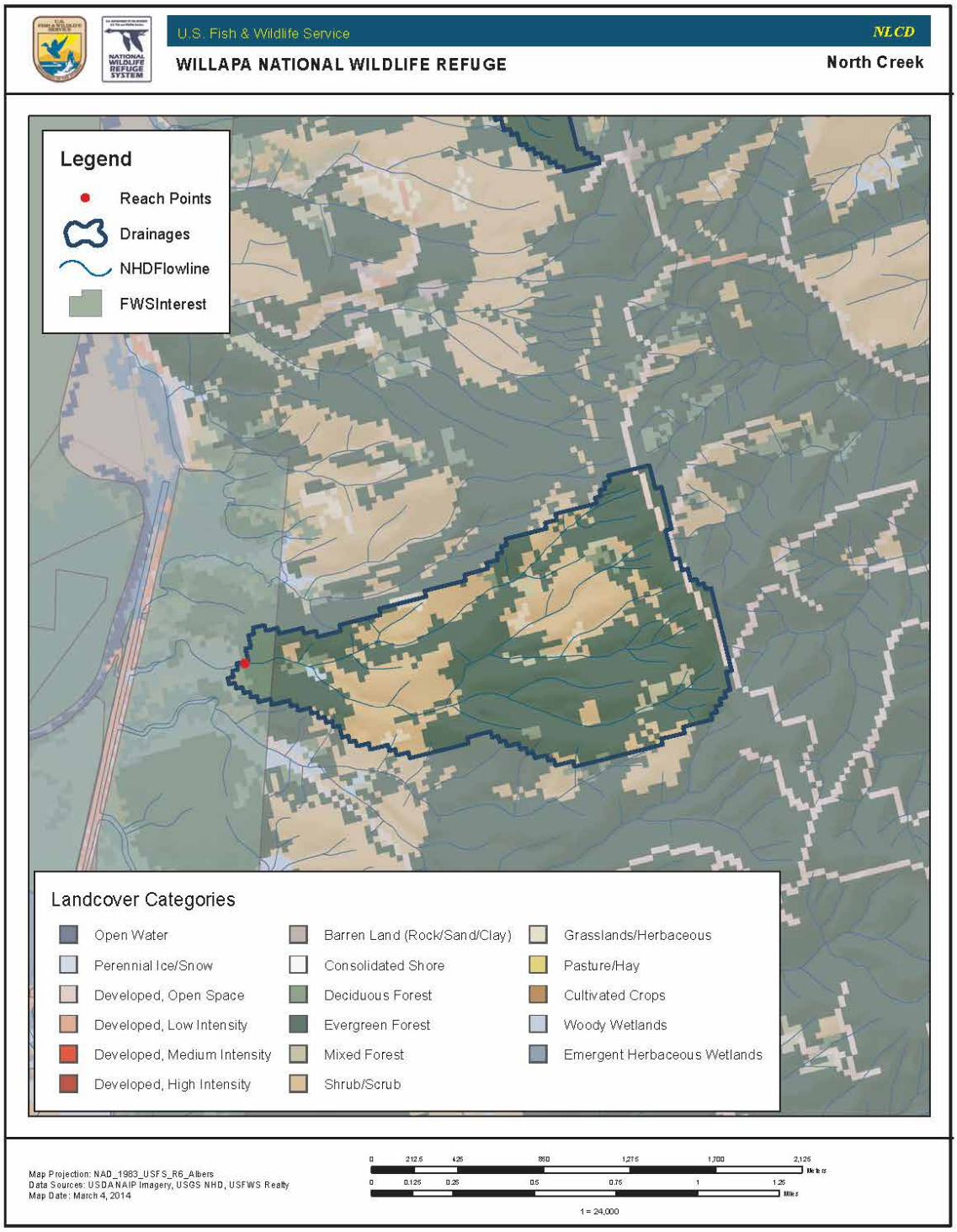
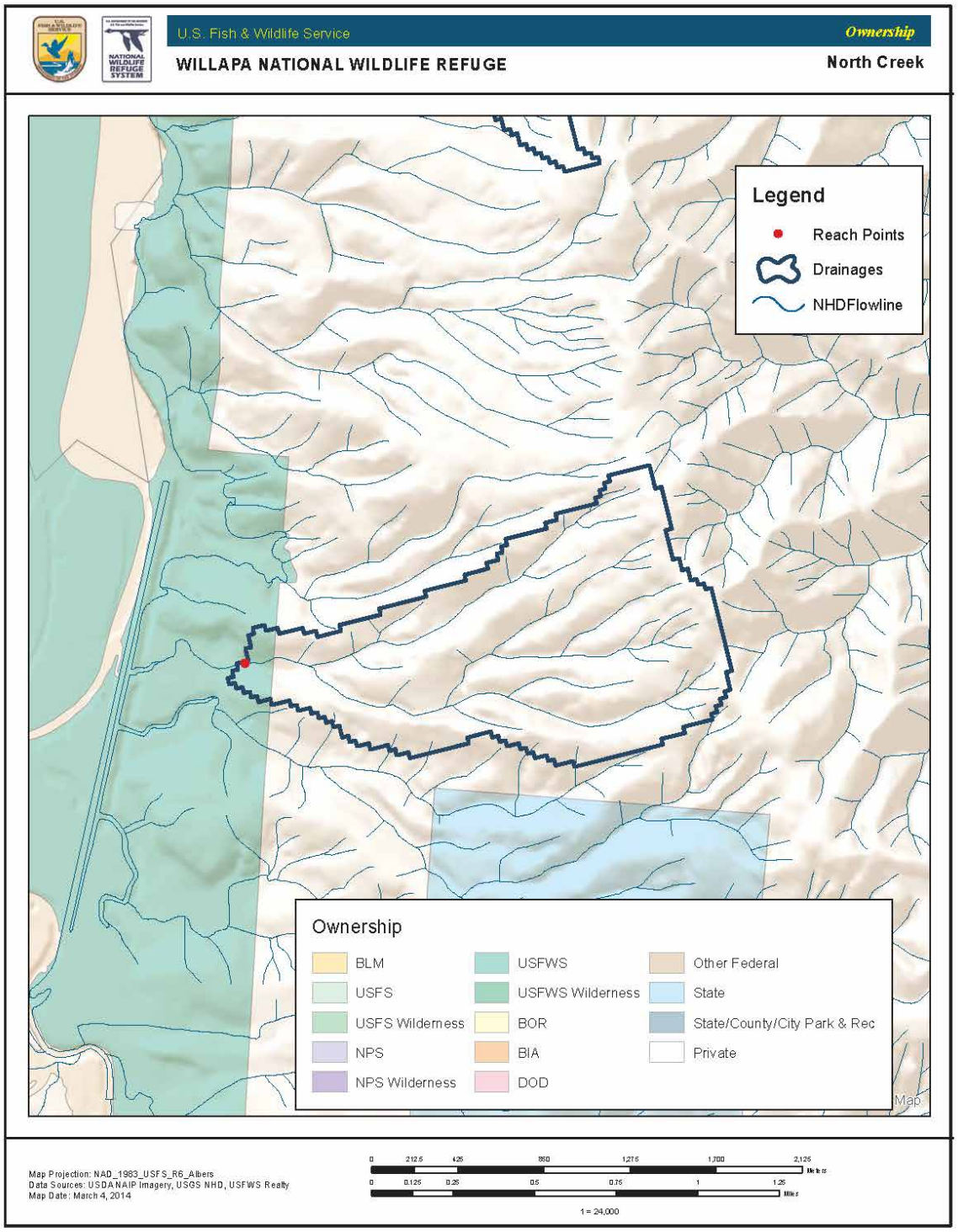
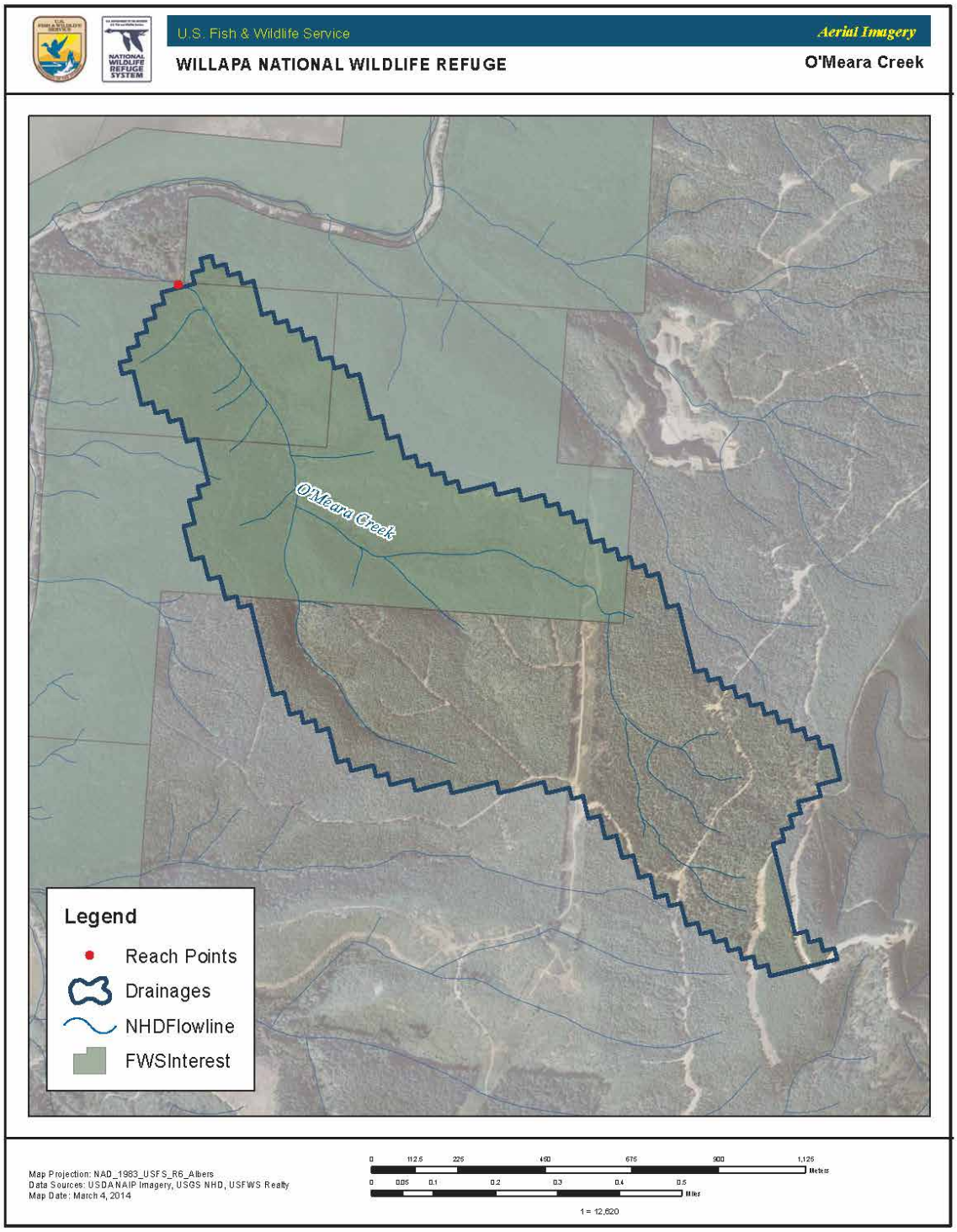

U.S. Fish & Wildlife Service
NLCD
BANDON MARSH NATIONAL WILDLIFE REFUGE
Fahys Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Fahys Creek
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 312.5 625 1,250 1,875 2,500 3,125
Meters
0 0.175 0.35 0.7 1.05 1.4 1.75
Miles
1 = 35,000

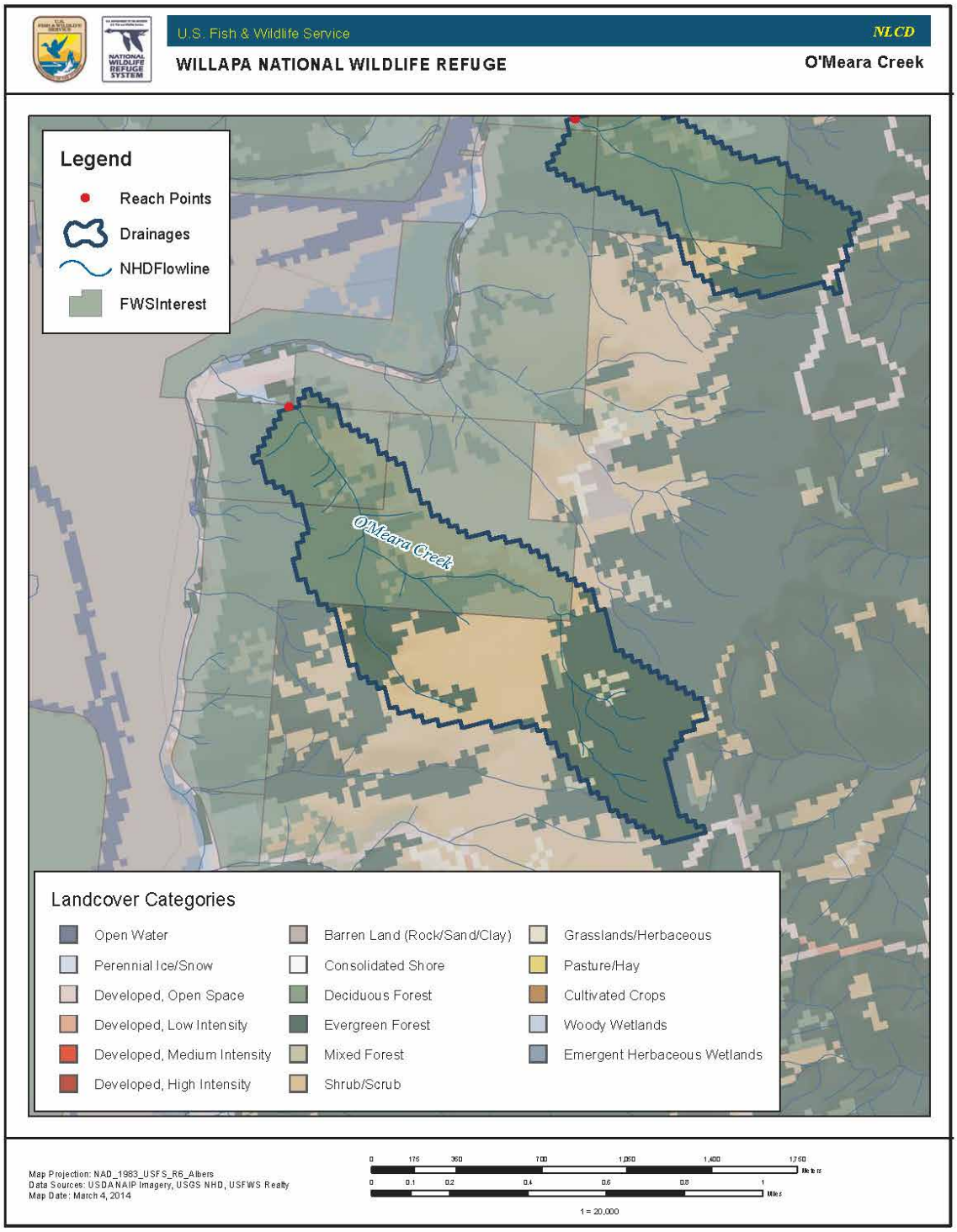

U.S. Fish & Wildlife Service
Ownership
BANDON MARSH NATIONAL WILDLIFE REFUGE
Fahys Creek
Legend
Reach Points
Drainages
NHDFlowline
Fahys Creek
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 310 620 1,240 1,860 2,480 3,100
Meters
0 0.175 0.35 0.7 1.05 1.4 1.75
Miles
1 = 35,000

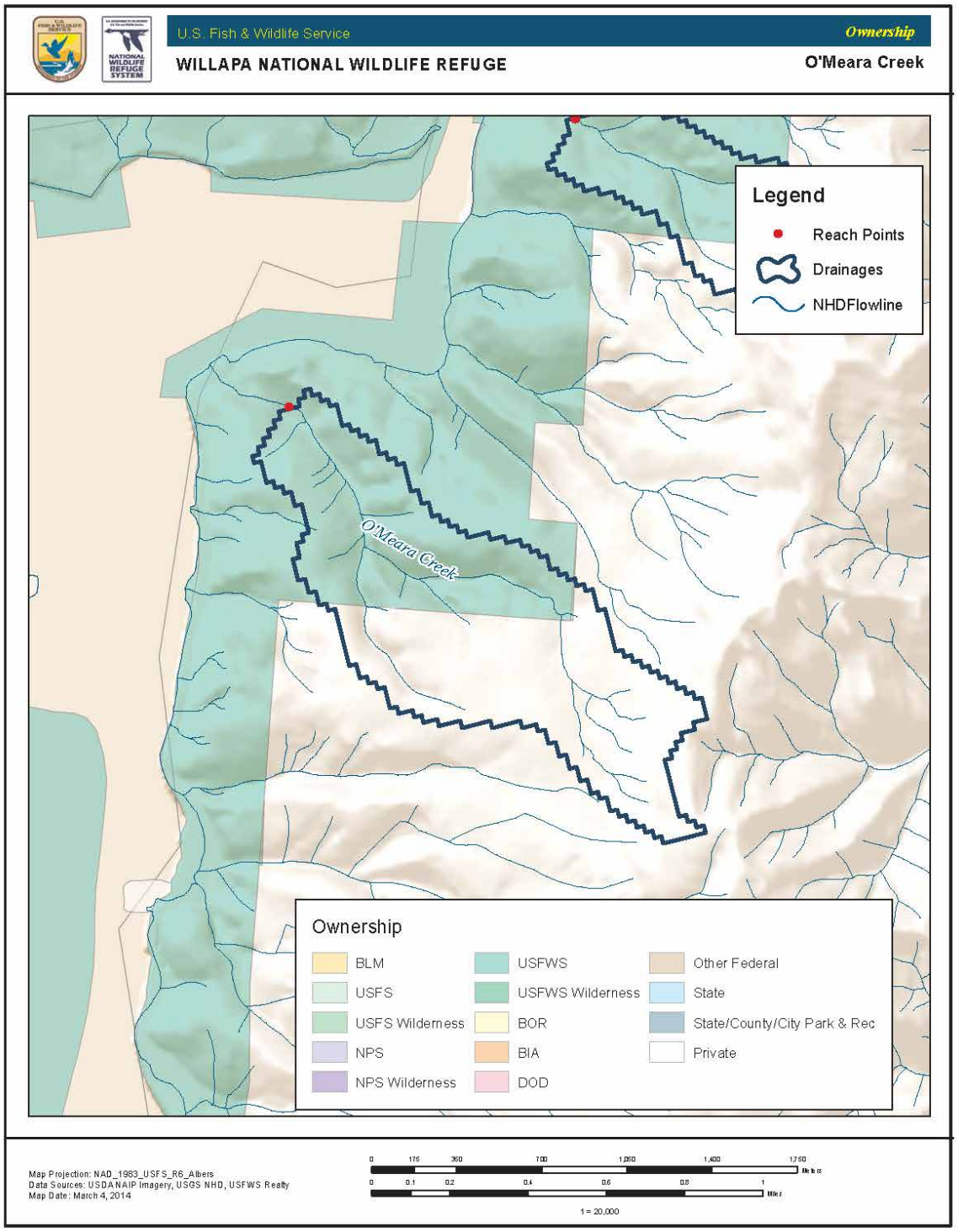

U.S. Fish & Wildlife Service
Aerial Imagery
WILLAPA NATIONAL WILDLIFE REFUGE
North Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 150 300 600 900 1,200 1,500
Meters
0 0.075 0.15 0.3 0.45 0.6 0.75
Miles
1 = 16,780

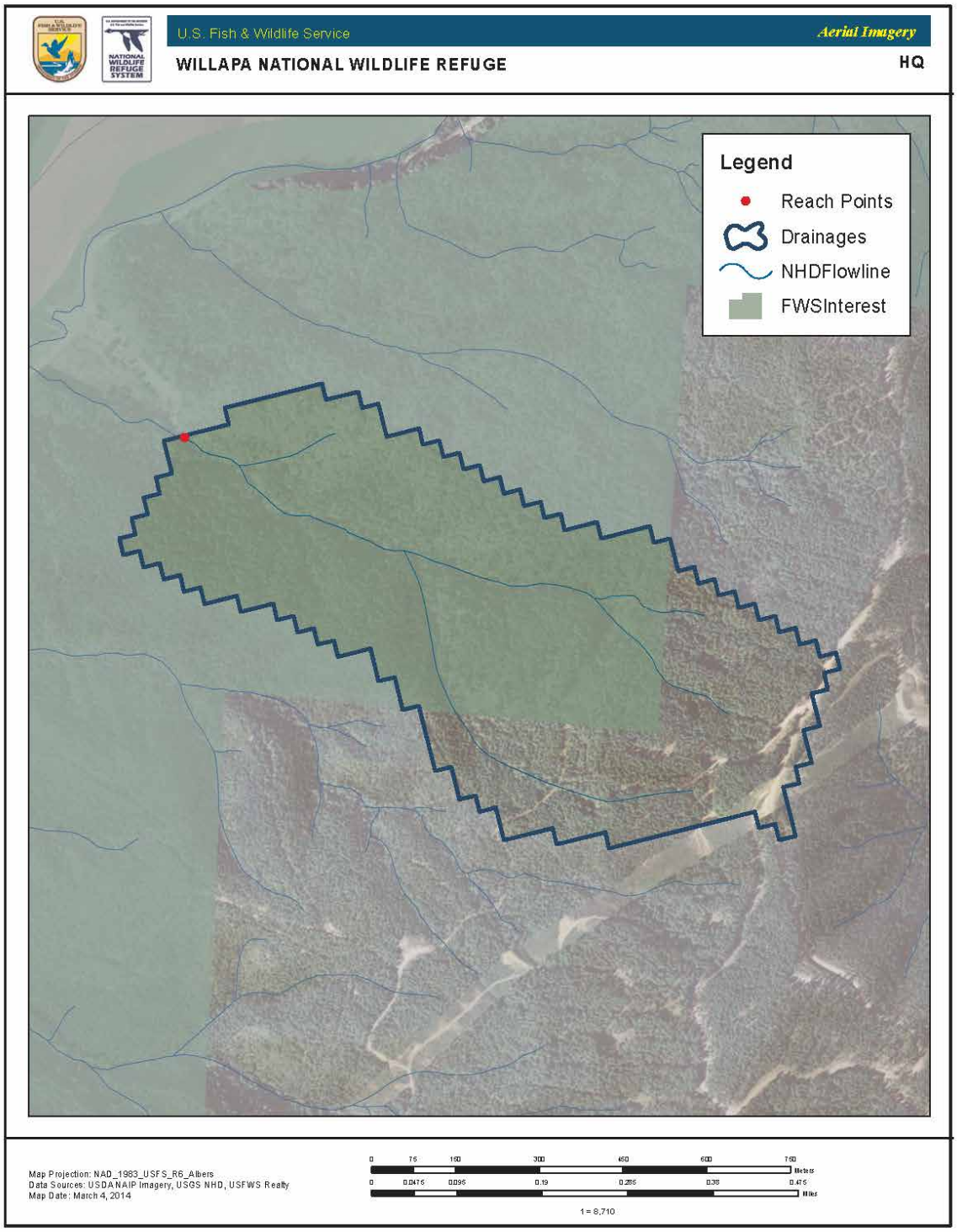

U.S. Fish & Wildlife Service
NLCD
WILLAPA NATIONAL WILDLIFE REFUGE
North Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 212.5 425 850 1,275 1,700 2,125
Meters
0 0.125 0.25 0.5 0.75 1 1.25
Miles
1 = 24,000

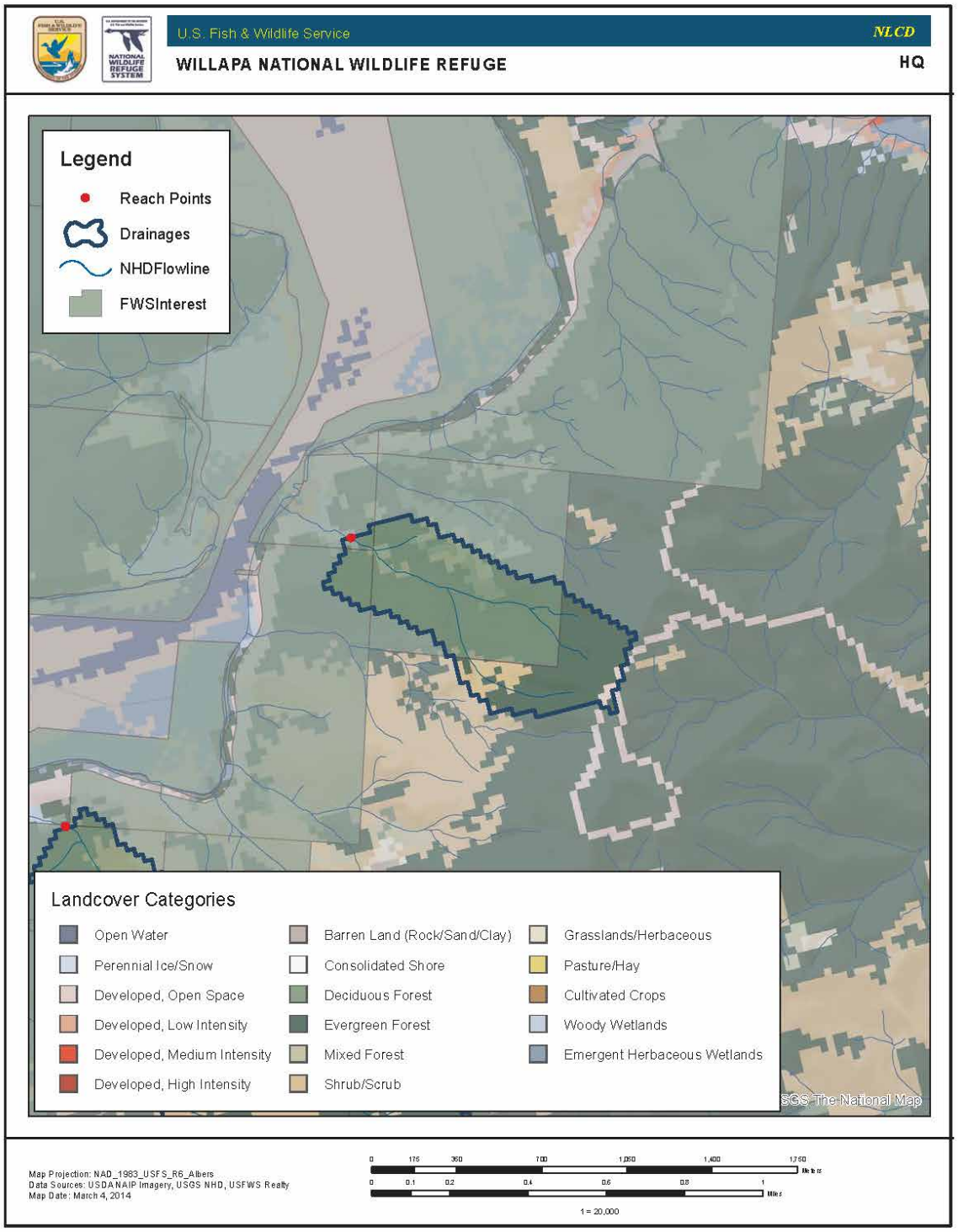

U.S. Fish & Wildlife Service
Ownership
WILLAPA NATIONAL WILDLIFE REFUGE
North Creek
Legend
Reach Points
Drainages
NHDFlowline
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 212.5 425 850 1,275 1,700 2,125
0 0.125 0.25 0.5 0.75 1 1.25
1 = 24,000

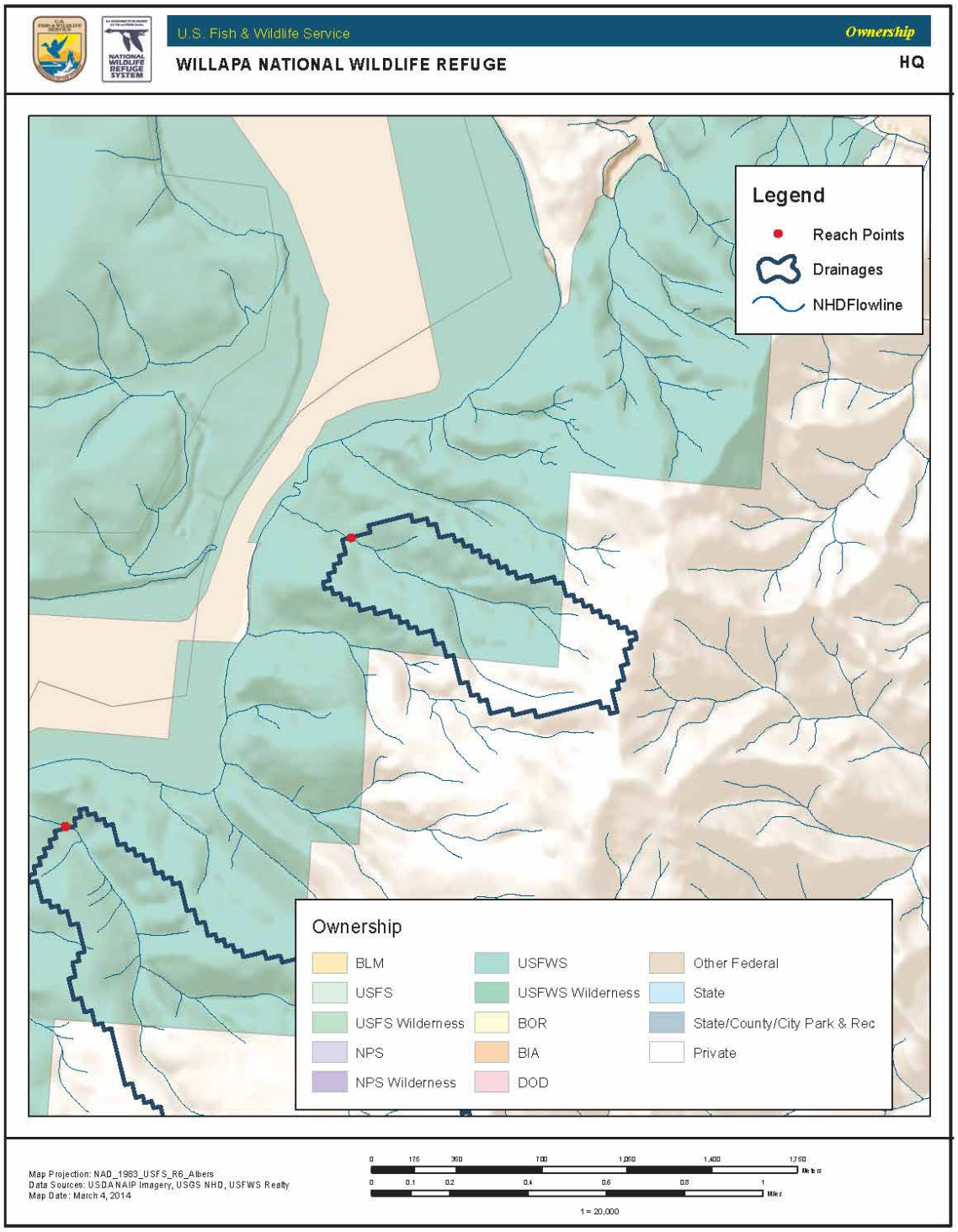

U.S. Fish & Wildlife Service
Aerial Imagery
WILLAPA NATIONAL WILDLIFE REFUGE
O'Meara Creek
O'Meara Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 112.5 225 450 675 900 1,125
Meters
0 0.05 0.1 0.2 0.3 0.4 0.5
Miles
1 = 12,820

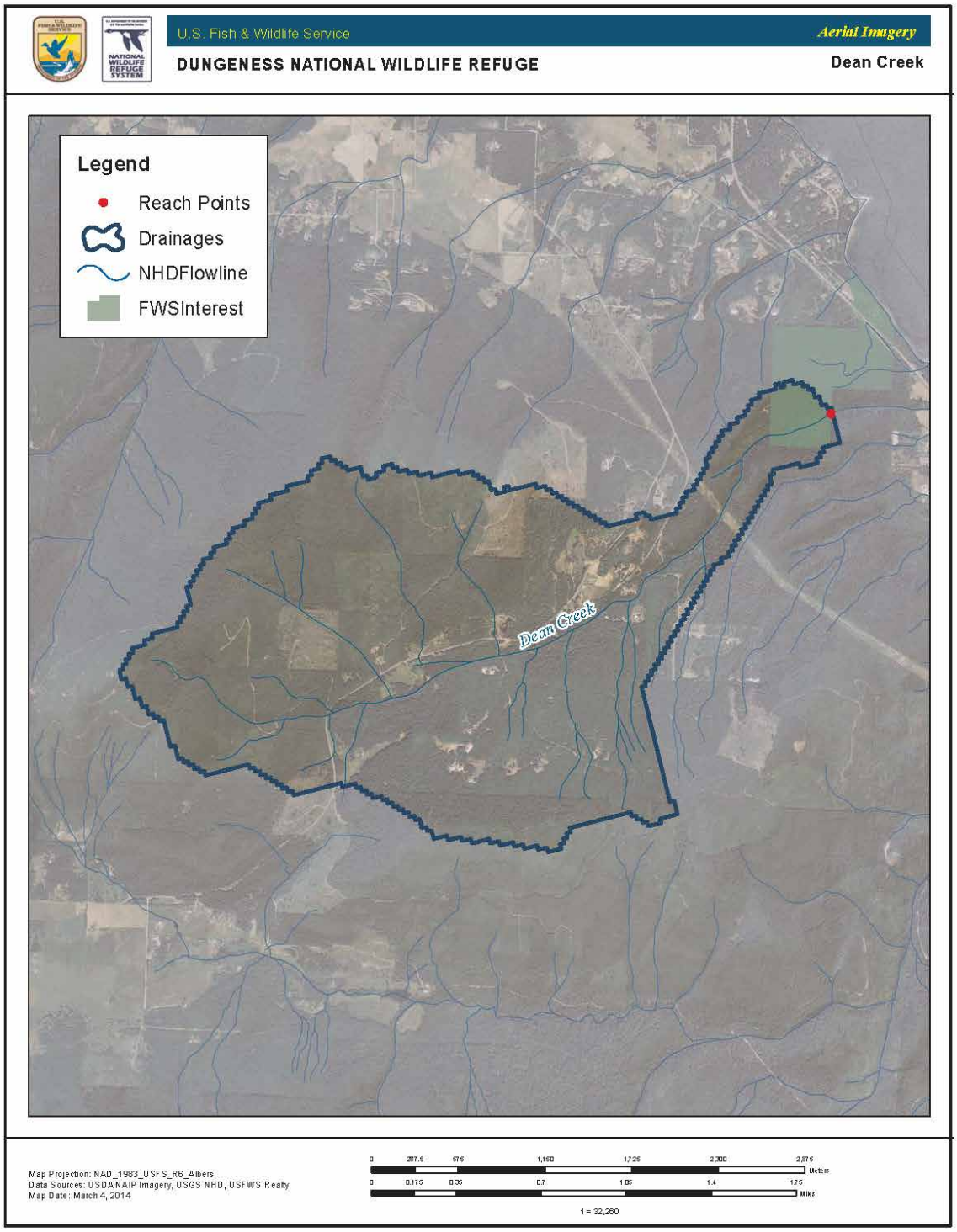

U.S. Fish & Wildlife Service
NLCD
WILLAPA NATIONAL WILDLIFE REFUGE
O'Meara Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
O'Meara Creek
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
1 = 20,000


U.S. Fish & Wildlife Service
Ownership
WILLAPA NATIONAL WILDLIFE REFUGE
O'Meara Creek
Legend
Reach Points
Drainages
NHDFlowline
O'Meara Creek
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
1 = 20,000


U.S. Fish & Wildlife Service
Aerial Imagery
WILLAPA NATIONAL WILDLIFE REFUGE
HQ
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 75 150 300 450 600 750
Meters
0 0.0475 0.095 0.19 0.285 0.38 0.475
Miles
1 = 8,710


U.S. Fish & Wildlife Service
NLCD
WILLAPA NATIONAL WILDLIFE REFUGE
HQ
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
USGS The National Map
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 175 350 700 1,050 1,400 1,750
Meters
0 0.1 0.2 0.4 0.6 0.8 1
Miles
1 = 20,000


U.S. Fish & Wildlife Service
Ownership
WILLAPA NATIONAL WILDLIFE REFUGE
HQ
Legend
Reach Points
Drainages
NHDFlowline
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 175 350 700 1,050 1,400 1,750
Meters
0 0.1 0.2 0.4 0.6 0.8 1
Miles
1 = 20,000


U.S. Fish & Wildlife Service
Aerial Imagery
DUNGENESS NATIONAL WILDLIFE REFUGE
Dean Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Dean Creek
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
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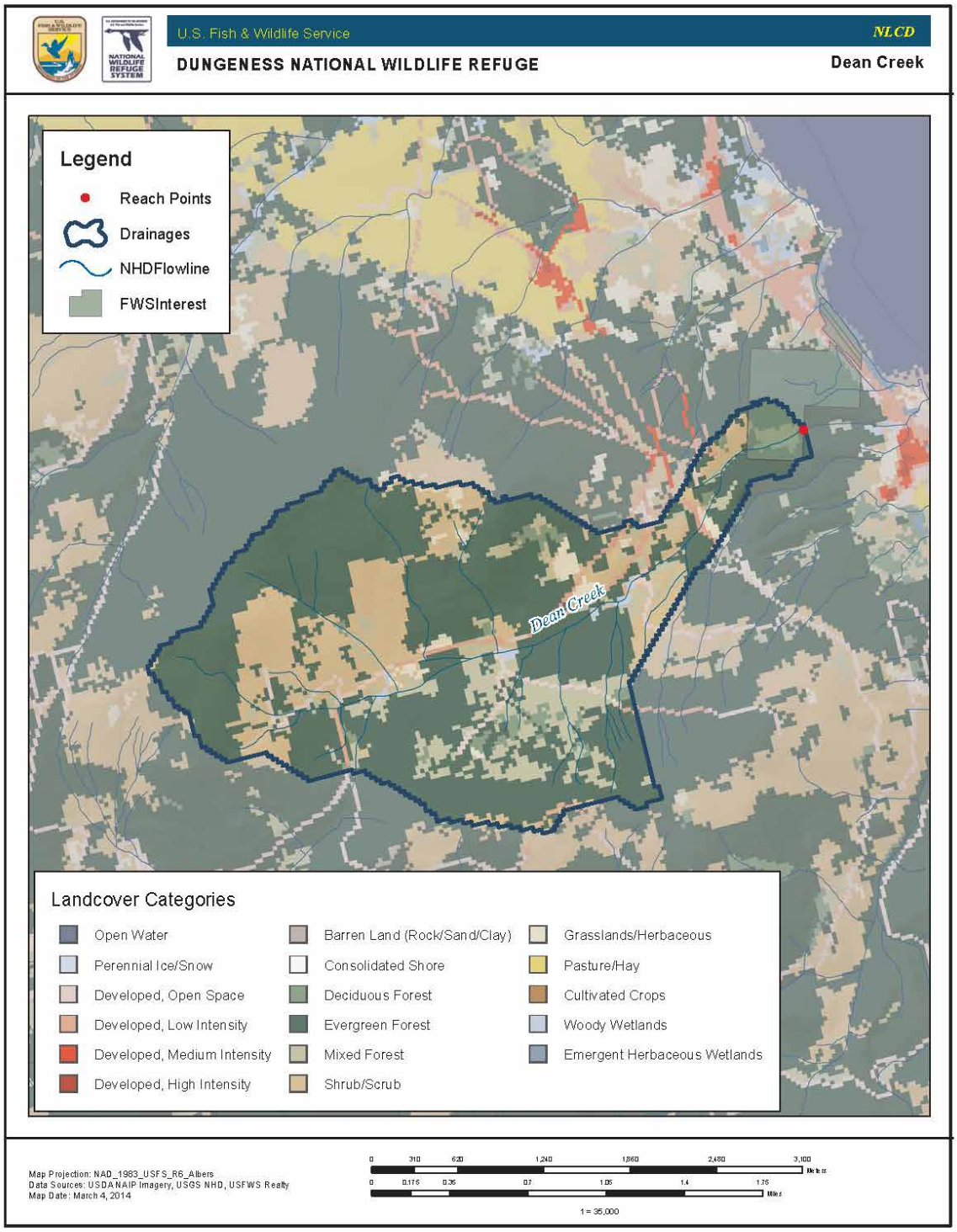
U.S. Fish & Wildlife Service
NLCD
DUNGENESS NATIONAL WILDLIFE REFUGE
Dean Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Dean Creek
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
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Miles
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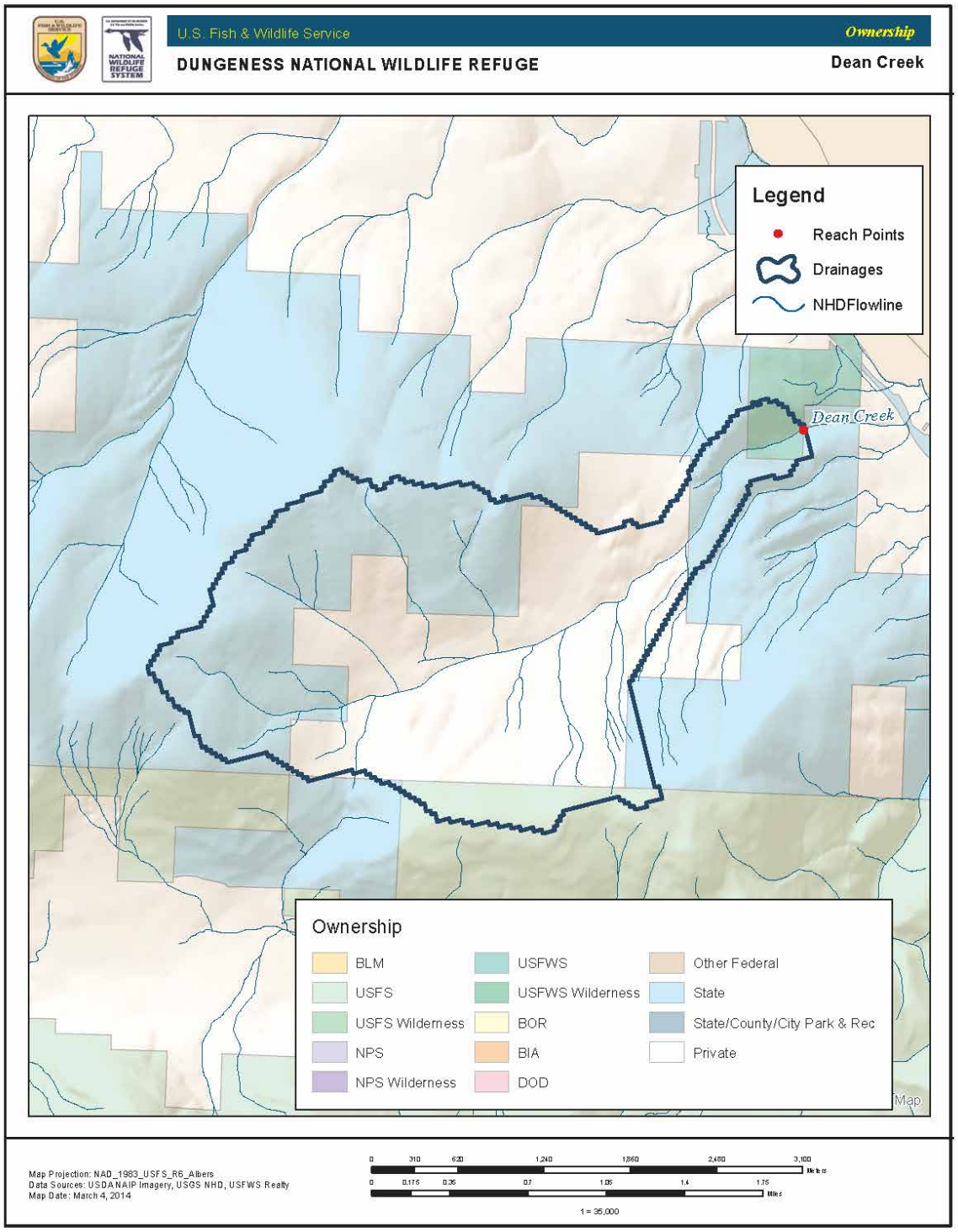
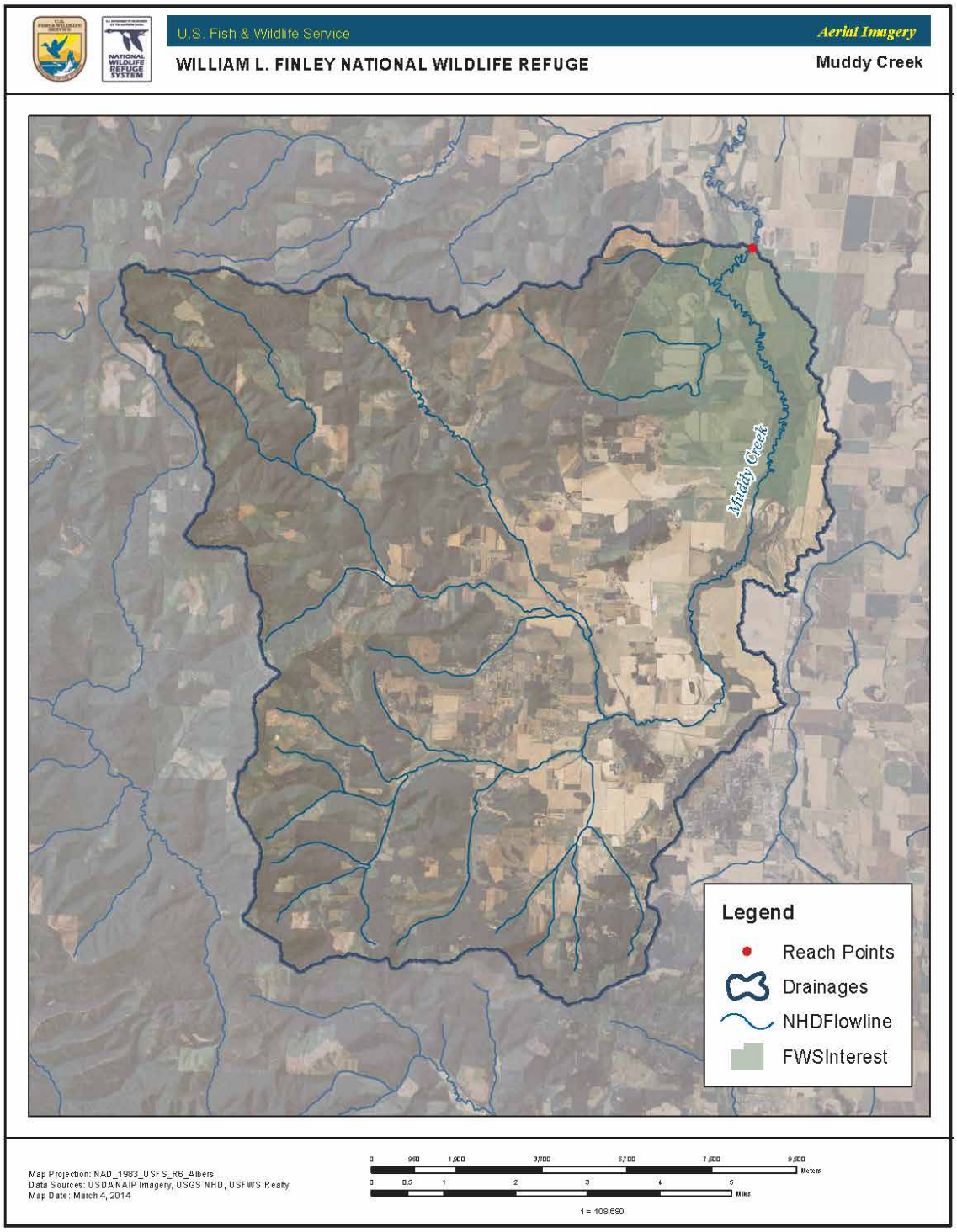

U.S. Fish & Wildlife Service
Ownership
DUNGENESS NATIONAL WILDLIFE REFUGE
Dean Creek
Legend
Reach Points
Drainages
NHDFlowline
Dean Creek
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 310 620 1,240 1,860 2,480 3,100
Meters
0 0.175 0.35 0.7 1.05 1.4 1.75
Miles
1 = 35,000


U.S. Fish & Wildlife Service
Aerial Imagery
WILLIAM L. FINLEY NATIONAL WILDLIFE REFUGE
Muddy Creek
Muddy Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
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Miles
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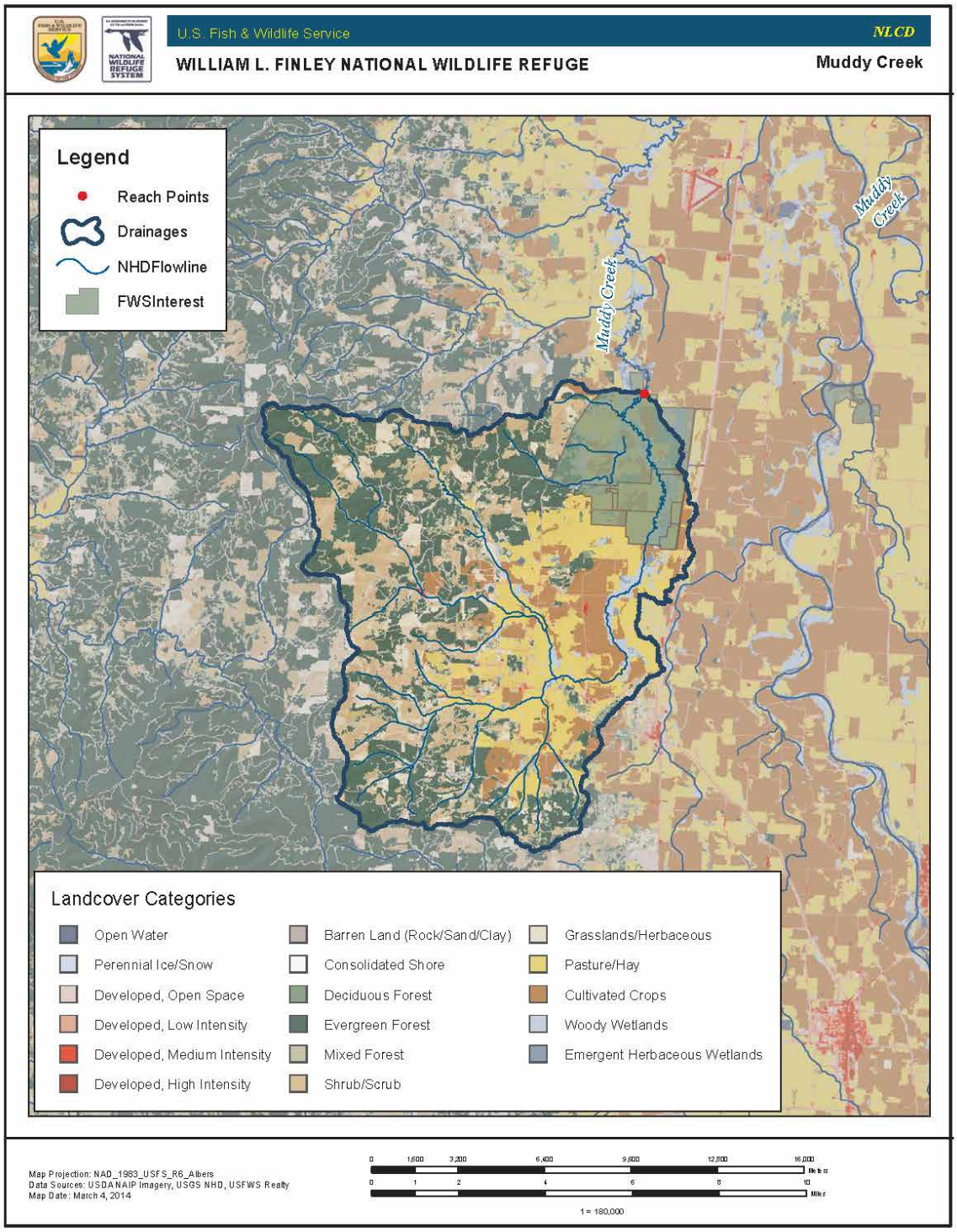
U.S. Fish & Wildlife Service
NLCD
WILLIAM L. FINLEY NATIONAL WILDLIFE REFUGE
Muddy Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Muddy Creek
Muddy Creek
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
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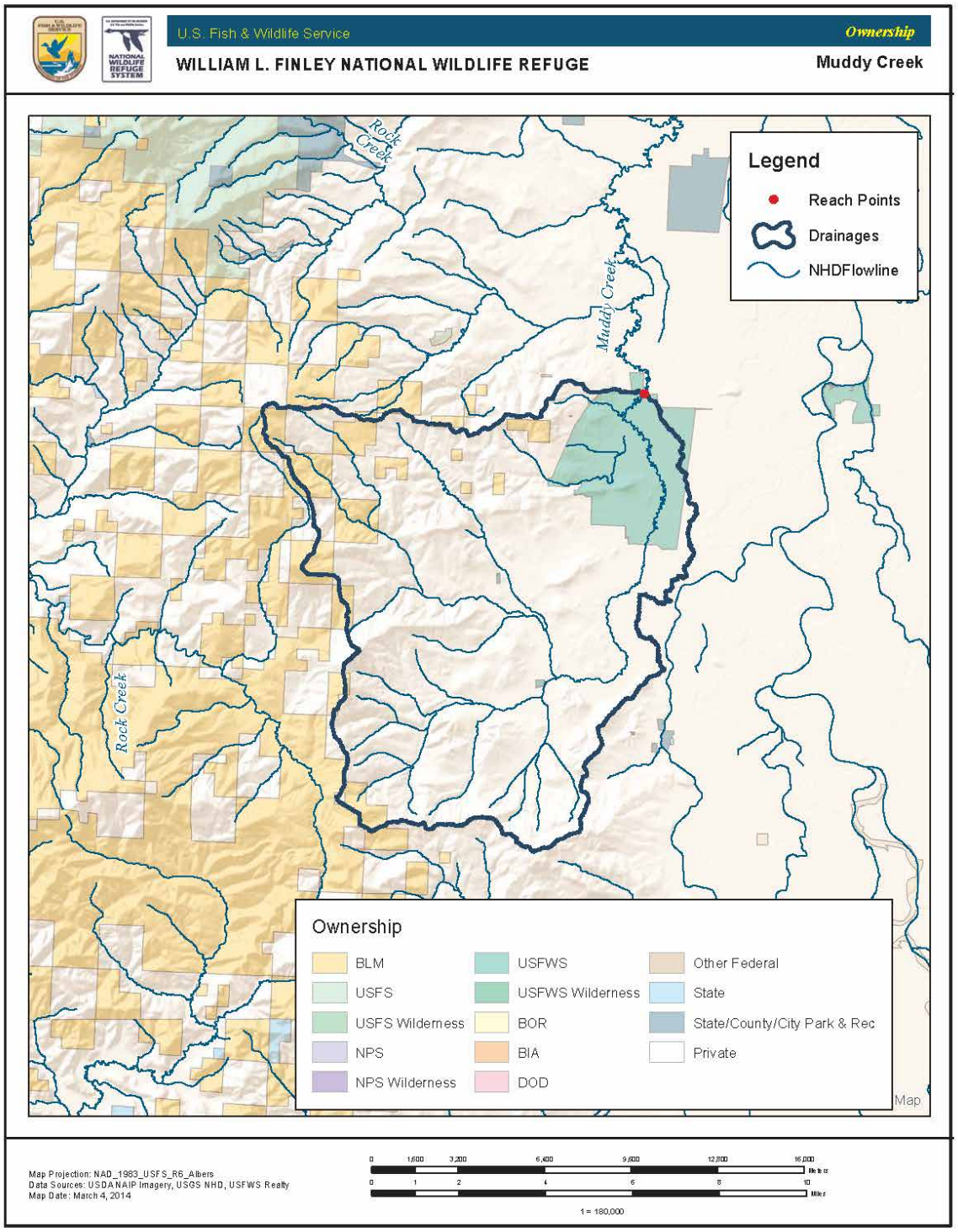
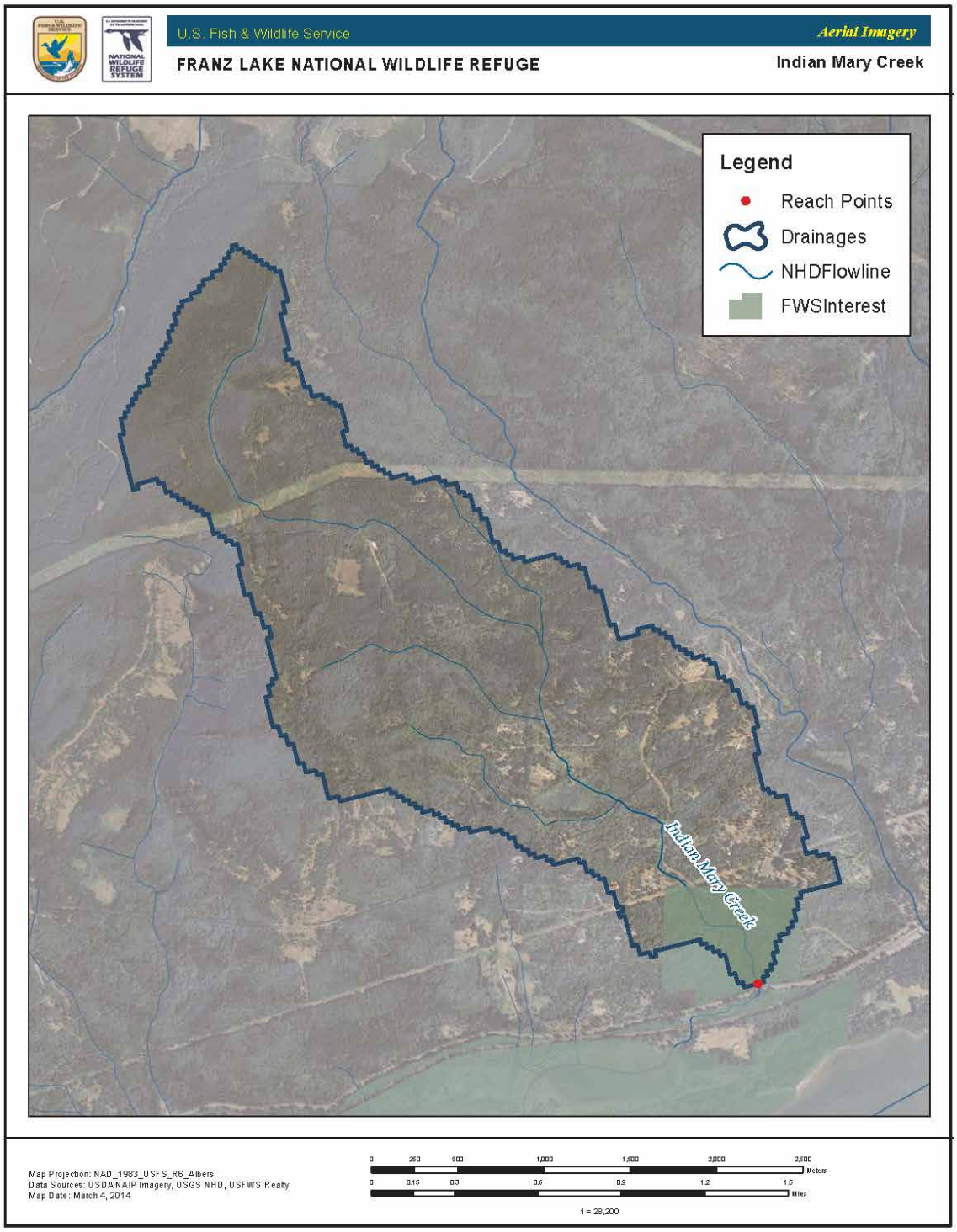
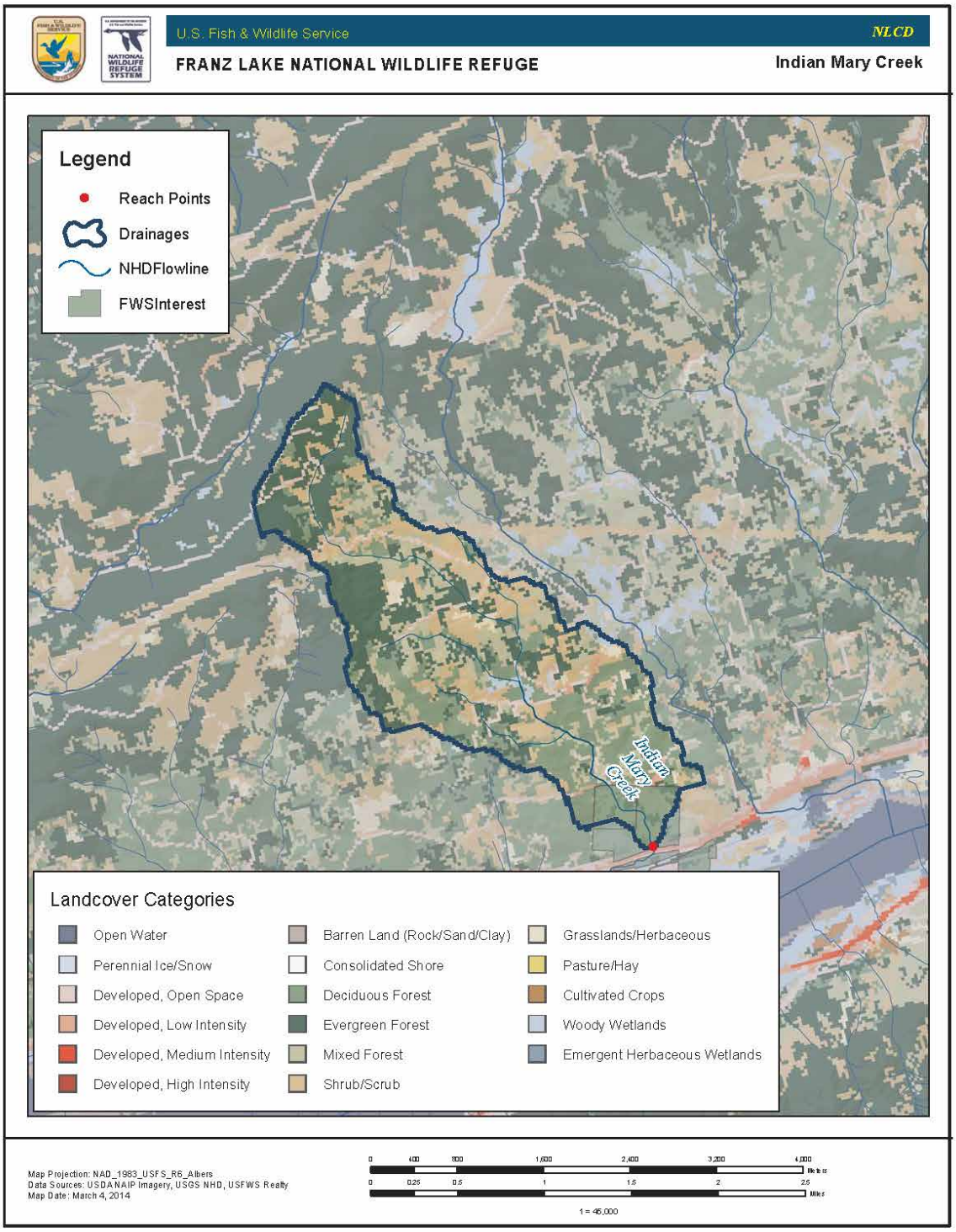
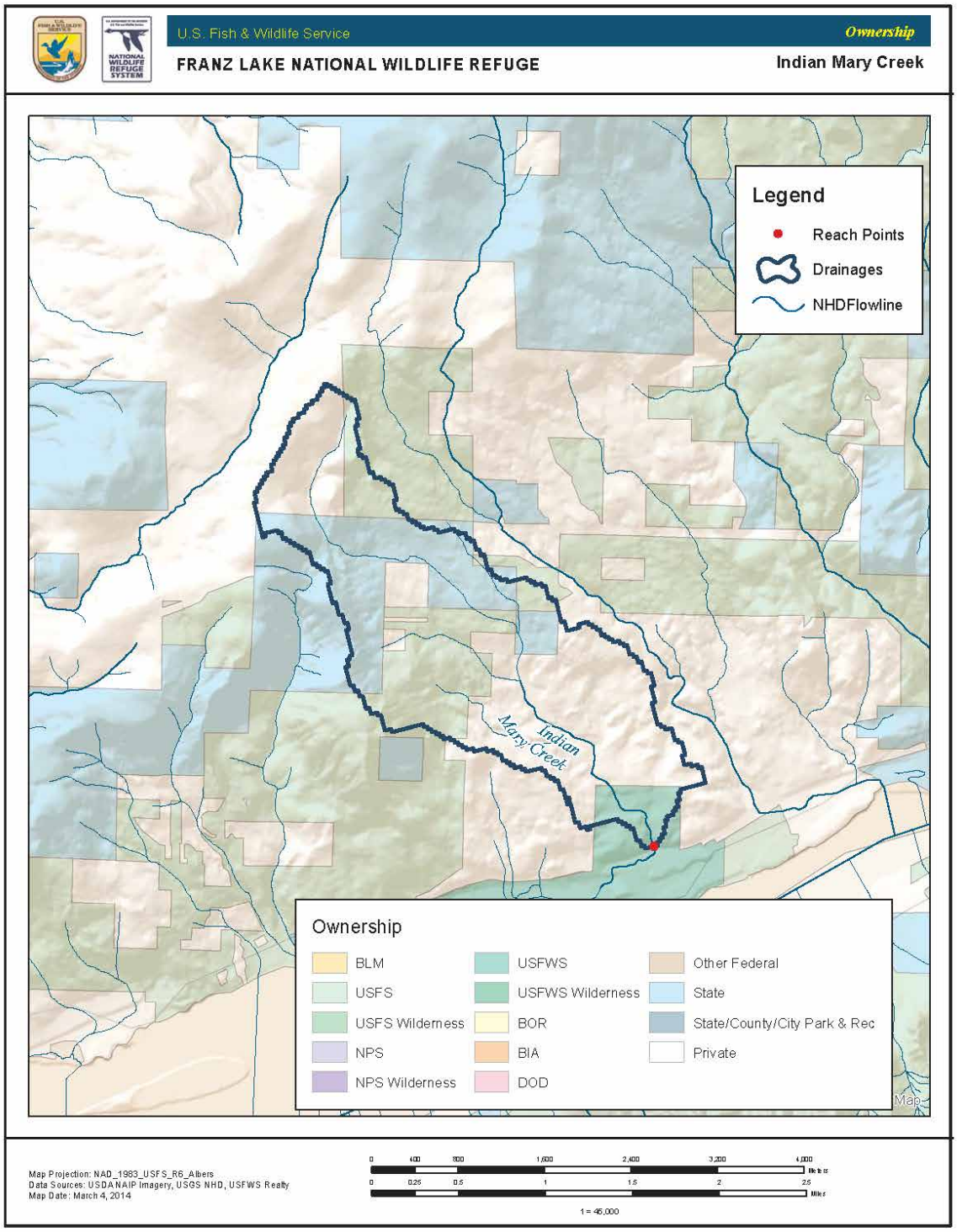
Meters
0 1 2 4 6 8 10
Miles
1 = 180,000

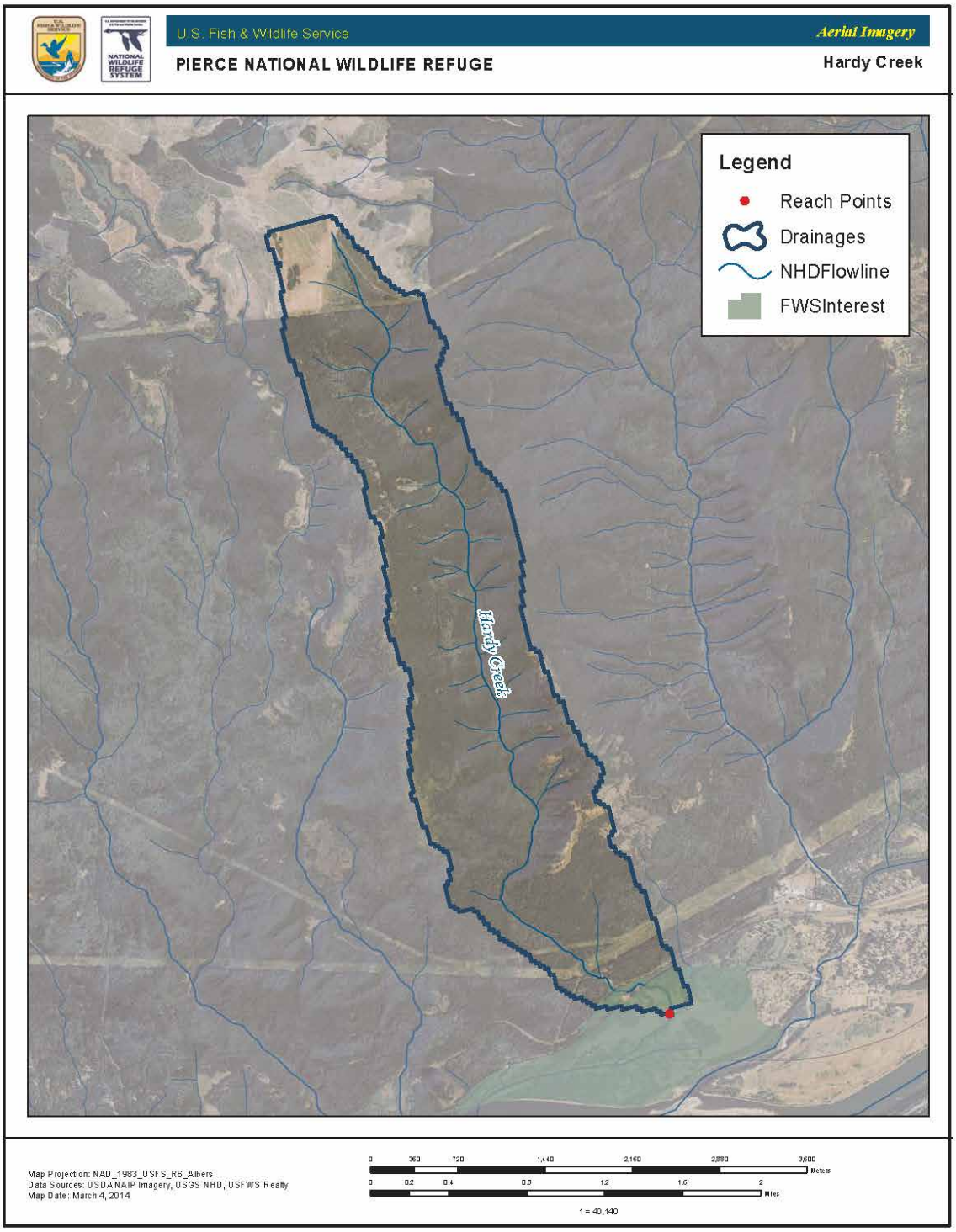

U.S. Fish & Wildlife Service
Ownership
WILLIAM L. FINLEY NATIONAL WILDLIFE REFUGE
Muddy Creek
Rock Creek
Muddy Creek
Rock Creek
Legend
Reach Points
Drainages
NHDFlowline
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 1,600 3,200 6,400 9,600 12,800 16,000
0 1 2 4 6 8 10
1 = 180,000

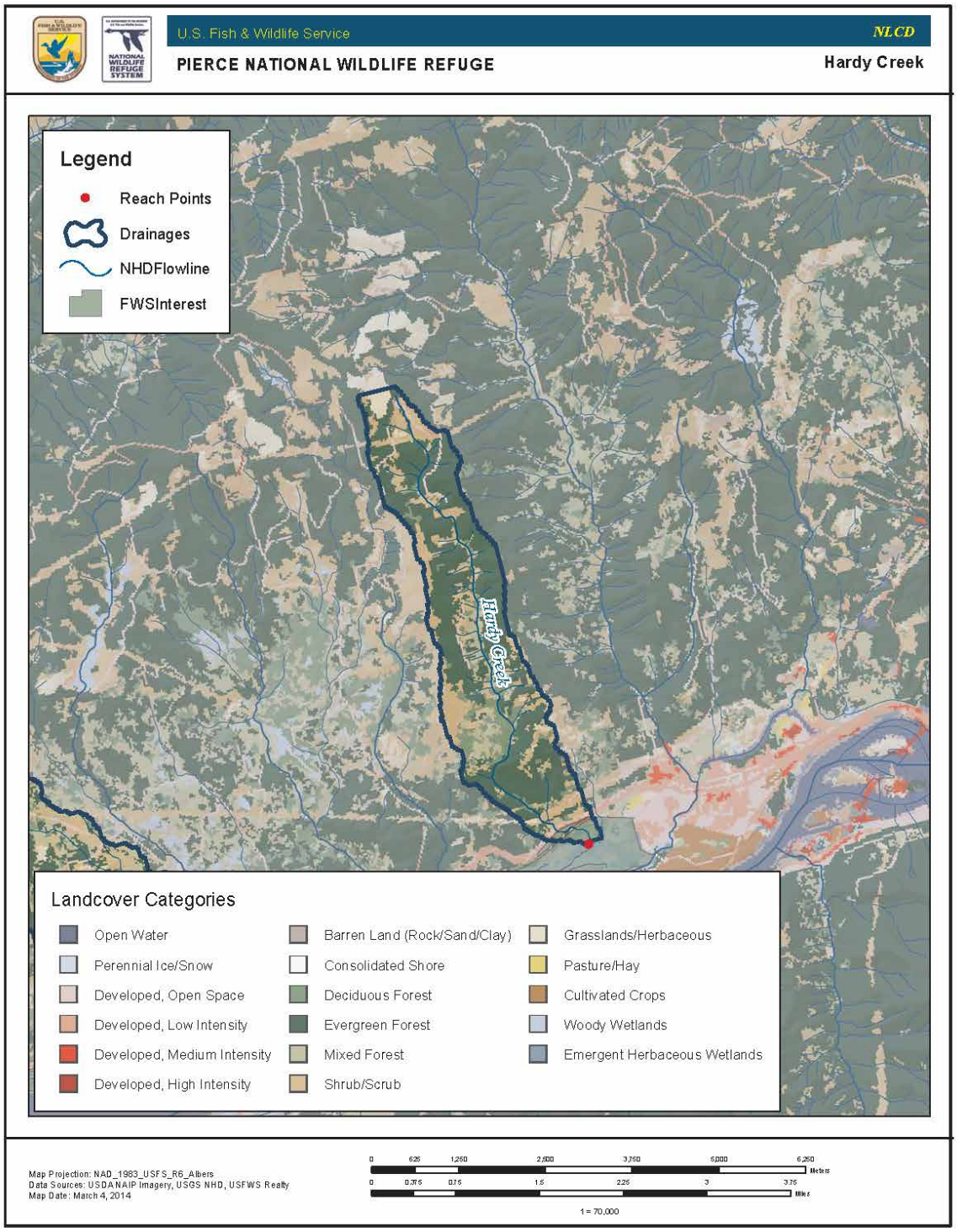
Northwestern Forested Mountains Ecoregion

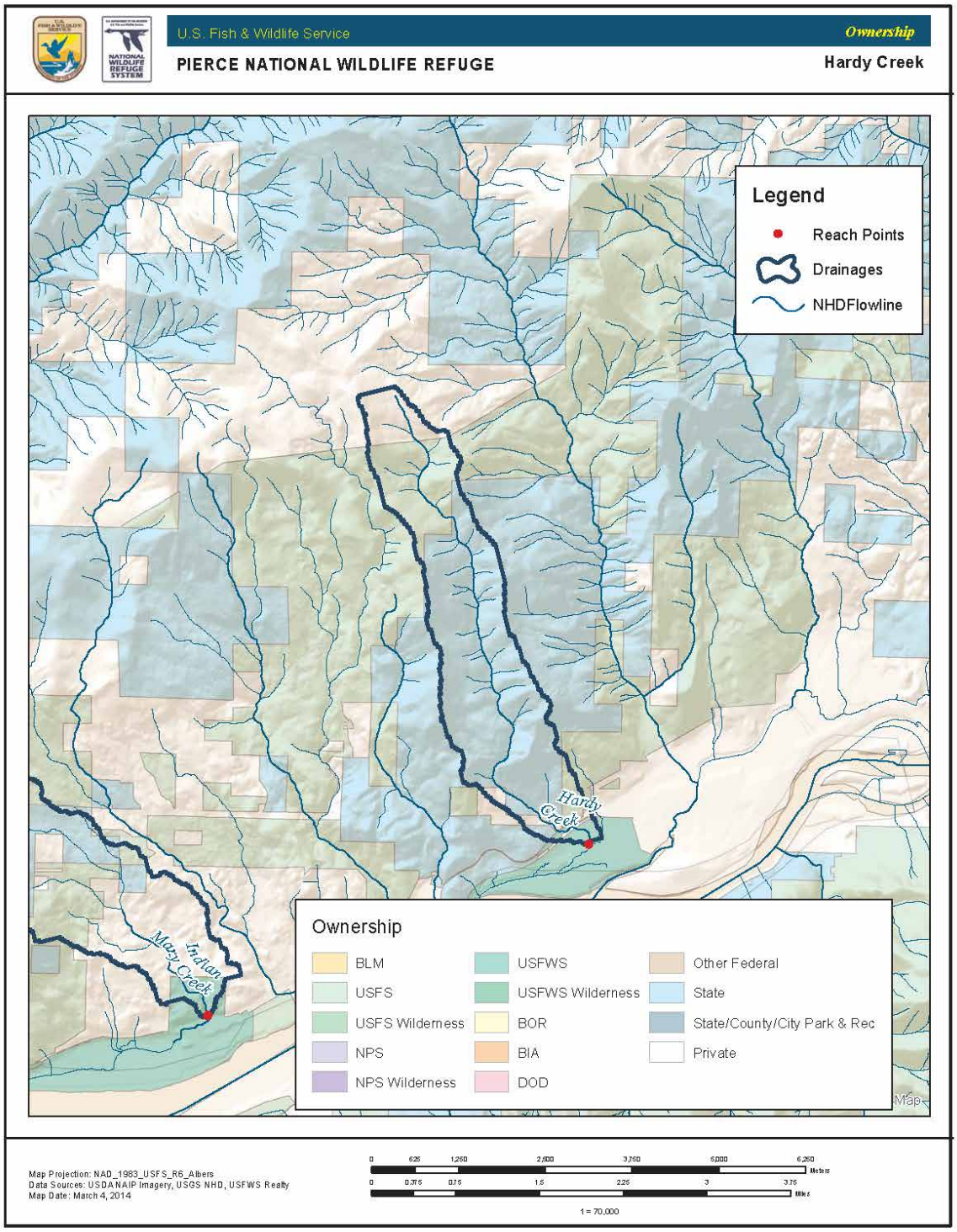

U.S. Fish & Wildlife Service
Aerial Imagery
FRANZ LAKE NATIONAL WILDLIFE REFUGE
Indian Mary Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Indian Mary Creek
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 250 500 1,000 1,500 2,000 2,500
Meters
0 0.15 0.3 0.6 0.9 1.2 1.5
Miles
1 = 28,200

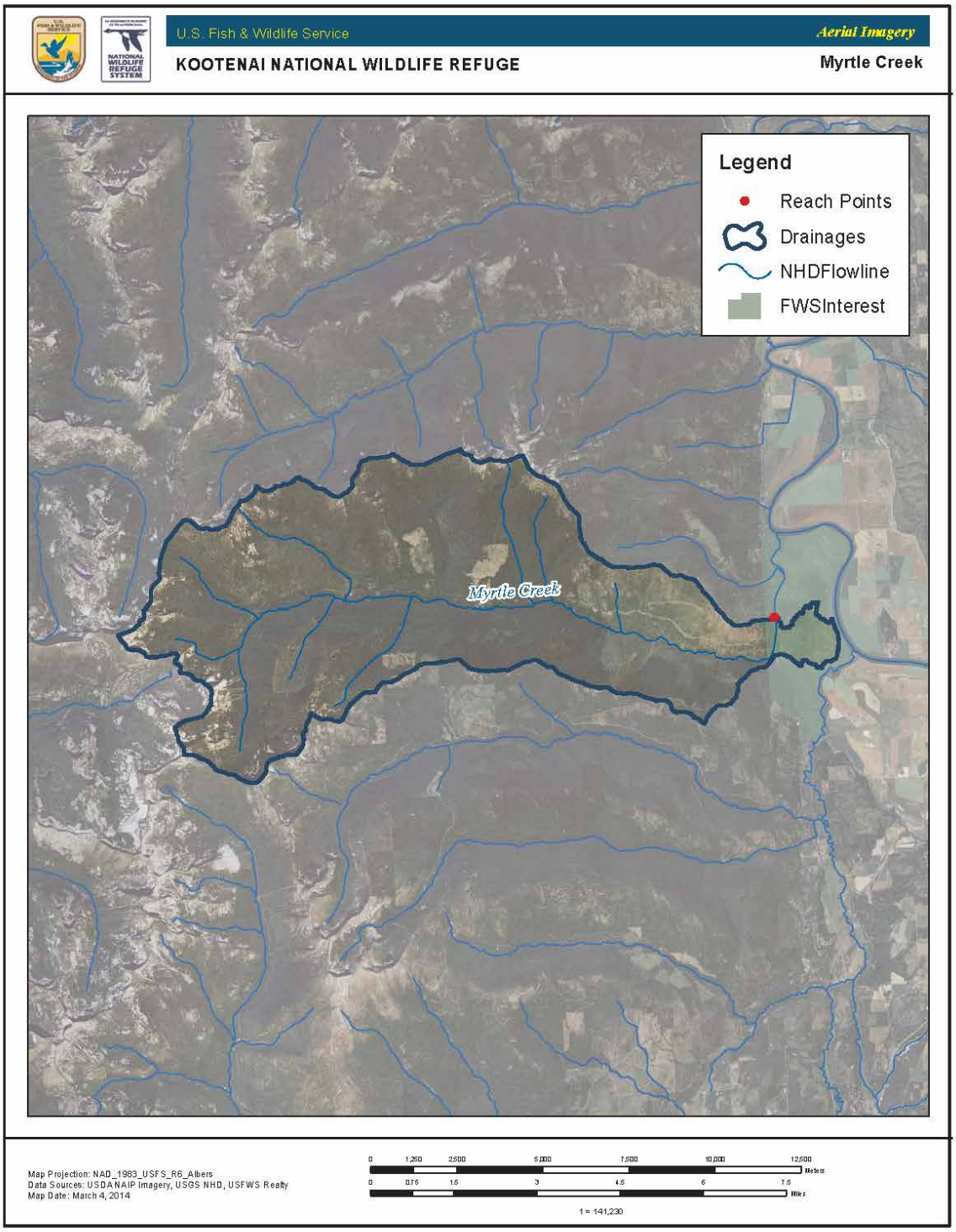

U.S. Fish & Wildlife Service
NLCD
FRANZ LAKE NATIONAL WILDLIFE REFUGE
Indian Mary Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Indian Mary Creek
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 400 800 1,600 2,400 3,200 4,000
Meters
0 0.25 0.5 1 1.5 2 2.5
Miles
1 = 46,000

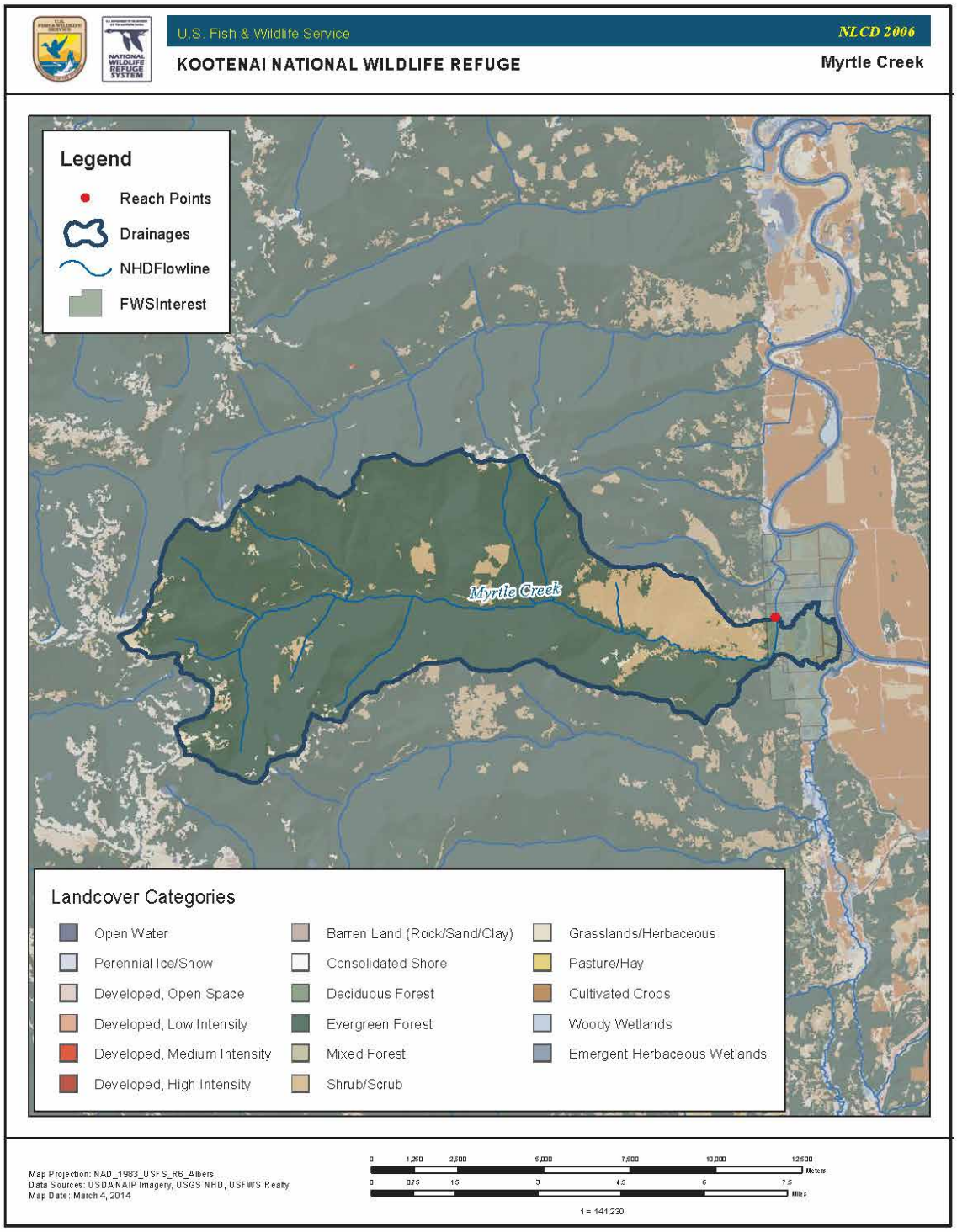

U.S. Fish & Wildlife Service
Ownership
FRANZ LAKE NATIONAL WILDLIFE REFUGE
Indian Mary Creek
Legend
Reach Points
Drainages
NHDFlowline
Indian Mary Creek
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 400 800 1,600 2,400 3,200 4,000
Meters
0 0.25 0.5 1 1.5 2 2.5
Miles
1 = 46,000

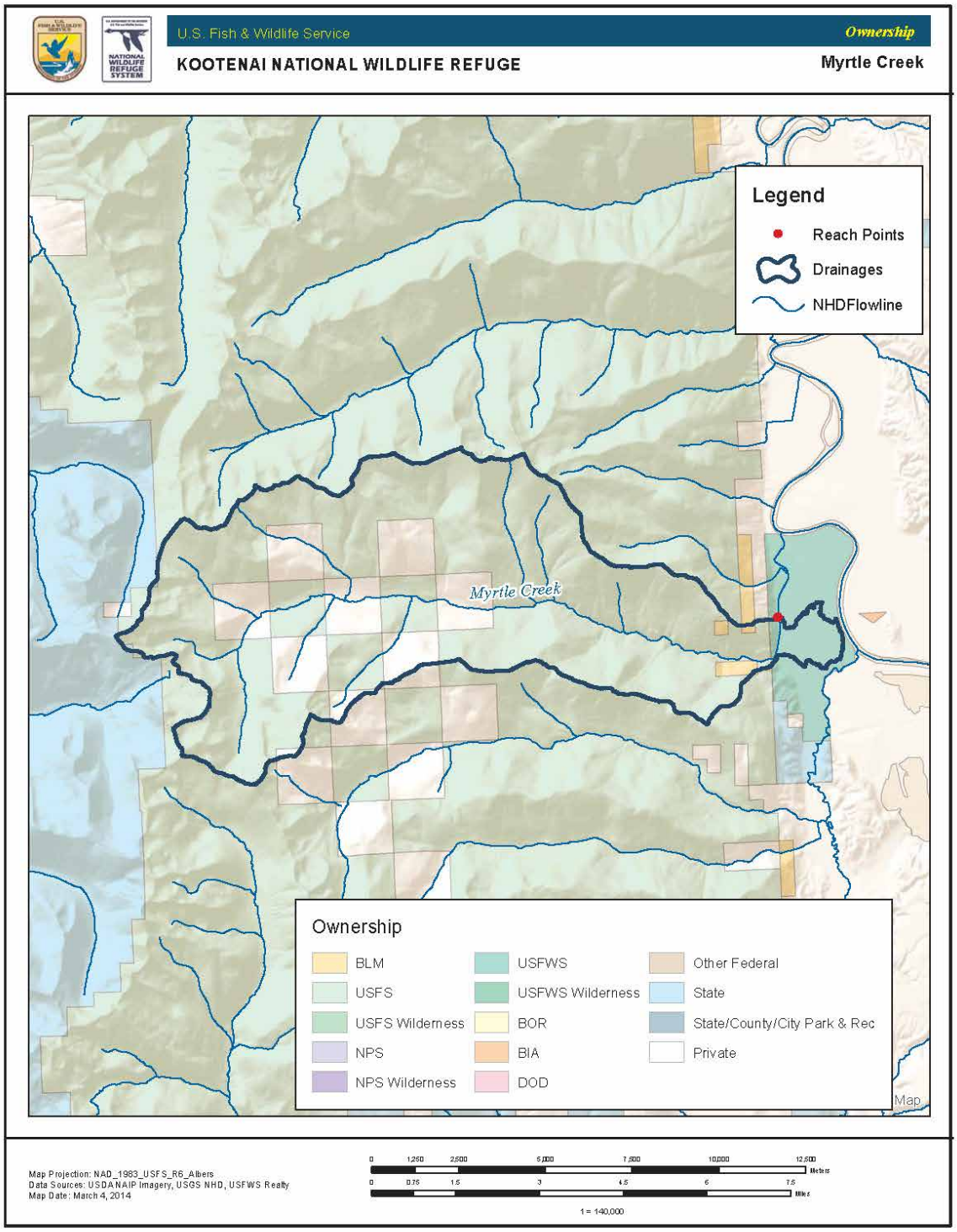

U.S. Fish & Wildlife Service
Aerial Imagery
PIERCE NATIONAL WILDLIFE REFUGE
Hardy Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Hardy Creek
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 360 720 1,440 2,160 2,880 3,600
Meters
0 0.2 0.4 0.8 1.2 1.6 2
Miles
1 = 40,140

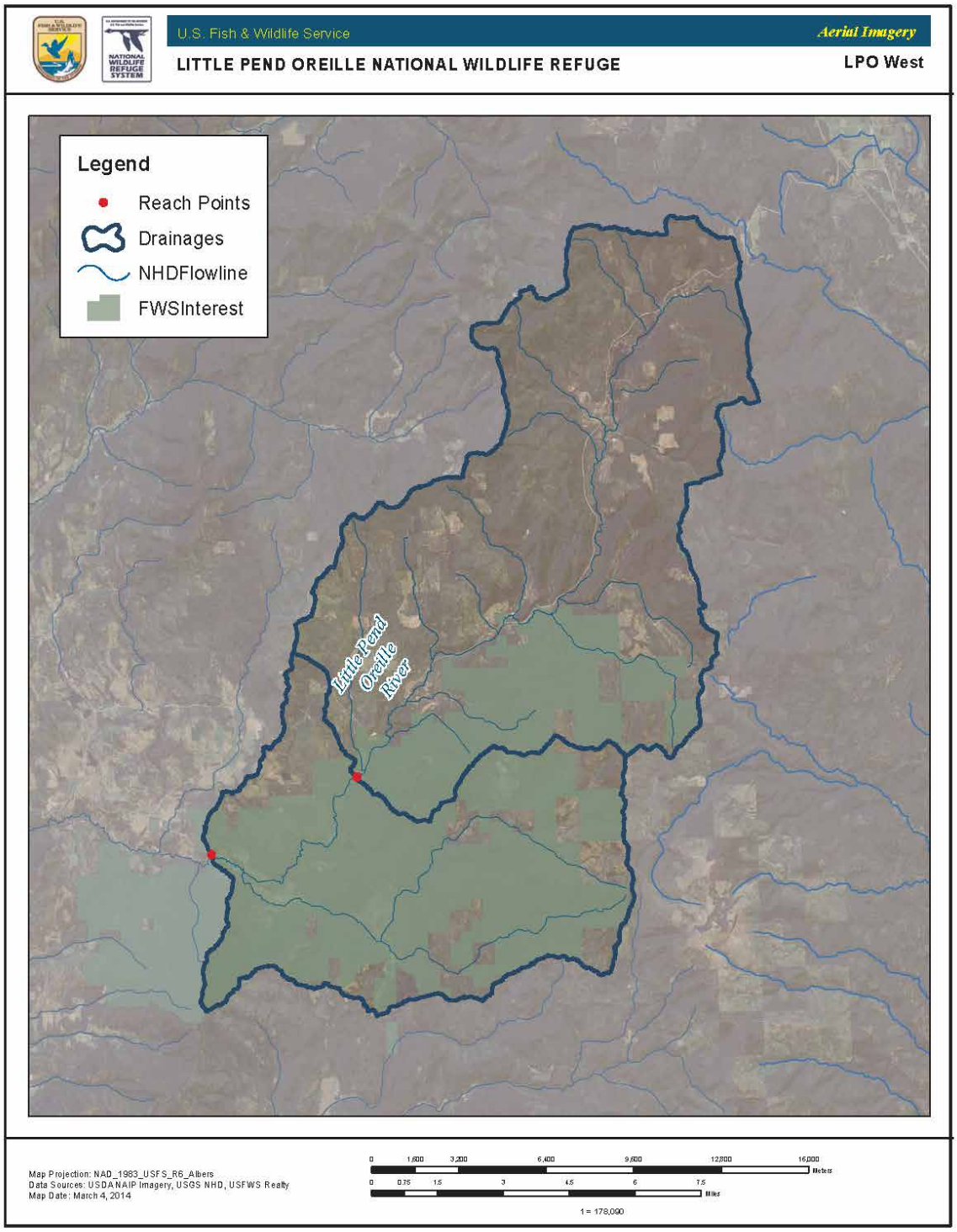

U.S. Fish & Wildlife Service
NLCD
PIERCE NATIONAL WILDLIFE REFUGE
Hardy Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Hardy Creek
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 625 1,250 2,500 3,750 5,000 6,250
Meters
0 0.375 0.75 1.5 2.25 3 3.75
Miles
1 = 70,000

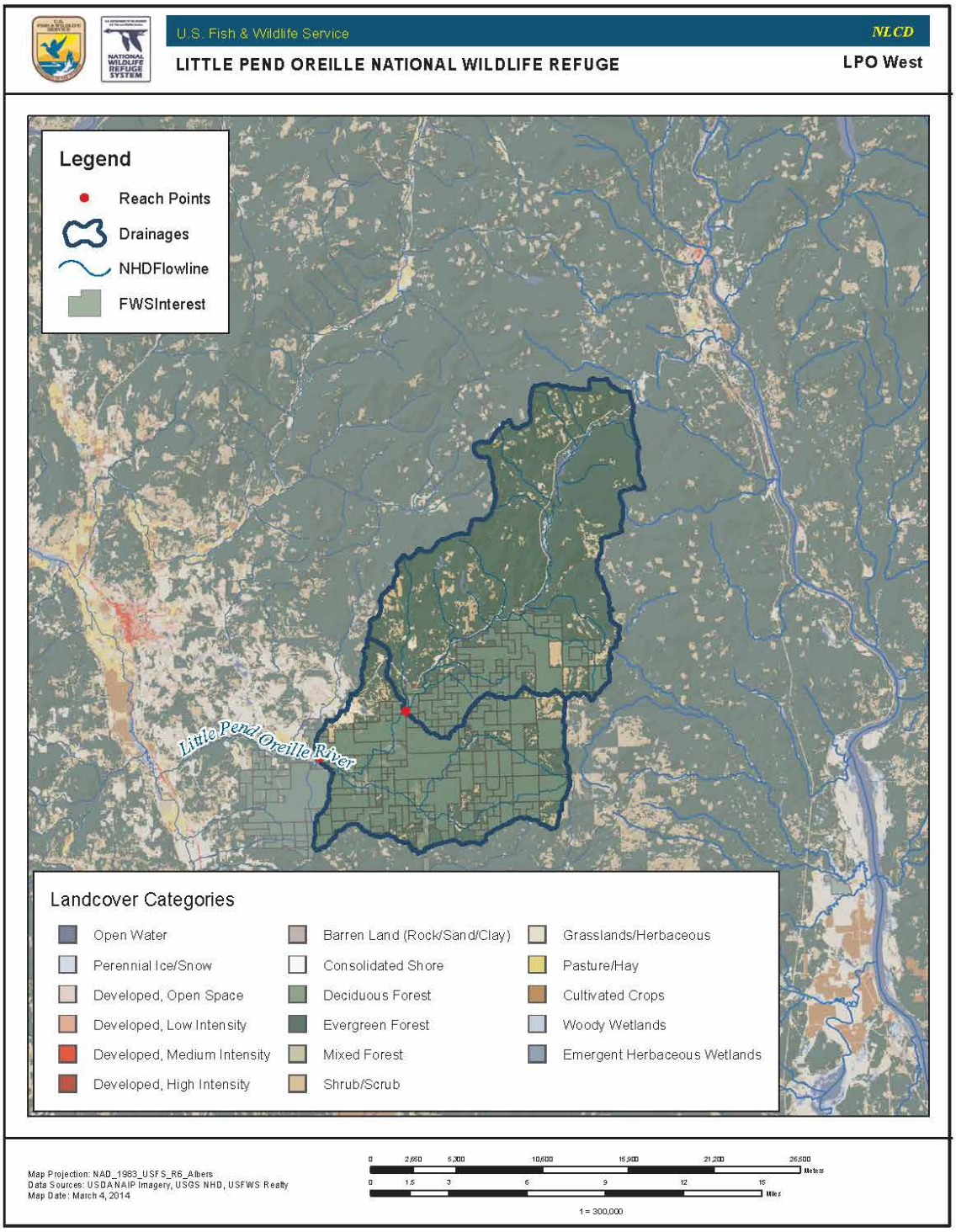

U.S. Fish & Wildlife Service
Ownership
PIERCE NATIONAL WILDLIFE REFUGE
Hardy Creek
Legend
Reach Points
Drainages
NHDFlowline
Hardy Creek
Indian Mary Creek
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 625 1,250 2,500 3,750 5,000 6,250
Meters
0 0.375 0.75 1.5 2.25 3 3.75
Miles
1 = 70,000

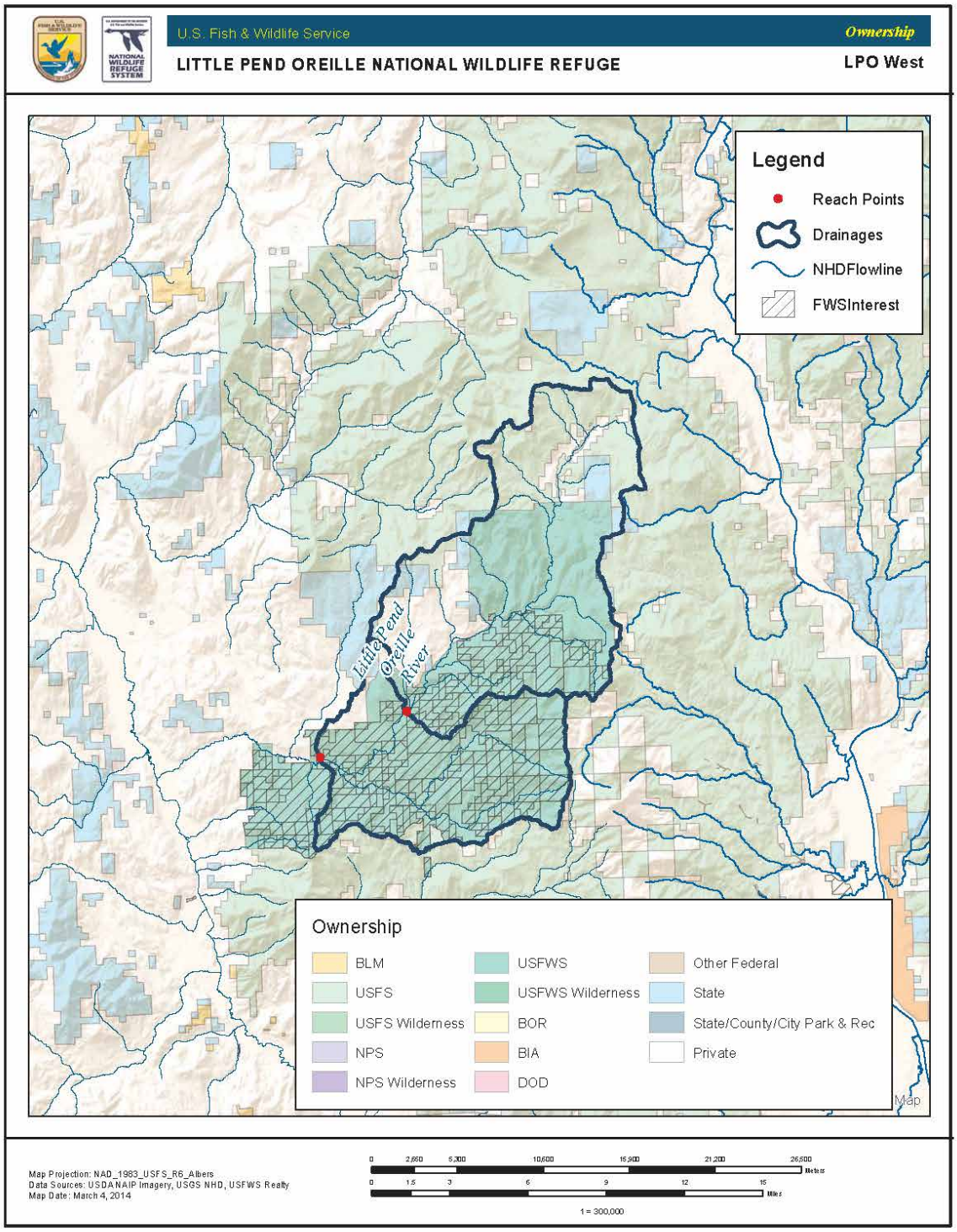

U.S. Fish & Wildlife Service
Aerial Imagery
KOOTENAI NATIONAL WILDLIFE REFUGE
Myrtle Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Myrtle Creek
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 1,250 2,500 5,000 7,500 10,000 12,500
Meters
0 0.75 1.5 3 4.5 6 7.5
Miles
1 = 141,230

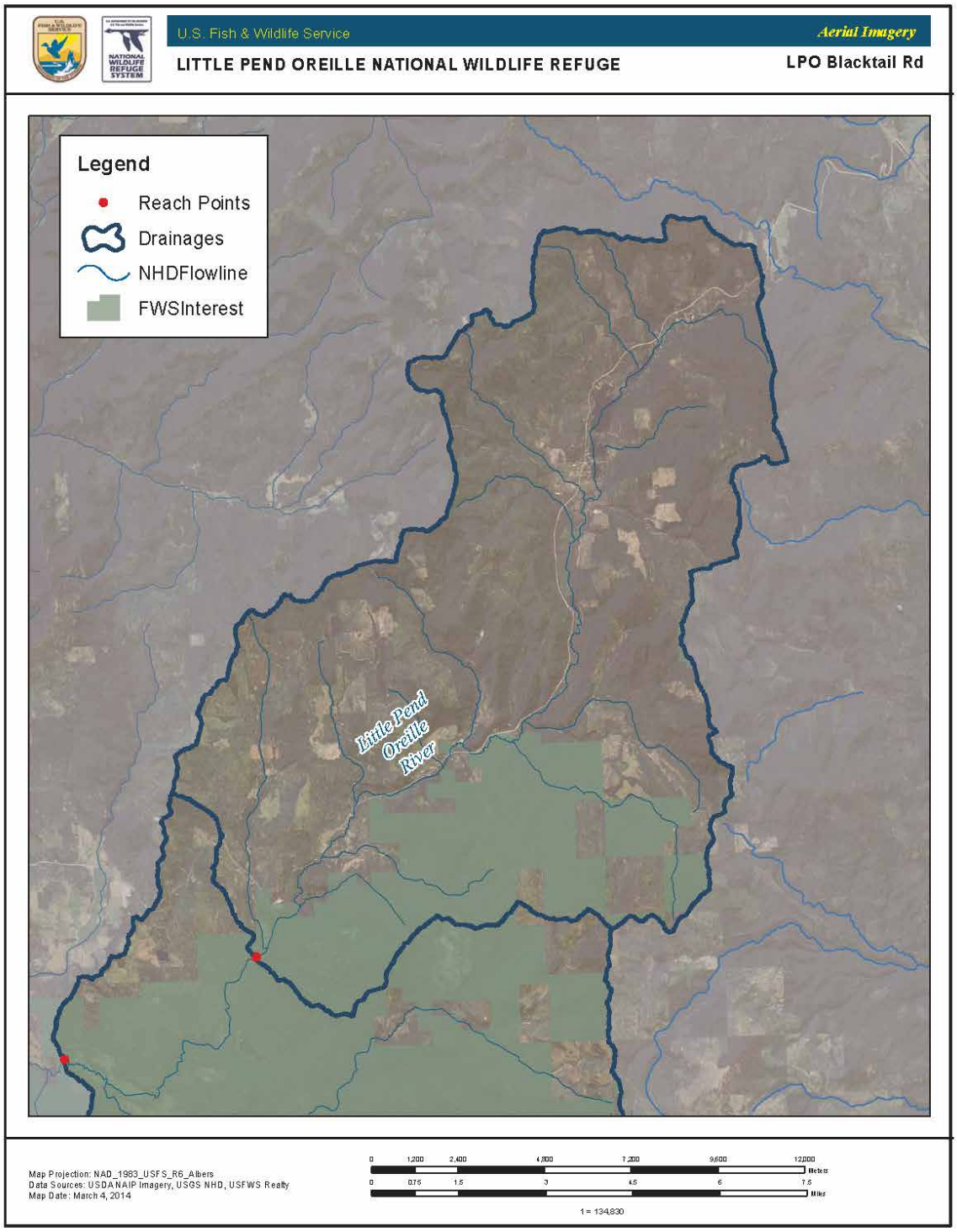

U.S. Fish & Wildlife Service
NLCD 2006
KOOTENAI NATIONAL WILDLIFE REFUGE
Myrtle Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Myrtle Creek
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 1,250 2,500 5,000 7,500 10,000 12,500
Meters
0 0.75 1.5 3 4.5 6 7.5
Miles
1 = 141,230


U.S. Fish & Wildlife Service
Ownership
KOOTENAI NATIONAL WILDLIFE REFUGE
Myrtle Creek
Legend
Reach Points
Drainages
NHDFlowline
Myrtle Creek
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 1,250 2,500 5,000 7,500 10,000 12,500 Meters
0 0.75 1.5 3 4.5 6 7.5 Miles
1 = 140,000


U.S. Fish & Wildlife Service
Aerial Imagery
LITTLE PEND OREILLE NATIONAL WILDLIFE REFUGE
LPO West
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Little Pend Oreille River
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 1,600 3,200 6,400 9,600 12,800 16,000
Meters
0 0.75 1.5 3 4.5 6 7.5
Miles
1 = 178,090


U.S. Fish & Wildlife Service
NLCD
LITTLE PEND OREILLE NATIONAL WILDLIFE REFUGE
LPO West
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Little Pend Oreille River
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 2,650 5,300 10,600 15,900 21,200 26,500
Meters
0 1.5 3 6 9 12 15
Miles
1 = 300,000


U.S. Fish & Wildlife Service
Ownership
LITTLE PEND OREILLE NATIONAL WILDLIFE REFUGE
LPO West
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Little Pend Oreille River
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 2,650 5,300 10,600 15,900 21,200 26,500
Meters
0 1.5 3 6 9 12 15
Miles
1 = 300,000

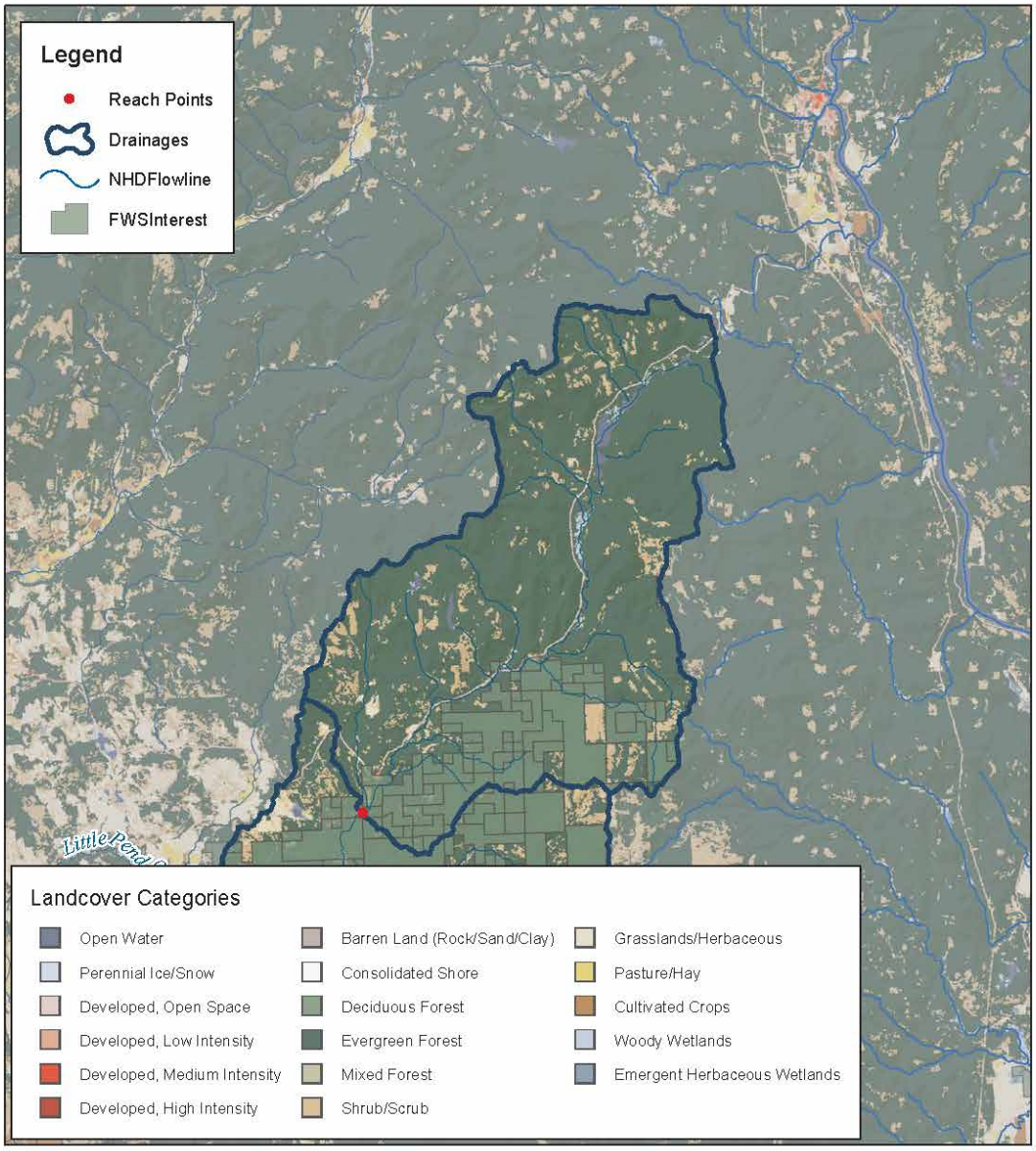

U.S. Fish & Wildlife Service
Aerial Imagery
LITTLE PEND OREILLE NATIONAL WILDLIFE REFUGE
LPO Blacktail Rd
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Little Pend Oreille River
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 1,200 2,400 4,800 7,200 9,600 12,000
Meters
0 0.75 1.5 3 4.5 6 7.5
Miles
1 = 134,830

U.S. Fish & Wildlife Service

NLCD

LITTLE PEND OREILLE NATIONAL WILDLIFE REFUGE

LPO Blacktail Rd

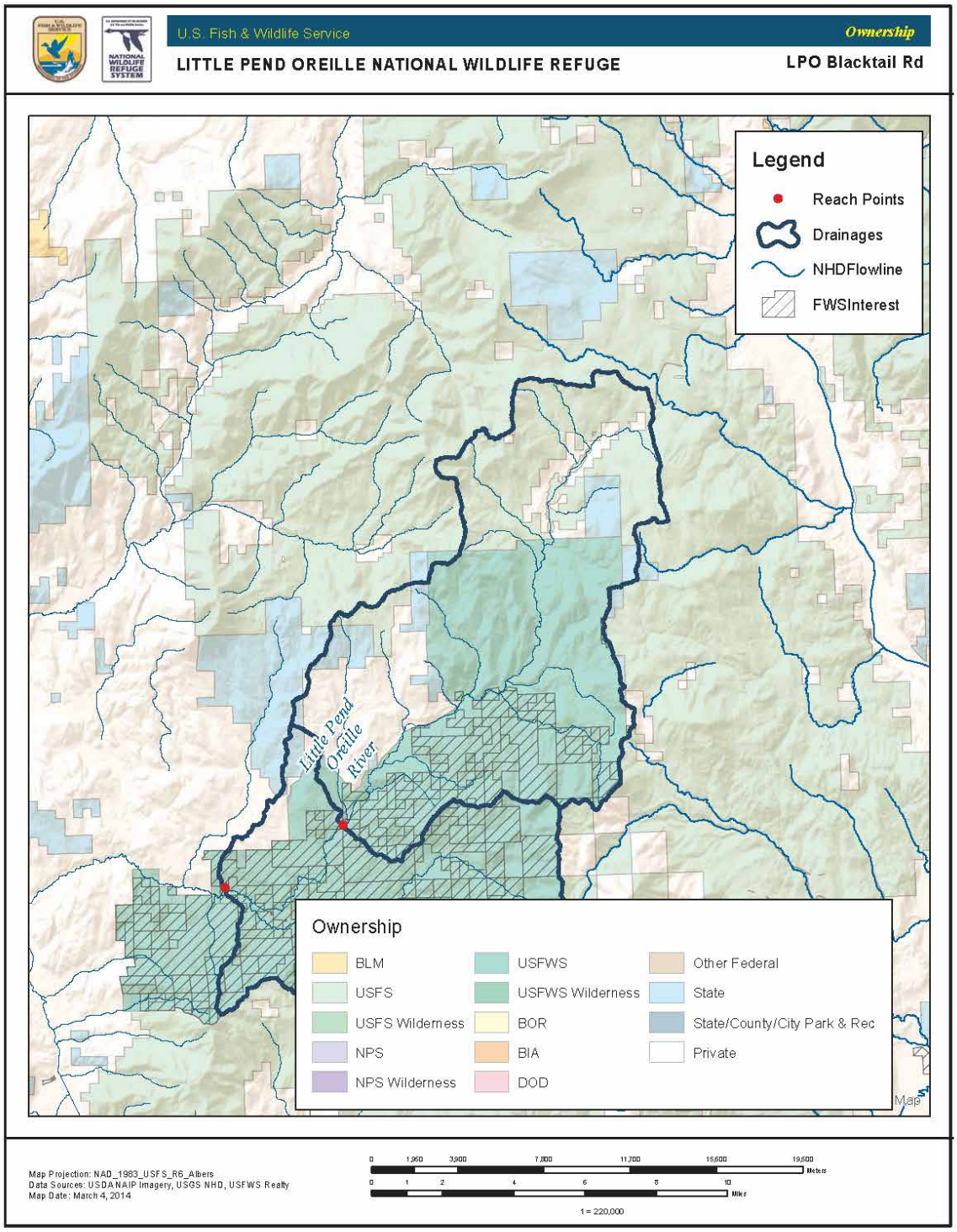


Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014

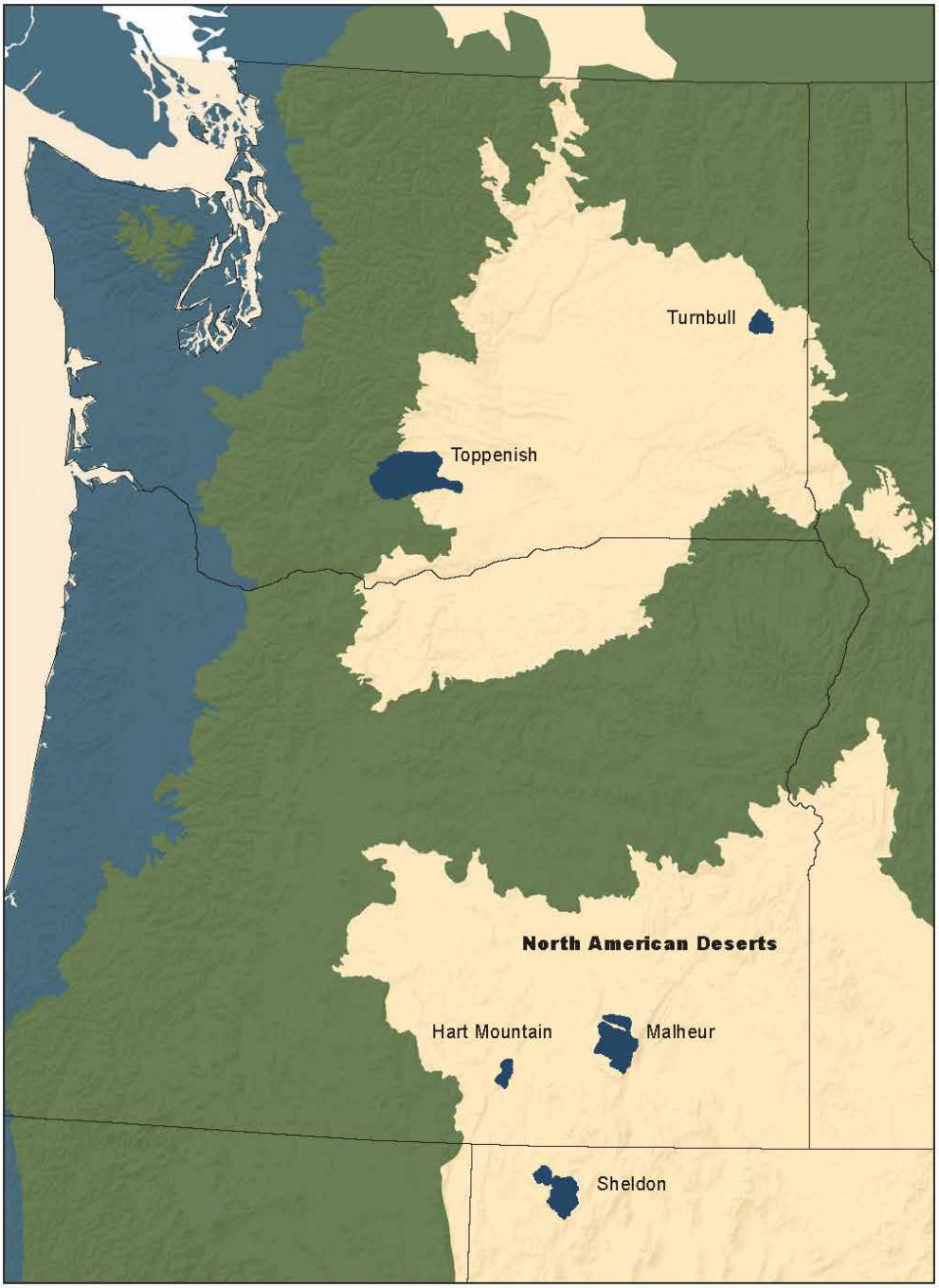
0 1,950 3,900 7,800 11,700 15,600 19,500 Meters

0 1 2 4 6 8 10 Miles

1 = 220,000


U.S. Fish & Wildlife Service
Ownership
LITTLE PEND OREILLE NATIONAL WILDLIFE REFUGE
LPO Blacktail Rd
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Little Pend Oreille River
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 1,950 3,900 7,800 11,700 15,600 19,500 Meters
0 1 2 4 6 8 10 Miles
1 = 220,000

North American Deserts Ecoregion

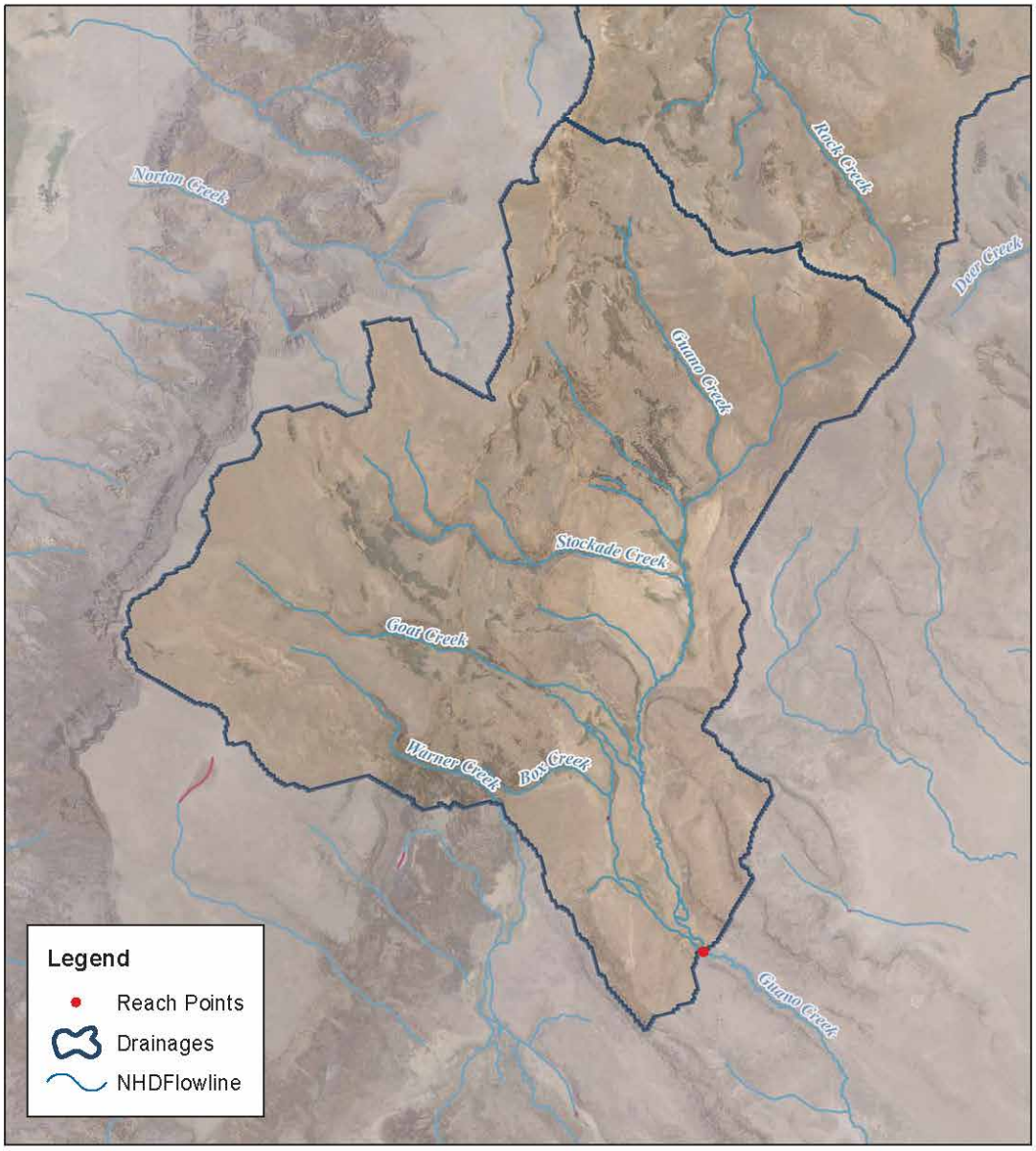


U.S. Fish & Wildlife Service

Aerial Imagery

HART MOUNTAIN NATIONAL ANTELOPE REFUGE

Guano Creek

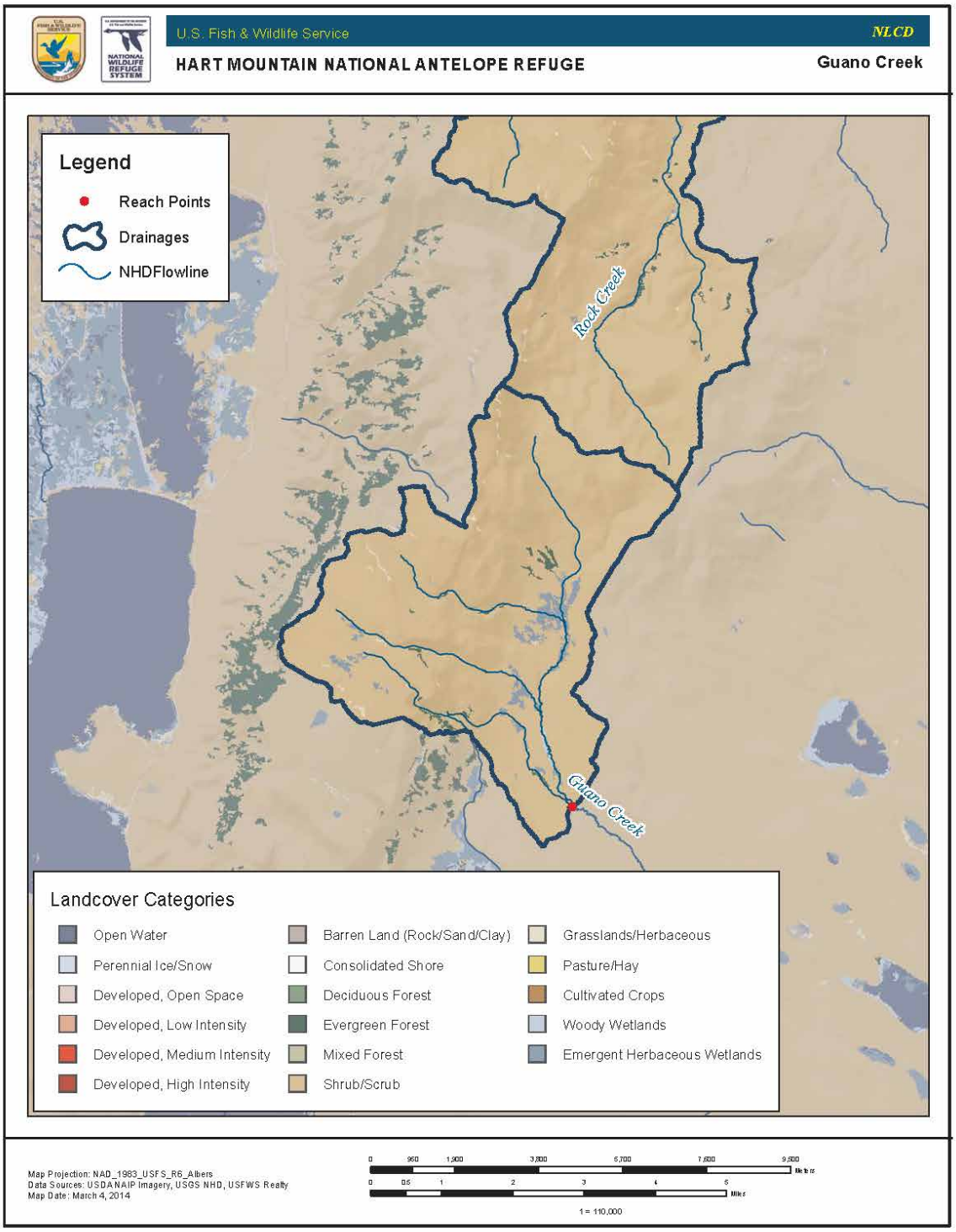


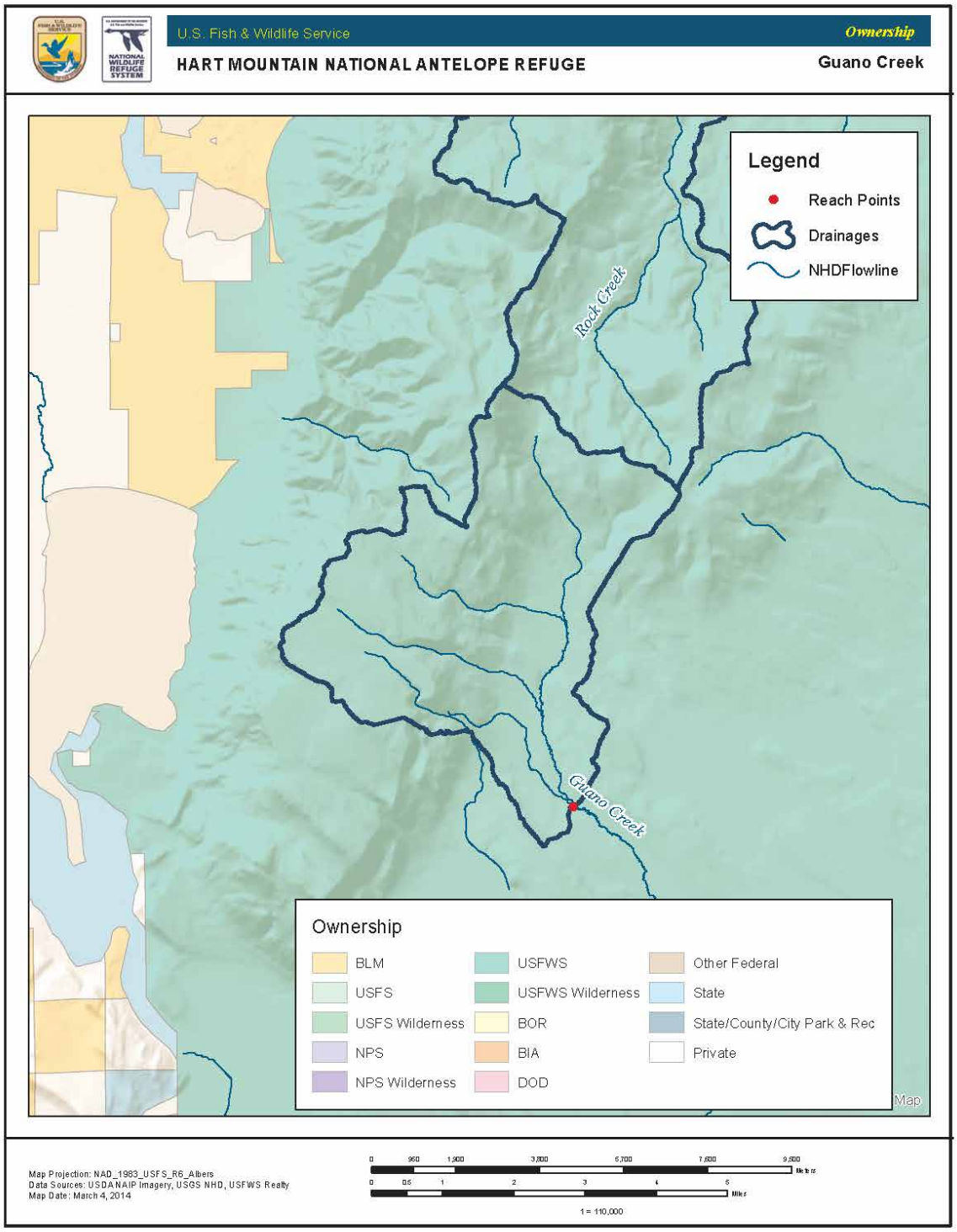
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014

0 550 1,100 2,200 3,300 4,400 5,500 Meters

0 0.35 0.7 1.4 2.1 2.8 3.5 Miles

1 = 63,370


U.S. Fish & Wildlife Service
NLCD
HART MOUNTAIN NATIONAL ANTELOPE REFUGE
Guano Creek
Legend
Reach Points
Drainages
NHDFlowline
Rock Creek
Guano Creek
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 950 1,900 3,800 5,700 7,600 9,500
Meters
0 0.5 1 2 3 4 5
Miles
1 = 110,000

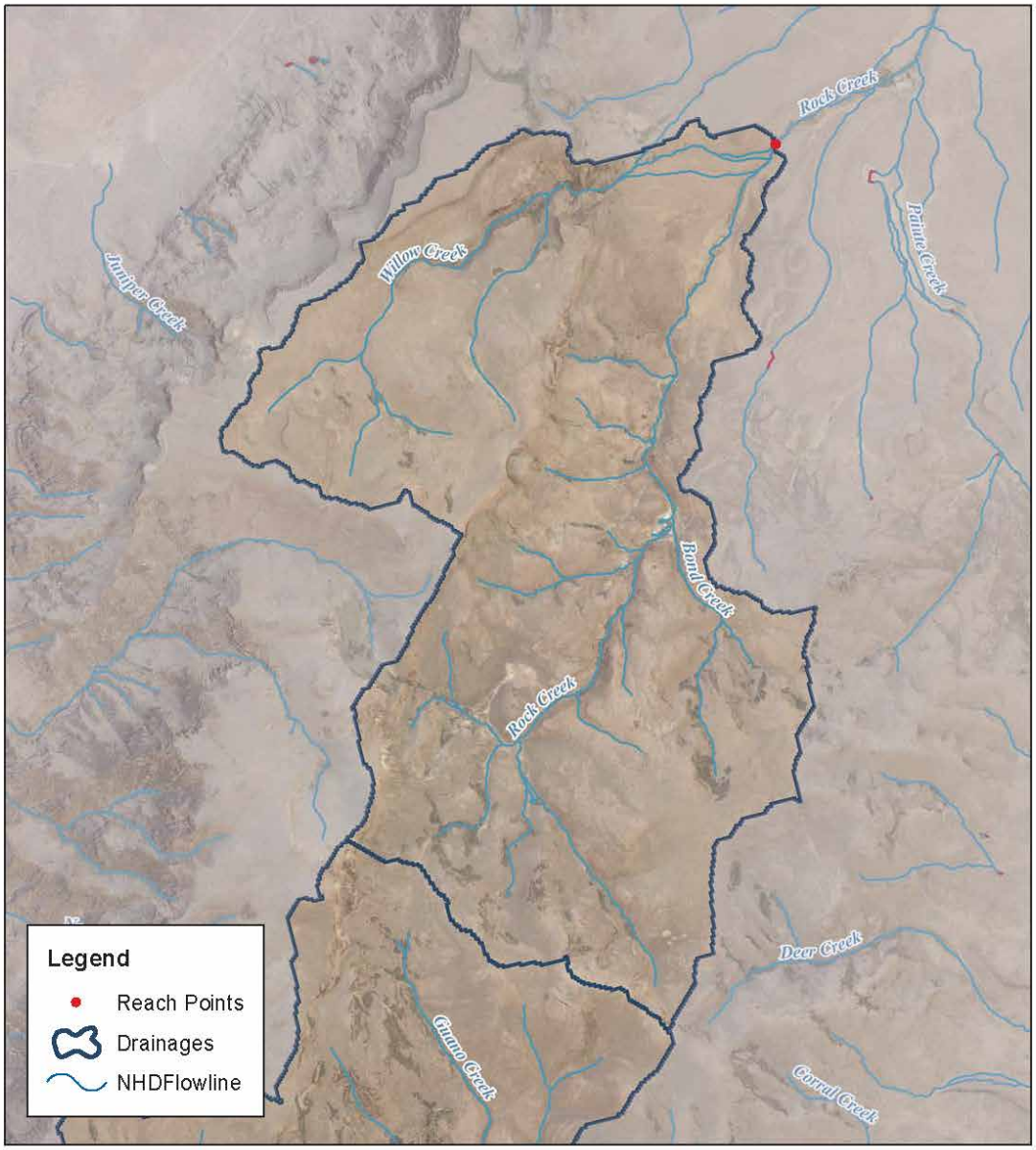

U.S. Fish & Wildlife Service
Ownership
HART MOUNTAIN NATIONAL ANTELOPE REFUGE
Guano Creek
Legend
Reach Points
Drainages
NHDFlowline
Rock Creek
Guano Creek
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
1 = 110,000

U.S. Fish & Wildlife Service

Aerial Imagery

HART MOUNTAIN NATIONAL ANTELOPE REFUGE

Rock Creek

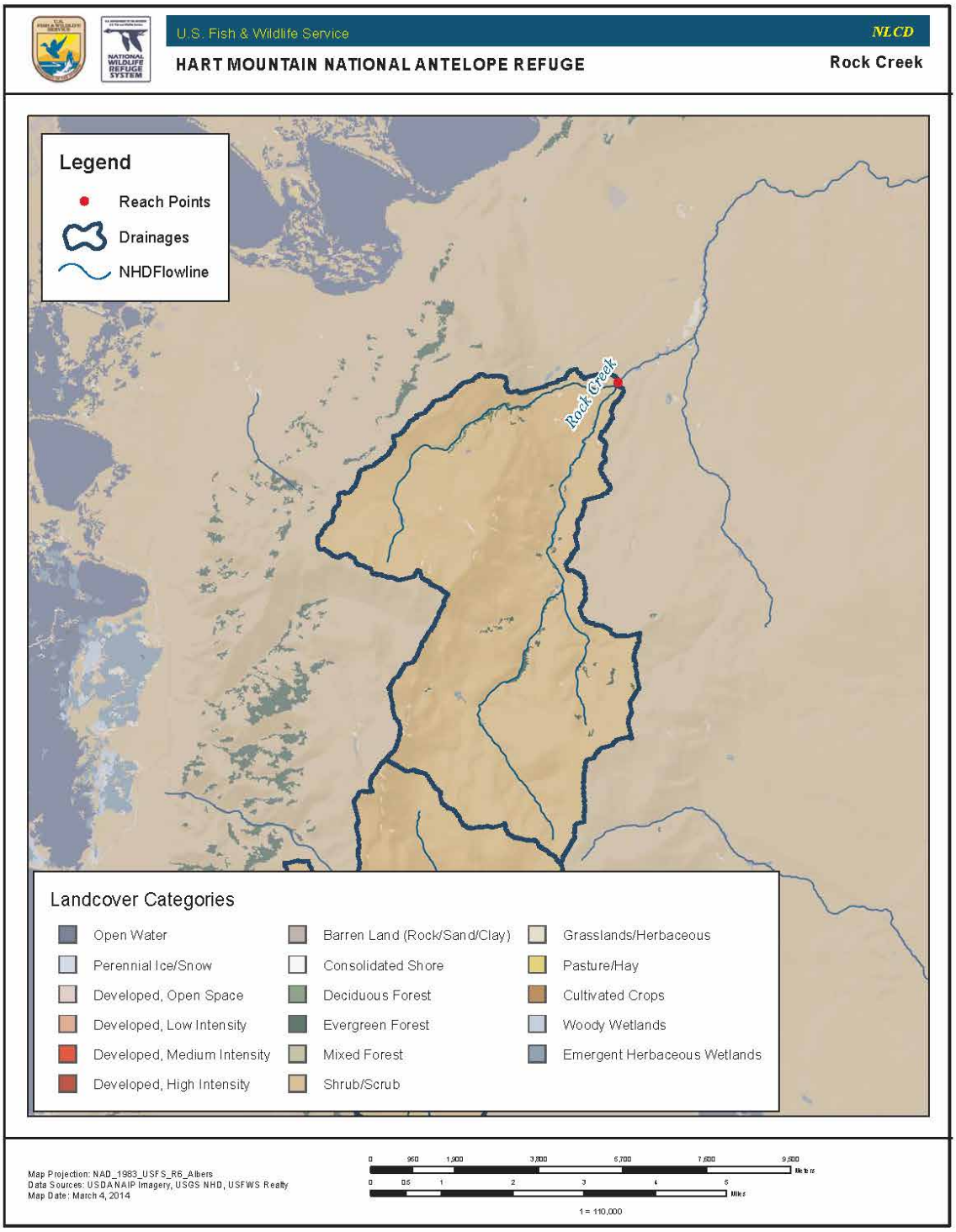


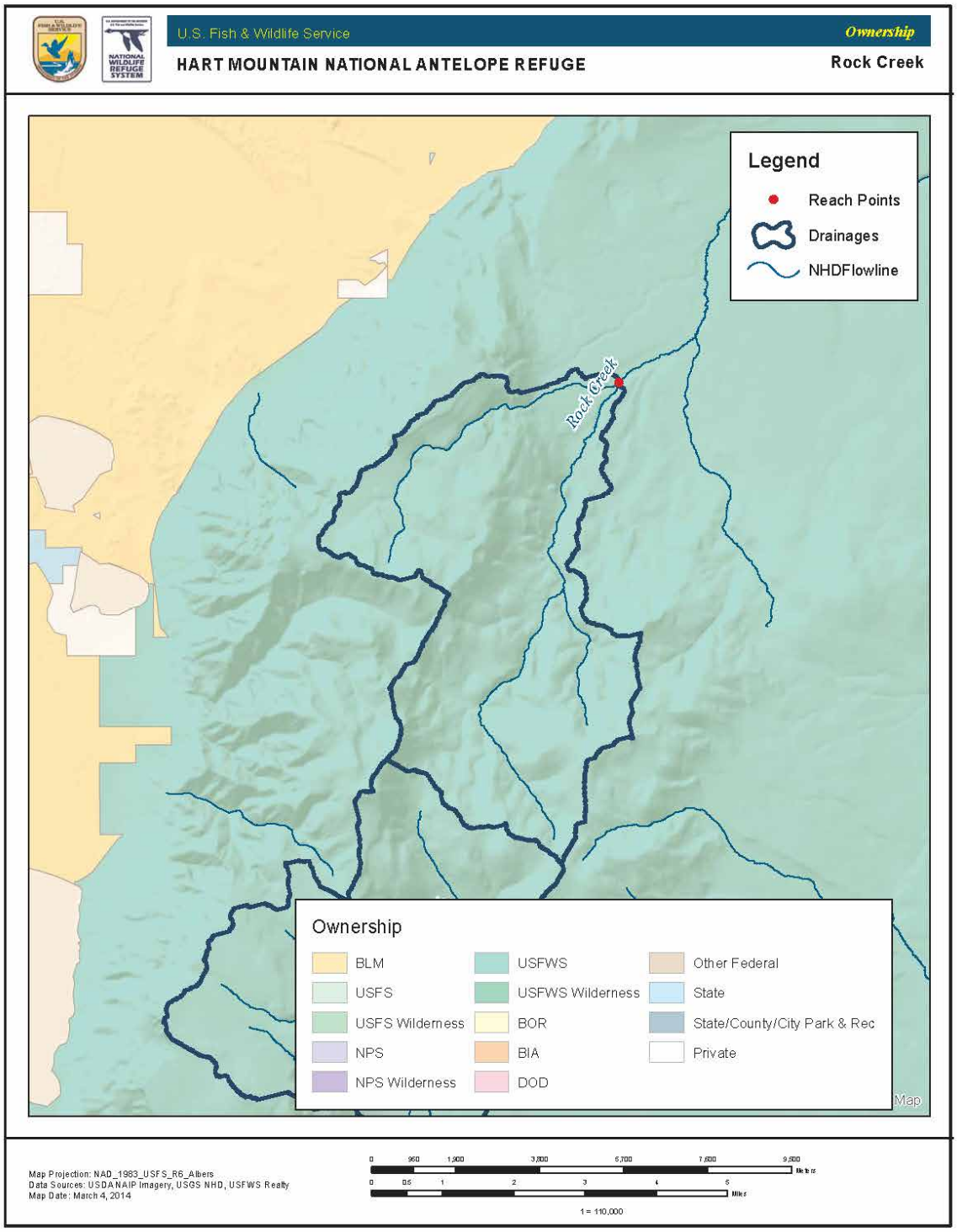
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014

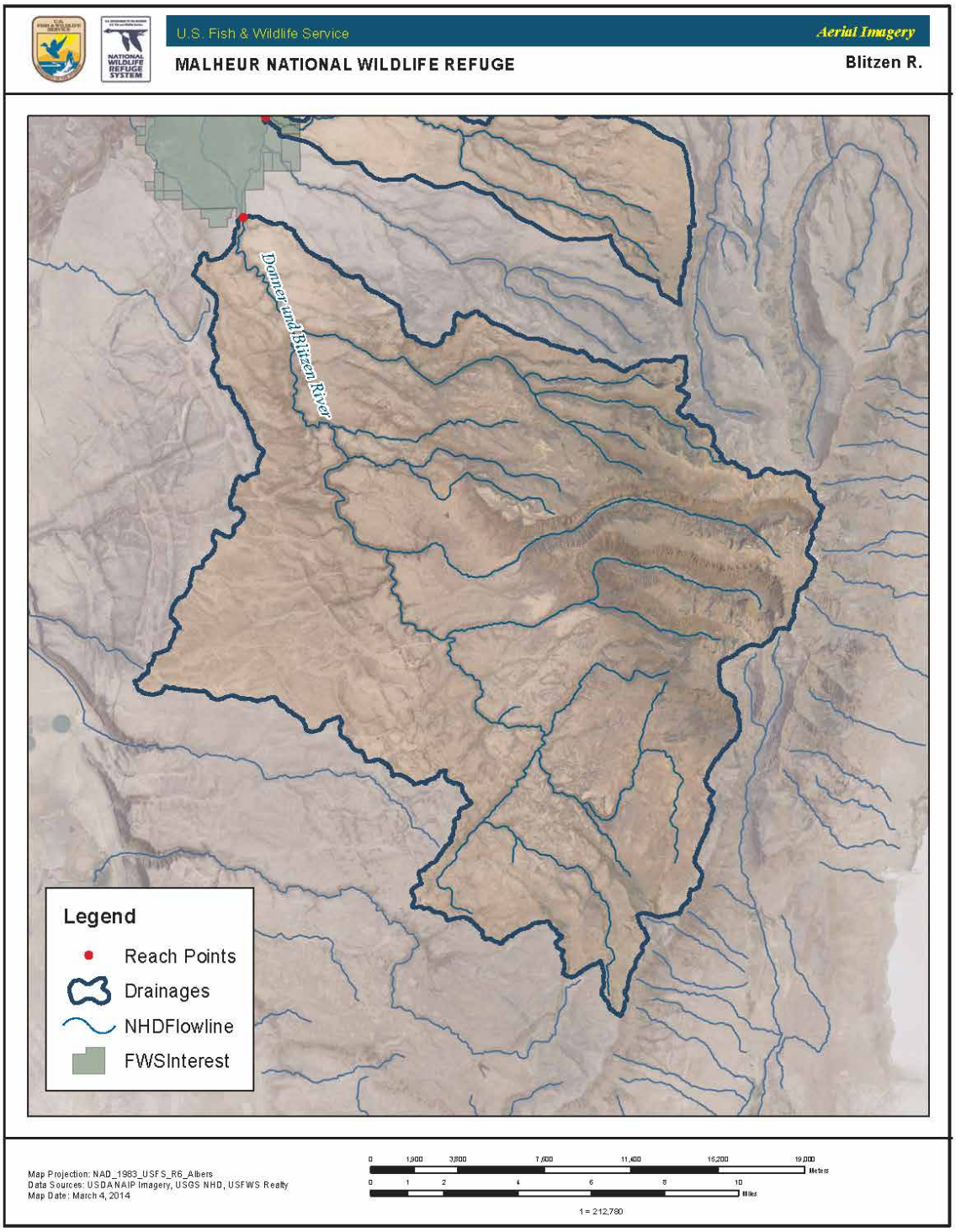
0 600 1,200 2,400 3,600 4,800 6,000 Meters

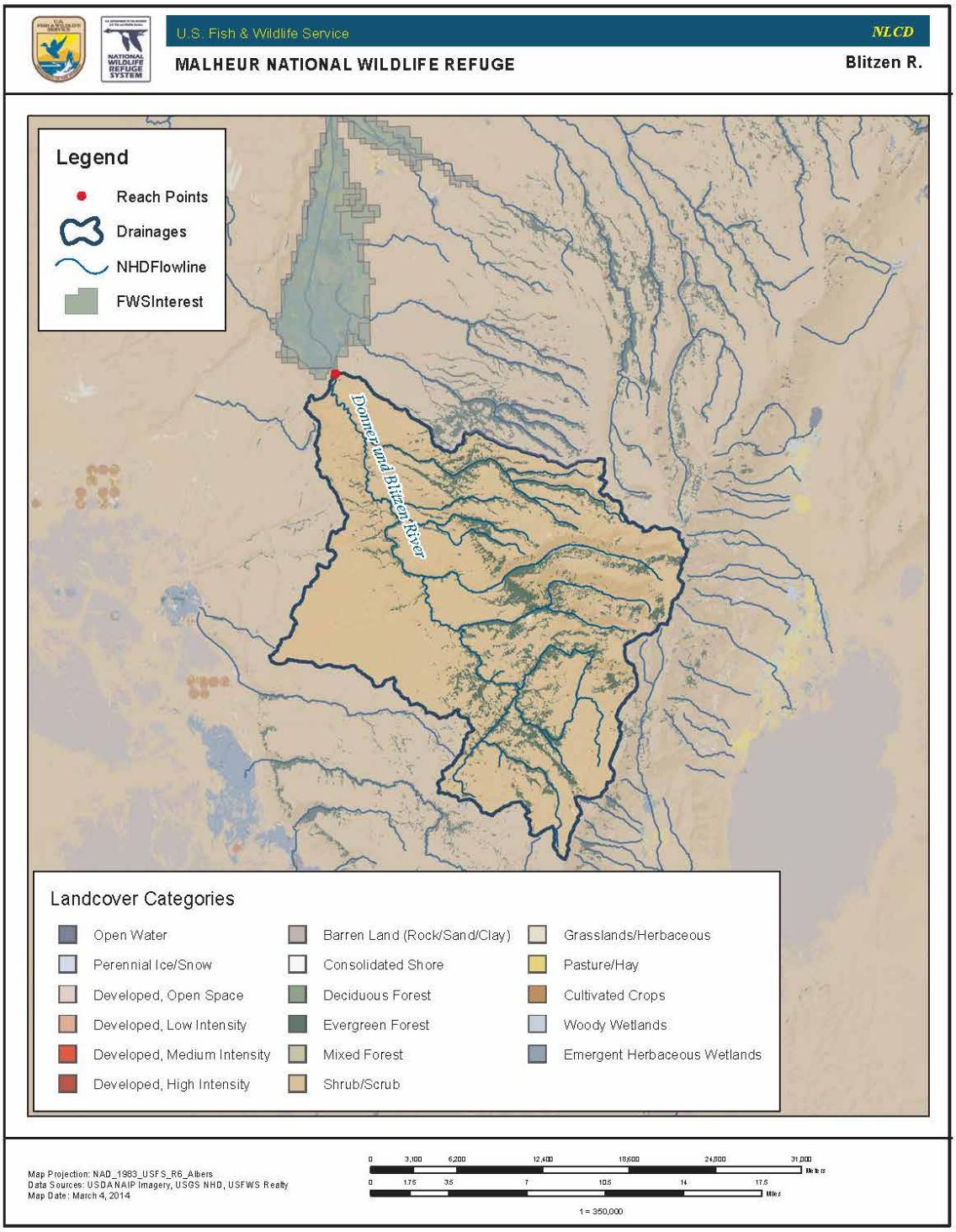
0 0.375 0.75 1.5 2.25 3 3.75 Miles

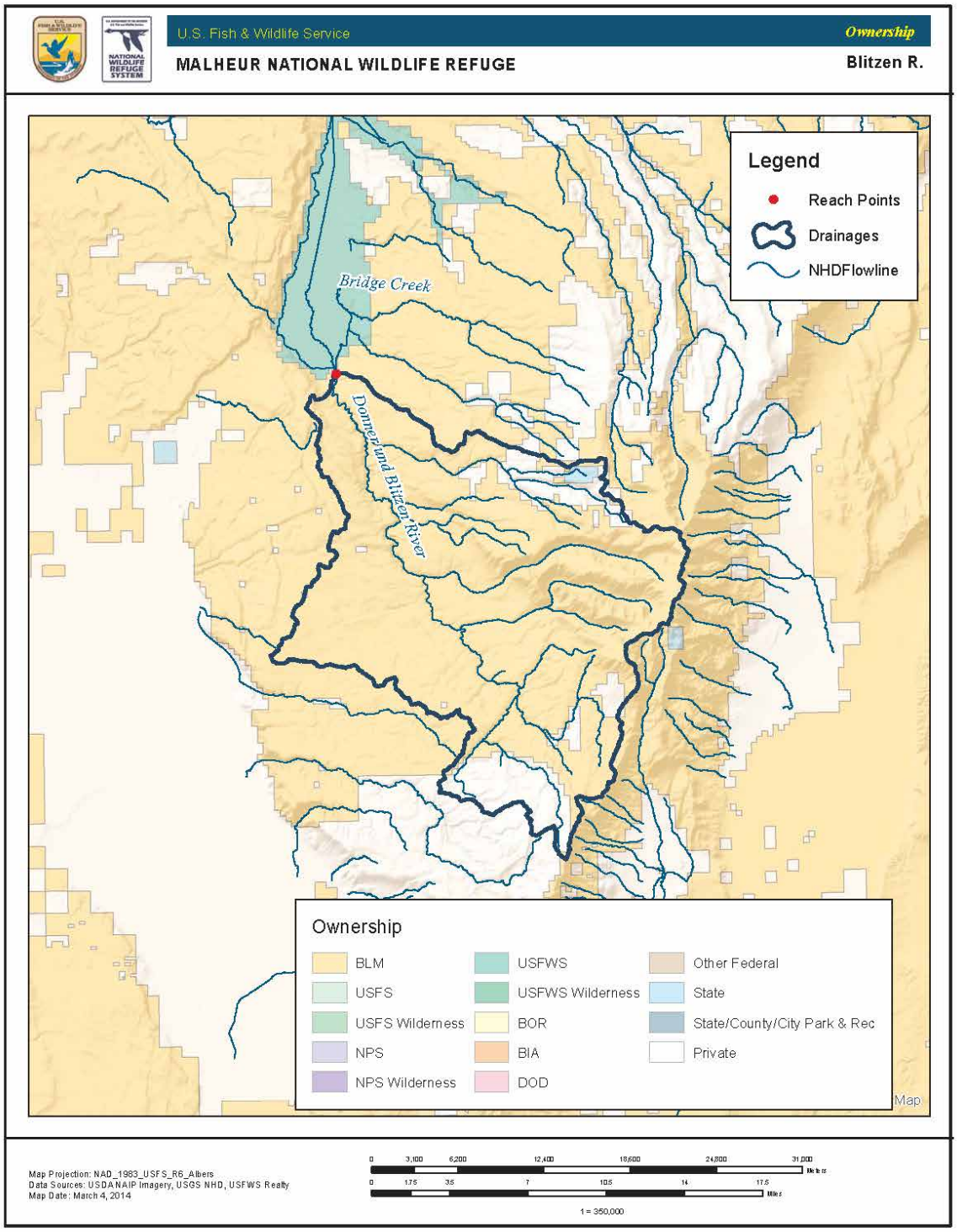
1 = 67,920

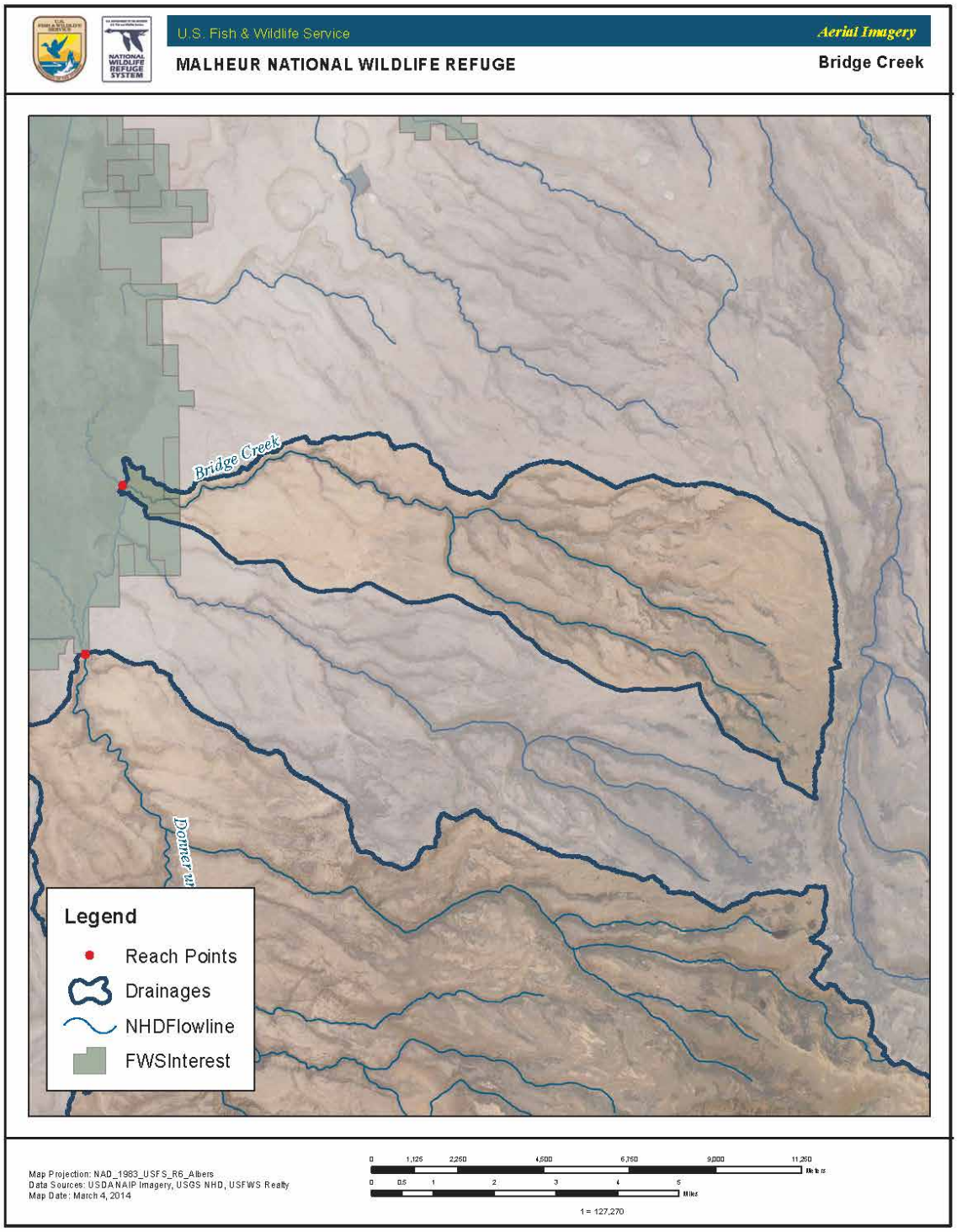

U.S. Fish & Wildlife Service
NLCD
HART MOUNTAIN NATIONAL ANTELOPE REFUGE
Rock Creek
Legend
Reach Points
Drainages
NHDFlowline
Rock Creek
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 950 1,900 3,800 5,700 7,600 9,500
Meters
0 0.5 1 2 3 4 5
Miles
1 = 110,000


U.S. Fish & Wildlife Service
Ownership
HART MOUNTAIN NATIONAL ANTELOPE REFUGE
Rock Creek
Legend
Reach Points
Drainages
NHDFlowline
Rock Creek
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 950 1,900 3,800 5,700 7,600 9,500
Meters
0 0.5 1 2 3 4 5
Miles
1 = 110,000


U.S. Fish & Wildlife Service
Aerial Imagery
MALHEUR NATIONAL WILDLIFE REFUGE
Blitzen R.
Donner und Blitzen River
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 1,900 3,800 7,600 11,400 15,200 19,000 Meters
0 1 2 4 6 8 10 Miles
1 = 212,780


U.S. Fish & Wildlife Service
NLCD
MALHEUR NATIONAL WILDLIFE REFUGE
Blitzen R.
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Donner und Blitzen River
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 3,100 6,200 12,400 18,600 24,800 31,000
Meters
0 1.75 3.5 7 10.5 14 17.5
Miles
1 = 350,000


U.S. Fish & Wildlife Service
Ownership
MALHEUR NATIONAL WILDLIFE REFUGE
Blitzen R.
Legend
Reach Points
Drainages
NHDFlowline
Bridge Creek
Donner und Blitzen River
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 3,100 6,200 12,400 18,600 24,800 31,000
Meters
0 1.75 3.5 7 10.5 14 17.5
Miles
1 = 350,000


U.S. Fish & Wildlife Service
Aerial Imagery
MALHEUR NATIONAL WILDLIFE REFUGE
Bridge Creek
Bridge Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 1,125 2,250 4,500 6,750 9,000 11,250
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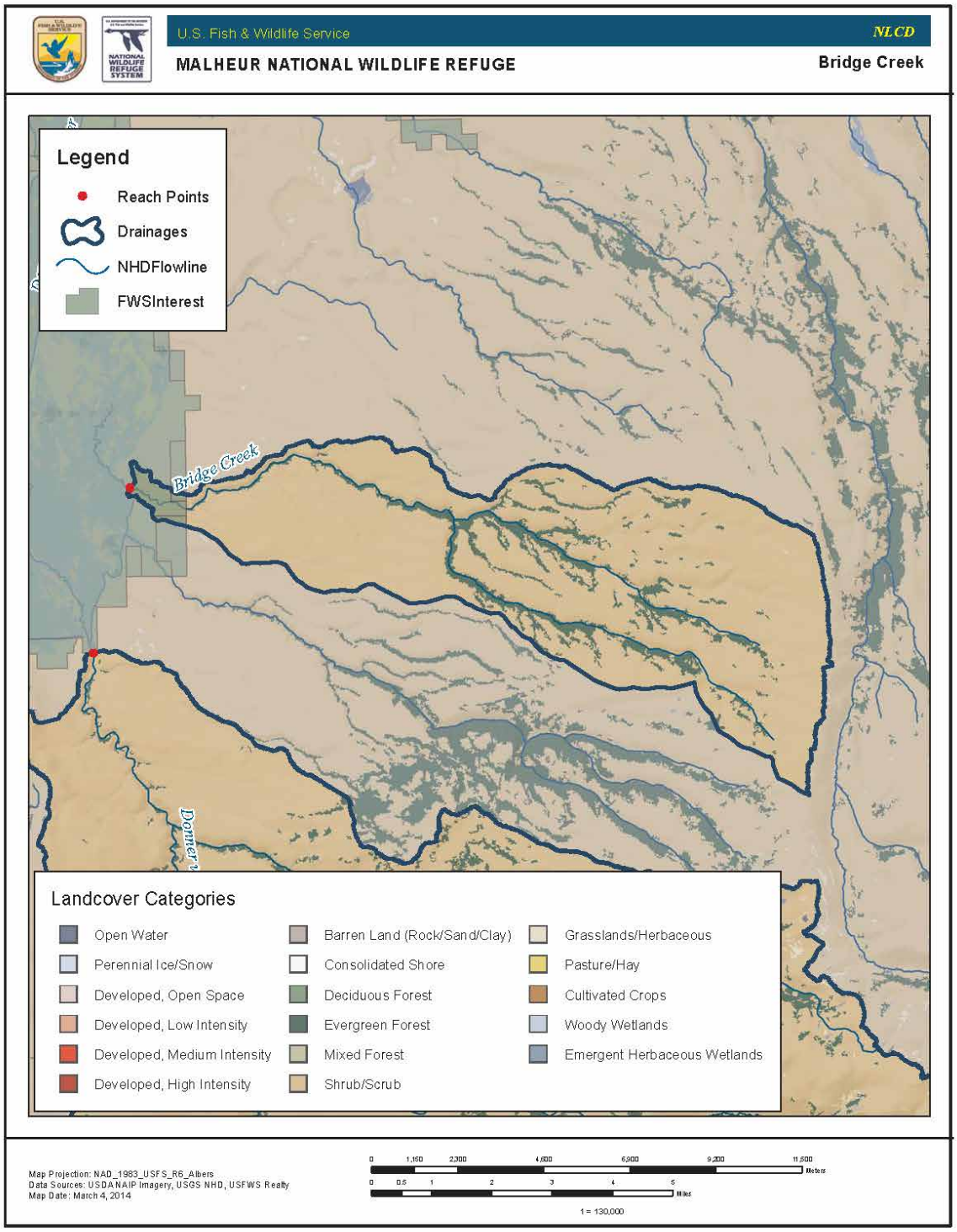
1 = 127,270


U.S. Fish & Wildlife Service
NLCD
MALHEUR NATIONAL WILDLIFE REFUGE
Bridge Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Bridge Creek
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
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Miles
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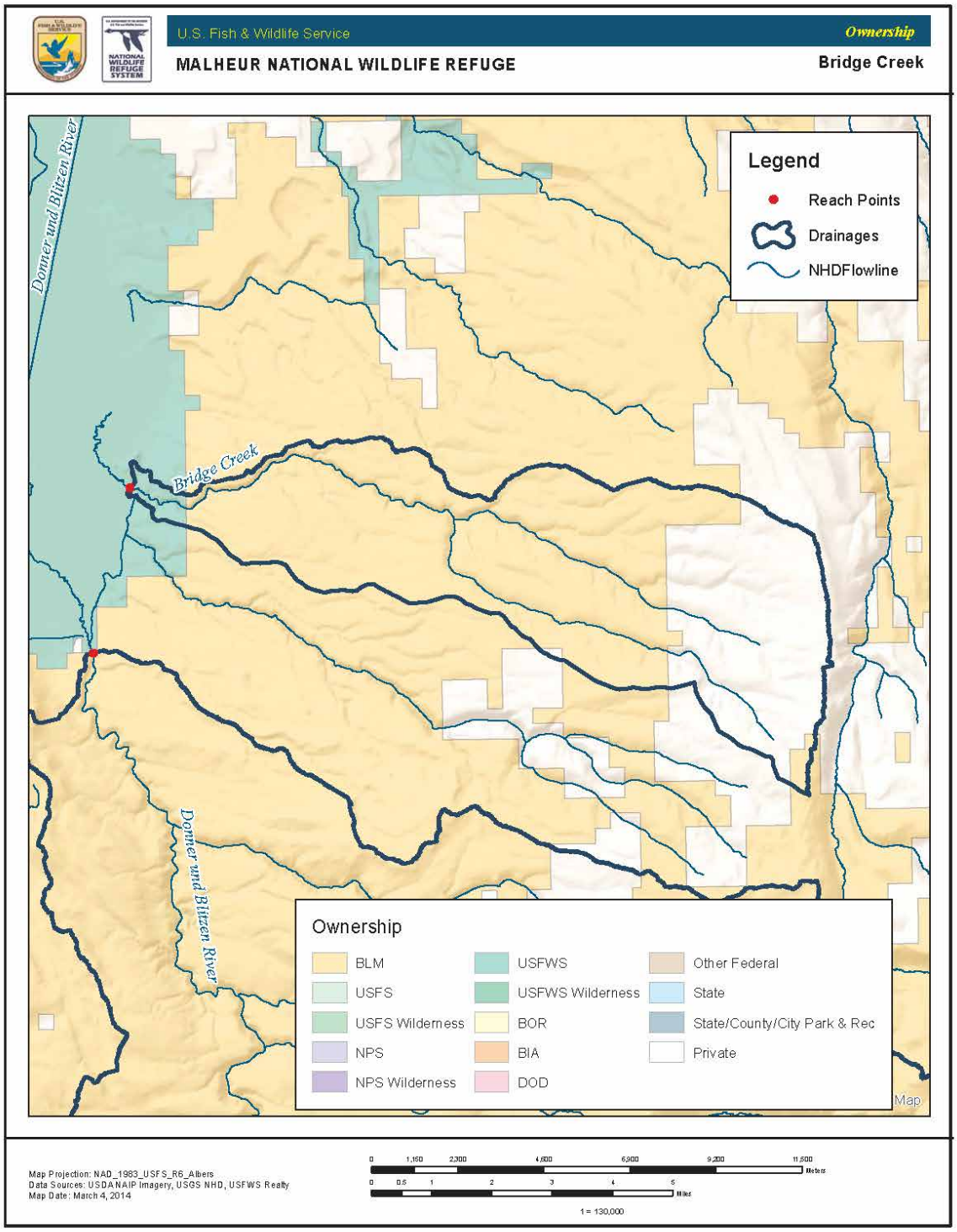
U.S. Fish & Wildlife Service
Ownership
MALHEUR NATIONAL WILDLIFE REFUGE
Bridge Creek
Legend
Reach Points
Drainages
NHDFlowline
Donner und Blitzen River
Bridge Creek
Donner und Blitzen River
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 1,150 2,300 4,600 6,900 9,200 11,500
Meters
0 0.5 1 2 3 4 5
Miles
1 = 130,000

U.S. Fish & Wildlife Service
Aerial Imagery
SHELDON NATIONAL WILDLIFE REFUGE
Fish Creek
Legend
Reach Points
Drainages
NHDFlowline
Fish Creek
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
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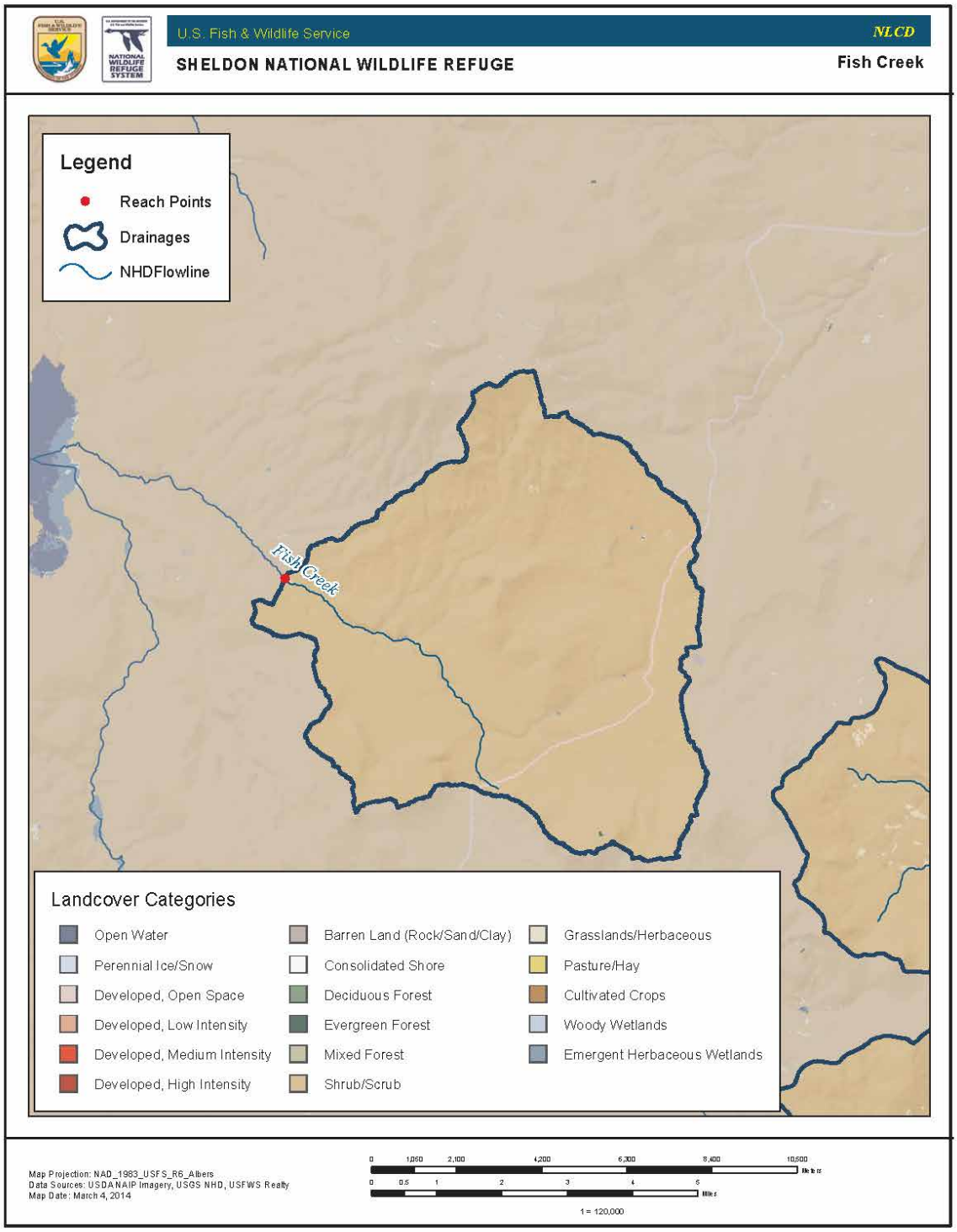
Miles
1 = 75,920


U.S. Fish & Wildlife Service
NLCD
SHELDON NATIONAL WILDLIFE REFUGE
Fish Creek
Legend
Reach Points
Drainages
NHDFlowline
Fish Creek
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 1,050 2,100 4,200 6,300 8,400 10,500
Meters
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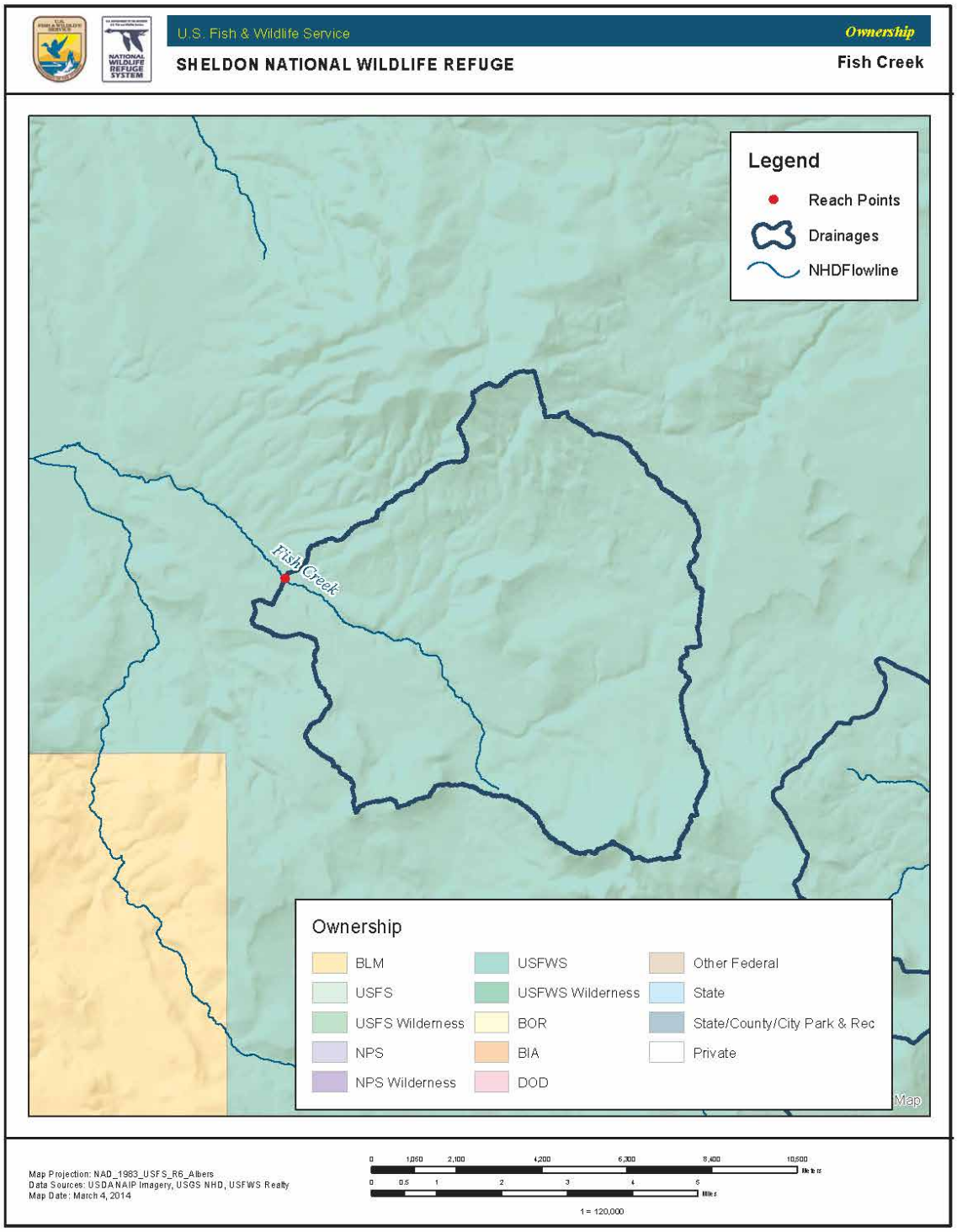
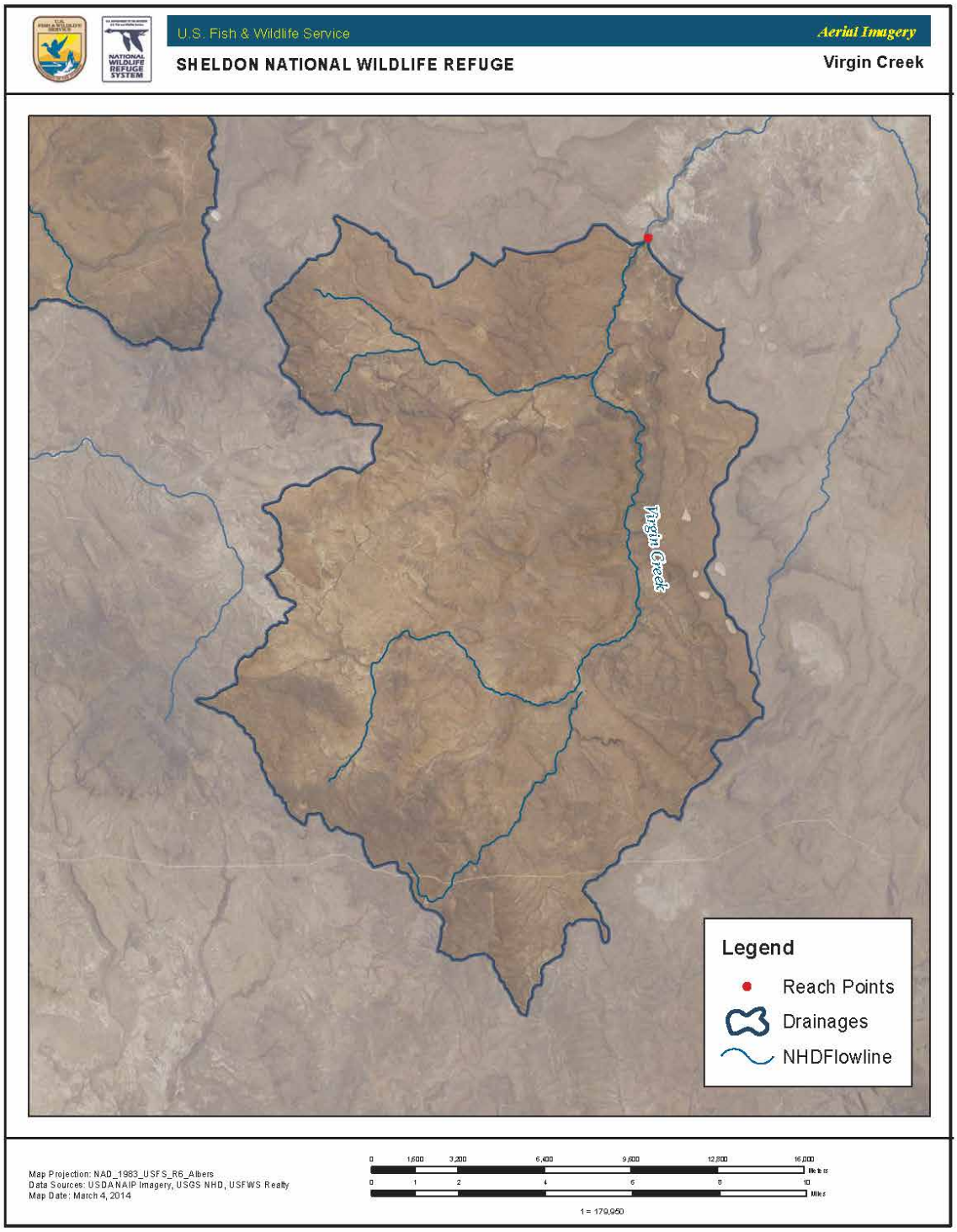
Miles
1 = 120,000


U.S. Fish & Wildlife Service
Ownership
SHELDON NATIONAL WILDLIFE REFUGE
Fish Creek
Legend
Reach Points
Drainages
NHDFlowline
Fish Creek
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
1 = 120,000


U.S. Fish & Wildlife Service
Aerial Imagery
SHELDON NATIONAL WILDLIFE REFUGE
Virgin Creek
Virgin Creek
Legend
Reach Points
Drainages
NHDFlowline
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
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Meters
0 1 2 4 6 8 10
Miles
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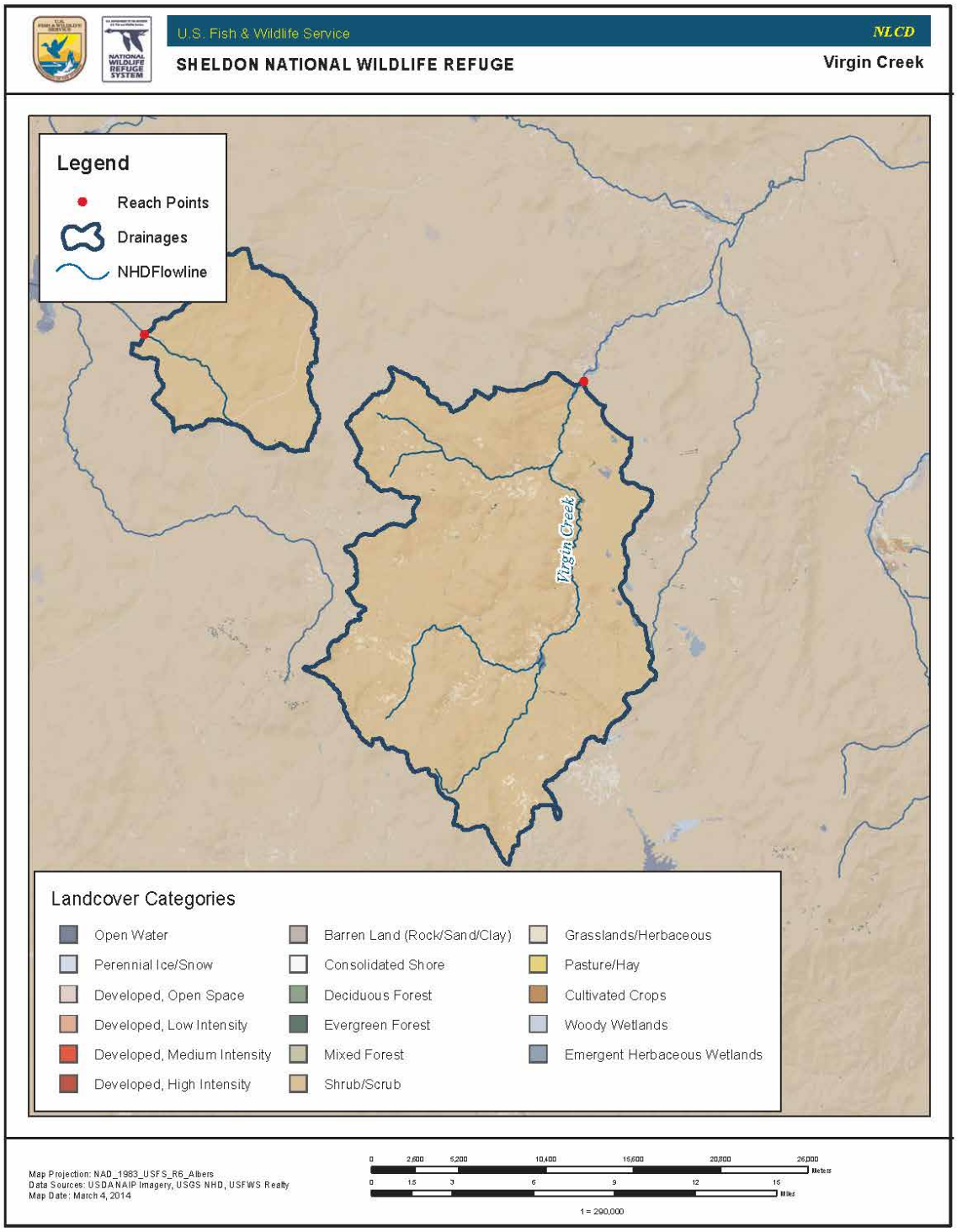
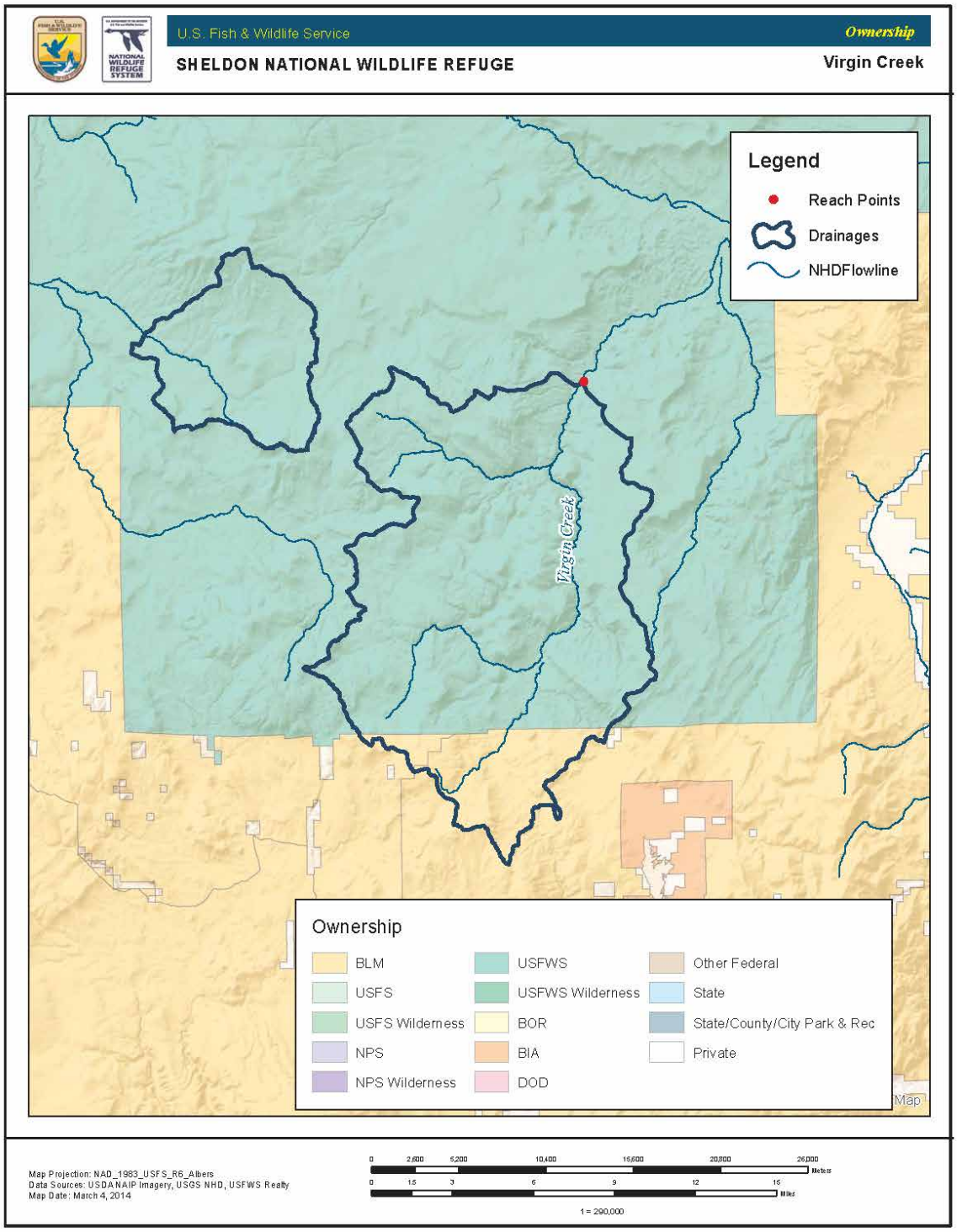
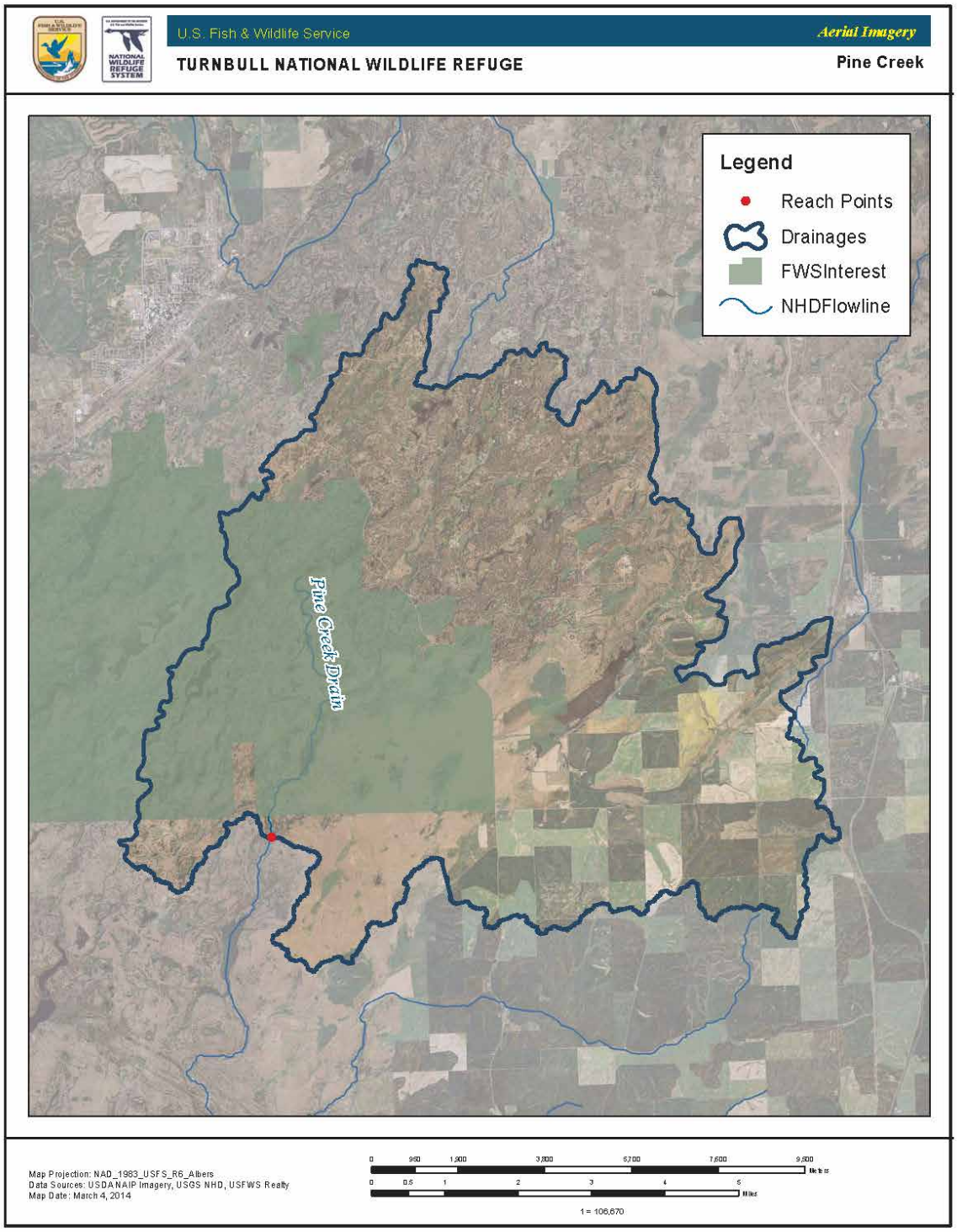

U.S. Fish & Wildlife Service
NLCD
SHELDON NATIONAL WILDLIFE REFUGE
Virgin Creek
Legend
Reach Points
Drainages
NHDFlowline
Virgin Creek
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 2,600 5,200 10,400 15,600 20,800 26,000 Meters
0 1.5 3 6 9 12 15 Miles
1 = 290,000


U.S. Fish & Wildlife Service
Ownership
SHELDON NATIONAL WILDLIFE REFUGE
Virgin Creek
Legend
Reach Points
Drainages
NHDFlowline
Virgin Creek
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 2,600 5,200 10,400 15,600 20,800 26,000 Meters
0 1.5 3 6 9 12 15 Miles
1 = 290,000


U.S. Fish & Wildlife Service
Aerial Imagery
TURNBULL NATIONAL WILDLIFE REFUGE
Pine Creek
Legend
Reach Points
Drainages
FWSInterest
NHDFlowline
Pine Creek Drain
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
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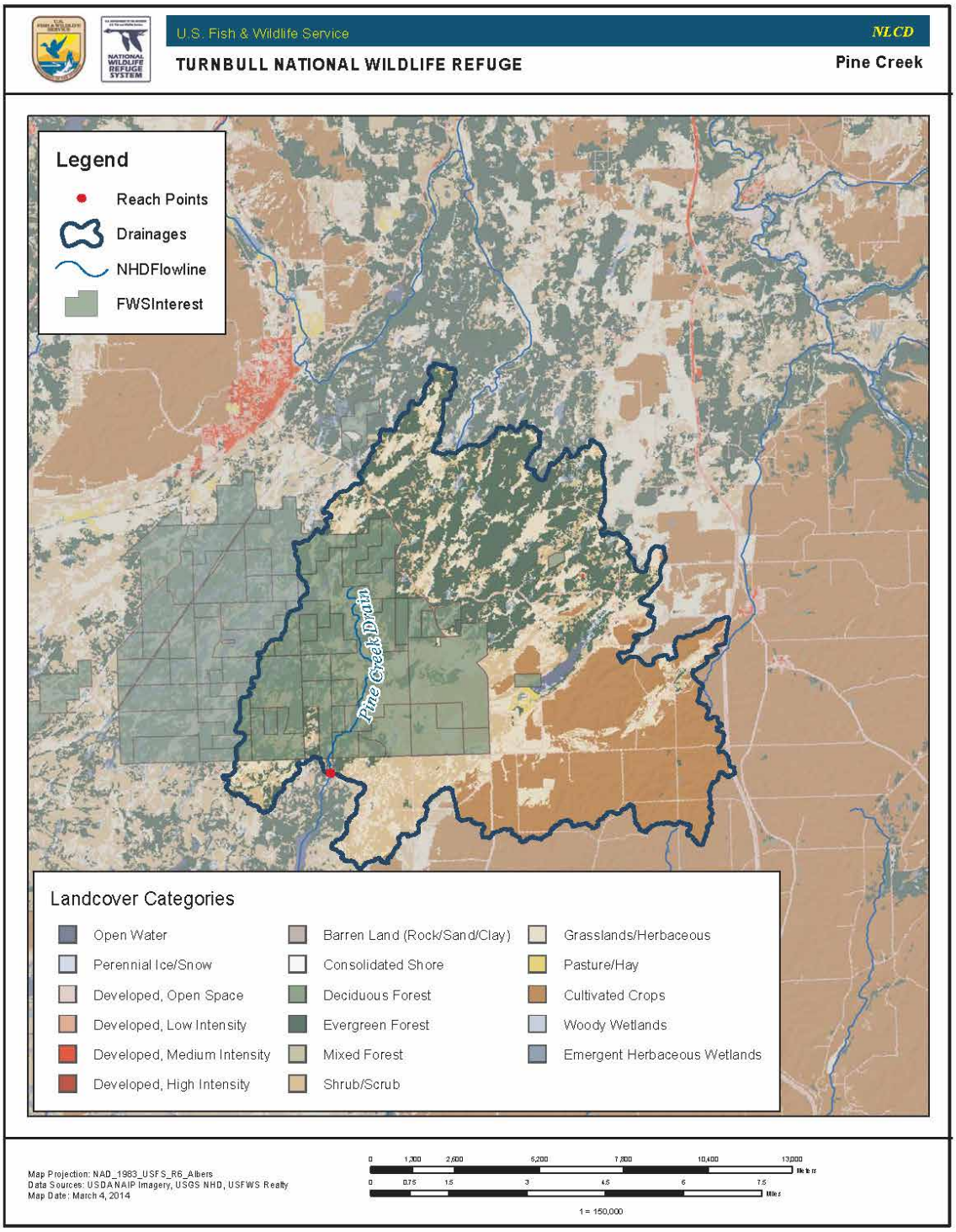
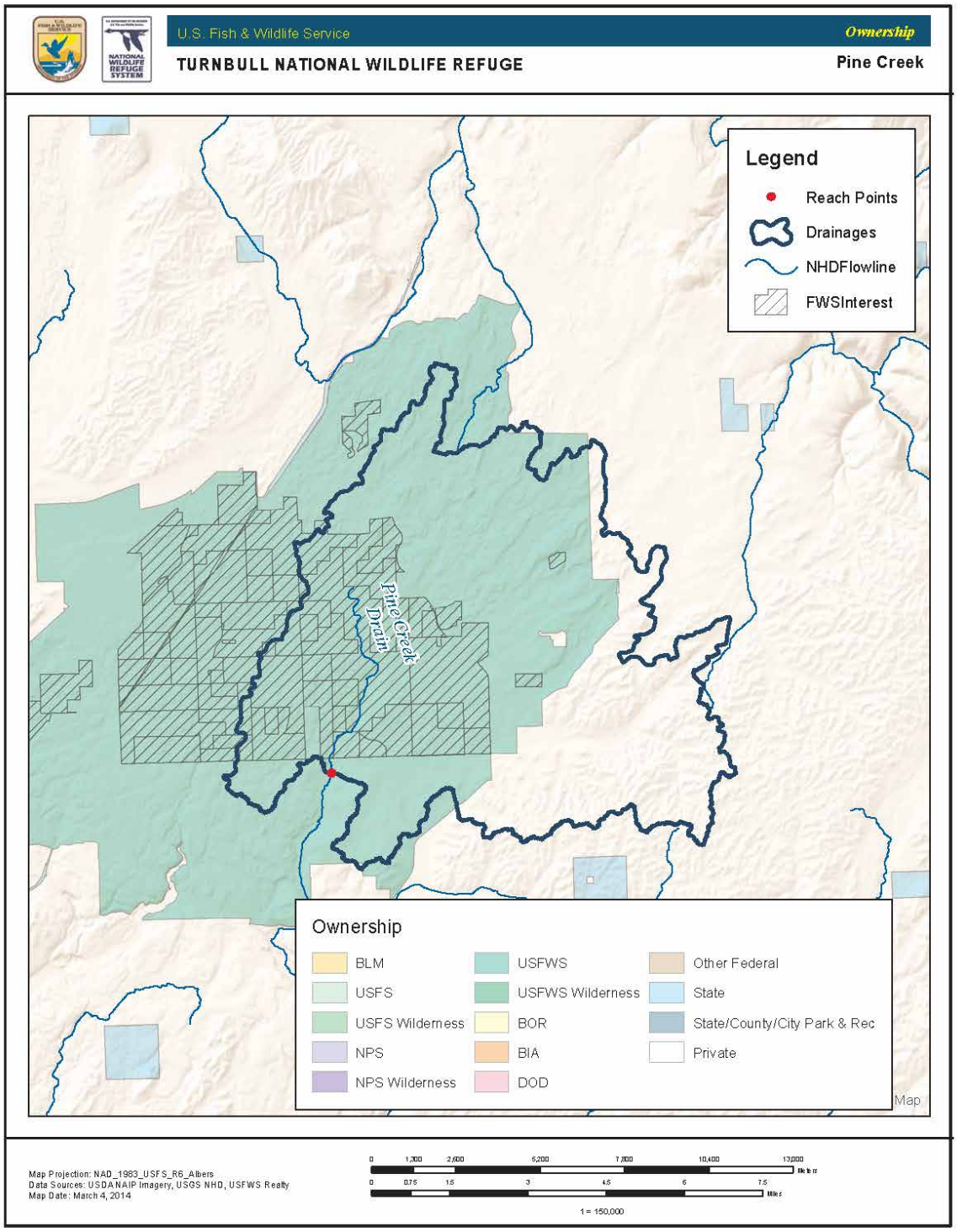
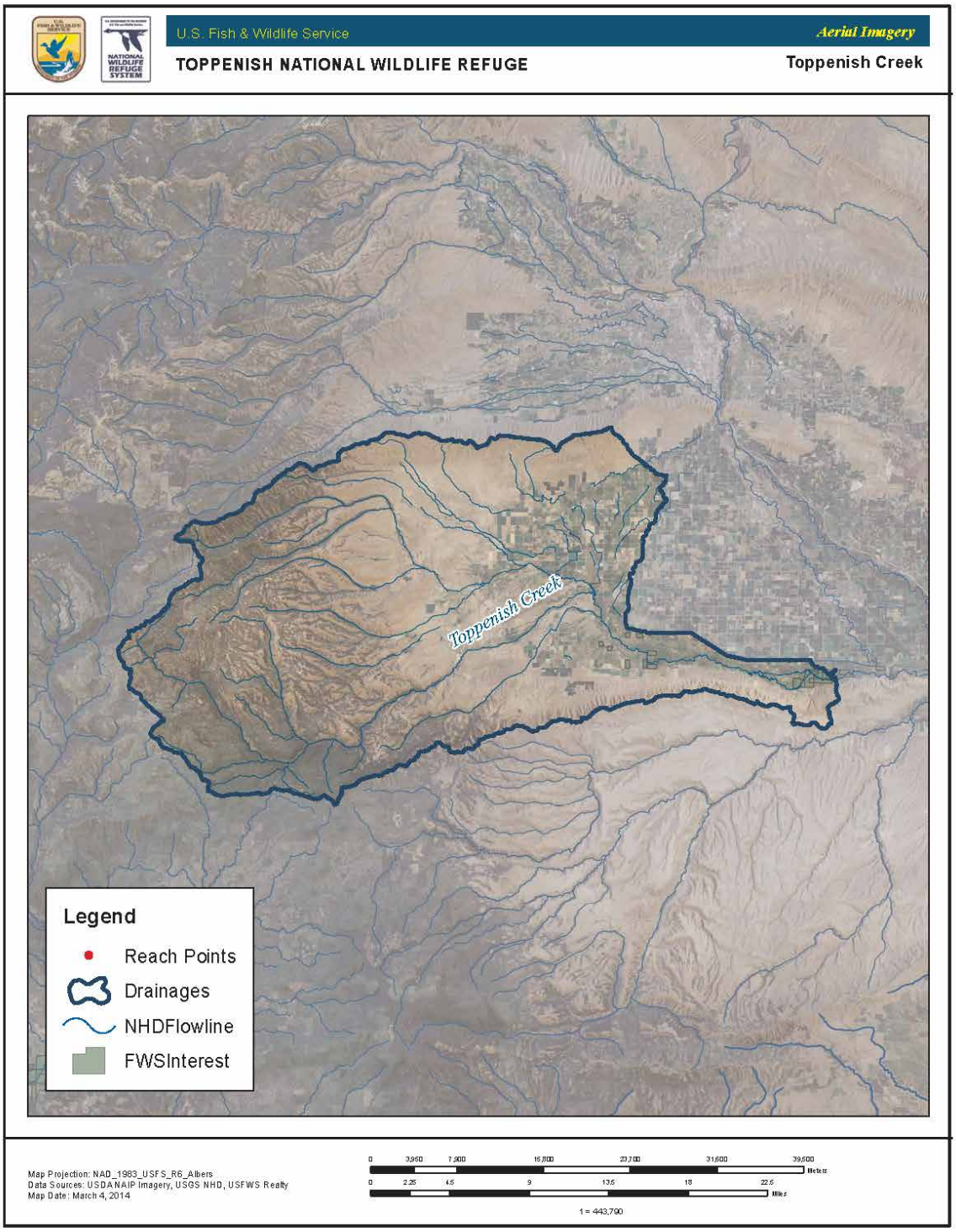
Meters
0 0.5 1 2 3 4 5
Miles
1 = 106,670


U.S. Fish & Wildlife Service
NLCD
TURNBULL NATIONAL WILDLIFE REFUGE
Pine Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Pine Creek Drain
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 1,200 2,600 5,200 7,800 10,400 13,000
Meters
0 0.75 1.5 3 4.5 6 7.5
Miles
1 = 150,000


U.S. Fish & Wildlife Service
Ownership
TURNBULL NATIONAL WILDLIFE REFUGE
Pine Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Pine Creek Drain
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 1,300 2,600 5,200 7,800 10,400 13,000
Meters
0 0.75 1.5 3 4.5 6 7.5
Miles
1 = 150,000


U.S. Fish & Wildlife Service
Aerial Imagery
TOPPENISH NATIONAL WILDLIFE REFUGE
Toppenish Creek
Toppenish Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
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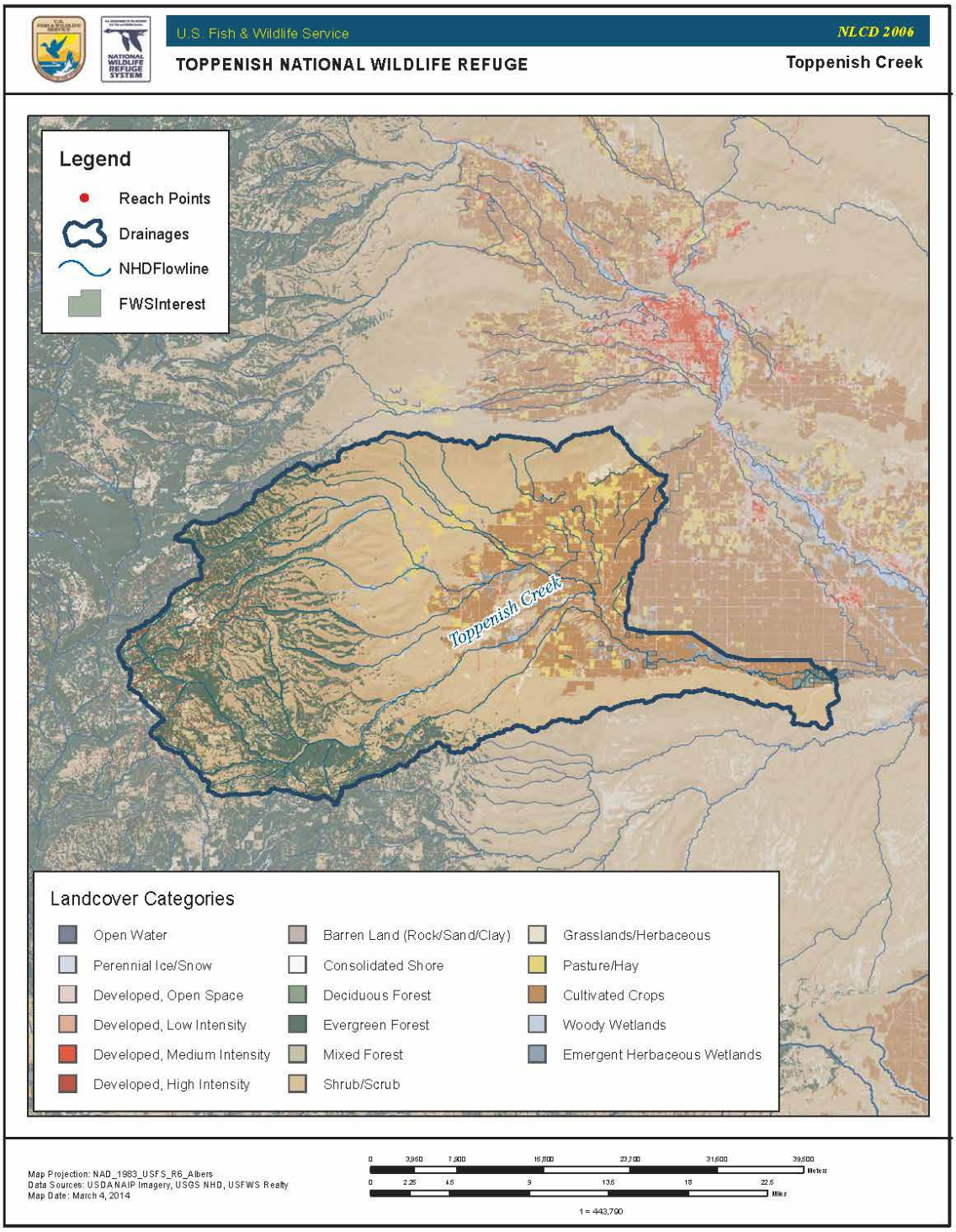
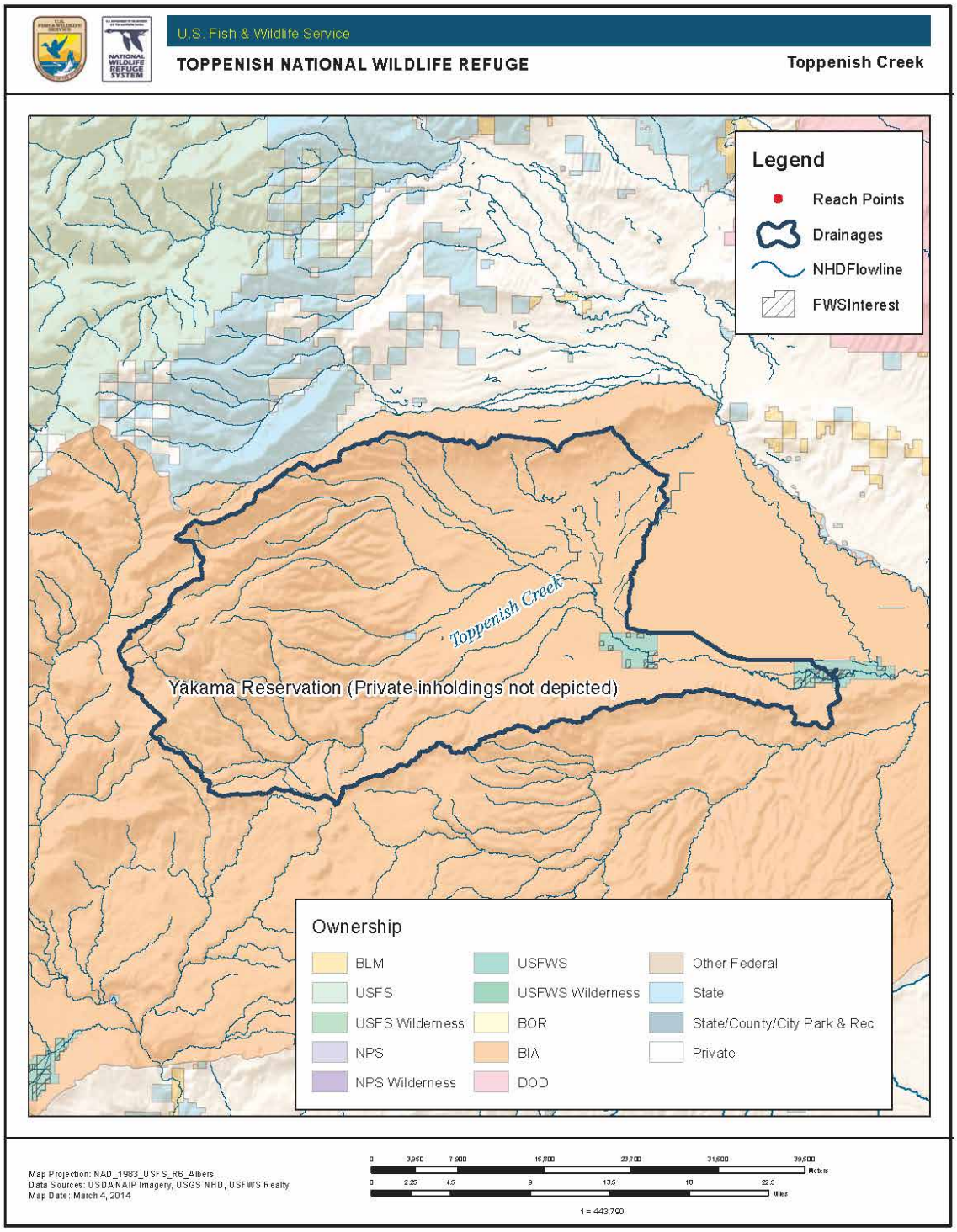
Meters
0 2.25 4.5 9 13.5 18 22.5
Miles
1 = 443,790


U.S. Fish & Wildlife Service
NLCD 2006
TOPPENISH NATIONAL WILDLIFE REFUGE
Toppenish Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Toppenish Creek
Landcover Categories
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Consolidated Shore
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grasslands/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 3,950 7,900 15,800 23,700 31,600 39,500 Meters
0 2.25 4.5 9 13.5 18 22.5 Miles
1 = 443,790

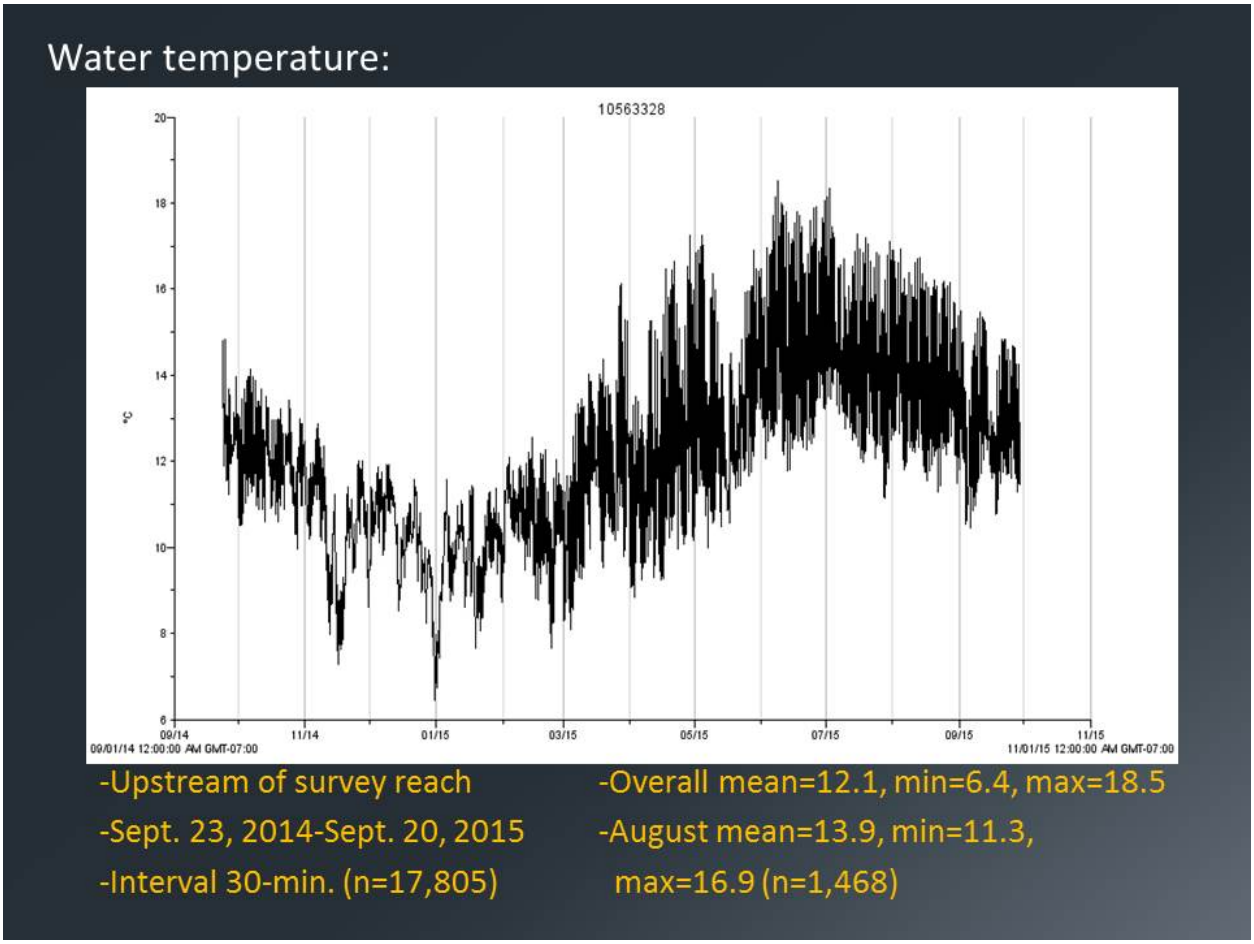

U.S. Fish & Wildlife Service
TOPPENISH NATIONAL WILDLIFE REFUGE
Toppenish Creek
Legend
Reach Points
Drainages
NHDFlowline
FWSInterest
Toppenish Creek
Yakama Reservation (Private inholdings not depicted)
Ownership
BLM
USFS
USFS Wilderness
NPS
NPS Wilderness
USFWS
USFWS Wilderness
BOR
BIA
DOD
Other Federal
State
State/County/City Park & Rec
Private
Map Projection: NAD_1983_USFS_R6_Albers
Data Sources: USDA NAIP Imagery, USGS NHD, USFWS Realty
Map Date: March 4, 2014
0 3,950 7,900 15,800 23,700 31,600 39,500 Meters
0 2.25 4.5 9 13.5 18 22.5 Miles
1 = 443,790

Appendix B. Water chemistry characteristics and electrofisher settings during vertebrate surveys in Bridge Creek, Muddy Creek, Little Pend Oreille River, Myrtle Creek, and Omeara Creek in 2015.

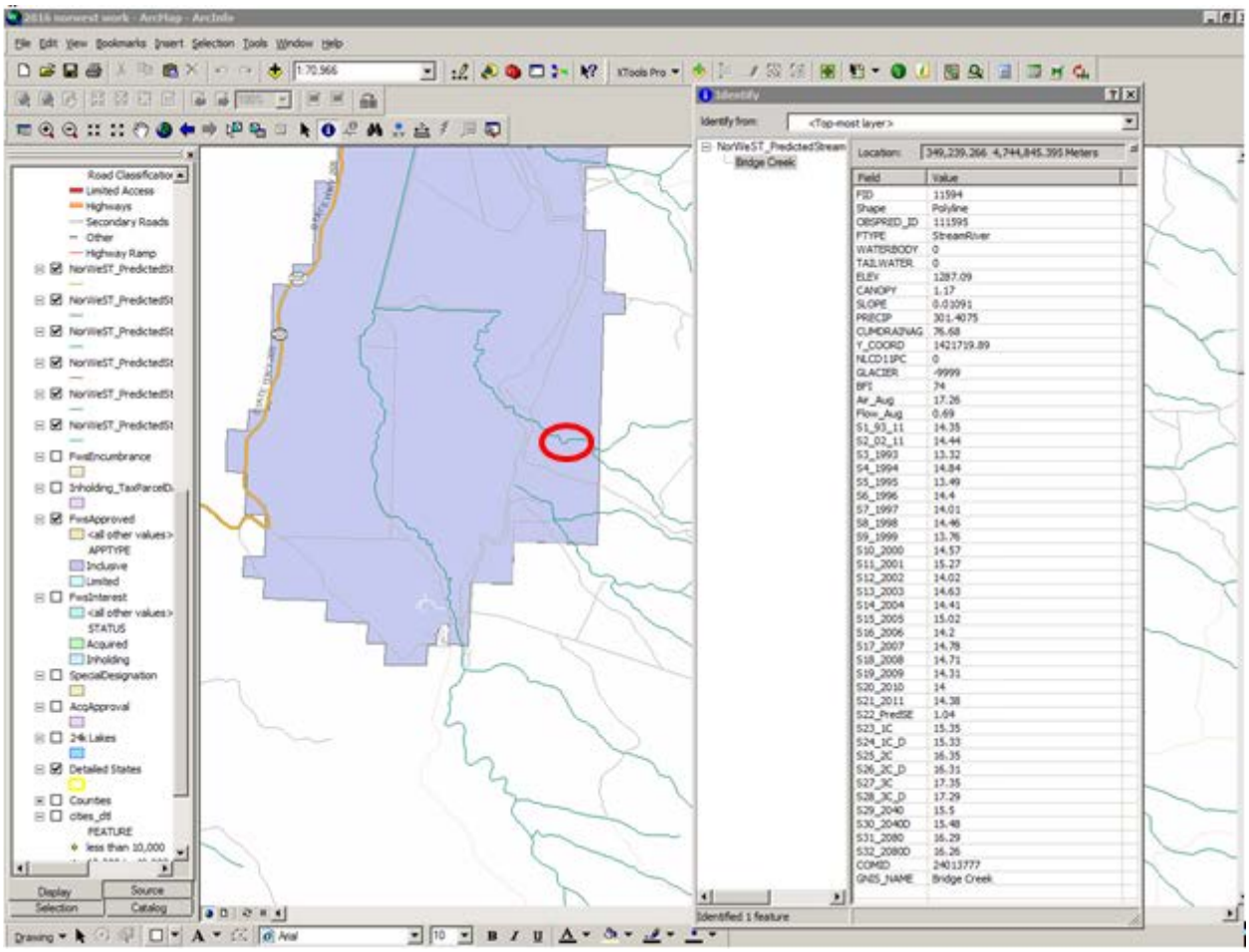
Date	Time	Water temperature (°C)	Dissolved Oxygen		pH	Conductivity		Electrofisher settings			
			(mg/l)	(%)		(µS)	(mg/l)	Volts	Frequency (Hz)	Duty Cycle (%)	Time (sec.)
						Bridge Creek					
Aug. 5	0930	13.5	10.82	103.5	7.81	105	55	335	25	25	5,016
Sept. 2	0830	12.9	10.82	99.7	8.11	110	55	335	25	25	4,536
Sept. 29	0835	11.0	10.81	99.4	8.11	115	55	335	10	25	3,216
						Muddy Creek					
Sept. 15	1015	13.5	5.21	50.9	7.19	95	45	335	25	25	4,428
Oct. 14	1030	13.0	6.50	63.7	6.98	80	40	335	25	25	3,384
						Little Pend Oreille River					
July 28	1130	14.5	8.7	89.0	-	185	-	500	45	12	4,711
Aug. 27	1130	13.0	-	-	-	-	-	600	60	-	2,845
Sept. 28	1115	7.0	-	-	-	110	-	450	45	12	2,327
						Myrtle Creek					
July 29	1145	14.0	-	-	-	-	-	900	-	-	7,988
Sept. 2	0915	13.0	-	-	-	-	-	879	-	-	8,840
Oct. 26	0847	5.0	-	-	-	-	-	878	-	-	5,705
						Omeara Creek					
July 17	0945	17.0	8.9	95.3	8.3	55		300	30	-	1,861
Sept. 0	1015	14.0	8.9	94.5	8.0	57		300	30	-	2,078
Oct. 15	0915	11.9	9.3	91.9	7.5	55		300	30	-	1,741

Appendix C. Example water temperatures from data loggers at each sentinel site, modeled stream temperatures at the sites from NorWeST and description of NorWeST historic and future stream temperature climate scenarios.
(www.fs.fed.us/rm/boise/AWAE/projects/NorWeST/ModeledStreamTemperatureScenariosMaps.shtml),

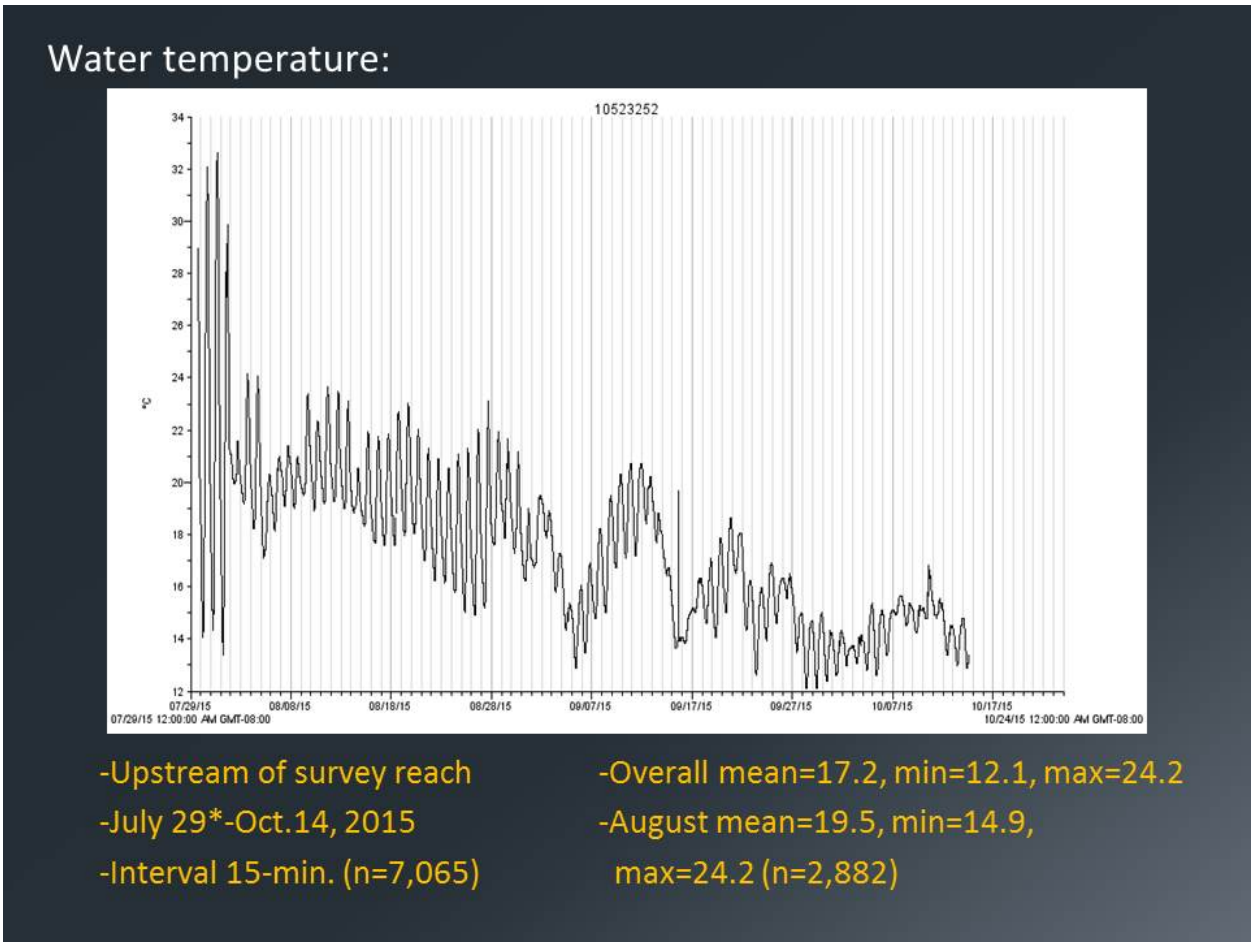
Bridge Creek



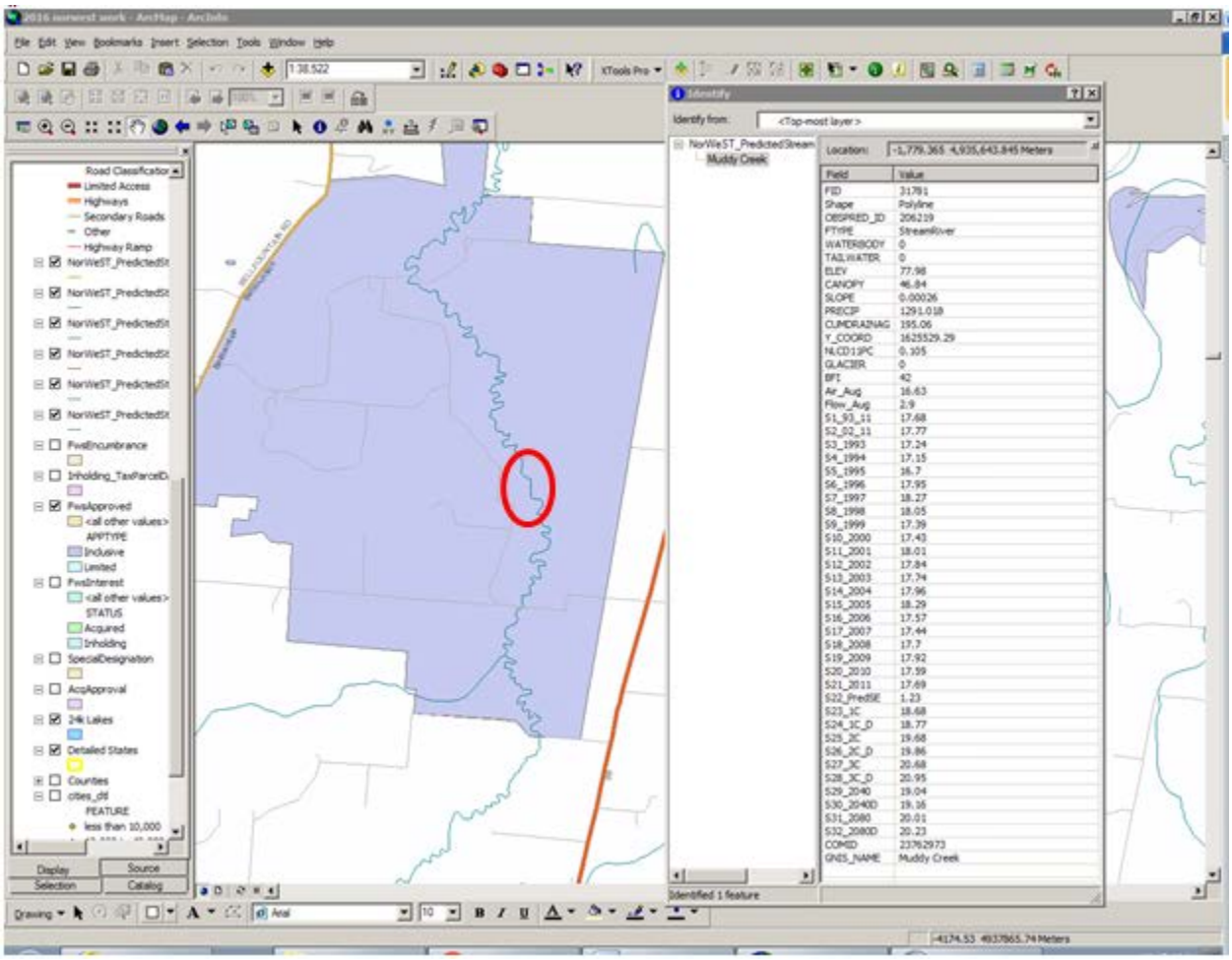
Bridge Creek—NorWeST data



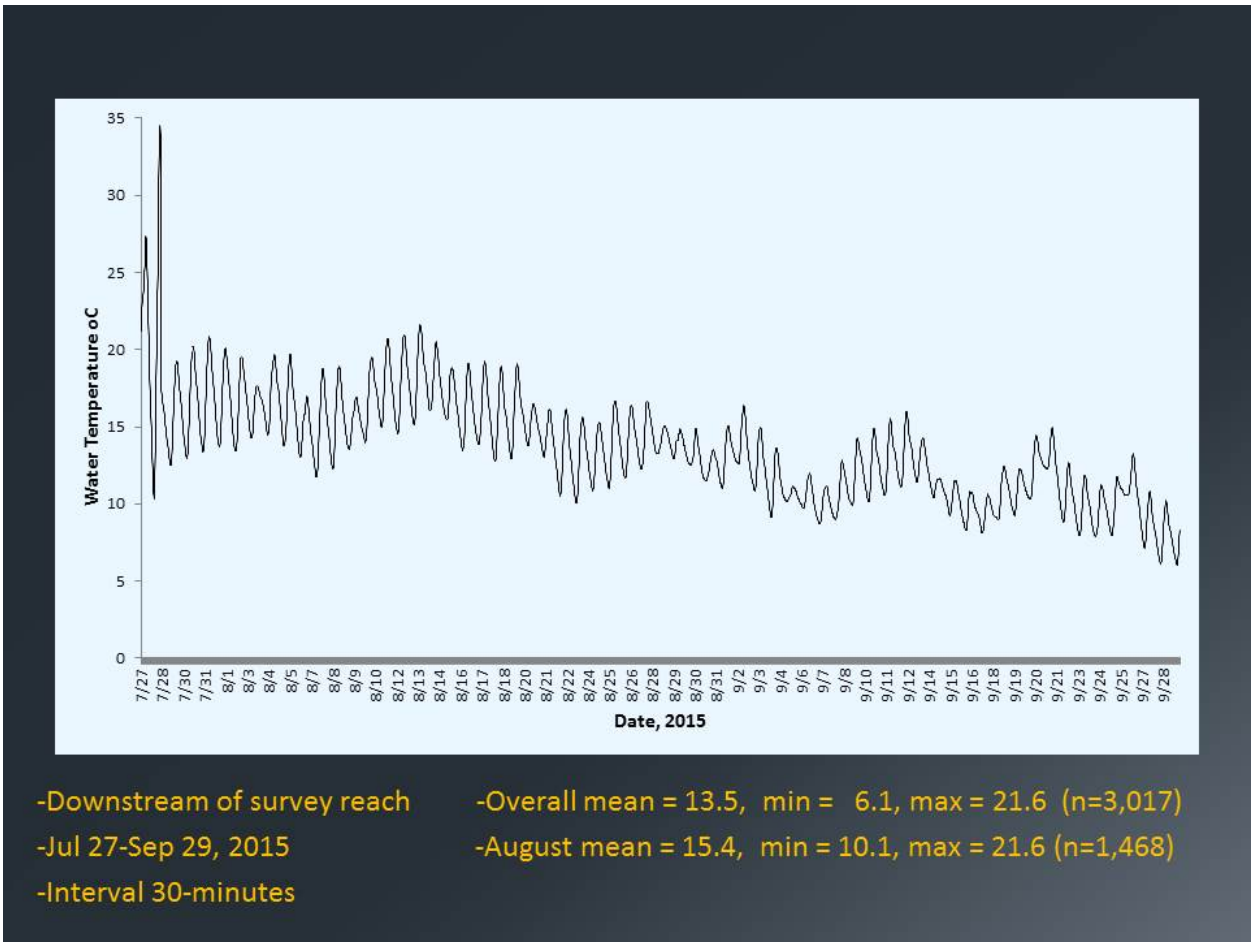
Muddy Creek


Water temperature:
10523252
°C
34
32
30
28
26
24
22
20
18
16
14
12
07/29/15
08/08/15
08/18/15
08/28/15
09/07/15
09/17/15
09/27/15
10/07/15
10/17/15
07/29/15 12:00:00 AM GMT-08:00
10/24/15 12:00:00 AM GMT-08:00
-Upstream of survey reach
-July 29*-Oct.14, 2015
-Interval 15-min. (n=7,065)
-Overall mean=17.2, min=12.1, max=24.2
-August mean=19.5, min=14.9,
max=24.2 (n=2,882)

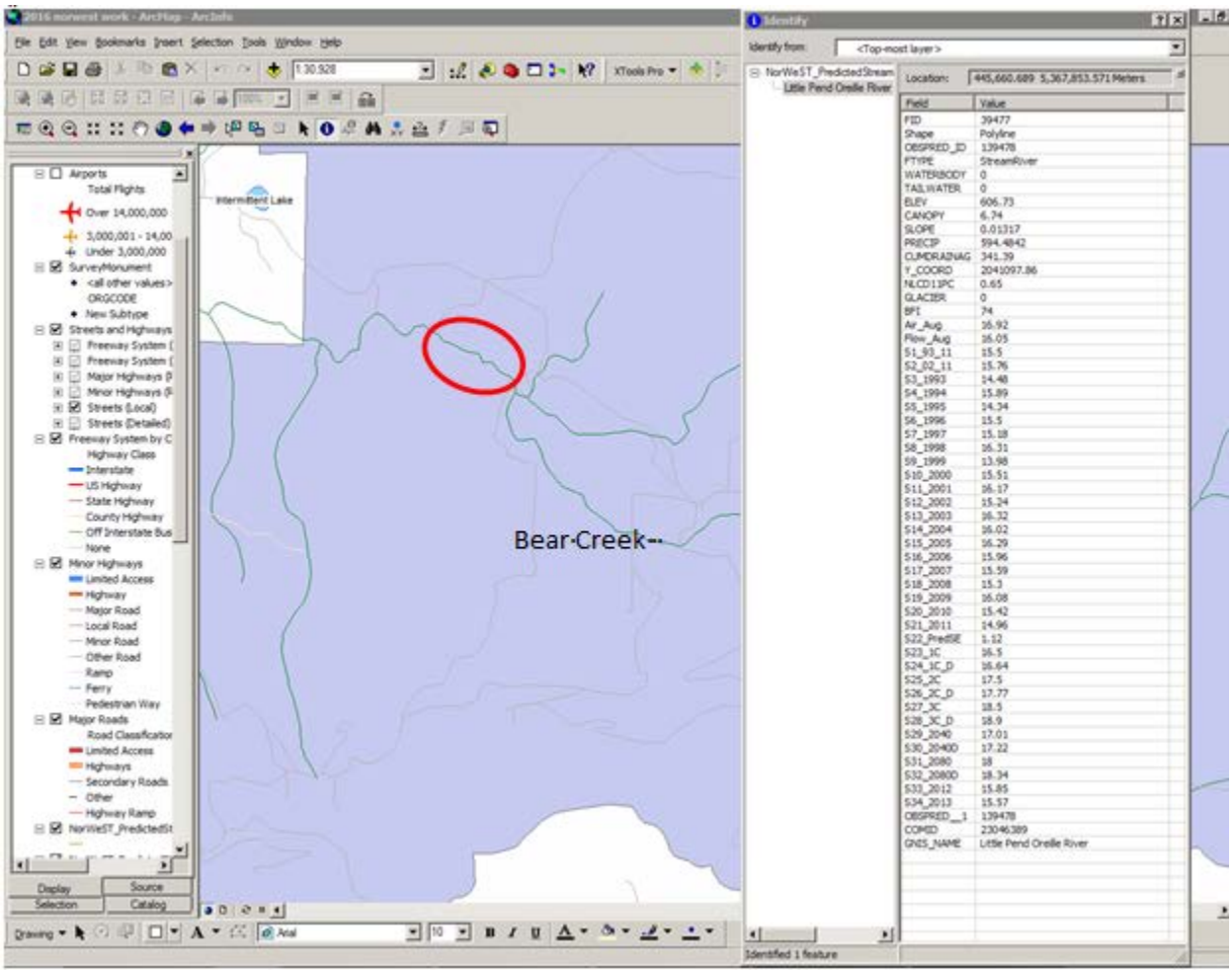
Muddy Creek—NorWeST data



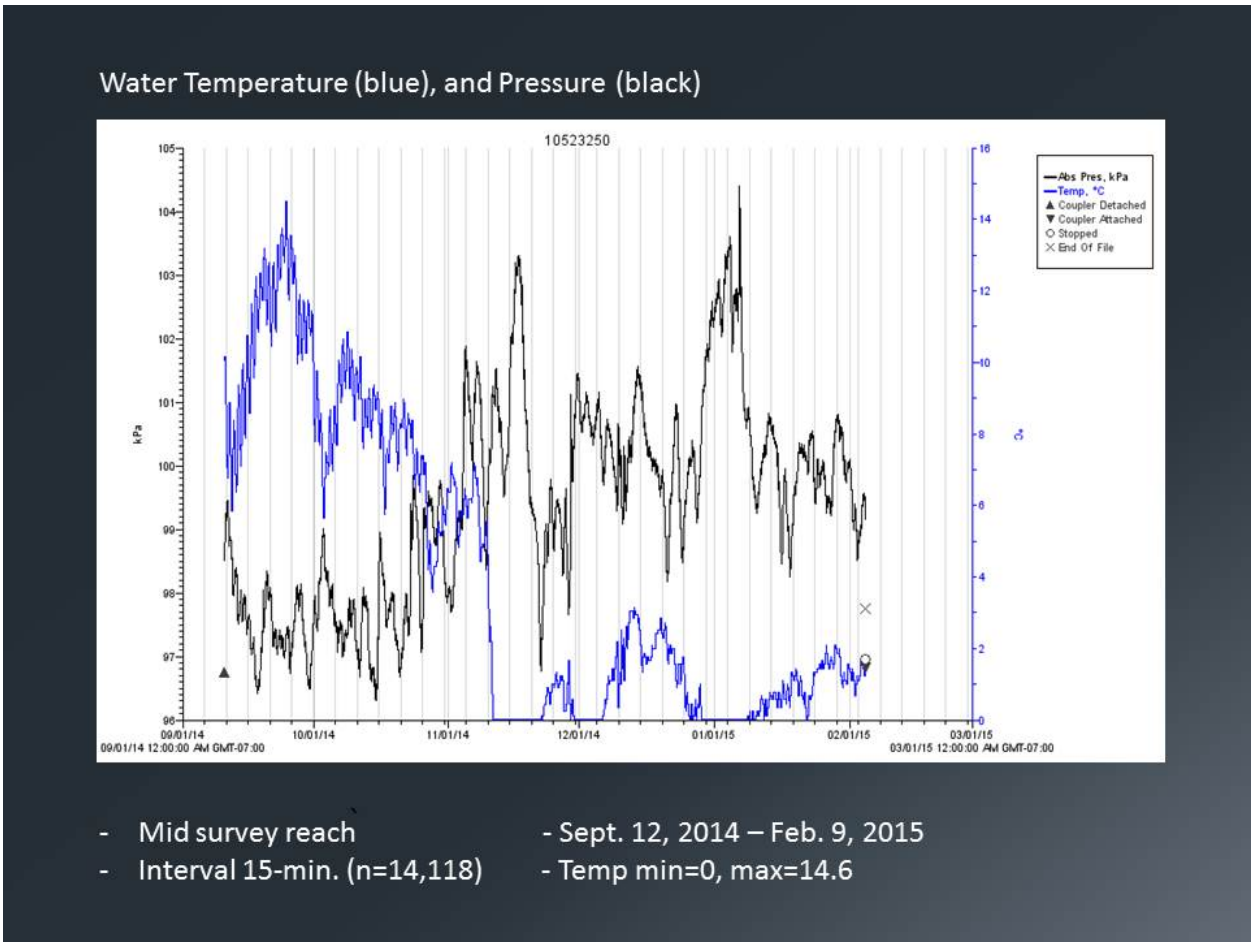
Little Pend Oreille River



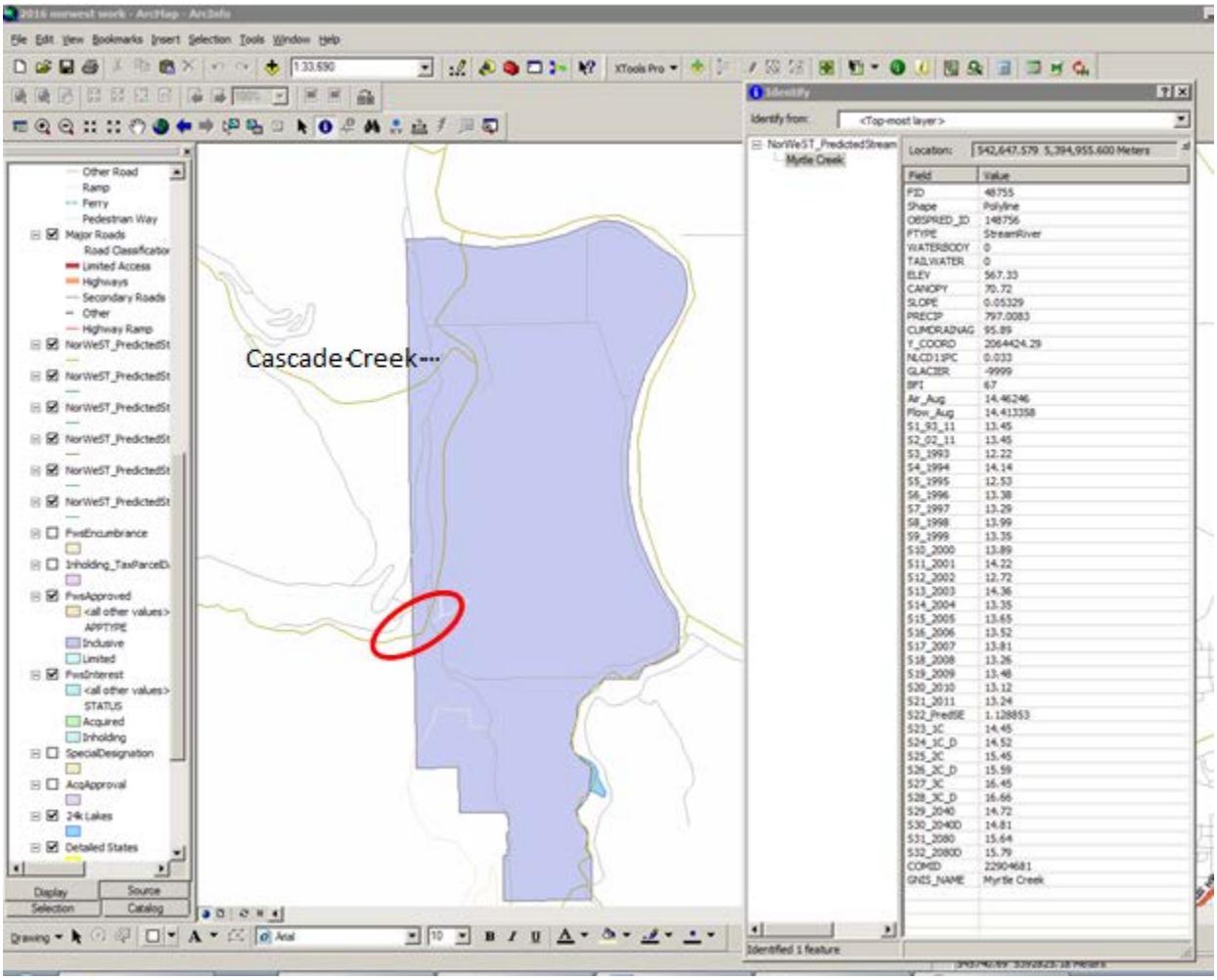
Little Pend Oreille River—NorWeST data



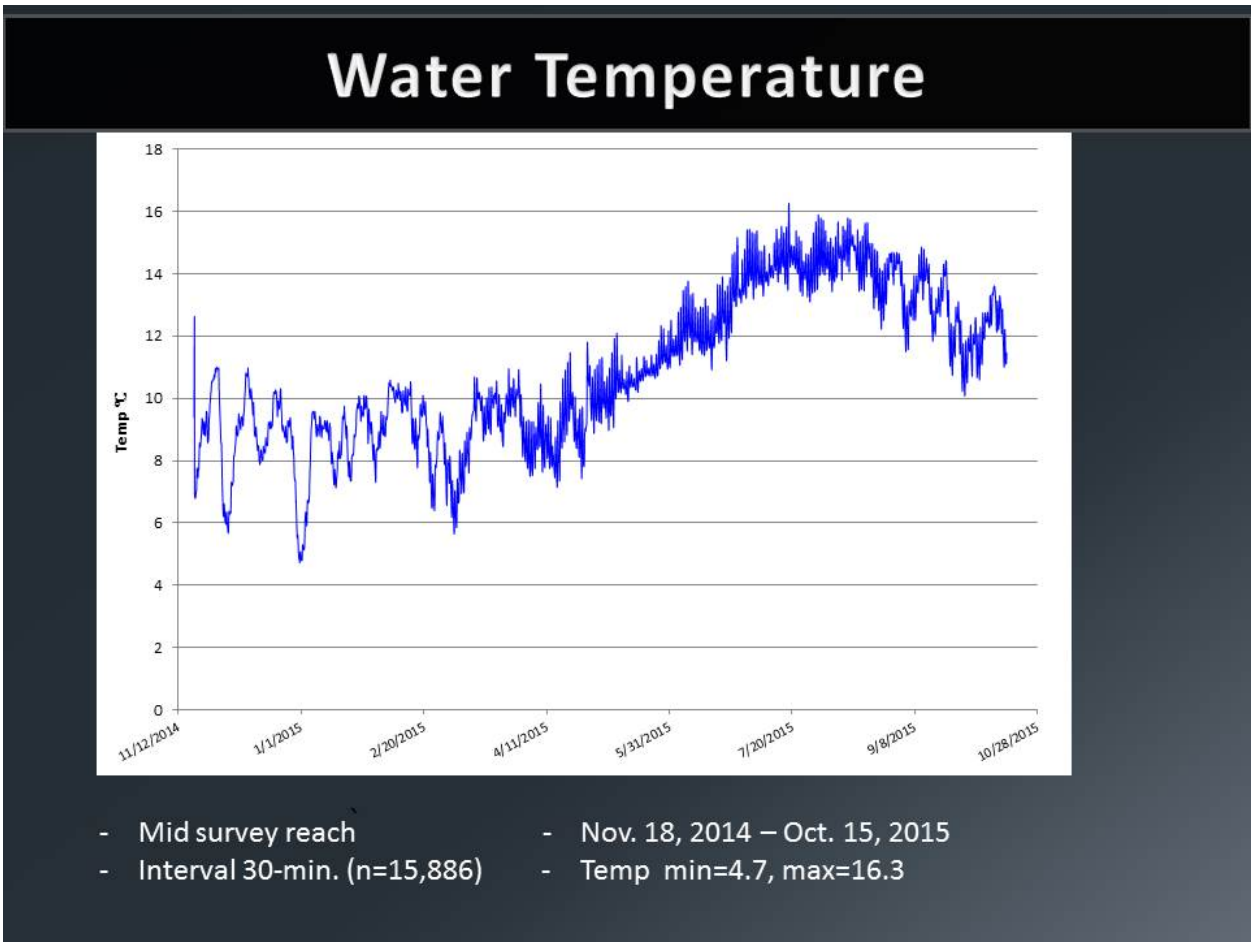
Myrtle Creek



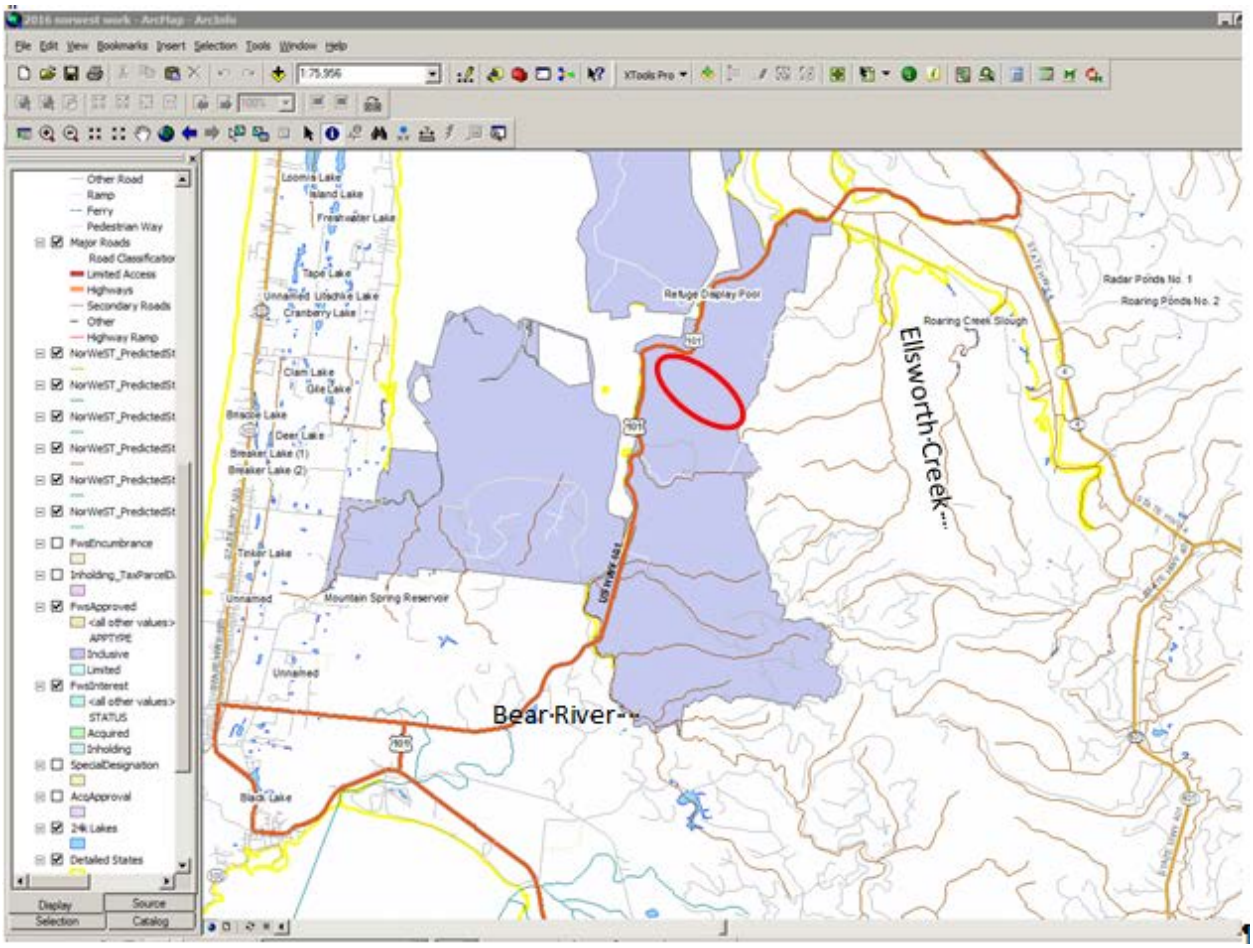
Myrtle Creek—NorWeST data



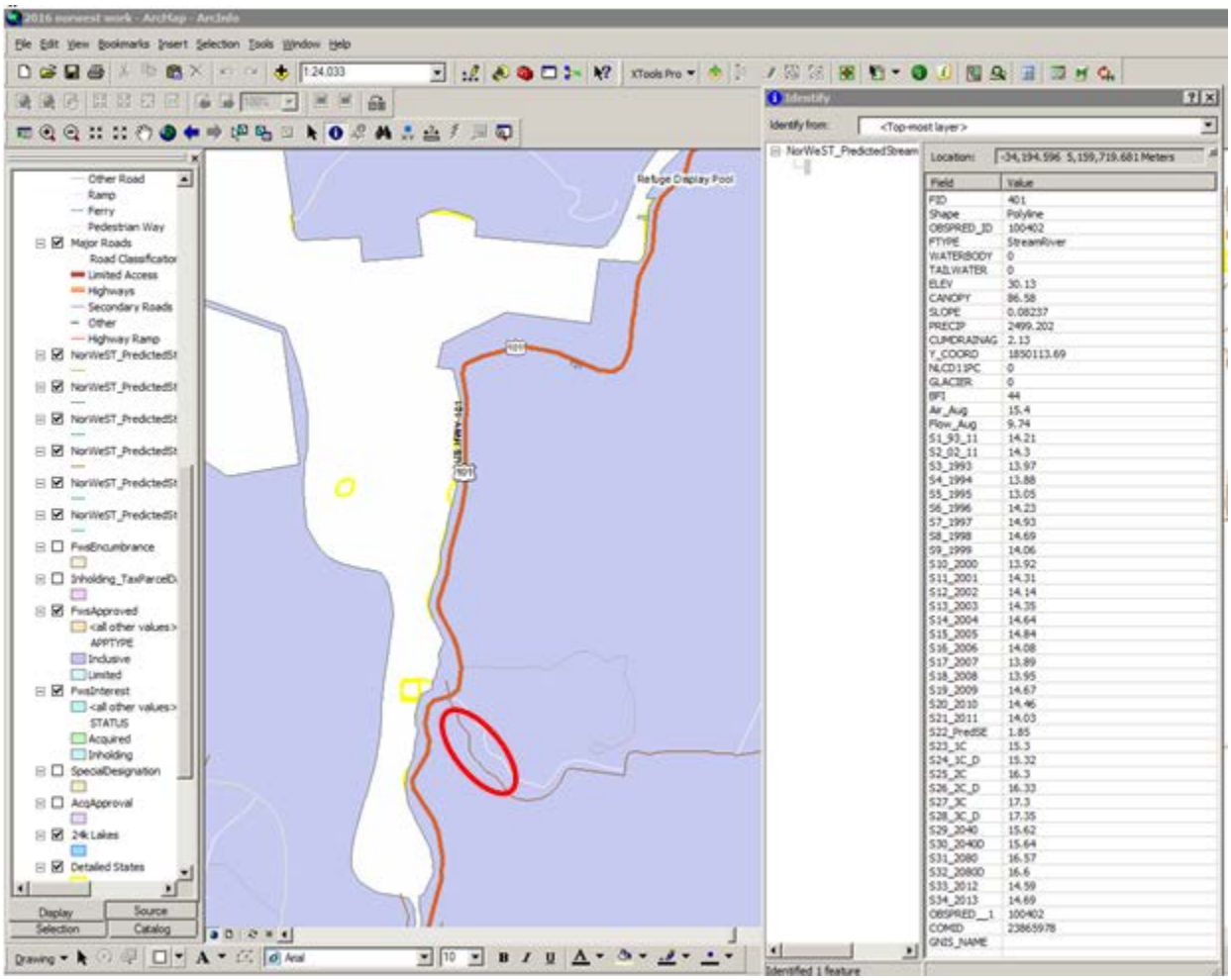
Omeara Creek



Omeara Creek—NorWeST data not available



NorWeST data for unnamed creek ~2 km south of Omeara Creek



Description of NorWeST historic and future stream temperature climate scenarios.

Scenario	**Description**
S1_93_11	Historical composite scenario representing 19 year average August mean stream temperatures for 1993-2011
S2_02_11	Historical composite scenario representing 10 year average August mean stream temperatures for 2002-2011
S3_1993	Historical scenario representing August mean stream temperatures for 1993
S4_1994	Historical scenario representing August mean stream temperatures for 1994
S5_1995	Historical scenario representing August mean stream temperatures for 1995
S6_1996	Historical scenario representing August mean stream temperatures for 1996
S7_1997	Historical scenario representing August mean stream temperatures for 1997
S8_1998	Historical scenario representing August mean stream temperatures for 1998
S9_1999	Historical scenario representing August mean stream temperatures for 1999
S10_2000	Historical scenario representing August mean stream temperatures for 2000
S11_2001	Historical scenario representing August mean stream temperatures for 2001
S12_2002	Historical scenario representing August mean stream temperatures for 2002
S13_2003	Historical scenario representing August mean stream temperatures for 2003
S14_2004	Historical scenario representing August mean stream temperatures for 2004
S15_2005	Historical scenario representing August mean stream temperatures for 2005
S16_2006	Historical scenario representing August mean stream temperatures for 2006
S17_2007	Historical scenario representing August mean stream temperatures for 2007
S18_2008	Historical scenario representing August mean stream temperatures for 2008
S19_2009	Historical scenario representing August mean stream temperatures for 2009
S20_2010	Historical scenario representing August mean stream temperatures for 2010

S21_2011	Historical scenario representing August mean stream temperatures for 2011

S22_PredSE	Standard errors of stream temperature predictions
S23_1C	Future scenario adds 1.00˚C to S1_93-11
S24_1C_D	Future scenario adds 1.00˚C to S1_93-11 but also accounts for differential warming of streams by using historical temperatures to scale temperature increases so that cold streams warm less than warm streams.
S25_2C	Future scenario adds 2.00˚C to S1_93-11
S26_2C_D	Future scenario adds 2.00˚C to S1_93-11 but also accounts for differential warming of streams by using historical temperatures to scale temperature increases so that cold streams warm less than warm streams.
S27_3C	Future scenario adds 3.00˚C to S1_93-11
S28_3C_D	Future scenario adds 3.00˚C to S1_93-11 but also accounts for differential warming of streams by using historical temperatures to scale temperature increases so that cold streams warm less than warm streams.
S29_2040	Future scenario based on global climate model ensemble averages that represent the A1B warming trajectory for 2040s (2030-2059). Future stream deltas within a processing unit were similar and based on projected changes in August air temperature and stream discharge.
S30_2040D	Future scenario based on global climate model ensemble averages that represent the A1B warming trajectory for 2040s (2030-2059). Future stream deltas within a processing unit were based on similar projected changes in August air temperature and stream discharge, but also accounted for differential warming of streams by using historical temperatures to scale temperature increases so that cold streams warm less than warm streams.
S31_2080	Future scenario based on global climate model ensemble averages that represent the A1B warming trajectory for 2080s (2070-2099). Future stream deltas within a processing unit were similar and based on projected changes in August air temperature and stream discharge.
S32_2080D	Future scenario based on global climate model ensemble averages that represent the A1B warming trajectory for 2080s (2070-2099). Future stream deltas within a processing unit were based on similar projected changes in August air temperature and stream discharge, but also accounted for differential warming of streams by using historical temperatures to scale temperature increases so that cold streams warm less than warm streams.

Appendix D. Little Pend Oreille River Invertebrates.

LPO Macroinvertebrate Survey dates:

-Aug. 27, 2015

Summary:

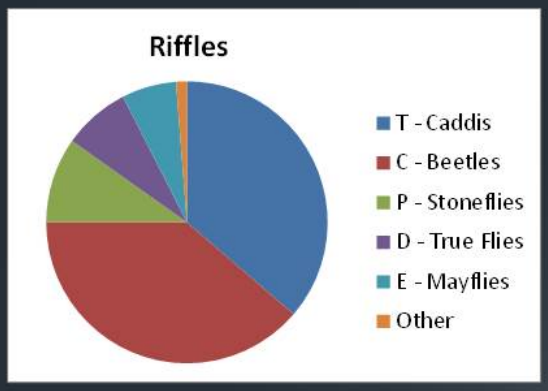
Ten kicknets/sample. 1 min kicking.

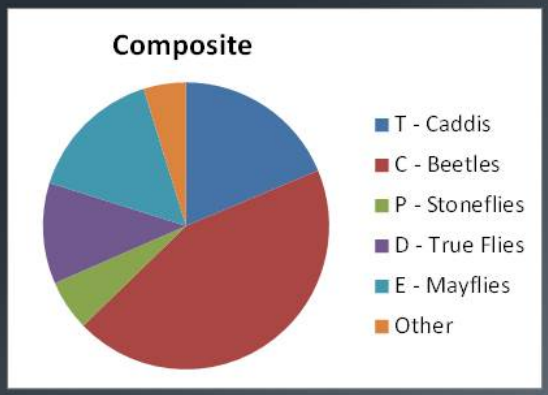
1 Composite sample at 10 transects.

1 Riffle sample in 10 riffles.

Samples sorted to Order and macro's counted.

Preserved samples archived.





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